Acta Limnologica Brasiliensia

Publication of the Brazilian Association of Limnology

Thematic Section "Neotropical Zooplankton Symposium"
Acta Limnologica Brasiliensia, 2025, vol. 37, e106
https://doi.org/10.1590/S2179-975X5624
ISSN 2179-975X on-line version

Cladocerans (Crustacea, Branchiopoda) from Mount Roraima, Venezuela, with new records for this country and the Neotropical region

Cladóceros (Crustacea, Branchiopoda) do Monte Roraima, Venezuela, com novos registros para este país e região Neotropical

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Cite as: Carvalho, V.V. et al. Cladocerans (Crustacea, Branchiopoda) from Mount Roraima, Venezuela, with new records for this country and the Neotropical region. *Acta Limnologica Brasiliensia*, 2025, vol. 37, e106. https://doi.org/10.1590/S2179-975X5624.

Abstract: Aim: Venezuela, located in the north of South America, has ecosystems with great potential for diversity. Among these ecosystems, Mount Roraima located at the border of Venezuela, Brazil, and Guyana, stands out. Mount Roraima is considered a conservation unit, and understanding its fauna is an important tool for species preservation. Its true biodiversity is underestimated, especially for microcrustaceans of the Superorder Cladocera. This study presents a preliminary inventory of the cladocerans of this mountain. **Methods:** Samples were collected from two ponds located in the upper part of Mount Roraima using a conical plankton net. The specimens were then analyzed, photographed, and identified. The richness and relative abundance in each sample were calculated. **Results:** Three species were recorded for the first time in Venezuela. There is a possibility that the Orinoco Basin endemic species *Streblocerus superserricaudatus* occurs in Brazil and Guyana, since the ponds are very close to the border of both countries. There is a co-occurrence of three *Flavalona* species in the territory of Roraima, a fact so far only known for Brazil. Adding the new records to the previously known lists, the cladoceran richness for Venezuela is now 105. **Conclusions:** Samplings in peculiar and remote environments have the potential to reveal new species and records. Further samplings are suggested on Mount Roraima to mitigate potential sampling biases.

Keywords: altitude; biogeography; Chydoridae; sampling effort; tepui.

Resumo: Objetivo: A Venezuela, situada ao Norte da América do Sul, possui ecossistemas com amplo potencial de diversidade. Dentre esses ecossistemas destaca-se o Monte Roraima, localizado na fronteira Venezuela, Brasil e Guiana. O Monte Roraima é considerado uma unidade de conservação e conhecer sua fauna é importante para auxiliar na preservação de espécies. Sua real biodiversidade está subamostrada, principalmente para os microcrustáceos da Superordem Cladocera. Este estudo apresenta um inventário preliminar dos cladóceros dessa montanha. **Métodos:** Foram realizadas

coletas em duas lagoas localizadas na parte alta do Monte Roraima com uma rede cônica de plâncton. Os animais então foram analisados, fotografados e identificados. A riqueza e abundância relativa para cada amostra foram calculadas. **Resultados:** Três espécies foram registradas pela primeira vez para a Venezuela. Existe a possibilidade da espécie endêmica *Streblocerus superserricaudatus* ocorrer no Brasil e na Guiana, pelo fato das lagoas estarem muito próximas à divisa dos dois países. Existe a sobreposição de três espécies de *Flavalona* no território do Roraima, algo que ocorre somente no Brasil. Adicionando os novos registros às listas anteriores conhecidas, a riqueza de cladóceros para a Venezuela agora é de 105. **Conclusões:** Amostragens em ambientes peculiares e de difícil acesso tem o potencial de revelar novas espécies e registros. Sugere-se novas coletas no Monte Roraima de forma a diminuir possíveis vieses amostrais.

Palavras-chave: altitude; biogeografia; Chydoridae; esforço amostral; tepui.

1. Introduction

Venezuela, located in the northern part of South America, is the sixth largest country in the continent in terms of land area, covering 916,44 km^2, representing 5% of the continent. It has a total of 7 Hydrographic Regions: Cuyuní, Orinoco, Gulf of Paria, Caribbean Sea, Lake Valencia, Casiquiare-Negro, and Lake Maracaibo (Venezuela, 2006). The country has a wide range of continental aquatic ecosystems, such as rivers, lakes, and ponds, with great biodiversity potential.

