

## Rediscovery of *Sphagnum perichaetiale* and *S. trinitense* (Sphagnaceae) in Puerto Rico

AMELIA MERCED<sup>1</sup>, STEVE MALDONADO-SILVESTRI<sup>2</sup> & TAMARA HEARTSILL-SCALLEY<sup>3,4</sup>

<sup>1</sup>Department of Biology, University of Puerto Rico Mayagüez, Mayagüez Puerto Rico 00981

✉ [amelia.merced@upr.edu](mailto:amelia.merced@upr.edu);  <https://orcid.org/0000-0003-4649-8126>

<sup>2</sup>Herbarium of the Botanical Garden of the University of Puerto Rico, San Juan, Puerto Rico 00926

✉ [lareselvadepuertorico@gmail.com](mailto:lareselvadepuertorico@gmail.com);  <https://orcid.org/0009-0007-4218-7415>

<sup>3</sup>USDA Forest Service, International Institute of Tropical Forestry, San Juan, Puerto Rico 00926

✉ [tamara.heartsill@usda.gov](mailto:tamara.heartsill@usda.gov);  <https://orcid.org/0000-0003-0550-4147>

<sup>4</sup>Department of Environmental Sciences, University of Puerto Rico Río Piedras, San Juan, Puerto Rico 00925

### Abstract

Two *Sphagnum* species thought to be extinct in Puerto Rico were rediscovered. The current distribution range of these species is substantially reduced compared to the historical distribution based on herbarium records. We contribute notes on *S. perichaetiale* and *S. trinitense* distribution, habitat, and a checklist of associated plant species. A key to the three extant *Sphagnum* species found in Puerto Rico is presented along with suggestions for conservation efforts to preserve *S. perichaetiale* and *S. trinitense*. The habitat where the species are found, white sand wetlands, is rare in Puerto Rico and has been subject to past and present disturbances. We suggest that protection of the current habitat is crucial for the preservation of these species and other rare plants.

**Key words:** bryophytes, coastal wetlands, peatmoss, tropics, conservation

### Introduction

Botanical explorations of the 19 and 20 century documented bryophytes for the islands of the Puerto Rico archipelago, some of which have not been found again (Sastre-DJ I & Santiago-Valentin 1996). Three species of *Sphagnum* are listed for Puerto Rico: *S. portoricense* Hampe (1852: 359) from high elevation at El Yunque National Forest, Carite Forest and Sierra de Pandura, *S. perichaetiale* Hampe (1848: 93) and *S. trinitense* Müller Halae (1848: 102) reported from Laguna Tortuguero Nature Reserve and the coastal plains between Dorado and Arecibo (Fig. 1) (Crum & Steere 1957, Sastre DJ & Buck 1993, Karlin 2006). During recent expeditions to the reported localities of *Sphagnum portoricense* we were only able to confirm the occurrence of this species within El Yunque National Forest, the populations previously documented from Cerro La Santa in the Carite Forest Reserve and Cuchilla de Panduras in Yabucoa were not found (Merced 2023). The other two species, *S. perichaetiale* and *S. trinitense* from the northern coastal plains were considered extirpated from Puerto Rico, since no records or sightings of the species existed in over 35 years and attempts to find them were unsuccessful (Sastre-DJ & Tan 1995, I. Sastre-De Jesús pers. comm. 2005). These local extinctions are possibly related to the habitat destruction associated to the draining of wetlands in the area and other human activities (Gómez-Gómez & Torres Sierra 1988, Sastre-DJ & Tan 1995).

*Sphagnum* dominated peatlands are found in boreal and temperate regions, and at high elevation in alpine or subalpine tropical regions; however, *Sphagnum* peatlands are very rare at low elevations in the tropics (Whitney *et al.* 2025). In a systematic effort to evaluate the status of the lost *Sphagnum* species in Puerto Rico we used information from herbarium collections to guide the search for these species. In this article we describe the historical and present distribution of these two *Sphagnum* species and describe the ecology of these mosses in the white sand wetlands of Puerto Rico. We also identify present and potential threats to extant local populations of *S. perichaetiale* and *S. trinitense* and current effort to protect these species and their habitat.

