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Ricciocarpos natans (Marchantiophyta, Ricciaceae), new to Costa Rica, with a survey of its presence in Latin America

Ricciocarpos natans (Marchantiophyta, Ricciaceae), nueva para Costa Rica, con una revisión de su presencia en América Latina

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Abstract:

Background and Aims: *Ricciocarpos natans* is one of the few species of truly aquatic hepatics. It has a subcosmopolitan distribution and appears to be more common in temperate areas. The species has been considered to be very rare in Central America where it was known only from Panama. The objective of this study is to report the presence of this species in Costa Rica and to survey its current distribution in Latin America.
Methods: We provide an overview of the distribution of the floating aquatic liverwort *Ricciocarpos natans* in Latin America based on literature, herbarium specimens and unequivocal photographic records across the region, as well as field work in Costa Rica.
Key results: *Ricciocarpos natans* is reported as new for Costa Rica. We provide the most complete survey to date of the geographic distribution of the species in Latin America.
Conclusions: Our survey shows that *Ricciocarpos natans* appears to be more common and widely distributed in the Neotropics than previously assumed. Its assumed rarity seems to be the result of insufficient collection efforts.

Key words: aquatic plants, geographic distribution, Neotropics, liverworts, wetlands.

Resumen:

Antecedentes y Objetivos: *Ricciocarpos natans* es una de las pocas especies de hepáticas verdaderamente acuáticas. Tiene una distribución subcosmopolita y parece ser más común en áreas templadas. La especie ha sido considerada muy rara en América Central, donde solo se conocía de Panamá. El objetivo de este estudio es reportar la presencia de esta especie en Costa Rica y revisar su distribución en América Latina.
Métodos: Brindamos una descripción general de la distribución de la hepática acuática flotante *Ricciocarpos natans* en América Latina con base en la literatura, especímenes de herbario y registros fotográficos inequívocos en toda la región, así como trabajo de campo en Costa Rica.
Resultados clave: *Ricciocarpos natans* se reporta como nueva para Costa Rica. Brindamos el estudio más completo hasta la fecha de la distribución geográfica de la especie en América Latina.
Conclusiones: Nuestro estudio muestra que *Ricciocarpos natans* parece ser más común y más ampliamente distribuida en el Neotrópico de lo que se suponía anteriormente. Su supuesta rareza parece ser el resultado de esfuerzos de recolección insuficientes.

Palabras clave: distribución geográfica, hepáticas, humedales, Neotrópico, plantas acuáticas.

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Introduction

The freshwater wetlands constitute one of the most productive ecosystems on Earth (Keddy, 2010) and they play a major role in the livelihoods of millions of people worldwide (Gokce, 2018). Most of the embryophytes that dominate freshwater wetland ecosystems are vascular plants, even though strictly aquatic species represent just 1% of all vascular plant species (Chambers et al., 2008). Non-vascular embryophytes (Bryophytes *sensu lato*) are more scarce and usually less conspicuous. Although dependent on water availability to release their male gametes, there are relatively few bryophyte species that could be considered strictly aquatic, i.e., require to be submerged or floating in water for extended periods of time to complete their life cycles (Chambers et al., 2008). According to Cook (1999), only 0.4-0.5% of all Bryophytes *sensu lato* could be considered as strictly aquatic, although a larger number could be helophytic or rheophytic (e.g., Shevock et al., 2017; Gradstein et al., 2018), semi-aquatic (growing underwater temporarily) or facultatively aquatic (mostly terrestrial species with occasional populations that can survive submerged permanently, Gradstein et al., 2018). Among liverworts, Cook et al. (1974) and Cook (1999) mention that only three genera have strictly aquatic representatives.

