Spatiotemporal Variations in Abundance and Biomass of Planktonic Ciliates Related to Environmental Variables in a Temporal Pond, Argentina

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(Accepted October 24, 2011)

Gabriela C. Küppers and María C. Claps (2012) Spatiotemporal variations in abundance and biomass of planktonic ciliates related to environmental variables in a temporal pond, Argentina. Zoological Studies 51(3): 298-313. This report describes the structure and seasonal dynamics of ciliated protozoa associated with variations in physicochemical characteristics of the environment in a temporary pond in Buenos Aires Province, Argentina. Plankton samples were obtained, and physicochemical variables were measured monthly for 2 yr. In total, 50 planktonic ciliates were recorded. The highest species richness occurred during the pond’s filling and stable-hydric phases. Upon the pond’s desiccation, the number of ciliate species decreased, with the lowest values being recorded in spring; while the highest abundance and biomass values were observed before drought periods. Ciliate diversity tended to be higher after a drought but decreased with pond desiccation. Most ciliate species were rare and found during filling periods. Vorticella convallaria, Pelagostrobilidium wilberti, and Coleps hirtus were dominant; Cyclidium glaucoma, Strobilidium caudatum, Pseudochilodonopsis piscatoris, Limnostrombidium viride, L. pelagicum, and Chilodonella sp. were common; and Pelagostrombidium mirabile and Rhabdostyla sp., an epibiont on cladocerans, were occasional. The 1st axis and the sum of all axes in the canonical correspondence analysis explained a significant portion of the variance in the ciliate data. Autumn and winter samples were grouped together corresponding to the highest conductivities, high precipitation, and low temperatures, properties which characterized the filling and stable-hydric periods. Species were mainly distributed according to conductivity and temperature gradients along the 1st canonical axis. The structure and temporal dynamics of planktonic ciliates from this temporary pond varied with changes in the physicochemical characteristics of the environment which were determined by flooding and desiccation.


Key words: Ciliophora, Temporary water body, Buenos Aires Province, Ecology.

Temporary bodies of water are natural environments that experience recurrent drought phases, but with biota that are well adapted to deal with water loss through drought-survival mechanisms such as diapause and the formation of resting structures (Williams 2006). Bodies of water of this type are spatially and temporally heterogeneous, exhibiting diel variations in their physicochemical characteristics, such as temperature increases from insolation and pH fluctuations as a result of algal and macrophyte photosynthesis (Podrabsky et al. 1998, Echaniz and Vignatti 2010). Ciliated protozoa are able to colonize and survive after the complete loss of water in such environments because many species can produce resting cysts under unfavorable conditions (Foissner 1987). Although ciliates are ubiquitous components of the microbial food web, and temporary waters can be widespread within Buenos Aires Province, Argentina during wet climatic conditions, ecological studies focusing on these microorganisms have not been carried out.

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In fact, ciliates from temporary bodies of freshwater have only scarcely been investigated worldwide (Andrushchyshyn et al. 2003, Williams 2006). In Argentina, ecological research on freshwater ciliates has been restricted to ultraoligotrophic Andean lakes of Patagonia (Modenutti 1997, Modenutti et al. 2000 2004 2005 2008, Modenutti and Pérez 2001, Modenutti and Balseiro 2002), with the rest of the territory remaining almost completely unexplored. Most of Buenos Aires Province is included within the Pampean Phyto-geographic Province (Cabrera 1994) and is characterized by a wet temperate climate with a mean annual precipitation of 800-1100 mm (Auge et al. 2002). On the basis of the behavior of its subterranean waters, Buenos Aires Province mostly belongs to the wet Chacopampean Plateau Hydrogeologic Province, which contains one of the most exploited hydrogeologic units in the country, the Puelche Aquifer (Auge 2004). Under wet climatic conditions, temporary ponds and pools are widespread in this province with their water supply coming mainly from rainfall, although subterranean waters can also contribute to the water input.