## Materials and methods

Specimens and records from MICH, NY, SJ and UPR herbaria were used to study the distribution of *S. perichaetiale* and *S. trinitense* (Table 1). We identify the historical distribution, main collectors, dates, and localities for these species. Using specimen descriptions and GPS coordinates georeferenced from specimens, we determined sites to visit. In addition, we identified potential habitats, lowland wetlands with open canopy and white sands (siliceous or quartz) substrates using Google Maps (Google n.d.). Multiple expeditions were made between 2020–2024 to search for *Sphagnum* at the Laguna Tortuguero Nature Reserve and other localities outside the reserve that shared similar conditions (Fig. 1). At the site where the two *Sphagnum* species were found, we counted and measured a number of patches. More than 13 visits were made to Ciénaga Prieta between February 2021 and February 2026. These visits allowed us to observe seasonal changes in the landscape, surface water dynamics, and the vegetation. To describe the associated vegetation, we established one 10 m x 10 m (0.01 ha) fixed square plot for each species, utilizing where most of the *Sphagnum* spp. occurred as the center. All species of vascular plants within were recorded, along with their botanical family and growth form (Table 2).

**TABLE 1.** List of herbarium specimens and localities for *Sphagnum perichaetiale* and *S. trinitense*. Specimens examined are marked with an asterisk (\*).

| <i>Sphagnum perichaetiale</i> Hampe     |   |                     |        |      |                  |                                                           |
|-----------------------------------------|---|---------------------|--------|------|------------------|-----------------------------------------------------------|
| Herbarium                               |   | Collector           | Number | Year | Locality         |                                                           |
| NY                                      |   | P. E. E. Sintenis   | s.n.   | 1887 | Bayamon          |                                                           |
| UPR                                     | * | A. A. Heller        | 1339   | 1899 | Vega Baja        |                                                           |
| NY                                      |   | L. M. Underwood     | 949    | 1901 | Manati/Vega Baja | Near R. R. track from Manati to Vega Baja                 |
| MICH                                    |   | A. Chase            | s.n.   | 1913 | Manati/Vega Baja | Laguna Tortuguero                                         |
| NY                                      |   | N. L. Britton       | 6679   | 1922 | Dorado           | Vicinity of Dorado                                        |
| SJ                                      | * | R. O. Woodbury      | s.n.   | 1960 | Manati           | Bo. Tierras Nuevas Salientes, just S of Laguna Tortuguero |
| NY                                      |   | G. R. Proctor       | 41126  | 1985 | Vega Alta        | Bo. Sabana, NE of Regadera                                |
| UPPRP                                   | * | A. Merced           | 343    | 2021 | Vega Alta        | Bo. Sabana, Ciénaga Prieta                                |
| UPPRP                                   | * | A. Merced           | 363    | 2021 | Vega Alta        | Bo. Sabana, Ciénaga Prieta                                |
| UPPRP                                   | * | A. Merced           | 419    | 2022 | Vega Alta        | Bo. Sabana, Ciénaga Prieta                                |
| MAPR                                    | * | A. Merced           | 827    | 2025 | Vega Alta        | Bo. Sabana, Ciénaga Prieta                                |
| <i>Sphagnum trinitense</i> Müller Halae |   |                     |        |      |                  |                                                           |
| Herbarium                               |   | Collector           | Number | Year | Locality         |                                                           |
| UPR                                     | * | A. A. Heller        | 1340   | 1899 | Vega Baja        |                                                           |
| NY                                      |   | L. M. Underwood     | 943    | 1901 | Manati/Vega Baja | Near R. R. track from Manati to Vega Baja                 |
| NY                                      |   | L. M. Underwood     | 950    | 1901 | Manati/Vega Baja | Near R. R. track from Manati to Vega Baja                 |
| NY                                      |   | N. L. Britton       | 6678   | 1922 | Dorado           | Vicinity of Dorado                                        |
| UPR                                     | * | N.L. & E.G. Britton | 7819   | 1923 | Manati/Vega Baja | West end of Laguna Tortuguero.                            |
| NY                                      |   | N. L. Britton       | 8008   | 1924 | Arecibo          | Laguna Tortuguero                                         |
| NY                                      |   | N. L. Britton       | 8992   | 1927 | Dorado           | Near Dorado                                               |
| NY                                      |   | N. L. Britton       | 8992   | 1927 | Dorado           | Near Dorado                                               |
| SJ                                      | * | R. O. Woodbury      | s.n.   | 1960 | Manati           | Bo. Tierras Nuevas Salientes, just S of Laguna Tortuguero |
| UPPRP                                   | * | A. Merced           | 376    | 2021 | Vega Alta        | Bo. Sabana, Ciénaga Prieta                                |
| MAPR                                    | * | A. Merced           | 826    | 2025 | Vega Alta        | Bo. Sabana, Ciénaga Prieta                                |