Among the few strictly aquatic Marchantiophyta, *Ricciocarpos* Corda (sometimes spelled "*Ricciocarpus*"), a monotypic genus that includes only *R. natans* (L.) Corda, is one of the most widespread (Gradstein et al., 2001; Bischler-Causse et al., 2005) and easily recognizable (at least the free-floating forms). Albeit it can be locally abundant, we suspect that *R. natans* has been underreported in the Neotropics, probably due to its small size and usually inconspicuous nature (pers. obs.), and perhaps due to neglect of the habitat by plant collectors. In Latin America distributional data seem to indicate that the species has been most frequently collected in the area covering south and southeastern Brazil and northeastern Argentina (Bischler-Causse et al., 2005), with fewer records at lower latitudes (several in the Amazon basin and the Pantanal region). In the present study we report the presence of *Ricciocarpos natans* in Costa Rica for the first time and provide an overview of the distribution of this taxon in Latin America based on herbarium, literature, and photographic records.

Materials and Methods

Field work

Field work was carried out in freshwater wetlands near Estero Damas, in the Distrito Parrita, Cantón Parrita, in the central area of Puntarenas province, Costa Rica, at 9°31'44.4''N 84°15'52.7''W (datum WGS84) and 6 m of elevation. These wetlands span both sides of the Costanera Sur Highway (National Route 34) between the towns of Palo Seco and Damas. The annual precipitation averages ca. 3500 mm, and the average temperatures range between 22.7 °C for the lows and 31 °C for the highs. There is a short dry season that extends from January to March (IMN, 2008). According to Tosi (1969), the Tropical Moist Forest Life Zone is typical in the area. However, not counting the mangrove forests of the Damas and Palo Seco estuaries, little forest cover remains in the immediate vicinity, as most of the land around the wetlands has been cleared for pasture or oil palm plantations.

Plant thalli were collected by hand both from the water surface and immediately adjacent wet mud. These were placed in paper envelopes and dried at room temperature for ca. 1 week. A few additional living thalli were collected with water from the wetland, placed in ziplock plastic bags, and brought to cultivation. The specimens were examined using hand lenses (Five Elements, Jewelers Loupe with Twin Lens, Model MJ368212, China) and dissecting microscopes (Carl Zeiss, ZEISS Stemi 508 Greenough Stereo Microscope, Jena, Germany). In order to identify them, we consulted Gradstein et al. (2001), Bischler-Causse et al. (2005), Madriñán et al. (2017) and Gradstein (2021).

Geographic data and collections examined

We also collected distributional data of *Ricciocarpos natans* from Latin America from the literature (see results and discussion), GBIF.org - Global Biodiversity Information Facility (GBIF, 2022), as well as the online databases of the AAU, CEN, COL, F, HVASF, INPA, MEXU, MO, NY, R, RB, and UPCB herbaria (acronyms according to Thiers, 2022). These data were complemented with unequivocal photographic evidence from the citizen science iNaturalist.org website (iNaturalist, 2022a). Because plants of *Ricciocarpos natans* can grow on mud and look similar to some *Riccia* L. species, we focused on free floating plants, herbarium specimens,

and literature records we could either see by ourselves or, if not, that were determined by experienced botanists (i.e., the authors of the treatments, see results) that are familiar with *Ricciocarpos natans*. All the specimens cited in "Examined herbarium material" were seen by us (as scanned specimens) and we added the name of the person who made the previous determination when explicitly stated in the specimen labels (if not stated we could not add it).

Results

Taxonomy

Ricciocarpos natans (L.) Corda in Opiz, Naturalientausch 12: 651. 1829.

≡ *Riccia natans* L., Syst. Nat., ed. 10: 1339. 1759.

TYPE: (illustration in) Dillenius, Hist. Musc., ed. 1: 536. Lichen 18. Tab. LXXVIII, fig. 18: (OXF, 2022) (lectotype: OXF!, designated by Iamonico and Iberite, 2014).

