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MICROCRUSTACEAN ASSEMBLAGES AND WATER QUALITY IN A HIGH-ALTITUDE POND IN SOUTH BRAZIL (PARANÁ)

Renê Skarabotto[1], Julia Madrid Urbano[2], Jorge Laço Portinho[3], Gilmar Perbiche-Neves[2]*

[1]Pontifícia Universidade Católica do Paraná, Centro de Ciências Biológicas e da Saúde, Rua Imaculada Conceição, 1155, Prado Velho, CEP: 80215-90,1Curitiba, Paraná, Brasil.

[2]Universidade Federal de São Carlos, Centro de Ciências da Natureza, Rodovia Lauri Simões de Barros, km 12 - SP-189, Aracaçu, Buri, CEP: 18290-000, São Paulo, Brasil.

[3]Embrapa Meio Ambiente, Rodovia SP-340, Km 127,5, Tanquinho Velho, CEP: 13918-110, Jaguariúna, São Paulo, Brasil.

E-mails: rene.bio@gmail.com; juliamadrid@gmail.com; jorgeportinho@gmail.com (*corresponding author); gilmarperbiche83@gmail.com

Abstract: The aim of this study was to assess the abundance and richness of microcrustacean, and water physical and chemical characteristics of a high-altitude pond in the Serra do Mar at State of Paraná. Water samples were collected quarterly between August 2015 and August 2016. Environmental conditions of pond were characterized by small pond size and depth, cold and well oxygenated water, and neutral or slightly acid pH. Mean total microcrustacean density was 945.0 ind m^{-3}, whereas total taxon richness was 3.40. The most abundant species was *Tropocyclops prasinus*. The small size and the isolament of the pond, and the low temperatures were related to the low species richness and abundance. This study is unprecedented to the State of Paraná. Future studies attempt to understand the environmental conditions and distribution of microcrustaceans from high-altitude ponds.

Keywords: Cladocera; Cyclopoida; geographic distribution; limnology; mountain aquatic fauna.

Zooplankton (Copepoda, Cladocera and Rotifera) living in high-altitude ponds must cope with harsh environments, such as low nutrients, low food availability, low temperature, short summer open-water period, and high solar radiation (Santos–Wisniewski *et al.* 2002, Manca & Armiraglio 2002, Ríos-Escalante *et al.* 2012). Recently, Tartarotti *et al.* (2017) showed that Copepods exposed to high levels of UV radiation (UVR) have up to ~ 11 times (mean 3.5) higher concentrations of photo-protective compounds (mycosporine-like amino acids, MAAs) in clear alpine lakes than from in turbid glacier-fed lakes. In addition, remote high-altitude ponds are in general pristine ecosystems much less influenced by pollution from agriculture and wastewater compared to lowland lakes. All these peculiarity environmental conditions can influence the pattern of diversity and distribution of zooplanktonic organisms (Manca & Armiraglio 2002).

While high-altitudinal ponds in Europe in general and in the Alps in particular have gained importance as biodiversity reserves (*e.g.* ‘‘egg banks’’, Manca & Armiraglio 2002) and as freshwater resources, we have little information about the diversity of the zooplankton communities in Brazilian high-altitudinal ponds (Santos-Wisniewsky *et al.* 2002, Eskinazi-Sant’Anna *et al.* 2011, Moreira *et al.* 2016). The reasons for this gap should be attributed to its isolation that increases the difficulty to access remote ponds (Martinelli 2007), and also because studies of high-altitudinal ponds have only recently become the hot topic for research in Brazil (Moreira *et al.* 2016). In this context, the aim of this study was to assess the abundance and richness of Copepoda and Cladocera species in a high-altitude pond in the Serra do Mar of the State of Paraná. Water physical and chemical characteristics were also assessed to describe the conditions of the high-altitude pond.

Serra do Mar mountain complex is part of the Atlantic Forest Biome, which extends from the Brazilian northeast to the extreme south at state of Rio Grande do Sul, distributed along the eastern coast of the Atlantic Ocean (Muylaert *et al.* 2018). The Paraná portion of the Atlantic

Forest at Serra do Mar is considered an almost intact redoubt of the original vegetal cover of this biome, due to the rugged relief that acts as a barrier that hinders human occupation (SEMA 2015). Perdidos Mountain (25º53’25’’ S, 48º57’25’’ W) is at the city of Guaratuba (Paraná state) and is under the Environmental Protection Area (APA) of Guaratuba, being one of the highest sites of the region at 1,443 meters above sea level (Figure 1A). Perdidos is a small pond at 1,412 m above sea level, approximately 288 m^2 of area with a maximum depth of 1.4 meters, formed by the natural damming of a fount (Figure 1B, C, D).