Mount Roraima, located on the border of Brazil, Venezuela, and Guyana, is a table-shaped mountain (tepui), with an elevation of 2,450 meters above sea level (IBGE, 2016). The site serves as a watershed divide between different basins, with streams originating from its different faces. Among the existing aquatic environments, there is a natural pool complex known as Laguna de La Puerta and Los Jacuzzi, located at the summit. The latter pool complex is used as a bathing area by visitors (Fernández-Delgado et al., 2016).

Among inland water microcrustaceans, cladocerans play an important role in energy and mass transfer within the trophic chain, feeding on phytoplankton and serving as food for other invertebrates and fish (Dodson & Frey, 2001; Santos-Wisniewski et al., 2011). Some species are also considered bioindicators of water quality, responding rapidly to changes in physical and chemical variables (Torres et al., 2019).

The first cladoceran studies in Venezuela focused mainly on regions with large lakes, such as Valencia and Maracaibo (Pearse, 1921; Brehm, 1953). This trend was observed throughout South America, as studies took a more ecological approach. During the second half of the 20th century, several expeditions focused on the Venezuelan rainforest and high-altitude regions were conducted, resulting in the description of numerous new taxa (e.g., Frey, 1980; Vasquez & Rey, 1989; Smirnov et al., 1995). The diversity of cladocerans in Venezuela has been summarized in the work of Roa & Lopez (2008) with 112 species, and more recently in the review of Rivas et al. (2023), which, after excluding several "species inquirenda" and taxonomically invalid names, indicated the occurrence of 102 species.

Studies of high-altitude cladocerans can be valuable from a biogeographic perspective, as these regions may harbor endemic species (Kotov, 2008; Kotov et al., 2010). The Tepuis Region in the state of Bolivar (southeastern Venezuela) has received little attention in cladoceran studies (Roa & Vasquez, 1991; Hudec, 1998). This is mainly due to the difficulty in accessing the region, as many rock formations have altitudes above 2000 m with steep, if not nearly vertical, edges. These factors may contribute to the inadequate sampling of cladocerans in Venezuela and the existence of biodiversity gaps, such as the Linean, Wallacean, and consequently the Darwinian (Brown & Lomolino, 1998; Diniz-Filho et al., 2013; Hortal et al., 2015).

Additionally, Mount Roraima is considered a conservation unit by the Venezuelan government for over 60 years (Venezuela, 1962), as well as by the other two countries that share its territory (Brazil and Guyana). It is a widely used site for ecotourism, and tourist access to the natural pools and rivers within the park, coupled with anthropogenic impacts such as the use of sunscreen, some disposal of garbage and other human waste (e.g., feces, toilet paper), and bottom stirring, among others, may contribute to the reduction of the biodiversity present there.

The present study provides a preliminary inventory of the cladoceran species found in two natural pools in the upper part of Mount Roraima, Venezuela.

2. Material and Methods

2.1. Study area

Sampling was conducted in February 2015 in the upper reaches of Mount Roraima (Figure 1) in two ecosystems: (I) in a natural pool within the complex known as Los Jacuzzi (coordinates: 5° 10' 26" N; 60° 45' 52" W), at an altitude of 2238 meters. These are shallow aquatic environments (maximum depth of 2 meters) with cold water and

rocky or crystalline bottoms (Figure 2A), and (II) in a shallow pool with a maximum depth of 40 cm (coordinates: 5º 9' 46" N; 60º 46' 26" W), at an altitude of 2281 meters, located after reaching the upper part of the mountain (Figure 2B).

2.2. Sampling and identification

Sampling was performed using a conical plankton net with a mesh size of 68 µm and a mouth opening of 30 centimeters, dragged horizontally for 10 meters, and filtered for a total of 353 liters per sample. The samples were the placed in Falcon tubes, identified, labeled, and fixed in 70% alcohol.

Later, the animals were taken to the laboratory, sorted, and quantified using a Zeiss Stemi - 305 EDU stereomicroscope. Specimens were analyzed on slides with glycerin under a Leica DMLB light microscope with an attached Flexacam C3 camera. Identification was carried out at the lowest possible taxonomic level using specialized literature (e.g., Elmoor-Loureiro, 1997; Smirnov et al., 1995; Sousa & Elmoor-Loureiro, 2019). Richness and relative abundance were calculated based on the number of individuals found in each sample. Important species, such as those with higher abundance and those considered as new records, were photographed.