Thallus more or less triangular, light green, sometimes dichotomously branched, forming rosettes; often two or four thalli (apparently derived from fragments of a single parental thallus) clumped together, attached to each other by their ventral scales; segments 3-6 mm wide, with a dorsal groove; ventral scales covering the whole underside of the thallus, dark brown, long-ligulate, to ca. 1 cm long, margins irregularly serrulate (Fig. 1).

Location and habitat in Costa Rica

The wetland where the Costa Rican *Ricciocarpos natans* specimens were found, is dominated by large populations of *Cyperus giganteus* Vahl and *Oxycaryum cubense* (Poepp. & Kunth) Palla in the most sun-exposed areas, and *Heliconia marginata* (Griggs) Pittier in areas closer to sparse tree cover. The wetland appears to be permanent, as even in the dry season it has standing water. The most abundant floating plant we found was an as-yet undetermined species of *Azolla* Lam. Other wetland plants found in this locality include *Caperonia palustris* (L.) A. St.-Hil., *Eichhornia crassipes* (Mart.) Solms, *Heteranthera limosa* (Sw.) Willd., *Heteranthera spicata* C. Presl, *Persicaria acuminata* (Kunth) M. Gómez and *Salvinia* sp.

We found relatively few thalli of *Ricciocarpos natans* (Fig. 1), most of which were floating in the less vegetated, open areas of the wetland, among the much more abundant *Azolla* sp. A few thalli, however, were found on wet mud, close to the waterline. Unlike the reddish *Azolla*, *Ricciocarpos natans* plants were bright green.

Material examined: COSTA RICA. Puntarenas, cantón Parrita, distrito Parrita, wetlands on the southern side of the Costanera Sur Highway, between Palo Seco and Damas, 9°31'44.4''N, 84°15'52.7''W (Datum WGS84), 6 m, 17.IX.2021, *R. Acuña C. et al. 2555* (USJ).

Additional examined material: BRAZIL. Amazonas, município Manaus, Lago Amazônico, Lago de águas lênticas, erva aquática, 26.IX.2017, *D. S. D. Jesus et al. 1* (INPA, determined by D. S. D. Jesus and L. O. Demarchi). Bahia, município Curaçá, Margem do Rio São Francisco, em frente à Pousada Recanto Campestre, 349 m, 24.VI.2016, *J. A. Siqueira Filho 3736* (HVASF, determined by J. A. Siqueira Filho). Goiás, município Formosa, Margem direita do rio Bezerra, cerca de 1 km a Leste da Lagoa Perta Pé (área do Exército), 5.III.2002, *G. Pereira-Silva et al. 6022* (CEN, determined by O. Yano). Mato Grosso do Sul, município Miranda, Río Miranda, Mata de Galeria, a beira do lago, 120 m, 28.VIII.1996, *D. P. Costa et al. 3209* (RB, determined by D. C. Cargill). Paraná, município Pontal do Paraná, Rio Guaraguaçu, 25°45'51.9''S, 48°33'18.21''W, 25.IX.2017, *E. S. Araujo and A. A. Padial 103* (UPCB, determined by E.S. Araujo). Pernambuco, município Cabrobó, Balsa, 8°33'44.0''S, 39°27'51.7''W, 28.I.2011, *A. C. C. P. Silva et al. 70* (RB, determined by F. A. Ferreira). Rio de Janeiro, município Cabo Frio, IX.1881, *C. A. W. Schwacke 3189* (RB, determined by D. C. Cargill). Rio Grande do Sul, município unknown, quinta prope oppidum Rio Grande, in paludibus (illegible), 4.XII.1892, *C. A. M. Lindman B-133* (R-Bryophyta). Santa Catarina, município Jaguaruna, swamp, 28.II.1952, *L. B. Smith and R. Reitz 5930* (R-Bryophyta). State not listed, Catalogus Geographicus Plantarum Brasilieae Tropicae, s.d., *Burchell 7426* (NY). PARAGUAY. Concepción, Río Napegue, flotante en palmar inundable de