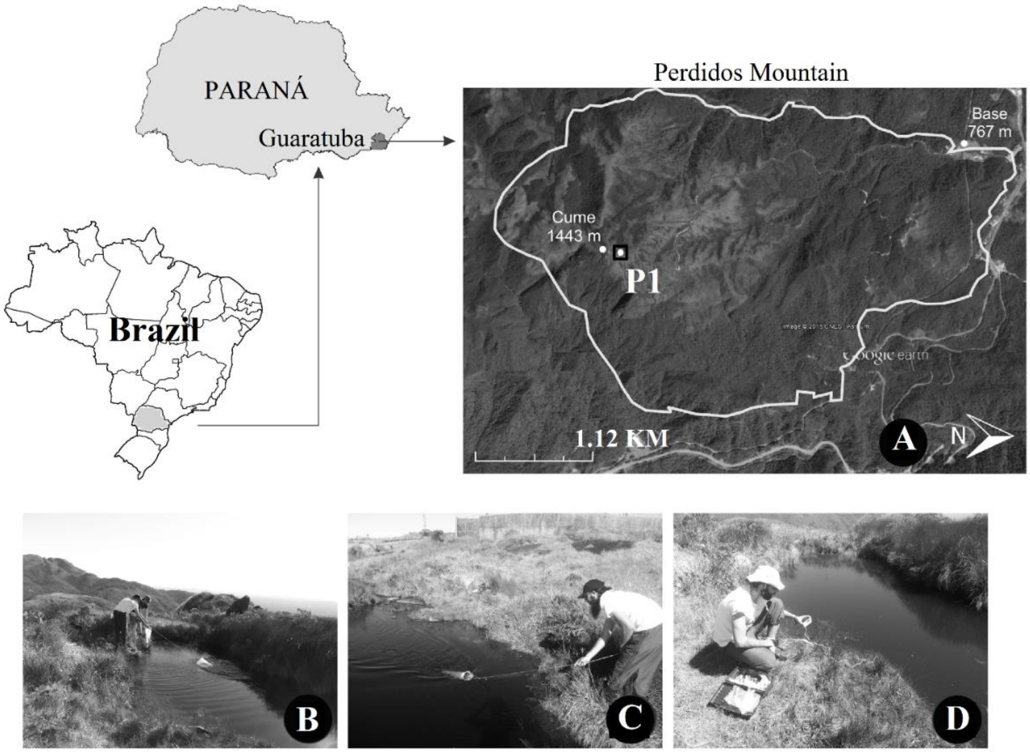

Figure 1. (A) Map showing the localization of study area in Guaratuba, Paraná, Brazil, P1 is the collection site. Altitudes are shown in A. B-D photos of zooplankton sampling at Perdidos small pond

The climate is subtropical humid mesothermic (Cfb; IPARDES 1991) and has regular pluviosity with annual average of 1,700 mm. Air temperatures range from 20.1 °C in the warmer months to 6.6 °C in the cold months, with an annual average of 14.3 °C, and the area is subject to frosts and partial freezing of the waters. The vegetation at the base of the mountain consists of the

Dense Ombrophila Montana Forest; as the altitude increases the vegetation is replaced by a phytogeographic group called the Alto-Montana Ecological Refuge (IPARDES 1991).

Zooplankton samples were collected between August 2015 and August 2016, totaling five sampling (August, December, March, June and September). At each sampling, a total of 2,000 L of water was obtained at different locations in the pelagic and littoral region of pond. Water samples were intensive collected with a 20 L bucket and filtered through a zooplankton net (55 µm). The samples were fixed with 70 % ethanol and stored in 300 ml plastic bottles. The zooplankton (cladocerans and copepods) were identified and counted under a stereo-microscope (50× magnification), the entire sample being included. The identifications were made according to specific literature such as Smirnov & Timms (1983), Reid (1985), Santos-Silva *et al.* (1989), Shiel (1995), Elmoor-Loureiro (1997) and Perbiche-Neves (2015).

At each sampling, the depth (cm) was measured using a Speedtech sonar (depthmate Portable Sounder), and water transparency (m) using a Secchi disk. A water sample was also obtained from the surface to measure four environmental variables: water temperature (ºC) using a digital thermometer (ETC®), and pH and dissolved oxygen (mg L^{-1}) determined using an Alfakit®. Air temperature was measured with a mercury thermometer.

During period of study, water transparency was 100 % of total depth (mean 77.9 ± 5.2 cm) in almost all samples. Mean air temperature was 25.74 ºC (± 10.0), whereas mean water temperature was 14.4 ºC (± 4.6). The measurement of pH in pond reveals that water was slight acid, with mean value of 6.5 (± 0). The average oxygen concentration was 6.3 mg L^{-1} (± 1.3).