**TABLE 2.** List of plants associated to *Sphagnum perichaetiale* and *S. trinitense*.

| Scientific name                                                                                                   | Family                    | Growth Form | <i>Sphagnum perichaetiale</i> | <i>Sphagnum trinitense</i> |
|-------------------------------------------------------------------------------------------------------------------|---------------------------|-------------|-------------------------------|----------------------------|
| <i>Didymopanax morototoni</i> (Aubl.) Decne. & Planch.                                                            | Araliaceae                | Tree        | √                             | √                          |
| <i>Tabebuia heterophylla</i> (DC.) Britton                                                                        | Bignoniaceae              | Tree        | √                             | √                          |
| <i>Telmatoblechnum serrulatum</i> (Rich.) Perrie, D.J.Ohlsen & Brownsey                                           | Blechnaceae               | Herb        | √                             | √                          |
| <i>Burmannia capitata</i> (Walter ex J.F.Gmel.) Mart.                                                             | Burmanniaceae             | Herb        | √                             | √                          |
| <i>Chrysobalanus icaco</i> L.                                                                                     | Chrysobalanaceae          | Shrub       | √                             | √                          |
| <i>Clusia rosea</i> Jacq.                                                                                         | Clusiaceae                | Tree        | √                             | √                          |
| <i>Ipomoea setifera</i> Poir.                                                                                     | Convolvulaceae            | Vine        | √                             | √                          |
| <i>Rhynchospora fascicularis</i> (Michx.) Vahl subsp. <i>fascicularis</i>                                         | Cyperaceae                | Herb        | √                             | √                          |
| <i>Rhynchospora rariflora</i> (Michx.) Elliott                                                                    | Cyperaceae                | Herb        |                               | √                          |
| <i>Rhynchospora intermixta</i> C.Wright                                                                           | Cyperaceae                | Herb        | √                             |                            |
| <i>Scleria microcarpa</i> Nees ex Kunth                                                                           | Cyperaceae                | Herb        |                               | √                          |
| <i>Drosera capillaris</i> Poir.                                                                                   | Droseraceae               | Herb        | √                             | √                          |
| <i>Chamaecrista diphylla</i> (L.) Greene                                                                          | Fabaceae-Caesalpinioideae | Herb        | √                             | √                          |
| <i>Andira inermis</i> (W.Wright) Kunth ex DC.                                                                     | Fabaceae-Faboideae        | Tree        | √                             |                            |
| <i>Zornia reticulata</i> Sm.                                                                                      | Fabaceae-Faboideae        | Herb        | √                             | √                          |
| <i>Hyptis atrorubens</i> Poit.                                                                                    | Lamiaceae                 | Herb        | √                             | √                          |
| <i>Cassytha filiformis</i> L.                                                                                     | Lauraceae                 | Vine        | √                             |                            |
| <i>Utricularia subulata</i> L.                                                                                    | Lentibulariaceae          | Herb        | √                             | √                          |
| <i>Miconia prasina</i> (Sw.) DC.                                                                                  | Melastomataceae           | Shrub       | √                             | √                          |
| <i>Miconia racemosa</i> (Aubl.) DC.                                                                               | Melastomataceae           | Shrub       | √                             | √                          |
| <i>Nepsera aquatica</i> (Aubl.) Naudin                                                                            | Melastomataceae           | Herb        | √                             | √                          |
| <i>Myrcia citrifolia</i> (Aubl.) Urb. var. <i>citrifolia</i>                                                      | Myrtaceae                 | Shrub       | √                             | √                          |
| <i>Guapira fragrans</i> (Dum.Cours.) Little                                                                       | Nyctaginaceae             | Tree        |                               | √                          |
| <i>Ouratea litoralis</i> Urb.                                                                                     | Ochnaceae                 | Shrub       | √                             | √                          |
| <i>Sauvagesia erecta</i> L.                                                                                       | Ochnaceae                 | Herb        | √                             | √                          |
| <i>Spathoglottis plicata</i> Blume                                                                                | Orchidaceae               | Herb        | √                             | √                          |
| <i>Anatherum virginicum</i> (L.) Spreng. var. <i>virginicum</i>                                                   | Poaceae                   | Herb        | √                             | √                          |
| <i>Dichantheium strigosum</i> (Muhl. ex Elliott) Freckmann subsp. <i>glabrescens</i> (Griseb.) Freckmann & Lelong | Poaceae                   | Herb        |                               | √                          |
| <i>Eragrostis elliottii</i> (Elliott) S.Watson                                                                    | Poaceae                   | Herb        |                               | √                          |
| <i>Trichantheium parvifolium</i> (Lam.) Zuloaga & Morrone                                                         | Poaceae                   | Herb        | √                             | √                          |
| <i>Myrsine cubana</i> A.DC.                                                                                       | Primulaceae               | Tree        |                               | √                          |
| <i>Hexasepalum apiculatum</i> (Willd.) Delprete & J.H.Kirkbr.                                                     | Rubiaceae                 | Herb        | √                             | √                          |
| <i>Palicourea croceoides</i> Ham.                                                                                 | Rubiaceae                 | Shrub       | √                             | √                          |
| <i>Spermacoe verticillata</i> L.                                                                                  | Rubiaceae                 | Herb        |                               | √                          |
| <i>Actinostachys pennula</i> (Sw.) Hook.                                                                          | Schizaeaceae              | Herb        | √                             |                            |
| <i>Smilax coriacea</i> Spreng.                                                                                    | Smilacaceae               | Vine        | √                             | √                          |
| <i>Xyris elliottii</i> Chapm.                                                                                     | Xyridaceae                | Herb        | √                             | √                          |
| <i>Zamia furfuracea</i> L.f. ex Aiton                                                                             | Zamiaceae                 | Shrub       | √                             |                            |

