LITTORAL CRUSTACEANS IN MOUNTAIN LAKES OF HUERQUEHUE NATIONAL PARK (38°S, ARAUCANIA REGION, CHILE)

BY

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ABSTRACT

The water bodies studied herein are located in the Huerquehue National Park, a mountain zone with *Nothofagus alpina*, *N. pumilio*, *N. dombeyi*, and *Araucaria araucana* forests, at 700-1500 m a.s.l. There are numerous oligotrophic lakes, with characteristics similar to the deep Araucanian lakes. Many of these small lakes are difficult to reach, because the only routes leading there are long mountain paths. The sites studied in the present paper are five lakes: the first is located at the basis of the mountains (700 m a.s.l.) and is fed by a river that reaches it from series of three other lakes higher in the mountains (1300 m a.s.l.), which are connected by small streams. These four lakes are inhabited by fish populations. The fifth site is a small, shallow, and fishless pond located at one of the highest sites in the park (1400 m a.s.l). Samples were collected for analysis of chlorophyll concentrations and for littoral, aquatic crustaceans. All sites are oligotrophic, and show low crustacean species richness. In the four lakes with fishes, the crustacean littoral fauna was composed of *Hyalella araucana* (Amphipoda) only. In the fifth lake, the crustaceans collected were *H. araucana*, copepods (*Boeckella gracilis* and *Mesocyclops longisetus*), and large cladocerans (*Scapholeberis spinifera* and *Simocephalus serrulatus*). A direct relationship between species richness and both chlorophyll a and humic acid concentrations was found at all sites studied. These results would agree with literature descriptions that indicate the role of ultraviolet radiation and trophic status as conditioning factors for aquatic communities in Patagonian fresh waters.

RESUMEN

Los sitios en estudio se encuentran localizados en el Parque Nacional Huerquehue, una zona montañosa con bosques de *Nothofagus alpina*, *N. pumilio*, *N. dombeyi* y *Araucaria araucana*, con altura sobre el nivel del mar entre 700 y 1500 metros. Dentro de este parque hay una serie de lagos oligotróficos, con características similares a los lagos Araucanos. Muchos de estos lagos son de difícil acceso, debido a que se puede llegar sólo por medio de largos senderos de montaña. En

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el presente artículo, se estudiaron cinco lagos. El primer sitio, se encuentra localizado en la base de las montañas (700 m.s.n.m), y éste es alimentado por un río, el cual proviene de una serie de tres lagos interconectados por pequeños ríos, en una zona más alta (1300 m.s.n.m). Estos cuatro lagos, presentan poblaciones de peces. Finalmente el quinto lago, es poco profundo, de pequeña superficie y sin peces, localizado en una de las zonas más altas del parque (1400 m.s.n.m). Se colectaron muestras para análisis de concentraciones de clorofila y ácidos húmicos y crustáceos acuáticos litorales. Todos los sitios estudiados son oligotróficos y mostraron una baja riqueza de especies. En los cuatro sitios con peces, la fauna de crustáceos litorales, estuvo compuesta por *Hyalella araucana* (Amphipoda). En el quinto lago, los crustáceos colectados fueron *H. araucana* y copépodos como *Boeckella gracilis* y *Mesocyclops longisetus*, y cladóceros de gran tamaño como *Scapholeberis spinifera* y *Simocephalus serrulatus*. Se observó una relación directa entre riqueza de especies con concentraciones de clorofila y ácidos húmicos en todos los sitios estudiados. Los resultados obtenidos, concuerdan con la literatura, que indican el rol de la exposición a la radiación ultravioleta y las condiciones tróficas como factores condicionantes de la estructura comunitaria en aguas continentales de la Patagonia.

