Desmid microalgae from lakes in the Andean Alpine paramos ecosystem of Colombia (South America)

Luz E. de-Bashan
Department of Soil and Agrifood Engineering, Faculty of Agriculture and Food Science, Laval University, Quebec, Canada, and,
Department of Biology, Pontificia Universidad Javeriana, Bogota, Colombia

John C. Donato
Department of Biology, The National University of Colombia, Bogota, Colombia

Microalgae from 17 tropical, alpine lakes in the paramo zone of the central and western Andean range in Colombia were evaluated for the presence of desmids (Chlorophyceae). Desmids are highly diverse unicellular green algae that are primary producers in fresh water ecosystems, are consumed by microfauna, and can serve as biological indicators of the biological health of fresh water bodies. Of 100 desmid taxa recorded, 43 are new records for Colombia. This study showed that all species detected have a cosmopolitan distribution. This taxonomic registry study describes all desmids species (in tables, in artwork and photos) detected in these alpine lakes and a key for identification of genera, species, and subspecies in this ecosystem. A literature list for further reading is included.

Key words: Alpine meadows, Andean tropical alpine lakes, Columbian alpine ecology, desmids, microalgae, paramos, taxonomy.

Dedication
This study is dedicated to the memory of the late Dr. Luis E. Mora-Osejo of the National University of Colombia, Bogota, Colombia.

Introduction

"Paramos" is a type of alpine meadow or mountain steppe located in the highlands (2800-4300 m.a.s.l.) of the central and northern Andean range in South America (8°N to 18°S). At high elevation of the central and northern Andes, paramos vegetation is composed of shrubs and grasses, is continuously cool to cold, and relatively dry because of rain shadow effects from the surrounding mountains. Within the paramos, mountain streams carrying snowmelt are the main source of water in the lakes. Despite their tropical location, and directly because of their high elevation, this is a cold ecosystem (0-15°C daily range with an annual average of about 10°C and no seasonal variations), frequently freezing during the night, yet supporting a rich and diverse plant and animal life, but few trees. High valley paramos ecosystems are water catchments in the northern Andes containing lakes formed from terminal Pleistocene mountain glacial processes, and now functioning as headwaters of many South American rivers.

Although the lakes are important for supporting urban and rural populations in the lower valleys, paramos had been studied mainly for their botanical interests and the impact of slash-and-burn practices (Keating 1997; Sklenar & Jorgensen 1999; Sklenar & Ramsay 2001; Suarez & Medina 2001).

Information regarding microbial primary production in the lakes comes from only two sources (Miller *et al*. 1984; Richerson & Carney 1988). The land and water microbial and microfaunal paramos communities are scarcely documented, involving only a handful of studies on mycorrhizae fungi (Barnola & Montilla 1997) and their impact (Chapela *et al*. 2001), grassland fungi (Gualdron-Arenas *et al.* 1997), lichens (Perez 1997), ciliates (Foissner 2000), algae (Taylor 1935), diatoms (Theriot *et al*. 1985) and microalgae in two paramos lakes in Colombia (Donato-Rondon *et al*. 1996), and phytoplankton in Lake Titicaca in Peru-Bolivia (Carney *et al*. 1987). Most of the groups of microalgae found in paramos ecosystems in Colombia have arctic-alpine and neotropical origins, with few endemics (West 1914; Coesel 1987).

Desmids are highly diverse unicellular green algae that are primary producers in fresh water ecosystems (Coesel 1996), are consumed by microfauna (Brook & Ells 1987), and can serve as biological indicators of the biological health of fresh water bodies (Coesel 2001). -Desmids are cosmopolitan microorganisms of tropical to arctic water bodies (Brook & Williamson 1983; Da Graca & De Moraes 1996). They occur as euplankton, tychoplankton, and periphyton. Coesel (1987, 1992) documented some desmids in Colombian paramos lakes. A preliminary account of this study was published in Spanish (Gonzalez-Gonzalez & Mora-Osejo 1996). This taxonomic study documents desmid genera, species, and subspecies found in 17 alpine lakes in Colombia and establishes a basis for further evaluation of highland aquatic ecosystems in South America.

Materials and Methods

Collection of samples

Specimens were collected in February 1985 by P.F.M. Coesel (University of Amsterdam, The Netherlands) and in October-November 1992 by John Donato (Pontificia Universidad Javeriana, Bogota, Colombia). The materials are preserved in the Colombian National Herbarium at the Colombian National University, Bogota. Each lake was sampled two or three times. In the taxonomic study performed in 1993, 40 samples were evaluated. The locations of the lakes are shown in Fig.1. Physico-chemical data were collected during sampling: electrical conductivity (conductimeter YSI 33), temperature, and pH (pH 210-Hanna Instruments, Italy). Additionally, analysis of ammonium, nitrates, and total phosphorus were done in the Laboratory of Water of the National University of Colombia, Bogota.