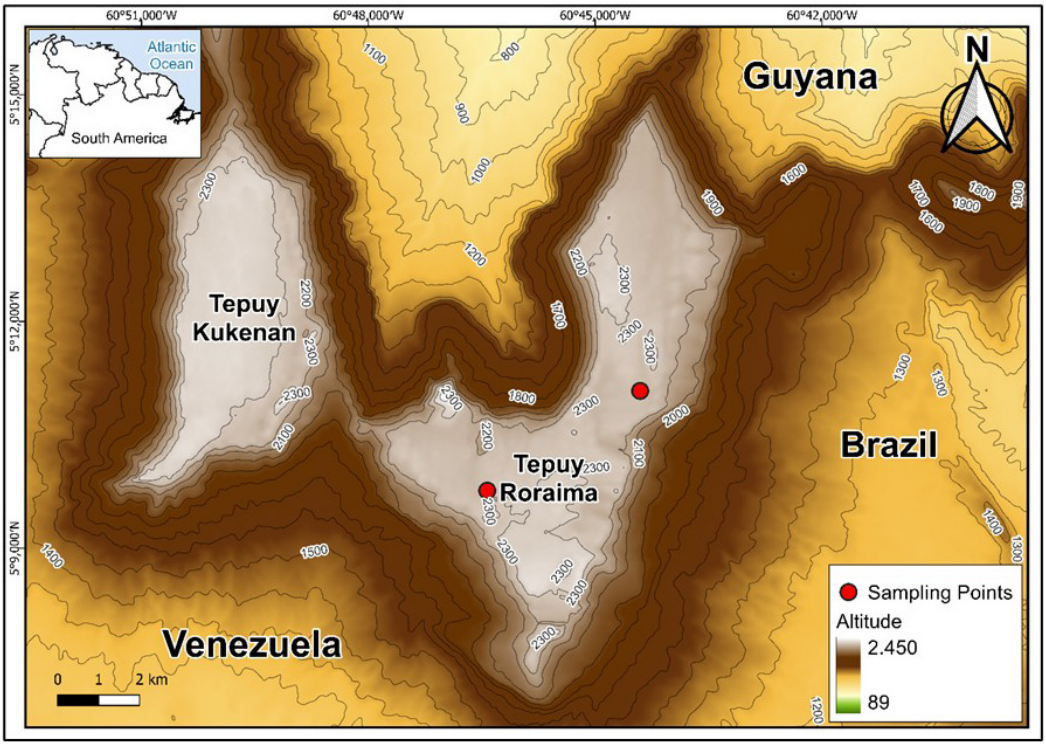

Figure 1. Sampling points and topographic map from Mount Roraima region.

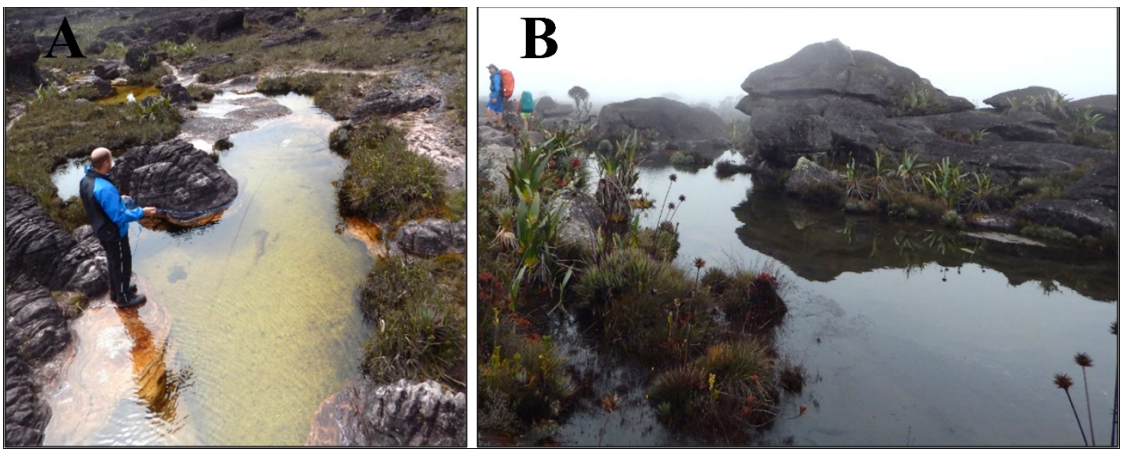

Figure 2. Sampling locations: A) Los Jacuzzi (LJ); B) Shallow Lagoon (SL). Sampling conducted in February, 2015.