The aim of the present study was to describe the structure and spatiotemporal dynamics of planktonic ciliated protozoa in a temporary pond, in relation to variations occurring in certain physicochemical characteristics of the environment.

**MATERIALS AND METHODS**

**Study site and sampling**

The study site is located about 40 km south of La Plata City, Buenos Aires Province, Argentina (35°05'S, 57°48'W), along one of the margins of Provincial Route 36 (Küppers et al. 2007). The pond is a temporary body of water that goes through prolonged drought phases in summer along with some minor pulses of short dry periods during an annual cycle. In stable-hydric periods, the pond is about 40 m long by 4 m wide, with a depth in the center of about 1 m. One area of the pond is colonized by aquatic vegetation, such as *Typha latifolia* L.; while the remaining areas either consist of open water or are covered by other macrophytes, such as *Ludwigia peploides* (Kunth) Raven and *Altenanthera philoxeroides* (Martius) Grisebach, during certain periods. Sampling was conducted from Jan. 2004 to Dec. 2005 at 3 representative sites according to the depth and retention of water by the substrate in order to test a possible desiccation gradient along the main axis of the pond. The shallowest zone, termed P1, tended to become dry faster than the others, while the center of the body of water and the zone dominated by *T. latifolia*, respectively called P2 and P3, were both deeper and retained more water.

Duplicate plankton samples were taken monthly by means of a wide-mouth 5-L bottle, from which 250 ml was fixed in situ with 2% (v/v) acetic Lugol’s solution in order to perform a quantitative analysis (Finlay and Guhl 1992). The rest of the sample was qualitatively analyzed in the laboratory by means of live observations, establishment of cultures, and silver impregnation with protargol (see below).

**Physicochemical variables**

Temperature, pH, total dissolved solids (TDS), and electrical conductivity were measured with a multiparameter probe (Horiba U21, Kyoto, Japan) at each sampling site. The dissolved oxygen (DO) concentration was estimated by the Winkler method (Clesceri et al. 1998). The depth was also measured at each sampling site, and diel-rainfall data were obtained from the Servicio Meteorológico Nacional (available at http://www.smn.gov.ar).

**Cell counting and identification of planktonic ciliates**

Fixed samples were allowed to settle by gravity in 10-ml chambers for 24 h, in order to scan the contents of the entire chamber under an inverted microscope at magnifications of 150× and 600× (Utermöhl 1958). To identify ciliates, live samples were observed under stereo- and bright-field microscopes. Cultures were established in Petri dishes with bottled spring water along with crushed wheat kernels to promote bacterial growth as a food source for the ciliates. Silver impregnation with protargol was performed according to Wilbert (1975). The taxonomic scheme followed Lynn (2008) with identification mainly based on Kahl (1930 1931 1932 1935), Foissner et al. (1991, 1992, 1994, 1995, 1999), Foissner and Berger (1996), and specific taxonomic papers.

**Biomass**

Ciliate biomass was calculated from the numerical abundance, mean cell biovolumes, and
a carbon-conversion factor. Biovolumes were
determined by measuring 30-150 Lugol-fixed cells
of each species and approximating the cell shapes
to geometrical figures (Hillebrand et al. 1999). This
value was multiplied by a factor of 1.4 to correct for
the shrinkage caused by the fixative used (Müller
and Geller 1993). The carbon-conversion factor
for ciliates is 0.19 pg C/µm³ for Lugol-fixed cells
according to Putt and Steocker (1989).

Data analyses

The relative occurrence of species was
determined by means of the Olmstead-Tukey
test (Sokal and Rohlf 1979), which considers
the abundance and frequency of occurrence of
a species. Accordingly, species were classified
as dominant when the relative abundance and
frequency of occurrence were higher than the
arithmetic mean for both parameters; common
when the relative frequency of occurrence was
higher than the corresponding arithmetic mean;
occasional, when the relative abundance was
higher than the corresponding arithmetic mean;
and rare, when the relative abundance and
frequency of occurrence were lower than their
respective arithmetic means.

