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Plankton of a high mountain shallow lake (Los Horcones, High Los Andes Cordillera, Mendoza, Argentina)

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Introduction

High mountain lakes have not been the subject of much limnological study in Argentina. The existing literature refers to studies carried out in the province of Tucumán (Villagra de Gamundi 1986a, 1994) and those from the province of Río Negro (Balseiro & Zagarese 1994, Modenutti & Guerrero 1994, Zagarese et al. 2000). Some taxonomic studies have also been carried out by Paggi & de Gamundi (1980), Locascio de Mitrovich (1986), Villagra de Gamundi (1986b) and Locascio de Mitrovich & Menu Marque (1994).

The present study is an initial analysis of the planktonic community of the shallow Lake Los Horcones, Aconcagua Provincial Park (Province of Mendoza, western Argentina). The pond is frozen during the winter and for part of the autumn. During the climbing season it is eutrophically impacted by the presence of animals used for the transportation of climbers and mountain equipment.

One of the main goals of this study was to obtain basic information from this pristine environment, little disturbed by anthropogenic actions. Therefore, the results were compared with those obtained from other high shallow lakes located in different regions.

Material and methods

Los Horcones Pond is 60 m long, 40 m wide, with a maximum depth of 6 m. It is located at 3000 m a.s.l. in the southern wall of Mt. Aconcagua (Fig. 1). The seasonal research of the plankton community was carried out during the 1999–2000 period. Various physical and chemical parameters were recorded: water temperature, conductivity, pH and transparency (Secchi disc). Duplicated phytoplankton and zooplankton samples were obtained with a Van Dorn sampler, on the surface in spring and summer and under the ice during autumn. In winter, the lake was frozen to the bottom. Zooplankton abundance was determined by sieving 25 L through a net (30-

Fig. 1. Location of the high mountain shallow Lake Los Horcones

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µm pore size) and then immediately preserving the animals in 4% formaldehyde. Phytoplankton samples were fixed with Lugol's solution. Samples were counted under inverted and stereo microscopes.

Results

The lake was characterised by a neutral pH only during spring 2000 during snowmelt, at all other times it was alkaline (8.2–8.9). The water temperature showed minimum values, resulting from the surface ice layers in winter (0 °C) and autumn (2.6 °C), with maximum values in spring–summer (8.4–12.7 °C). Conductivity was high, with an average value of 817 µS cm^{-1} (794–853), due to the lithology of the catchment area. Transparency extended to the maximum depth during spring and summer. In the autumn, the Secchi disk recorded 2 m, owing to the ice layer on the surface. The littoral sector of the lake is colonised by aquatic vegetation (*Chara* sp.).

The zooplankton at the Los Horcones Lake is composed of a low number of species. The maximum specific richness (number of species) was recorded in summer and autumn 1999 (18 and 24 species, respectively). On the other sampling occasions, the community did not exceed 10 species, (Fig. 2). The calanoid *Boeckella gibbosa* was always present, whereas the cyclopoid *Microcyclops anceps* was absent during summer 2000. Specimens of *Chydorus* cfr. *sphaericus* were recorded on all occasions except in spring. Two species of the genus *Notholca* were found in most seasons. The change between the littoral and pelagic zones was brought about by the volume reduction of the pond during a dry period (1999), with the incorporation of benthic and periphytic species in the open water (Fig. 3). Some species of *Lecane* (*L. hamata*, *L. lunaris*, *L. closterocerca*) were recorded on the same occasions as *Lepadella* spp. and *Colurella* spp. Ostracods and amphipods frequented the pelagic zone of the pond. Thecamebians, such as *Arcella hemisphaerica*, *Cyphoderia ampulla* and *Difflugia* spp., integrated into the community, in addition to some ciliates (species of *Urotricha*, *Bursaridium*, *Monodinium*, *Vorticella* and *Astylozoon*). The zooplankton, including non-planktonic species, showed their maximum density in the summer, with 89 ind. L^{-1} and the minimum in autumn (37 ind. L^{-1}). The body size of *B. gibbosa* adults (n = 180) exhibited seasonal differences. Larger sizes were recorded during the autumn sampling (May 2000), before the lake froze, with an average length of 1.204 mm (1.056–1.411), with lower values in summer and spring.