3. Results

A total of 9 cladoceran species were identified, distributed in 2 families (Table 1), Chydoridae (8 species) and Macrothricidae (1 species). Of the four species of the genus *Flavalona* Sinev & Dumont, 2016 recorded in the Neotropical region (Sousa & Elmoor-Loureiro, 2018), three of them occur in Mount Roraima (*Flavalona asymmetrica* Brehm, 1931; *Flavalona iheringula* Kotov & Sinev, 2004; and *Flavalona margipluma* Sousa, Santos, Guntzel, Diniz-Filho, de Melo Júnior & Elmoor-Loureiro, 2015 (Figures 3E-G)). It must be highlighted that these three records of *Flavalona* are new for Venezuela. When these new records are added to the list obtained of Rivas et al. (2023), the number of species recorded for the Venezuela is 105. Among these species, *F. asymmetrica* (Figures 3C-D) was the only one that occurred in two ponds and showed the highest contribution in terms of relative abundance (59.82%).

The only species of Macrothricidae found in these ponds, was *Streblocerus superserricaudatus* Smirnov, Alvarez & Castillo 1995, (Figures 4A-C) and presented the second highest relative abundance (15.72%) (Table 1).

4. Discussion

Studies of high-altitude cladocerans in South America have intensified in the last two decades, with the description of new species, as well as the reallocation of taxa described in new genera (Alonso & Sinev, 2017; Alonso & Kotov, 2017; Paggi & Herrera-Martinez, 2020). These studies have focused on the Andean region, an important biodiversity hotspot for the continent. Other studies in high altitude environments in South America have focused on the Itatiaia (Rio de Janeiro) and Mantiqueira (São Paulo) mountain ranges in Brazil, as well as Guaratuba, in the state of Paraná (Santos-Wisniewski et al., 2002, Sousa et al., 2014, Skarabotto et al., 2020).

Studies on cladoceran diversity in Mount Roraima are limited. Hudec (1998) described some species of Aloninae for Roraima. In the same study, a species of *Acroperus* Baird, 1843 was identified and explicitly considered different from *Acroperus harpae* Baird, 1843. Sinev & Elmoor-Loureiro (2010) suggested that these Venezuelan populations represent the species *Acroperus tupinamba* (Figures 3A-B), based on characters such as body shape, setae and denticles of the valves, as well as the postabdominal claw length.

Table 1. Species list, occurrence among sampled sites, and relative abundance. (SL- Shallow Lagoon, LJ – Los Jacuzzi).

Taxon	SL	LJ	Abundance (%)
Macrothricidae Norman & Brady, 1867			
Streblocerus superserricaudatus Smirnov, Alvares & Castillo,1995		x	15.72
Chydoridae Dybowsky & Grochowski, 1894 *emend.* Frey, 1967			
Aloninae Dybowsky & Grochowski, 1894 *emend.* Frey, 1967			
Acroperus tupinamba Sinev & Elmoor-Loureiro, 2010		x	9.17
Alona isabellae Sousa, Elmoor-Loureiro & Santos, 2016		x	1.75
Biapertura ossiani Sinev, 1998		x	5.24
Flavalona asymmetrica Sousa & Elmoor-Loureiro, 2018	x	x	59.82
Flavalona iheringula (Sinev & Kotov, 2004)	x		0.44
Flavalona margipluma (Sousa, Santos, Güntzel, Diniz-Filho, de Melo-Júnior & Elmoor-Loureiro, 2015)	x		1.31
Chydorinae Dybowsky & Grochowski, 1894 *emend.* Frey, 1967			
Alonella dadayi Birge, 1910		x	4.80
Paralona pigra (Sars, 1862)		x	1.75
TOTAL			100