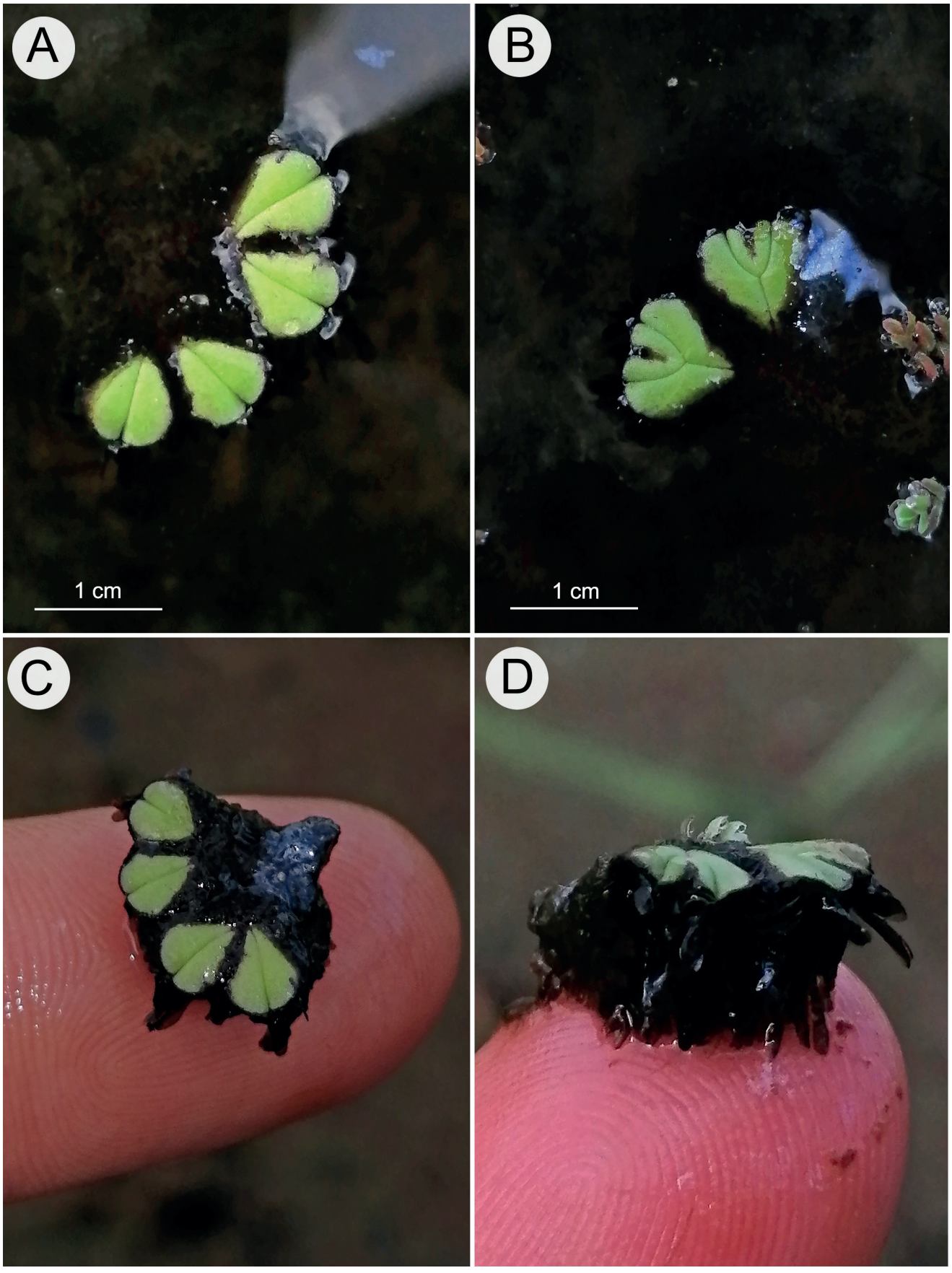

Figure 1: *Ricciocarpos natans* (L.) Corda from Costa Rica (voucher: *Acuña et al. 2555*, USJ). A, B. thalli floating in their habitat. C, D. thalli taken out of the water to show the ventral scales, top and side views, respectively.