INTRODUCTION

The water bodies located in the southern Andes in Chile are mainly characterized by their relatively great depth, large surface, oligotrophy, and glacial origin (Soto & Zúñiga, 1991; Steinhart et al., 2002). They have a zooplankton assemblage characterized by a predominance of calanoid copepods, which is due to their oligotrophic status (Soto & Zuñiga, 1991; De los Ríos & Soto, 2006). Another important factor that regulates the zooplankton, is the exposure to natural ultraviolet radiation, which currently shows an increase in southern Patagonia (Villafañe et al., 2001; Marinone et al., 2006). This UV radiation (UVR) would cause low survival in some vulnerable zooplankton species (De los Ríos, 2005; De los Ríos & Soto, 2005; Marinone et al., 2006). However, there are no studies of UVR effects on littoral microinvertebrates of Chilean lakes, while probably the microfauna in littoral zones would be more exposed to natural ultraviolet radiation than the zooplankton in the water column (Burks et al., 2002). Studies of littoral micro-crustaceans in Chilean lakes are mainly restricted to the presence of copepods and cladocerans (Araya & Zúñiga, 1985; Ruiz & Bahamonde, 1989), and it is probable that other crustaceans, like Amphipoda are also present (González, 2003).

The present study was done in Huerquehue National Park, a Chilean government protected area characterized by mountains with *Nothofagus alpina* (Poepp. & Endl.) Oerst. *N. pumilio* (Poepp. & Endl.) Krasser, and *N. dombeyi* (Mirb.) Oerst. forests at 700 m a.s.l., and *A. araucana* K. Koch forests at 1300 m a.s.l (Pauchard & Alaback, 2004). This park has numerous oligotrophic lakes (Steinhart et al., 2002), eight of which can be accessed via mountain roads, while some of these are located at least at 8 km from the main access to the park. The importance of these water bodies is their condition of being practically unpolluted and pristine, due to

low human intervention (Steinhart et al., 1999, 2002). Thus, the native fauna can be studied here under conditions of non-intervention. The aim of the present study was to determine the presence of crustaceans in the littoral environment, as a first approach to the unpolluted lakes in the Araucania mountain region. The results will also provide a basis for studying of some similar lakes in the Andes in southern Chile and Argentina.

MATERIAL AND METHODS

The studied site was visited from December 2005 to March 2006. Five lakes were taken into consideration: Tinquilco lake (fig. 1), is located at the main access of Huerquehue National Park (39°10′00″S 71°43′25″W, 763 m a.s.l.), and receives many small streams from the mountains. One of these streams, called Tinquilco, is the effluent of a network of at least three lakes located higher in the mountains. These small lakes, called Verde (39°08′10″S 71°42′33″W, 1254 m a.s.l.), Toro (39°08′20″S 71°42′33″W; 1245 m a.s.l.) and Chico (39°08′21″S, 71°42′33″W, 1240 m a.s.l.), are connected by small streams. The only access to these water bodies is by walking approximately seven kilometers along mountain paths. The fifth and last study site, Los Patos Lagoon (39°10′30″S 71°42′12″W, 1450 m a.s.l.), is located in one of the highest sites in the park, at one hour walking from the three small lakes (fig. 1). As access to this site is problematic, it was visited only on 10 February 2006. The lakes Verde, Toro, Tinquilco, and Chico, house fishes (salmonids and *Galaxias* spp.), whereas Los Patos Lagoon does not have any fish fauna (pers. obs.). By lack of the proper access, it was not possible to measure the area of the lakes Tinquilco, Verde, Toro, and Chico. For Los Patos lagoon, because it is very small, the surface is estimated as less than 1 km^2 and the mean depth is less than 0.5 m. Samples were collected for determining the chlorophyll a concentration (Wetzel & Likens, 1991), and humic acids (Kronberg, 1999). Also, horizontal hauls were taken in the pelagic zone and in littoral zones with an Apstein net with 20 cm mouth diameter and 100 μm mesh size. Zooplankton specimens were fixed with absolute ethanol and were identified with descriptions of Araya & Zúñiga (1985), Reid (1985), Bayly (1992), Pilati & Menu-Marque (2002), and González (2003).

Information of maximum and accumulated ultraviolet radiation for Temuco (38º41′S 72º35′W) for the summer of 2005-06 (December-March) was taken into consideration, measurements were made with a spectroradiometer Li-Cor model 1800, and the data thus obtained include a radiation spectrum between 300 and 1100 nm.