The phytoplankton included 55 species (39 diatoms, 11 chlorophytes and 5 cyanophytes). The highest specific richness was observed in autumn 2000 (25 species) and spring (20 species in spring 1999 and 22 species in spring 2000) (Fig. 4). The highest density was detected in spring 2000 (3904 cell mL^{-1}) followed by spring 1999 (1979 cell mL^{-1}). In autumn 1999 and summer 1999, the density diminished to 303 and 68 cell mL^{-1}, respectively. The summer and autumn seasons had the highest calculated diversity values, with low

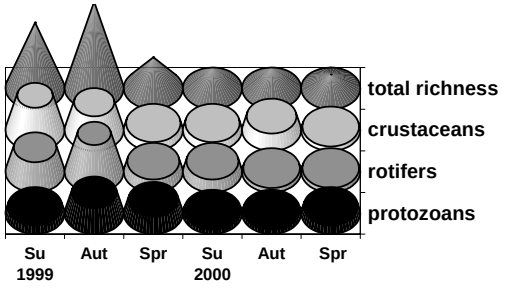

Fig. 2. Seasonal variations of the relative specific richness (number of species) of zooplankton in the high shallow Lake Los Horcones during the period 1999–2000.

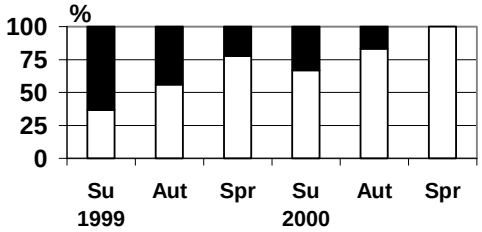

Fig. 3. Seasonal variations of euplanktonic (white) and littoral (black) species of zooplankton in the high shallow Lake Los Horcones during the period 1999–2000.

dominance (Fig. 4). In contrast, the lower diversity values and highest dominance were found during spring owing to the abundance of cyanophytes, with *Lyngbya limnetica* as the dominant species. The presence of *Pseudanabaena catenata* was recorded in the spring of 2000. This species had not been observed the previous year during the same season. The chlorophytes were at a maximum in the autumn, with a dominance of filamentous species. The diatoms were present at all seasons (Fig. 5). The species *Achnanthes minutissima, Amphora ovalis, Cymbella cistula, Denticula elegans*, *Fragilaria ulna*, *Gomphonema constrictum, Navicula cryptocephala, N. peregrina* and *Synedra minuscula* were present on all sampling occasions. These species were tolerant to low temperatures. *Amphora ovalis* was more abundant in autumn. *Achnanthes minutissima* had its maximum in summer (46%). *Cyclotella meneghiniana, Cymatopleura solea, Eunotia lunaris, Ephitemia zebra* and *Rhopalodia gibba* occurred only in autumn. *Rhopalodia gibba* and *R. gibberula* were the most abundant species (54%) in that season. These epiphyte species were found attached to the ice on this sampling occasion. *Synedra actinastroides* and *C. cistula* were exclusive to the 1999 spring samples, whereas *Diatoma vulgare, Navicula scleviscensis, N. radiosa, Pinnularia gibba* and *Surirella robusta* were recorded in spring 2000.

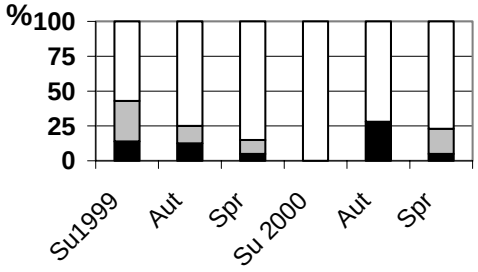

Fig. 4. Seasonal changes in the composition of phytoplankton in the high shallow Lake Los Horcones during the period 1999–2000 (black: chlorophytes, shaded: cyanophytes, white: diatoms).

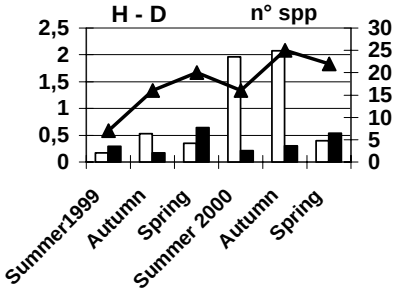

Fig. 5. Seasonal changes in the specific richness (number of species), specific diversity (Shannon index) and dominance (Simpson index) of phytoplankton in the high shallow Lake Los Horcones during the period 1999–2000 (line with triangles: specific richness, black bars: dominance, white bars: specific diversity).