Copernicia alba, 22°58'32.9''S, 57°43'38.5''W, 17.IX.1997, *F. Mereles and M. Soloaga 7117* (F).

Selected records from iNaturalist

ARGENTINA. Buenos Aires, Partido Monte, San Miguel de Monte, 19.IX.2021, observation by RAP (iNaturalist, 2022b). Corrientes, Departamento San Martín, cerca de Yapeyú, 25.VII.2021, observation by Enzo Edgardo Ferreyra (iNaturalist, 2022c). La Pampa, Departamento Utracán, General Acha, 22.X.2021, observation by Daniel Óscar Molina (iNaturalist, 2022d).

BRAZIL. Acre, município Rio Branco, Área de Proteção Ambiental Lago do Amapá, 18.IX.2021, observation by Gabriel Fernando (iNaturalist, 2022e). Amazonas, município Manaus, Manaus, INPA, 18.VIII.2017, observation by Nate Hartley (iNaturalist, 2022f). Rio Grande do Sul, município Rio Grande, near Saco do Silveira, 31.X.2020, observation by Vinicius S. Domingues (iNaturalist, 2022g). São Paulo, município Mogi das Cruzes, Mogi das Cruces, wetlands between Colégio Mello Dante and Rio Tietê, 16.VI.2022, observation by Yoannis Domínguez (iNaturalist, 2022h)

CHILE. Valparaíso, Provincia Valparaíso, Humedal de Mantagua, 8.IV.2020, observation by Lorena Flores Toro (iNaturalist, 2022i).

COLOMBIA. Huila, municipio Pitalito, Humedal La Conoca, 30.XI.2021, observation by Jorge L. Peña (iNaturalist, 2022j).

ECUADOR. Sucumbíos, cantón Shushufindi, cerca de laguna Pilchicocha, 12.XII.2017, observation by Michael Hogan (iNaturalist, 2022k).

MEXICO. Querétaro, municipio Cadereyta de Montes, Jardín Botánico Regional de Cadereyta "Ing. Manuel González de Cosío", 17.V.2021, observation by José Aranda Pineda (iNaturalist, 2022l).

PERU. Loreto, provincia Maynas, cerca del Área de Conservación Ambiental Garzal de Santa María de Fátima 11.VII.2018, observation by Ignacio Torres García (iNaturalist, 2022m).

URUGUAY. Rocha, cerca de Santa Isabel, 13.VIII.2020, observation by Ramiro Pereira Garbero (iNaturalist, 2022n).

Distribution of *Ricciocarpos natans* in Latin America

We found evidence that in Latin America this species has been collected previously in Mexico, Cuba, Panama, Venezuela, Colombia, Ecuador, Peru, Bolivia, Paraguay, Brazil, Uruguay, Argentina and Chile, at elevations ranging from sea level to ca. 2800 m (Bischler-Causse et al., 2005, with updates). Ours, the first record for *R. natans* in Costa Rica, is the first anywhere between Panama and Mexico (Fig. 2).

A synthesis of the known distribution of *Ricciocarpos natans* in Latin America (Fig. 2) is presented hereafter.

WEST INDIES: so far, the species has been reported only for Cuba (Howe, 1923; Gradstein et al., 2001; Bischler-Causse et al., 2005; Gradstein, 2021). We were unable to find information about the exact localities where the species was collected, but it is likely that the specimen *Wright 3964* (NY, 2023) could be the basis for Howe's record for the island.

MEXICO: Bischler-Causse et al. (2005) and Mendoza-Ruiz (2008) mentioned the presence of this species in the states of Hidalgo, Jalisco, México, Morelos, San Luis Potosí and Tabasco. We also found evidence of its presence in Querétaro (iNaturalist, 2022l).