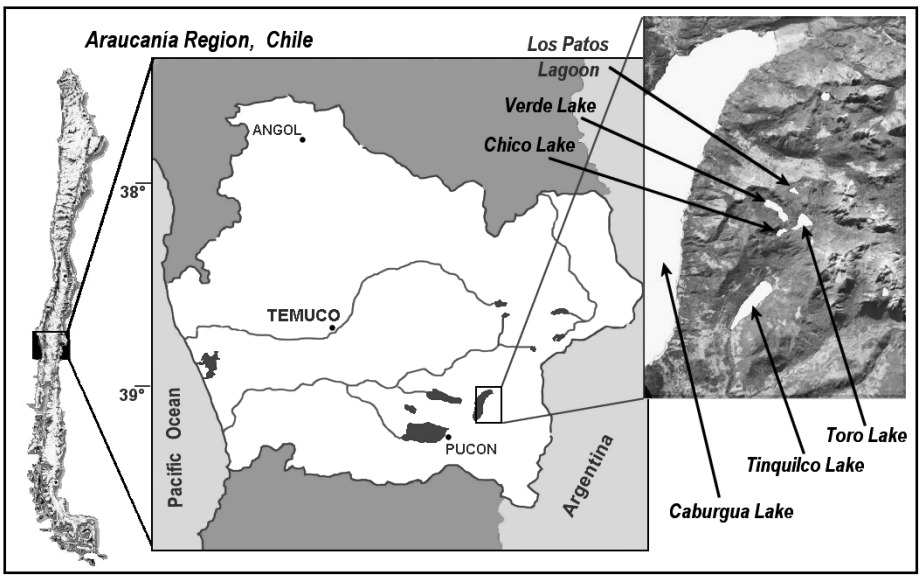

Fig. 1. The studied zone of Huerquehue National Park, between 700 and 1500 m a.s.l., and the five lakes that are reported upon in the present paper.

RESULTS AND DISCUSSION

The studied sites show low chlorophyll concentrations and relatively low contents of humic acids (table I). The crustacean fauna was characterized by the presence of the amphipod, *Hyalella araucana* (Grosso & Peralta, 1999) for all sites studied, and in the four lakes with fishes there were found no other crustaceans as littoral fauna, with the exception to Verde Lake. In this lake, we also found the calanoid copepod, *Boeckella gracilis* (Daday, 1902), but this species was rare in the littoral zone. For Los Patos lagoon, no zooplankton was collected, but copepods and cladocerans were found as fauna associated to submersed macrophytes. The collected specimens are specified in table I; these results indicate the presence of the copepods, *Boeckella gracilis* and *Mesocyclops longisetus* (Thiébaud, 1912), and of large cladocerans, viz., *Scapholeberis spinifera* (Nicolet, 1879) and *Simocephalus serrulatus* (Koch, 1841). Data on species richness reveal a direct relationship with the chlorophyll and humic acids concentrations, the more significant with the chlorophyll concentration ($R^2 = 0.929$, $p < 0.01$) in comparison to humic acids ($R^2 = 0.789$, $p < 0.01$; fig. 2).

The low values of chlorophyll and humic acids obtained are similar to the observations in other Chilean mountain lakes (Soto & Campos, 1995). The first chlorophyll concentrations for lakes in Huerquehue National Park were measured by Steinhart et al. (2002), and are similar to the results obtained in the present study (table I). The southern Chilean and Argentinean lakes have relatively low

TABLE I
Average chlorophyll *a* and humic acids concentrations, and species reported in the littoral fauna of the studied sites in Huerquehue National Park

	Lakes				
	Tinquilco	Toro	Chico	Verde	Los Patos
Chlorophyll concentration (μg/l)	1.6	1.5	1.9	2.0	2.9
Humic acids (mg/l)	2.7	6.2	1.2	3.7	12.3
Cladocera, Daphniidae					
Simocephalus serrulatus (Koch, 1841)					X
Scapholeberis spinifera (Nicolet, 1879)					X
Copepoda, Calanoida, Centropagidae					
Boeckella gracilis (Daday, 1902)				X	X
Copepoda, Cyclopoida, Cyclopidae					
Mesocyclops longisetus (Thiébaud, 1912)					X
Amphipoda, Hyalellidae					
Hyalella araucana (Grosso & Peralta, 1999)	X	X	X	X	X

X, present as reported herein.

concentrations of dissolved organic carbon (Morris et al., 1995; Soto & Campos, 1995; De los Ríos & Soto, 2006), a component of humic substances. Although humic acids are only an approximation for studing dissolved organic carbon (Kornberg, 1999), the results obtained in the present study (table I), would be similar to results of dissolved organic carbon for other Argentinean and Chilean lakes (Morris et al., 1995; De los Ríos & Soto, 2006).