The Kolmogorov-Smirnov normality test
was first performed (Zar 1996). Then, a factorial
analysis of variance (ANOVA) was used to assess
significant differences in physicochemical variables
and ciliate abundance, biomass, and species
richness throughout the study period and between
sampling stations.

The diversity index of Shannon and Wiener
(H') and evenness (E') (Magurran 1988) were
calculated by means of the program, Mvsp 3.1
(Kovach 2002), in order to describe the relationship
between the species richness and abundance
distribution among species throughout the study
period.

To elucidate the relationship between ciliate
abundances and physicochemical variables, a
multivariate analysis was conducted by means of
the program CANOCO 4.1 (ter Braak and Šmilauer
1998). Ciliate-species data were analyzed by a
detrended correspondence analysis to determine
the length of the gradient of the axes. Since the
gradient was 4.04 standard deviation units for the
1st axis, a canonical correspondence analysis
(CCA) was performed (ter Braak and Prentice
1988). Colinearity among the environmental data
was checked on the basis of the variance-inflation
factor (VIF < 20). Finally, a stepwise forward
selection and Monte-Carlo permutation test (with
499 unrestricted permutations) were used to select
environmental variables that were significantly
correlated (p < 0.05) with the axes (ter Braak and
Šmilauer 1998). The analysis was carried out with
square-root-transformed numerical abundances
and log-transformed physicochemical variables,
except for pH. Species with an occurrence
frequency of 1 and an abundance of < 500
individuals (ind.)/L were excluded from the analysis
in order to minimize the influence of rare taxa.
Before the CCA, Pearson's correlation coefficients
were calculated to determine redundant
parameters among the environmental variables
which could then be discarded.

Optima and ranges of tolerance to the
physicochemical variables were calculated for
species with an occurrence frequency of > 20%
by means of the respective equations for the
weighted average and weighted standard deviation
(Potapova and Charles 2003).

RESULTS

Hydric changes and succession of aquatic
communities

During the study period, the body of water
experienced 3 prolonged droughts, in the summers
of 2004 (from Jan. to Apr.) and 2005 (from Jan. to
Mar.) and from mid-spring 2005 through summer
2006, with minor drought pulses occurring in Oct.
2004 and May 2005. During these desiccation
periods, amphibious macrophytes developed,
such as Alternanthera philoxeroides and
Ludwigia peploides. These plants persisted in the pond
throughout the 1st dry summer, during the filling
phase in autumn, and until July 2004. Site P3
was colonized by Typha latifolia, which tended
to expand so as to occupy a progressively larger
area by the end of the sampling period. During
the stable-hydric phase in winter, the macrophytes
decomposed to produce a major input of organic
matter to the pond. Subsequently, in their
absence, open waters predominated at sites P1
and P2, while T. latifolia continued to occupy a
substantial area at P3.

Physicochemical variables

The water was well oxygenated (47%-90%
water saturation) with DO concentrations of
3.31-11.24 mg/L (Fig. 1). The temperature varied
Fig. 1. Physicochemical variables in the temporary pond under study in 2004 and 2005.
markedly from one season to the next, ranging 3.27-21.2°C. Slightly acid to alkaline pHs were observed (6.13-9.7). In 2004, the conductivity was high before the summer drought with the highest values recorded at site P1 (2300-2410 µS/cm), whereas in 2005 the highest values were observed during the filling periods at P1 as well (2610-3210 µS/cm). The lowest conductivities were recorded at P3 before the summer drought in 2005 (700 µS/cm). In general, conductivity decreased from P1 to P3 (Fig. 1). TDS showed the same pattern of variation as conductivity, with values ranging 0.05-0.21 g/L. During 2005, the depth at the sampling sites was slightly higher than in 2004 (19-23 vs. 10-17 cm, respectively), but the time of water retention was lower from the time the pond dried out in Nov. rather than Jan. Site P1 tended to dry out before the other two, possibly because of higher water retention by the substrate. Site P1 tended to dry out before the other two, possibly because of higher water retention by the substrate at P3, since that site had progressively become colonized by *T. latifolia*. In terms of rainfall (Fig. 2), 2004 was the drier year, although the greatest rainfalls did occur in Apr. 2004 (248 mm), which tended to fill the pond. In 2005, 2 rainy periods occurred in spring/summer and autumn/winter, but perhaps high temperatures and evapotranspiration during the summer prevented the pond from completely filling. Throughout the sampling period, the conductivity (*F* = 9.35, *p* = 0.000), temperature (*F* = 91.55, *p* = 0.000), and pH (*F* = 358.09, *p* = 0.000) significantly varied; whereas between sampling sites, only the conductivity (*F* = 15.1, *p* = 0.000) and depth (*F* = 6.64, *p* = 0.007) exhibited significant differences.