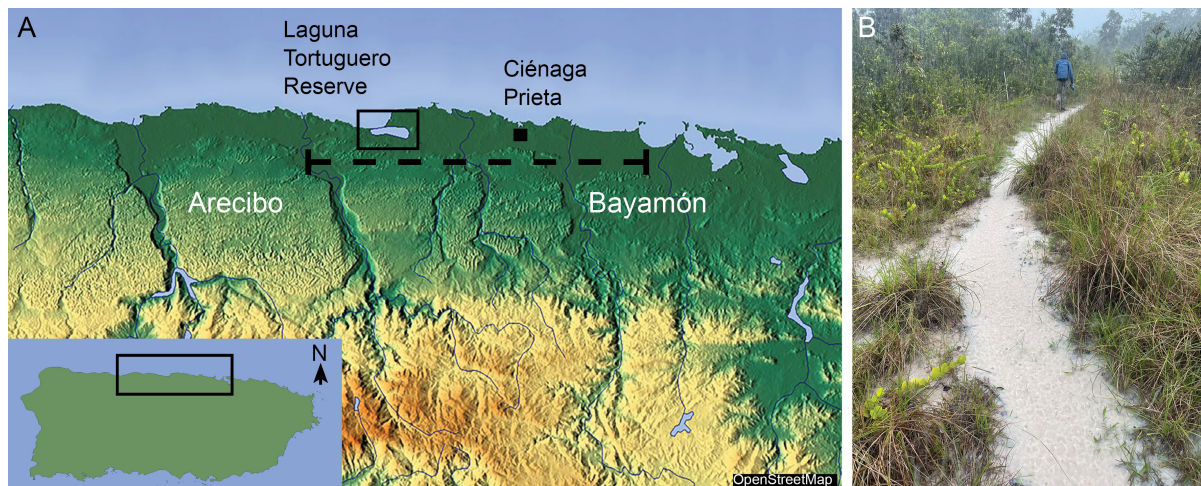


**FIGURE 1.** A. Map of the island of Puerto Rico showing past and present distribution of *S. perichaetiale* and *S. trinitense*. Historical distribution range (dash line) is estimated based on herbarium records with unspecified localities between Arecibo and Bayamón; the municipalities of Manatí, Vega Baja, Vega Alta and Dorado are in this range, also the Laguna Tortuguero Reserve (rectangle). Present distribution (square) is restricted to Ciénaga Prieta, Bo. Sabana in Vega Alta. B. Wetland habitat of white siliceous sand.