CENTRAL AMERICA: previously known from Panama (Stotler et al., 1998; Bischler-Causse et al., 2005) and now, from the Pacific slope of central Costa Rica. The authors of this paper have explored in detail many wetlands across Costa Rica, but were able to find the species only at one location (see above). The presence of the species in Costa Rica had not been reported before (e.g., Dauphin, 2005), although Dauphin et al. (1998) mentioned that its occurrence in the country was to be expected.

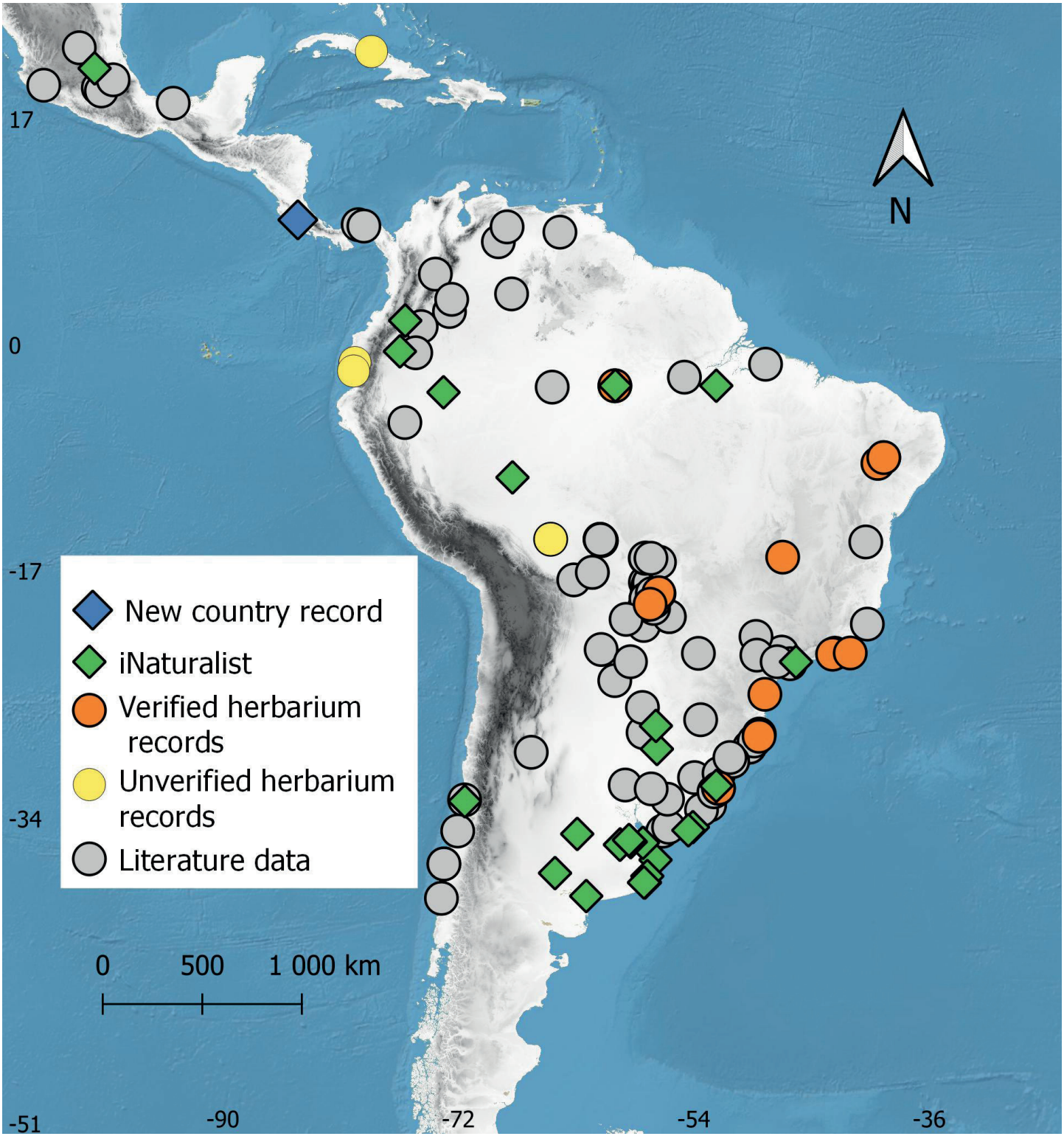

Figure 2: Distribution of *Ricciocarpos natans* (L.) Corda in Latin America based on a revision of the literature, observed herbarium specimens, unequivocal photographic records (iNaturalist, see text for details) and selected unverified specimens from Cuba, western Ecuador and northern Bolivia.

VENEZUELA: the presence of *Ricciocarpos natans* has been reported from the Orinoco basin in the states of Anzoátegui, Apure, and Cojedes (Rial and Lasso, 1998; Infante-Sánchez and Heras-Pérez, 2002; Rial, 2006).

COLOMBIA: although Gradstein and Uribe (2016) and Gradstein (2021) reported the species only from the Andes of Cundinamarca, Álvaro-Alba et al. (2011), Madriñán et al. (2017) and Rial (2018) mentioned its presence in the extensive lowlands of the Amazon and Orinoco basins in the departments of Caquetá, Guainía, Guaviare and Meta. We also found evidence of its presence in Huila (iNaturalist, 2022j).

ECUADOR: Terneus (2007) reported this species from the Amazon basin in the province of Sucumbíos. An additional record was recently posted online from the same province (iNaturalist, 2022k). Earlier, the specimens *L. B. Holm-Nielsen & S. Jeppesen 70* and *E. Terneus & E. Landolt 483* were collected in the province of Guayas (AAU, 2023). The species is lacking in the catalogues by León-Yánez et al. (2006) and Gradstein (2020).