**Species richness, abundance, and biomass**

In total, 50 planktonic ciliates were recorded, belonging to 18 orders (Table 1). The Sessilida, Halterida, Peniculida, Chlamydodontida, Strombiida, and Choreotrichida were the most species-rich orders. The highest species richness occurred during the filling and stable-hydric phases in the winter of both years. With increases in temperature and the consequent desiccation of the pond, the number of ciliate species decreased with the lowest values recorded in spring (Fig. 3). In contrast, the highest abundances were observed before the droughts (49,100 ind./L in Sept. 2004 at P3 and 37,350 ind./L in Oct. 2005 at P2), while generally higher values were recorded at P3 (Fig. 3). In 2004, the Halterida (43.2%), Prorodontida (22.6%), and Strombiida (17.7%) were the most abundant orders. In 2005; however, the Halterida (30.9%), Sessilida (19.6%), Choreotrichida (8.9%), and Strombiida (7.4%) were the most abundant. The remaining orders represented < 5% of the total abundances during both years. The species that made the greatest contributions to the relative abundance of each order were *Halteria grandinella* (Halterida); *Coleps hirtus* (Prorodontida); *Pelagostrombidium mirabile, Limnostrombidium viride*, and *L. pelagicum* (Strombiida); *Vorticella convallaria* and *Rhabdostyla* sp. (Sessilida); and *Pelagostrobilidium wilberti* and *Strobilidium caudatum* (Choreotrichida).

The highest biomass values were likewise recorded before the droughts (1881 µg C/L in Sept. 2004 at P3 and 1529 µg C/L in Oct. 2005 at P2), but a higher biomass was present at P3 throughout the sampling period (Fig. 3). In 2004, the most plentiful orders in terms of biomass were the Strombiida (30.1%), Prorodontida (12.9%), Sessilida (11.1%), Halterida (10.7%), and Peniculida (10.5%); while in 2005 the corresponding data were the Sessilida (21.3%), Choreotrichida (16.6%), Strombiida (16.3%), and Halterida (13.3%). Species that made the greatest contributions to the total biomass were *Pelagostrombidium mirabile* (Strombiida); *Pelagostrobilidium wilberti* and *Strobilidium caudatum* (Choreotrichida); *Coleps hirtus* (Prorodontida); *Vorticella convallaria* and *Rhabdostyla* sp. (Sessilida); *Halteria grandinella* (Halterida); and *Frontonia atra, F. leucas*, and *Paramecium caudatum* (Peniculida).

Throughout the study period, the number of ciliate species, the abundance, and the biomass significantly varied (*F* = 3.65, *p* = 0.009; *F* = 4.19, *p* = 0.005; *F* = 2.98, *p* = 0.026, respectively), while between sampling sites, differences were not statistically significant.
Diversity

The greatest diversity (H' = 0.97) was recorded during a stable-hydric phase in July 2005, characterized by both a high species richness and evenly distributed abundances (E' = 0.76). On the contrary, the lowest diversity and evenness were observed in Dec. before the summer drought of 2004 (H' = 0.18; E' = 0.19). In Nov. 2004, after a short drought interval, ciliate diversity and evenness reached maximum values (H' = 0.76; E' = 0.76), but the species richness was relatively low, compared to that recorded during stable-hydric periods. In general, the diversity tended to be higher or at a maximum after droughts, but then decreased along with the desiccation of the pond (Fig. 4).