The presence of *Boeckella gracilis* in Chile is restricted to a few mountain lakes (Menu-Marque et al., 2000), whereas the presence of *Mesocyclops longisetus* agrees with literature descriptions that indicate its occurrence north of 39°S (Pilati & Menu-Marque, 2002). The occurrence of *Scapholeberis spinifera* and *Simocephalus serrulatus* has been reported for the littoral zones of large and deep Chilean lakes located between 38° and 39°S (Ruiz & Bahamonde, 1989). Also, *S. spinifera* was described from the littoral zones of shallow Argentinean Andean mountain lake at 41°S (Olivier, 1962) and from shallow ponds in southern Chilean Patagonia (Ekman, 1900). The presence of four species of small littoral Crustacea is in agreement with the mean species richness of Chilean lakes (Soto & Zuñiga, 1991; Soto et al., 1994). This low species richness would be due to the relatively low chlorophyll concentration (Soto & Zuñiga, 1991; Steinhart et al., 2002). Although the sampled period corresponds to the period of maximum zooplankton abundance in Chilean lakes (Wölfl, 1996), the data can be considered representative. The problematic access obviously limits the possibility to visit the studied site on a more frequent or regular schedule.

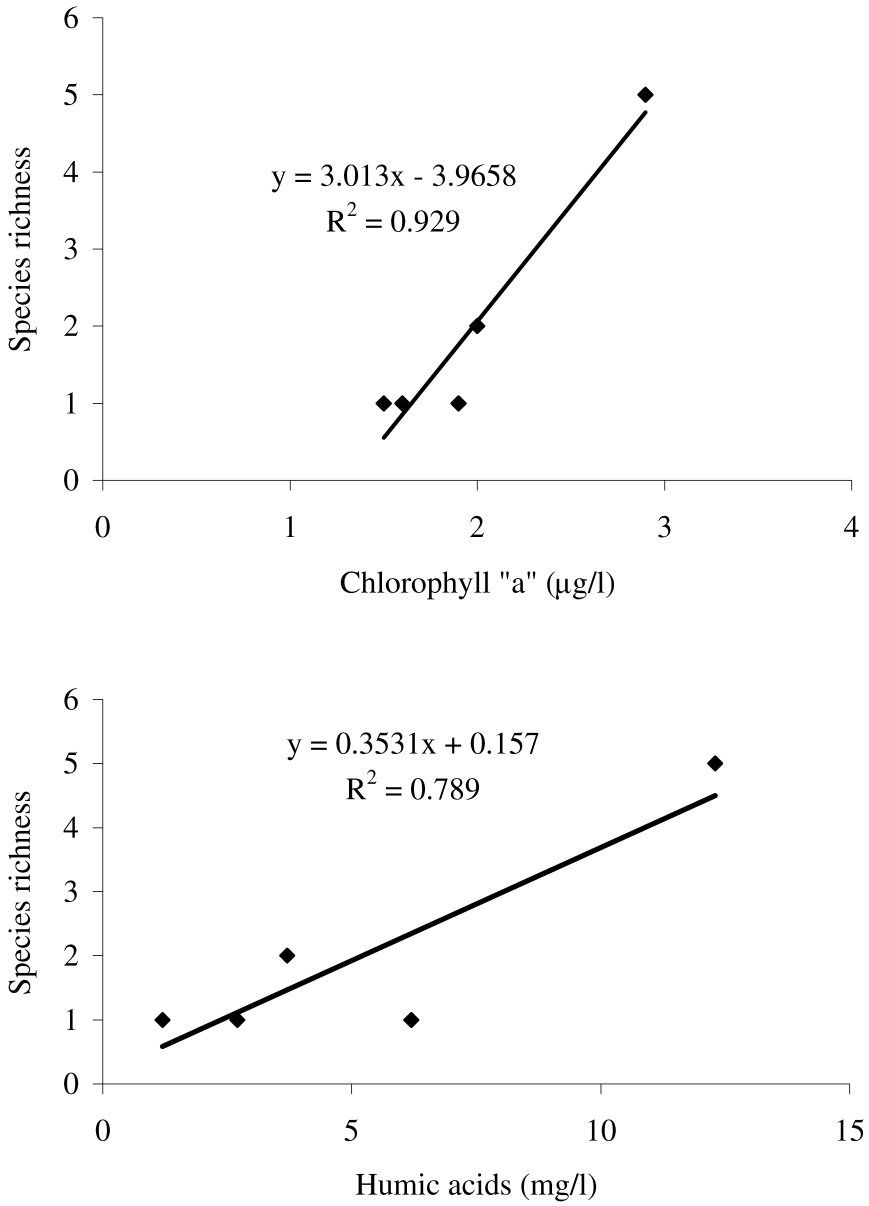

Fig. 2. Relationships between chlorophyll *a* and humic acids concentrations on the one hand, with established species richness of littoral microcrustaceans, on the other, for the five lakes in Huerquehue National Park.

For Los Patos lagoon, the presence of both daphniids and copepods probably indicates both a sufficiently high chlorophyll concentration and a sufficiently low conductivity, because both these conditions are favourable to sustain daphniid

TABLE II
UV-B radiation, daily maximum (W/m^2) and doses (kJ/m^2), for Temuco ($38^o41'S$ $72^o35'W$), between December 2005 and March 2006

Date	Maximum (W/m^2)	Doses (kJ/m^2)
28-Dec-2005	4.30	107.6
29-Dec-2005	3.50	86.8
03-Jan-2006	3.40	73.8
10-Jan-2006	4.00	91.4
25-Jan-2006	4.20	100.8
26-Jan-2006	4.20	97.6
01-Feb-2006	4.10	99.4
13-Feb-2006	4.20	101.9
02-Mar-2006	3.00	69.5
03-Mar-2006	3.20	59.4
17-Mar-2006	2.50	46.4
24-Mar-2006	2.00	43.2

populations in shallow ponds (Soto & De los Ríos, 2006). Nevertheless, the species of copepods and cladocerans were found hidden in the littoral vegetation, probably as a photoprotective response against the penetration of ultraviolet radiation (Burks et al., 2002). This UV radiation showed high values between December 2005 and March 2006, according to measurements carried out in the city of Temuco (table II), located 120 km to the northwest. According to Cabrera et al. (1995), the values of UVR measured in Temuco (100 m a.s.l.), can be approximately 10% lower than the incident radiation in the Huerquehue National Park (average altitude 1100 m a.s.l.), thus reaching levels close to those reported by Tartarotti et al. (1999) for the Laguna Negra ($33°35'S$ $70°04'W$).