PERU: the species has been reported so far only from the northeastern Amazon basin in the department of Loreto (Bischler-Causse et al., 2005).

BOLIVIA: Churchill et al. (2009) mentioned this species from the lowlands of the department of Santa Cruz. According to TROPICOS (2023), the species is also known from the department of Beni (*Sanjinés 505*, LPB, fide TROPICOS, 2023).

BRAZIL: according to Gradstein and Costa (2003), Bischler-Causse et al. (2005), Yano and Bordin (2017) and Gissi and Peralta (2022), *Ricciocarpos natans* is widely distributed in Brazil and found in the states of Amazonas, Bahia, Espírito Santo, Goiás, Mato Grosso, Mato Grosso do Sul, Pará, Paraná, Pernambuco, Rio de Janeiro, Rio Grande do Sul, Santa Catarina, and São Paulo. We also found evidence of its presence in Acre (iNaturalist, 2022e).

PARAGUAY: Mereles et al. (2015) mentioned this species for the departments of Alto Paraguay, Boquerón, Ñeembucú and Presidente Hayes. However, the only specimen we were able to examine comes from Concepción.

ARGENTINA: Bischler-Causse et al. (2005), Hässel de Menéndez and Rubies (2009) and Fuertes and Manzano (2017) included the provinces of Buenos Aires, Corrientes, Entre Ríos, Formosa and La Rioja as part of the range of *Ricciocarpos natans*. We also found evidence for its presence in La Pampa (iNaturalist, 2022d).

URUGUAY: Bischler-Causse et al. (2005) mentioned the species for San José and mapped it for other three departments (Fig. 83 in Bischler-Causse et al., 2005), including Canelones. We also found evidence of its presence in Rocha (iNaturalist, 2022n).

CHILE: Rodríguez (1977), Bischler-Causse et al. (2005) and Cuvertino et al. (2005) reported the species from the regions of Araucanía, Biobío, Maule and Valparaíso.