Occurrence of ciliate taxa

Most (85%) of the planktonic ciliates from the temporary pond under study were rare, i.e., these taxa occurred at low abundances and frequencies (Table 1, Fig. 5). *Halteria grandinella*, hypotrichs, *Vorticella convallaria*, *Pelagostrobilidium wilberti*, and *Coleps hirtus* were dominant; while *Cyclidium glaucoma*, *Strobilidium caudatum*, *Pseudochilodonopsis piscatoris*, and *Limnostrombidium*

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<th>Taxa</th>
<th>Occ. (%)</th>
<th>Optima and tolerance range</th>
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Table 1. (continued)

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</table>

Cond., conductivity (µS/cm); DO, dissolved oxygen (mg/L); Temp., temperature (°C).
viride, *L. pelagicum*, and *Chilodonella* sp. were common. The euplanktonic species *Pelagostrombidium mirabile* and *Rhabdostyla* sp., an epibiont on cladocerans, were occasionally found. Among the dominant taxa, *Halteria grandinella* was present in the pond throughout the entire study period at abundances ranging 400-16,970 ind./L. The peak value, which occurred in Sept. 2004, represented 59% of the total abundance recorded during that month. In 2005, *H. grandinella* reached maxima in Aug. (7270 ind./L) and Oct. (7470 ind./L), and constituted 62% and 29% of the respective total abundances recorded during those months (Fig. 3). Hypotrichs were frequent in the pond at abundances ranging 67-1900 ind./L and peaked in Nov. 2004 (883 ind./L,

![Graph showing abundance and biomass of ciliate species.](image)

**Fig. 3.** Absolute and percent (pie plots) abundance and biomass values of ciliate species. Numbers above the abundance bars indicate the species richness.
at 40% of the total abundance) and Aug. 2005 (1900 ind./L, at 17% of the total abundance). *Vorticella convallaria* was more abundant in 2005 than in 2004 (133-1850 ind./L vs. 50-317 ind./L, respectively) and peaked in Apr. (1417 ind./L, at 20% of the total abundance) and Sept. 2005 (1850 ind./L, at 61% of the total abundance). In that last month, its biomass of 287 µg C/L represented 80% of total biomass recorded for the month (Fig. 3). *Pelagostrobilidium wilberti* was described as a new species in this pond (Küppers et al. 2006), and in the present study, occurred at abundances that ranged 33-1467 ind./L. Maximum abundances were recorded in Sept. 2004 (1467 ind./L, at 5% of the total abundance) and July 2005 (1400 ind./L, at 26% of the total abundance) along with respective maximum biomasses of 116 and 111 µg C/L. In July 2005, the biomass of *P. wilberti* represented 38% of the total biomass recorded that month (Fig. 3). *Coleps hirtus* had 2 abundance maxima, first in Dec. 2004 (11,400 ind./L, at 87% of the total abundance) and then in Oct. 2005 (3150 ind./L, at 12% of the total abundance), before prolonged droughts on both occasions. The highest biomass of this species likewise occurred in Dec. 2004 (292 µg C/L, at 80% of the total biomass) and in Oct. 2005 (81 µg C/L; Fig. 3).

Among the common taxa, *Cyclidium glaucoma* exhibited the highest abundance in June 2005 (2950 ind./L, at 13% of the total abundance) and the highest biomass (5.62 µg C/L). *Strobilidium caudatum* ranged in abundance from 17 to 2070 ind./L, with maximum values recorded in Apr. and July 2005 (2070 and 780 ind./L, respectively), representing 28% of the total abundance in Apr. Whereas the maximum biomass of *S. caudatum* in 2004 was 12 µg C/L during Sept., in 2005, the value reached 135 µg C/L (at 23% of the total abundance) during

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**Fig. 4.** Ciliate diversity (Shannon and Wiener index, H') and evenness (E') over the study period.