Donato-Rondon *et al*. (1996) described sampling procedures in detail. Briefly, samples of phytoplankton were collected with 30-μm mesh phytoplankton nets from a depth of one meter or 3.5 meters. The samples were immediately fixed in a common preserving solution (Schwoerbel 1975) (distilled water, 4% formaldehyde, 70% acetic acid). Samples of periphyton were scraped with a spatula from the undersurface of rocks in shallow water near the lakeshores (Lowe & Laliberte 1996). Tychoplankton were squeezed from the roots of aquatic macrophytes (*Potamogeton* spp*., Myriophyllum* spp*., Callitriche nubigena, Nitella* spp*.,* and *Sphagnum* spp.) (Coesel 1987). Samples were fixed in a preserving solution (distilled water, ethyl alcohol, and formaldehyde in a 6:3:1 ratio).

Results

Identification of desmids

As a group, desmids are easily identified by morphological characteristics, including cell shape and dimensions. Species were identified using a light microscope (model, Zeiss, Germany) and inverted light microscope (Axiovert Zeiss, Germany). A brief description was added to each identified species, since morphology may change in different environments. Since there is no comprehensive identification dictionary for desmids, the following studies were used to identify species (Coesel 1979, 1981, 1983, 1985; Croasdale *et al*. 1983; Prescott *et al*. 1972, 1975, 1977, 1981, 1982). As multiple keys for identification of desmids from other environments were used simultaneously, including some published in difficult-to-obtain manuals, an identification key for desmids from this alpine environment was developed for the species identified in this study (see keys).

One hundred desmid taxa were recorded, 43 are new records for Colombia (See artwork, photos and tables).

Physico-chemical characteristics of the lakes: Surface temperature in all lakes fluctuated between 10-12°C with no annual variations. Electrical conductivity in

Lakes Presentación, Verde, Magdalena, Rebolledo, Larga, Buitrago, San Rafael, and Santiago was <20 μs cm^{-1}. Electrical conductivity in Lake Cumbal is significantly higher (> 75 μs cm^{-1}) and pH in all lakes was approximately neutral, except Lake Buitrago (pH 6.2), In all the lakes, low concentrations of ammonium (< 2 μmol l^{-1}) were found, except Lakes Cumbal, Larga, Rebolledo, Buitrago, and Verde, which had concentrations of ammonium higher than 3 μmol l^{-1}. In all lakes, except Magdalena and Santiago, concentrations of nitrates were lower than 0.2 μmol l^{-1}. In the latter two lakes, concentrations of nitrates were about 0.8 μmol l^{-1}. Concentrations of total phosphorus in all lakes was high, ranging from 1.0 to 4.0 μmol l^{-1}.

Discussion

Analyses of physico-chemical water properties of paramos lakes showed low electrical conductivity, neurtal pH (slightly acid in some lakes), limited nitrogen, and varying levels of phosphorus. These characteristics are typical of high mountain lakes in Ecuador (Steinitz-Kannan *et al*. 1983; Miller *et al*. 1984), Venezuela (Gessner 1955; Lewis & Weibazahn 1976), and Lake Titicaca in Bolivia (Richerson *et al*. 1977; Vincent *et al*. 1985). The community of desmids in lakes in the paramos areas of Colombia resembles the ones reported for high Andean lakes in Bolivia and Ecuador (Iltis 1991; Steinitz-Kannan *et al*. 1983); where 91% of the recorded taxa are cosmopolitan, and the remaining 9% were restricted to temperate zones. According to Coesel (1992), most of the desmids from the high elevations of some tropical regions are found also in lowland areas in the same region, where diversity and variety is significantly higher than at elevations above 2000 m.a.s.l. The Andean chain is an obliged path for organisms between North and South America.Therefore, it became a filterfor the distribution of species in lowland areas (Coesel *et al*. 1988). This fact could explain the presence in these lakes of worldwide distribution species, and some of distribution restricted to North America.

In summary, the desmids in Andean lakes of the paramos in Colombia are mostly cosmopolitan and are associated with fresh water with low electrical conductivity, low temperature, neutral or very weakly acid pH, and limited nitrogen, but but a wide range of phosphorus.

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