## Results and discussion

*Sphagnum perichaetiale* Hampe (1848: 93) (sect. *Sphagnum*):—Forms compact cushions that are green-yellowish to reddish in color, these are medium size plants, with capitulum of 1.5cm (Fig. 2A, C–D). Stems have branch fascicles of 2 spreading and 1–2 pendulous branches; branch leaves are short and blunt, and stem cortical cells have weak to conspicuous spiral reinforcing fibrils. Chlorophyllous cells, in cross section, are rectangular to elliptic, exposed on both sides of the leaf. *Sphagnum sintenisii* Müller Halae and *S. erythrocalyx* Hampe ex Müller Halae are synonyms of *S. perichaetiale* (Griffin 1981, WFO 2024).



**FIGURE 2.** *Sphagnum* species rediscovered and their habit. A. *Sphagnum perichaetiale* B. *Sphagnum trinitense* C–D. *S. perichaetiale* grows by grasses and sedges forming compact cushions of robust plants. E–F. *S. trinitense* grows under the shade of *Icacos* shrubs and forms loose mats of delicate plants. Scale bar = 1 cm.

***Sphagnum trinitense*** Müller Halae (1848: 102) (sect. *Cuspidata*):—Forms disperse carpets above water level or immersed in water, they have a bright light green color, these are small delicate plants with capitula of 0.5–1.0cm (Fig. 2B, E–F). Stems have branch fascicles of 2–3 elongated, thin spreading branches and 1–3 pendulous branches; branch leaves are ovate to ovate-lanceolate with serrate margin, and stem cortical cells are not differentiated. Chlorophyllous cells, in cross section, are triangular to trapezoid, more exposed on the convex surface of the leaf. *S. cuspidatum* var. *serrulatum* (Schlieph.) Schliephacke is a synonym of *S. trinitense* (Robinson *et al.* 2023).

**Rediscovery:**—In 2021, *Sphagnum perichaetiale* and *S. trinitense* were rediscovered, restricted to a single locality in an unprotected wetland, Ciénaga Prieta, located in the northern coastal plains of Puerto Rico (Bo. Sabana, Vega Alta) at an elevation range of 0–10 meters above sea level (Fig. 1). After many attempts, the two species were not found at the Laguna Tortuguero Nature Reserve (Manatí-Vega Baja). Small to medium patches of *S. perichaetiale* were found off a trail, in Ciénaga Prieta, in a wet sand area surrounded by grasses, sedges, and shrubs. Patches of *S. perichaetiale* were not found near any superficial water body. Months later, we found *S. trinitense* in a recently inundated area associated also with grasses, sedges and shrubs. Five populations of *S. perichaetiale* and two populations of *S. trinitense* were documented and measured. The two larger populations of *S. perichaetiale* occupied an area of approximately 4.6 m x 5 m and 7 m x 3 m, while the two populations of *S. trinitense* measured 2.5 m x 0.5 m and 5 m x 0.5 m. Depth of *Sphagnum* layer ranged from 2–30 cm. The presence of small patches of *S. perichaetiale* in distant areas could indicate the establishment of new populations. However, we did not find sporophytes in any of the populations.

**Key to the species of *Sphagnum* in Puerto Rico (modified from Crum & Steere 1957):**—Order Sphagnales: Branches in fascicles, crowded at stem in dense heads (capitulum); leaf cells unistratose, with large, fibrillose, hyaline cells arranged among linear green cells.

1. Small delicate plants with capitula of 0.5–1.0cm, outer cortical cells of stems and branches without fibrils (efibrillose), branch leaves lanceolate and slightly concave ..... *S. trinitense*
- Robust plants with capitula larger than 1.5cm, outer cortical cells of stems and branches with spiral fibrils (fibrillose), branch leaves ovate and strongly concave ..... 2
2. Cortical cells of branches funnel-shaped at base and nested into the cell below, chlorophyll cells triangular in section, exposed on the inner surface of the leaf ..... *S. portoricensis*
- Cortical cells of branches plane or slightly receding (not funnel-shaped) at base, chlorophyll cells subrectangular or lenticular in section ..... *S. perichaetiale*

**Distribution:**—*Sphagnum perichaetiale* has a worldwide distribution; in the Caribbean it is present in all of the Greater Antilles and in some of the Lesser Antilles (GBIF 2026a). *Sphagnum trinitense* occurs from the east coast and south of North America (from Massachusetts to Mississippi) and in some of the Caribbean islands (Jamaica and Puerto Rico) (Andrus 2007, GBIF 2026b). Genetic analysis revealed that *S. trinitense* from Puerto Rico is closely related to populations in South Carolina (Robinson *et al.* 2023).