Discussion

The zooplankton at Los Horcones Lake is composed of a low number of species, this being a typical feature of high elevation environments (MIRACLE 1978, MODENUTTI & GUERRERO 1994, VILLAGRA DE GAMUNDI 1994). The macrozooplankton were more prevalent than the microzooplankton, presumably because of the lack of fish predation. This is in agreement with the results of VILLAGRA DE GAMUNDI (1994) from 18 high shallow lakes from Tucumán Province. Other similarities between the mentioned environments were the conductivity values and the finding of a large quantity of resistant cladoceran eggs during the entire sampling period (VILLAGRA DE GAMUNDI 1986a, 1994). This result was probably a response to the fluctuating and rigorous conditions of the environment. The macroplankton composition is restricted to two copepods species (one calanoid and one cyclopoid) and three cladocerans species comparable to those found in the high tropical lakes of the 'Paramo' region (GAVIRIA 1993). *Boeckella gibbosa* is the most important component of the lake zooplankton and this species is a characteristic inhabitant of the high shallow lakes of the Cordillera de los Andes (BALSEIRO & ZAGARESE 1994, LOCASCIO DE MITROVICH & MENU MARQUE 1994, MODENUTTI & GUERRERO 1994, ZAGARESE et al. 2000). The specimens of *B. gibbosa* showed red coloring throughout the entire sampling

period, as this pigmentation protects them from solar radiation; it is not disadvantageous as there are no records of invertebrate and vertebrate predators in the lake (BALSEIRO & ZAGARESE 1994). The specimens of *Hyalella curvispina*, in addition to occasional plankton components, also had reddish coloring, while *M. anceps* was characterized by a dark grey colour. The chydorids recorded did not have obvious pigmentation protecting them against solar radiation. Adults, in addition to nauplii and copepodites of *B. gibbosa*, did not show preferences for particular depths. They were even found in the most superficial strata, thus confirming their resistance to radiation. This had been pointed out by BALSEIRO & ZAGARESE (1994), although these authors found them at the deepest sectors of Toncek Lake (Río Negro), associated with food sources. The size increase recorded in autumn could be linked to the accumulation of reserves for survival in winter conditions. It should be mentioned that the individuals at Los Horcones Lake were smaller than those referred to by MODENUTTI (1993) from a high lake in Patagonia with populations of *Hexarthra bulgarica*. The difference could be connected to the fact that, at Los Horcones Lake, their main food sources are diatoms and filamentous chlorophytes, as the presence of rotifers is constricted to species with lorica. Females bearing eggs were found even during autumn when temperatures were lower than 5 °C; this is concordant with the results of MODENUTTI & GUERRERO (1994) concerning the low number of large-sized eggs. Rotifers do not play an outstanding role in the planktonic community, as most of the species were constrained to certain times of the year, and only in low numbers. On several occasions it was possible to find rotifers with periphytic habits, resulting from the shallow depth of the environment and from the presence of aquatic vegetation. The scarcity of planktonic rotifers could be related to the water pH as well as to the altitudinal location of the lake, coinciding with observations carried out in high lakes in Canada (MC NAUGHT et al. 2000). Another similarity is the frequent occurrence of *Notholca* species that are common components of lakes in high sites, and that of *L. ovalis*, which is very common in shallow high lakes.

The phytoplanktonic composition of Los Horcones Lake differs widely from that which has been recorded in Patagonian high lakes. As these lakes are ultra-oligotrophic, they are dominated by flagellate taxa (ZAGARESE et al. 2000). The phytoplankton of Los Horcones Lake is mainly composed of diatoms, with the species displaying a wide tolerance to adverse conditions (*D. elegans, F. ulna, N. cryptocephala, N. peregrina* and *S. minuscula*). Most of the observed diatoms preferred alkaline conditions, e.g. *A. ovalis*. *D. elegans*, *N. cryptocephala, R. gibba* and *F. ulna*. Likewise, some of the recorded species are indicators of environments with high conductivity values, e.g. *N. peregrina, C. meneghiniana* and *R. gibberula*. The presence of species such as *Nitzschia palea* and *Pinnularia gibba* are indicative of a possible incipient degree of eutrophication resulting from tourist activities in the summer season.

It can be concluded that the low biodiversity recorded in this seasonal study could be linked to certain features of the lake, such as its high elevation and its ion content, and that the few species recorded are adapted to life under its extreme conditions. This high shallow lake is very sensitive to temporal environmental disturbances (eutrophication) and it is desirable to apply corrective efforts to protect against this anthropogenic impact.

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