**Fig. 5.** Frequency of occurrence of ciliate species according to the Olmstead-Tukey test.
Apr. (Fig. 3). *Pseudochilodonopsis piscatoris* peaked in June 2005 (1650 ind./L) after a short drought pulse during May; likewise, the highest biomass of that species (51 µg C/L) was recorded during the same month. *Limnostrombidium* spp. (i.e., *L. viride* and *L. pelagicum*) reached abundances that varied 17-850 ind./L, but maximum abundance values were recorded in Aug. 2004 (850 ind./L) and Oct. 2005 (567 ind./L) along with peak biomass values (113 and 75 µg C/L, respectively) in those same 2 mo. *Chilodonella* sp. reached a maximum abundance in Nov. 2004 (280 ind./L); but in 2005, this species exhibited very low, although less variable, abundances (30-50 ind./L) and biomasses (0.31-0.5 µg C/L; Fig. 3).

Among the occasional taxa, *P mirabile* was recorded from July to Sept. 2004, with maximum abundance and biomass in Sept. (7870 ind./L, at 27% of the total abundance and 601 µg C/L, at 50% of the total biomass). In 2005, this species was only recorded in Oct. (4970 ind./L, at 18% of the total abundance; 379 µg C/L, at 39% of the total biomass). *Rhabdostyla* sp. was registered as an epibiont on cladocerans, but only twice: in Sept. and Oct. 2005, although with a high abundance before a drought period (9217 ind./L, at 35% of the total abundance). In the latter month, the biomass of *Rhabdostyla* sp. represented 15% of the total biomass recorded during that month (Fig. 3).

**Ciliate assemblages relative to environmental variables**

According to the CCA, ciliate assemblages located along the 1st axes were mainly related to conductivity, rainfall, and temperature. The 1st canonical axis and the sum of all canonical axes explained a significant portion of the variance in ciliate data (*F*-ratio = 3.21, *p* = 0.01 and *F*-ratio = 2.52, *p* = 0.002, respectively). The environmental variables that were significantly correlated with the canonical axes after performing the Monte-Carlo permutation test were rainfall (*F*-ratio = 2.82, *p* = 0.006), conductivity (*F*-ratio = 2.66, *p* = 0.006), temperature (*F*-ratio = 2.43, *p* = 0.002), DO (*F*-ratio = 2.32, *p* = 0.008), and pH (*F*-ratio = 2.12, *p* = 0.008). Although inflation factors of all variables included in the analysis were < 20 deviation units, the parameter of TDS was excluded because of its direct relationship with conductivity. The 1st canonical axis explained 34% of the variance of the species-environment relationship, while the 2nd axis accounted for 61% of the cumulative variance.

**DISCUSSION**

According to Williams (2006), the definition of a temporary body of water requires a consideration of the cyclic nature of related droughts, with the duration and intensity of the droughts constituting the best criteria for assigning the term, "temporary". In the pond under study, intense drought periods occurred during the summers, although some
briefer dry periods took place in autumn and spring with the persistence of scattered small hollows of water. Hence, the pond underwent annual seasonal droughts during the period of time studied, alternating between wet and dry periods in a predictable pattern.