The historical distribution range of these two species in Puerto Rico is in the north-central coastal plains, occurring in ditches and on wet white sands (Crum & Steere 1957). Herbarium specimens of *S. perichaetiale* and *S. trinitense* from Puerto Rico were collected from 1887 to 1927, followed by one collection of both species in 1960 and a single collection of *S. perichaetiale* in 1985, thus most collections are from over 80 years ago (Table 1). In Puerto Rico, *S. perichaetiale* was reported for Bayamón, near Dorado, by the railroad tracks (R.R. in the label) from Manatí to Vega Baja, Vega Baja, Laguna Tortuguero and Vega Alta (Fig. 1). *Sphagnum trinitense* was reported near Dorado, by the railroad tracks from Manatí to Vega Baja, Vega Baja and Laguna Tortuguero (Fig. 1). Descriptions in herbarium specimens do not include specific information about the locality or coordinates, some include scant habitat information such as ‘sandy shore’ and ‘wet bank’.

Based on the surveys made in this study we document that the present distribution of *S. perichaetiale* and *S. trinitense* in Puerto Rico is considerably smaller than the historic distribution based on herbarium records (Table 1). Both species are restricted to a coastal plains lowland wetland area in Bo. Sabana in Vega Alta, Puerto Rico (Fig. 1). Extant population distributions described here are supported with specimens collected and deposited at the UPRRP and MAPR herbaria (Table 1).

**Habitat description:**—*Sphagnum perichaetiale* and *S. trinitense* occur on white silica quartz sands marsh in wet or seasonally inundated, nutrient-poor wetland, and surrounded by vegetation that does not form a continuous canopy, thus dominated by grasses, sedges, and specialized wetland plants. These marshes are mostly rain-fed (weakly minerotrophic), or sustained by a high-water table, but can also be subject to occasional flooding events.

**Associated vegetation:**—Although *S. perichaetiale* and *S. trinitense* share several associated species, we observed

some differences in their immediate habitat composition. *Sphagnum perichaetiale* encircles the bases of tuft mounds formed by a community of *Anatherum* P.Beauv. and *Rhynchospora* Vahl spp., under a fragmented shrubby layer of *Chrysobalanus icaco* L., *Miconia racemosa* (Aubl.) DC., and *Clusia rosea* Jacq. In contrast, *S. trinitense* occurs in shaded drainage ditches, depressions, and swales that seasonally flood. It is sheltered by mostly caespitose (*Anatherum virginicum* var. *virginicum* Campbell, *Rhynchospora rariflora* (Michx.) Elliott, *Scleria microcarpa* Nees ex Kunth, and *Xyris elliottii* Chapm.) and scrambling (*Trichantheum parvifolium* (Lam.) Zuloaga & Morrone) grasses and sedges, surrounded and shaded by *Chrysobalanus icaco* shrubs (Table 2). We speculate that this overlap creates moisture retention below, likely aiding the mosses in withstanding periods of extreme heat and preventing desiccation. We observed a similar association for *S. portoricense* in Puerto Rico, found in trails and open areas in El Yunque National Forest (Howard 1968, Karlin 2006, Merced 2023), which also grows intimately associated with scrambling grasses like *Isachne angustifolia* Nash and *Steinchisma laxum* (Sw.) Zuloaga, as well as other caespitose grasses, sedges, and herbaceous wetland species, which are surrounded or overlaid by sparse woody vegetation.

We identified a total of 39 plant species, with 26 shared between both sites (Table 2). Most species recorded are herbaceous, and all but two are native. The two non-native species observed were the orchid *Spathoglottis plicata* Blume and the shrub *Zamia furfuracea* L.f. ex Aiton. The first species was introduced through the ornamental trade several decades ago and is now widespread throughout the island (Ackerman 2017). While the latter also shares an ornamental origin, it has not been previously vouchered and represents a newly introduced and naturalized species record for Puerto Rico.