Thus, as apparently the chlorophyll *a* concentrations are sufficient, the photoprotection against UVR given by the littoral vegetation observed in Los Patos lagoon can be considered also sufficient to allow sustained daphniid populations. These results are in agreement with experimental evidence for pigmented daphniids of shallow Patagonian fishless ponds (De los Ríos, 2005). The difference is, that in Los Patos lagoon the submersed vegetation probably would provide photoprotection against UVR, and in this scenario the micro-crustaceans would develop horizontal migrations, as was described by Burks et al. (2002) for wetlands. The shallow depth of the water in Los Patos Lagoon combined with its mountainous characteristics, ensure that the whole water column can be penetrated by UVR, similar to descriptions for water bodies of Argentinean Patagonia such as lakes Toncek, Los Juncos, and Ezquerra (Zagarese et al., 1997a, b), and Laguna Negra, located in central Chile (Cabrera et al., 1997; Tartarotti et al., 1999).

The correlations of species richness with chlorophyll concentrations are in agreement with previous assumptions of community ecology theory, that postulate

a direct relationship of species richness and environmental productivity (Jaksic, 2001). Similar results were reported for Chilean lakes located between 36° and 52°S, for both littoral and pelagic species. These reports described low species richness and proposed a potential role for oligotrophy as a regulator of species richness (Soto & Zúñiga, 1991). The direct correlation between species richness and humic acids concentration would be explained by the potential screen effects against ultraviolet radiation that these substances have (Morris et al., 1995), since exposure to UVR would cause mortality in some vulnerable species (De los Ríos, 2005; De los Ríos & Soto, 2005). Marinone et al. (2006) describe a potential effect of natural ultraviolet radiation on zooplankton species richness in Chilean and Argentinean lakes. This relation would be explained by the high transparency of the water column due to low dissolved organic carbon concentrations in those water bodies (Morris et al., 1995; De los Ríos & Soto, 2006).

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