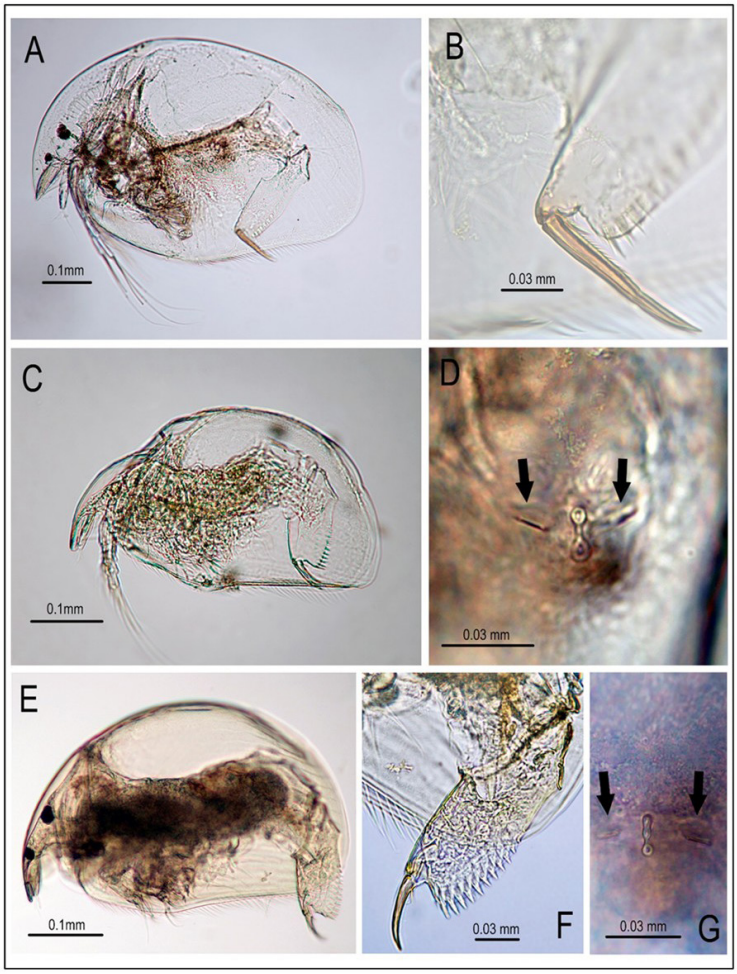

Figure 3. Chydoridae recorded to Mount Roraima. A) Lateral view of *Acroperus tupinamba* Sinev & Elmoor-Loureiro, 2010. B) *idem*, postabdominal claw. C) Lateral view of *Flavalona asymmetrica* Sousa & Elmoor-Loureiro, 2018. D) *idem*, main and lateral head pores (arrow). E) Lateral view of *Flavalona margipluma* Sousa, Santos, Güntzel, Diniz-Filho, de Melo-Júnior & Elmoor-Loureiro, 2015. F) *idem*, postabdomen; G) idem, main and lateral head pores (arrow).

Paralona pigra, Sars,1862 a species of Chydoridae, exhibits a wide geographic distribution. The species was initially described by Sars as *Chydorus piger*, and during the 20th century, the genus underwent several revisions (Lilljeborg, 1900; Flossner, 1962; Sramek-Husek et al., 1962), leading to the creation of the genus Paralona (Sramek-Husek, 1962). The first documented record of the species in Venezuela was reported in a stream in Tepui Auyan in the 1991 (Roa & Vasquez, 1991). Subsequent collections in the same region have continued to document the species (Dumont & Smirnov, 1996; Hudec, 1998; Roa & Lopez, 2008). In literature, there are evidences for the potential for cryptic diversity within this species, based on some characters such as the setulation pattern of the ventral margin of valves, the distance between head pores, and morphology of the thoracic limbs (Dumont & Smirnov, 1996).

Concerning the three identified species of *Flavalona*, *F. asymmetrica* is a neotropical species recorded only in Brazil, but now it has an extended geographical distribution. Another point to highlight is that in Roraima there is a co-occurrence of the three species of the gender *Flavalona* (*F. asymmetrica*, *F. iheringula* and *F. margipluma*). In Brazil, for example, this overlap only occurs in an area of the Federal District that intersects the Hydrographic Regions of Paraná, São Francisco, and Tocantins-Araguaia (Sousa & Elmoor-Loureiro, 2018).