The water temperature exhibited a wide range of variation as a result of the low depth of the pond and elevated light penetration. Fluctuations in pH values registered may have been related to the accumulation of organic matter before the summer droughts and to the development of aquatic macrophytes, such as *A. philoxeroides* and *L. peploides*, plants which are commonly found in pampean shallow lakes and streams (Lahitte et al. 1997). Values of conductivity and TDS were higher than those characteristic of ponds in which the water supply comes mainly from rainfall (Gibbs 1970, Baca and Threlkeld 2000), thus indicating a possible connection with saline subterranean water. The Puelche and Pampeano aquifers are characterized by high salinity levels (Auge 1997 2005) and thus possibly contributed to filling the pond. Echaniz and Vignatti (2010) recorded conductivities that ranged 310-3730 µS/cm in an episodic wetland from La Pampa Province, where the highest values occurred during desiccation periods and were attributable to a concentration process through evaporation. In the pond we studied, the greatest conductivities were recorded during a desiccation period in 2004; this period was characterized by high temperatures, low levels of precipitation, and the consequent concentration of organic matter and ions. In contrast, in 2005, when precipitation increased, the higher conductivity values recorded during the filling and part of the stable-hydric period of the pond were possibly due to infiltration by aquifer water. This latter input would also explain the high conductivities recorded during that period, when dilution from the rainfall would otherwise have been expected.

Along the longitudinal axis of the pond,
from sites P1 to P3, significant differences were observed in conductivity and depth, thus constituting a possible spatial desiccation gradient extending from site P1, which usually dried out earlier than the other 2 sites, through sites P2 to P3, where the persistent presence of *T. latifolia* may have contributed to higher water retention by sediments. Despite these differences, ciliate abundance and biomass values did not significantly differ between sampling sites. In contrast, significant temporal differences were observed in ciliate abundance and biomass values at each of the sites and in values of temperature, pH, conductivity, and TDS.

Because, as stated earlier, most ecological studies on freshwater ciliates from Argentina were restricted to ultraoligotrophic Andean lakes (Modenutti 1997, Modenutti et al. 2000 2004 2005).

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**Fig. 7.** Canonical correspondence analysis scatterplot of species and environmental variables.
In contrast, in the present investigation, haptorid ciliates such as *Amphileptus* sp., *Chaenea* sp., *Dileptus* sp., *Spahtidium* sp., *Lacrymaria olor*, and *Lagynophrya* sp. were recorded only rarely, but the scuticociliate, *Cyclidium glaucoma*, was quite common. In the temporary pond studied here, prorondotids were particularly abundant during the spring, and *Coleps hirtus* was the species that contributed the most to the total abundance. Hatano and Watanabe (1981) found *Coleps* sp. to be dominant in a small pond with an input of leaf litter, although in laboratory experiments, this ciliate was seen to increase in abundance when supplied with dead copepods as food. *Coleps hirtus*, a bacterivore-detritivore, is histophagous on dead vegetal and animal matter (Foissner et al. 1999). In this pond, this species seemed to find optimal conditions for developing its populations in the spring, when the environment was drying out. *Halteria grandinella* was the most abundant species during autumn and winter. This species is cosmopolitan and is found in a wide range of habitats (Foissner et al. 1999). *Limnostrombidium pelagicum* and *L. viride* were common during autumn and winter 2004, but *Pelagostrombidium mirabile* replaced those species with an increase in temperature in spring.

The highest ciliate abundance and biomass values in this temporary pond occurred before drought periods, with the most abundant being *H. grandinella* and species of the *Strombidida* and *Sessiliida (> 20 µm in length)*. Song (2000) observed a considerably higher abundance and biomass of ciliates in the lake Houhu (China), with maximum values of 87,710 ind./L and 3013.58 µg C/L and the most abundant members being scuticociliates (*C. glaucoma*) followed by tintinnids and "naked oligotrichs". In contrast, Sime-Ngando and Hartmann (1991) observed considerably lower ciliate abundance and biomass values in Lake Aydat (France) compared to values from the present study, with maxima of around 7800 ind./L and 190 µg C/L, with the dominant ciliates being scuticociliates (mainly *Cyclidium* sp.) and small oligotrichs (< 50 µm in length).