We were unable to find any record or evidence of the presence of *Ricciocarpos natans* in most of the West Indies (with the exception of Cuba), the Guianas and Central America north of Costa Rica.

Discussion

Ricciocarpos natans is a very distinctive plant and it could be confused reasonably only with *Riccia*, the much more species-rich and the other known genus in Ricciaceae. However, as Gradstein et al. (2001), Bischler-Causse et al. (2005), Madriñán et al. (2017) and Gradstein (2021) indicate, *Ricciocarpos* specimens are usually floating on water, unlike *Riccia* that are usually terrestrial. We also noticed that the specimens we collected had abundant, long, and dense ventral scales (Fig. 1); with the help of a dissecting microscope, we observed that these ventral scales were long-ligulate (unlike the much shorter scales of *Riccia*) and with serrulate margins (a diagnostic characteristic of this taxon), important traits that Bischler-Causse et al. (2005) mention as differences between both genera of Ricciaceae. According to these authors, the plants are monoecious with the gametangia and sporophytes in the dorsal groove.

Ricciocarpos natans is widely distributed in the temperate zones of both hemispheres (Gradstein et al., 2001),

but appears to be more scattered in the tropical areas. Although previous works, such as Gradstein et al. (2001), Bischler-Causse et al. (2005), Terneus (2007), Mereles et al. (2015), Madriñán et al. (2017) and Gradstein (2021), show the species is widely distributed in Latin America and could be found from sea level to almost 3000 m a.s.l., this paper demonstrated that the current number of records from Latin American has increased considerably since the study by Bischler-Causse et al. (2005). However, the quantity of herbarium specimens and observations in most countries of the region remain very low and populations of *Ricciocarpos natans* seem to be often far apart from each other. The species is usually sterile and is rarely seen with sporophytes (Bischler-Causse et al., 2005).

Although no abundance estimates for these plants in Latin America were found, we suggest that the apparent localized distribution pattern and scarcity in the tropical regions of Latin America could be an artifact from undercollection (the plants being quite small and usually not occurring in large groups, although there are exceptions: iNaturalist, 2022f). Nevertheless, we suspect that other factors may also be at play regarding this apparent (or real) rarity, but so far, no detailed systematic study in Latin America has been made to determine which ecological factors (biotic and abiotic) could play a role affecting the abundance of *Ricciocarpos natans*. This species is also considered scarce yet widely distributed across Africa (Blockeel et al., 2008), a continent that covers a similar latitudinal range as Latin America. Gradstein (2021) mentions that this species can be found "scattered at high elevations in the tropics"; however, most of the specimens we examined, and most records in both the literature and consulted databases, come from low elevation areas under 500 m a.s.l., in particular from the Orinoco and Amazon basins and the Pantanal region of Brazil. Our survey also demonstrates that, although still scattered, *Ricciocarpos natans* could be more common than assumed in previous works. However, it is puzzling how vast areas of seemingly potentially suitable habitats in the region remain devoid of this species (as our experience in Costa Rica could suggest, where only a single population has been located).

Although Costa Rica is considered one of the best explored tropical countries botanically, new occurrence records are to be expected for members of the aquatic flora that are known both to the north and south of the country, but that have eluded previous detection. As it has been shown (Crow et al., 1987; Blanco and Jiménez, 2019; Acuña-Castillo et al., 2021, and the present contribution), some new records were from poorly collected wetland localities that may be considered "less spectacular" than Palo Verde in Guanacaste, Caño Negro in Alajuela and Tortuguero in Limón, underlining the importance of also inventorying small wetlands.

Author contributions

RAC, JEJ and LEBS carried out the field studies. RAC conceived the study and compiled the distributional information about the species. JEJ prepared figure 1. LEBS prepared figure 2. RAC and MAB compiled the bibliography. RAC wrote the manuscript with contributions from all the authors. All authors contributed to the discussion, revision and final approval of the manuscript.

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