For both *Sphagnum* species, the dominant and most abundant associated species are the shrub *Chrysobalanus icaco*, followed by the grass *Anatherum virginicum* var. *virginicum*. Among the native species recorded in the wider locality, five of them; *Actinostachys pennula* (Sw.) Hook., *Burmannia capitata* (Walter ex J.F.Gmel.) Mart., *Drosera capillaris* Poir., *Rhynchospora rariflora*, and *Utricularia subulata* L. are listed as critical elements of the flora of Puerto Rico by the Department of Natural and Environmental Resources (DNER 2008a), while others are generally considered rare and/or restricted to the white sand habitats in Puerto Rico.

**Landscape and land use history in Ciénaga Prieta:**—The Ciénaga Prieta wetland is located in the northern coastal plain, among coastal sand dunes (no longer existing) and karst uplands, occurring over the Vega Alta aquifer, between the valley of the Cibuco river and the Laguna Tortuguero watershed (Gómez-Gómez & Torres-Sierra 1988, Delgado 2000). The landscape is dominated by marsh type wetlands with rare blanket quartz sands substrates (Fig. 1B). Longer hydroperiod favors herbaceous vegetation, in contrast to wetlands with shorter inundated periods which favor development of woody vegetation (Lugo *et al.* 2001). The Ciénaga Prieta marsh is the main surface water body formed by the Vega Alta aquifer (Veve & Taggart 1996, Sepúlveda 1999, Lugo *et al.* 2001).

Historically, the hydrologic connection of Ciénaga Prieta to the karst aquifers included greater discharge into the marsh and maintained a larger area of open water than what is found at the time of our current study. Gómez-Gómez and Torres-Sierra (1988) estimated that by 1985 Ciénaga Prieta was receiving four times less aquifer discharge than it had in the 1930's, and this resulted in a 3 m decrease in the water table, in addition to being subjected to changes in land cover and topography for transportation and urban infrastructure. Many drainage ditches in the coastal plain wetlands and the creation of a drainage channel from Ciénaga Prieta to the Río Cibuco exacerbated the decline in the marsh water table and surface waters. It was documented that before the drainage channel, Ciénaga Prieta had a water level altitude of 3.66 m above sea level (Gómez-Gómez & Torres-Sierra 1988). The changes in surface topography and land cover, in addition to more contemporary increased aquifer withdrawals, have resulted in the fragmentation and present diminished condition of this marsh habitat (Lugo *et al.* 2001, Sepúlveda 1999).

**Conservation efforts:**—After the rediscovery and further surveys to confirm the range of these species, we searched for a mechanism to provide protection to these locally rare bryophytes. In 2023, *S. perichaetiale* and *S. trinitense* were listed as critical elements of the flora of Puerto Rico by the Department of Natural and Environmental Resources of Puerto Rico. These are the first bryophytes added to the list. Although this status does not provide legal protection to the species, it recognizes them as important components of an ecosystem, a metric used to calculate the value of a particular habitat (DNER 2008b) especially when present in lands considered for development or protection. All extant populations are currently outside protected land.

Past and present threats to *S. perichaetiale* and *S. trinitense* populations include reduction in population size, habitat destruction by human activities such as deforestation, urban encroachment, illegal garbage disposition, and fires set to abandoned cars (also described in Sastre-DJ & Tan 1995, Sastre-DJ & Santiago-Valentin 1996). Based on the NatureServe Conservation Status Assessment (Master *et al.*, 2012), *S. trinitense* and *S. perichaetiale* can be preliminarily assigned an S1 rank (Subnationally Critically Imperiled) in Puerto Rico. Land management, particularly draining of the channels, changes the phreatic level of the remaining wetlands resulting in drier conditions. Efforts to

protect the two *Sphagnum* species could include the protection of a reasonable extension of their white sands habitat wetland and reintroduction to protected lands such as the Laguna Tortuguero Nature Reserve. The blanket white sands substrate type is uncommon in Puerto Rico, which further supports the need for the conservation of this fragmented and rare habitat.

## Conclusions

The rediscovery of *S. perichaetiale* and *S. trinitense* after decades of not being observed in the wild, suggests that in spite of disturbances these species can survive in contemporary times. It also shows that natural areas not currently protected may yield botanical novelties, which may in addition bring forth their consideration and need for their protection. The reduced distribution of *S. perichaetiale* and *S. trinitense* seems to be the result of anthropogenic changes in the landscape. Similarly, the distribution of *S. portoricense* is also restricted to a single forest in Puerto Rico, though the underlying causes are unknown. The type collection of *S. portoricense* was described from Puerto Rico and it would be a great loss if it becomes extirpated from the island.