The only Macrothricidae found in this study, *S. superserricaudatus* is endemic to the Orinoco Hydrographic Region, Venezuela. The first description of *S. superserricaudatus* was based on material collected in lentic environments, mainly in shallow puddles, some located at high altitudes, such as Auyan Tepui in the state of Bolivar

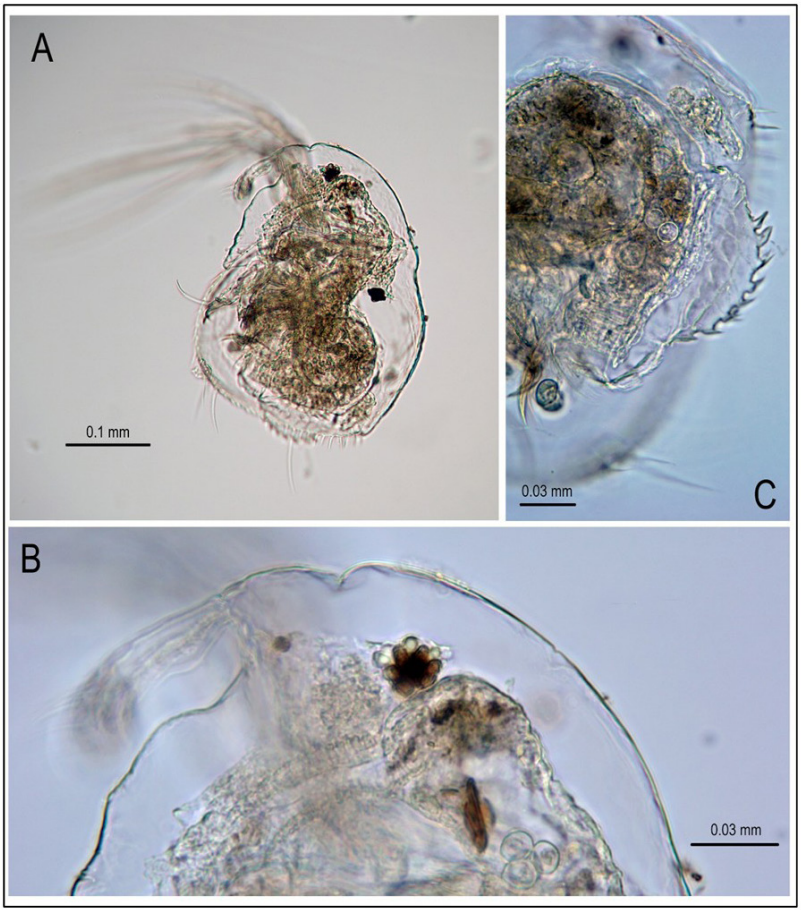

Figure 4. *Streblocerus superserricaudatus* Smirnov, Alvares & Castillo, 1995 from Mount Roraima; A) Habitus. B) Head. C) Postabdomen.

(Smirnov et al., 1995). Due to the geographical location of the environments studied here, it is possible that *S. superserricaudatus* also occurs in Brazil and Guyana in the same rock formations. An inventory with an increase in the number of new environments in Mount Roraima is necessary to verify this hypothesis of geographic distribution expansion, for this species.

The sampling carried out on Mount Roraima focused on shallow environments, mainly with the presence of macrophytes. Possibly for this reason, few planktonic animals were found. Hudec (1998) showed the same trend, finding Chydoridae, Macrothricidae and only two species of Daphniidae that are not exclusively planktonic: *Ceriodaphnia pulchella* G.O. Sars, 1862, and *Simocephalus acutirostratus*, King, 1853.

From the biogeographical point of view, it is important to sample in littoral zones, since the largest family of cladocerans (Chydoridae) predominates in this type of habitat. Samplings only in limnetic zones limits the true knowledge of the fauna of a given region (Elmoor-Loureiro, 2000). New expeditions to the Mount Roraima should be conducted to mitigate potential sampling biases.

We hope that the new occurring species in this study can serve as a stimulation for future researches on high altitude cladocerans, improving the actual sampling effort and knowledge of these regions.

Acknowledgements

The authors thank CAPES-PROEX for granting a scholarship (number 3300406-4), which provided financial support throughout the research period.

Data availability

The entire dataset supporting the results of this study has been published in the article itself.

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Received: 10 June 2024
Accepted: 25 June 2025

Associate Editor: Cláudia Bonecker.