In the CCA, ciliates were distributed along conductivity and temperature gradients and were grouped in assemblages that corresponded to (i) filling of the pond and the stable-hydric phase after summer droughts, (ii) desiccation of the pond (mainly spring samples), (iii) filling periods after a short drought interval, and (iv) complete prolonged desiccation during the summer that followed. Most dominant and common species were distributed in the filling and stable-hydric periods, and appeared to prefer medium to high conductivities, low temperatures, and high DO. Taxa like *Drepanotrema* sp., *Cinetochilum margaritaceum*, *Euplotes* sp., *Stylonychia mytilus*, and other hypotrichs, as well as *Cyclidium glaucoma*, are mostly bacterivorous; and their presence may have been related to the decomposition of macrophytes that persisted in the pond after the drought as a result of the development of bacteria. *Cyclidium glaucoma* is known to tolerate a wide salinity range (Finlay et al. 2006). This species was found at higher conductivity values in the pond. *Coleps hirtus* and *Brachonella spiralis* were related to the highest temperatures and lowest DO concentrations. *Brachonella spiralis* is known to inhabit anoxic and sulfide-rich environments (Foissner et al. 1992), and those conditions possibly prevailed at the time before the pond’s complete desiccation. The histophagous detritivore *C. hirtus*, could have taken advantage of concentrations of dissolved and suspended matter before the summer drought. The occasional *Rhabdostyla* sp. and *P. mirabile* were mainly related to lower conductivities and rainfall that occurred during desiccation of the pond in spring.

Maximum diversity was observed during the filling and stable-hydric phases of the pond together with a high species richness and evenness. The diversity tended to decrease toward the end of the hydroperiod, with the lowest values recorded before a drought in addition to the lowest evenness data, thus indicating the presence of dominant species. Such species were *C. hirtus* in Dec. 2004 and *Rhabdostyla* sp. and *H. grandinella* in Oct. 2005. According to the
intermediate-disturbance hypothesis, diversity maximizes at intermediate levels of perturbation so as to allow the coexistence of competitive and opportunistic species (Connell 1978). If the entire cycle of filling and desiccation of the pond is considered, a disturbance gradient could be defined where only the right-hand side of Connell’s bell-shaped curve of disturbance is detected (Adams 2009) upon inspection of figure 4. In this respect, species richness and diversity tended to decline with greater and/or more-frequent disturbances. Many ciliates are able to survive unfavorable environmental conditions by forming resting cysts (Foissoner 1987). These dormant structures then persist in the dried bed of the pond until rainfall refills it with water in the next hydroperiod. If the availability of water is to be considered one of the most influential conditions for the development of ciliates in this temporary pond, the filling phase would promote massive excystations of ciliates, with a consequent high species richness ensuing after a drought. During the stable-hydric period, more-complex processes of intra- and interspecific interactions may take place, such as competition and predation, which could have resulted in the dominance of 1 species over others. Finally, when the environment has become unfavorable through desiccation of the pond, along with the consequent changes in physicochemical and biological variables that take place under such conditions, only a few species could persist. Accordingly, repopulation of the pond by most species occurred when the pond was refilling, and they were furthermore considered rare according to the Olmstead-Tukey test. During the rest of the hydroperiod, certain dominant and commonly found species prevailed, such as *H. grandinella*, the hypotrichs, *Vorticella convallaria*, *C. hirtus*, Pelagostrobilidium wilberti, Strobilidium caudatum, *L. pelagicum*, *L. viride*, and *C. glaucoma*. Ultimately, only a small number persisted, such as *C. hirtus* and *H. grandinella*, with the appearance of an occasional few, such as Rhabdostyla sp., after the pond’s desiccation. This type of habitat is considered a suitable system for testing ecological concepts (Williams 2006), so the present study could be complemented, in the future, by further laboratory experiments in order to investigate the various assumptions postulated above.

Acknowledgments: Dr. D. Haggerty, a career investigator and native English speaker, edited the final version of the manuscript. Financial support was obtained from the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). This is contribution no. 915 from the Instituto de Limnología Dr. R.A. Ringuete.

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