Mean of total zooplankton density (Copepoda and Cladocera) was 945.0 ind m^{-3}, with a large variability (minimum value was 450 and maximum 2715 ind m^{-3}), whereas total taxon richness was 3.40 (± 1.8). We registered the occurrence of three taxa of zooplankton (*Tropocyclops prasinus*, *Simocephalus semiserratus*, *Ilyocryptus spinifer;* Table 1). Two juvenile phases (nauplii and copepodites) of Copepoda were found in all samples, and were the most abundant zooplankton in the samples. Regards to adults' phases, *T. prasinus* exhibited major frequency and mean density compared to *S. semiserratus* and *I. spinifer* in both 2015 and 2016 years (Table 1).

Table 1. Frequencies of occurrences (%) and average density (ind m^{-3}) (± sd) of microcrustaceans recorded in the Perdidos Mountain.

Taxa	(%)	(ind m^{-3})
Copepoda		
Cyclopoida		
Nauplii Cyclopoida	100	459.0 (± 516.6)
Copepodite Cyclopoida	100	309.0 (± 330.3)
Tropocyclops prasinus Fischer, 1860	100	138.0 (± 123.9)
Cladocera		
Daphiinidae		
Simocephalus semiserratus Sars, 1901	40	33.0 (± 65.72)
Ilyocryptidae		
Ilyocryptus spinifer Herrick, 1882	20	6.0 (± 13.4)
Total		945.0 (± 1000.1)

In general, environmental conditions of Perdidos pond correspond to a typical "high mountain condition" in tropical regions, characterized by small pond size and depth, cold and well oxygenated water, and neutral or slightly acid pH (Santos–Wisniewski *et al.* 2002, Van Colen *et al.* 2017, Barta *et al.* 2018). The low mean taxon richness of microcrustacean (S = 3.40) observed in the present study, is similar to findings by Ríos-Escalante *et al.* (2012) in ponds and pools of altitudes in the northern region of the Chilean Patagonia (Icalma – altitude 1,154 m, S = 3, Verde – altitude 1,100 m, S = 2; Captrén – altitude 1,100 m, S = 3). Many zooplankton species distributions are limited by density-independent factors, such as low temperature, and because of the pound geographic isolation, since microcrustaceans depend on vector to passively dispersed between habitat (Brock *et al.* 2003, Gyllström & Hansson 2004). All these cenarios are present in high mountain condition and could explain the low richness observed.

Nevertheless, Barta *et al.* (2018) recorded six taxa of microcrustacean (*Boeckella occidentalis*, *Cyclops/Metacyclops*, *Bosmina longirostris*, *Chydorus sphaericus*, *Daphnia* sp., and *Eurycercus* sp.) in 16 lakes located in the Ecuadorian Andes. In addition, Moreira *et al.* (2016) registered 29 taxa of zooplankton, being 8 Cladocera and 21 Rotifera in Lagoa Seca, a small pond in high-altitude are located at Itacolomi State Park, a Conservation Unit situated in the Districts of Ouro Preto and Mariana (Minas Gerais state). The high cladoceran diversity in the last study is probably related to the size of lake studied (> 300 m^2) and presence of arms in the form of narrow canals radiating in several directions, and being covered by macrophytes, which act as both shelter against predator and food source (Moreira *et al.* 2016, Barta *et al.* 2018).

Among the species recorded it was not possible to identify any species assemblage characteristic of a particular type of high-altitude water bodies. The identified species are not endemic to high-altitude regions and have been found in other localities (Reid 1993, Shiel 1995). The two species of cladocerans, *S. semiserratus* and *I. spinifer*, presents ecological characteristics that could explain their success in this pound. This is a low depth pond and the first species is usually found in shallow regions of water bodies (Shiel 1995). There is also banks of filamentous algae, a habitat where the second species is usually found (Smirnov & Timms 1983).

Since this study is pioneer in the state of Paraná, more research is necessary in these high-altitudinal regions to create a database for future attempts to understand the environmental conditions and distribution of species of microcrustaceans from these sites. High-altitudinal ponds are, in general, much less influenced by pollution from agriculture and wastewater compared to lowland lakes (Manca & Armiraglio 2002). This condition does not necessarily imply that these ecosystems are pristine because many pollutants are introduced through regional and long-range atmospheric transport (Manca & Armiraglio 2002). Without basic information about the taxa living in these habitats, it is not possible to carry out future assessments of impacts, especially the anthropogenic ones, or even to understand the complexity of these ecosystems (Eskinazi-Sant'anna *et al.* 2011).

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