A recent discovery of a lowland tropical peatland with *Sphagnum* groundcover in Belize might be the only one documented to this date (Whitney *et al.* 2025). *Sphagnum* species are cold adapted which limits their establishment at low elevations in warm tropical regions (Ma *et al.* 2022). However, Whitney *et al.* (2025) noted that other tropical coastal peatland with *Sphagnum* might be underreported and fragmented. Although, the discrete patches of *S. perichaetiale* and *S. trinitense* found in Puerto Rico are not dominant in the landscape, they could be remnants of a similar mosaic wetland assemblage. These discoveries highlight the scarcity of knowledge about tropical lowland *Sphagnum* ecosystems (Whitney *et al.* 2025) and supports the importance of our finding. White sands are found in other locations in the Caribbean and the Americas, at each location they contain many distinct vegetation types, composed of unique plant communities often dominated by endemic, rare and specialized vegetation species (Adeney *et al.* 2016). The Ciénaga Prieta marsh, despite historical degradation and current threats by anthropogenic impacts, exemplifies this habitat and is one of the few remaining white sand wetlands in Puerto Rico.

Although in Puerto Rico only 29% of herbaceous wetlands are protected, once they are protected, previously fragmented wetlands often become aggregated, maintaining or increasing their occupied area (Gao & Yu 2014), which is an additional benefit to protection in designated reserves. Land protection management actions may be beneficial for species relying on wetland habitats for survival, especially for species that may be occurring in sub-optimal habitat or near their distribution limit, which may further affect species diversity and ecosystem function of wetland communities (Yu *et al.* 2019). Laws and regulations that protect water sources and wetlands have been effective mechanisms for wetland preservation. Baseline information provided here that identifies the habitat and the ecological conditions that support these species yield important insights for proper management and conservation of this unique white sand wetland in Puerto Rico. The protection of Ciénaga Prieta would be significant for a number of rare plant species that locally only exist here, including the two *Sphagnum* species.

## Acknowledgements

This project was supported by the USDA FS State, Private and Tribal Forestry program at the International Institute of Tropical Forestry, in collaboration with the University of Puerto Rico-Río Piedras, Herbarium of the Biology Department. We thank Garry Potts, Kevin Carlin, Magaly Figueroa, Juan Córdova and James Ackerman for their help with logistics, materials and facilities. We are immensely grateful to the people that have accompanied us to the field, Kurt Miller, Gabriel Muriente Pastrana, Joel A. Mercado-Díaz, Lara M. Sánchez-Morales, Omar Monzon-Carmona, Miriam Toro Rosario, Erik Ruiz Parrilla. We thank José Sustache from the PR Department of Natural Resources and the SJ Herbarium, James Ackerman at the UPRRP Herbarium, and Eugenio Santiago at the UPR Herbarium for access to the collection and help in finding specimens. Sean Robinson, Marta Nieto-Lugilde and the laboratory of Jonathan Shaw at Duke University helped to corroborate the species of *Sphagnum* for specimens collected by AM. We thank the reviewers for their comments which improved our manuscript.

## References

- Ackerman, J.D. (2017) Orchidées invasives: accélération de la colonisation et de la propagation. *L'Orchidophile* 213: 167–173.
- Anderson, A.B. (1981) White-Sand Vegetation of Brazilian Amazonia. *Biotropica* 13: 199–210.  
<https://doi.org/10.2307/2388125>
- Andrus, R.E. (2007) *Sphagnum trinitense*. In: Flora of North America Editorial Committee (Eds.) *Flora of North America North of Mexico*, Vol. 27. Oxford University Press, New York & Oxford, pp. 85.  
[https://doi.org/10.1663/0013-0001\(2007\)61\[312b:fonano\]2.0.co;2](https://doi.org/10.1663/0013-0001(2007)61[312b:fonano]2.0.co;2)
- Crum, H.A. & Steere, W.C. (1957) The mosses of Porto Rico and the Virgin Islands. *Scientific Survey of Porto Rico and the Virgin Islands* 7: 396–599.
- Delgado, C.I. (2000) *The nature, origin and occurrence of quartz sand deposits in Puerto Rico*. University of Puerto Rico, Mayagüez, 119 pp.
- DNER (2008a) *Elementos críticos de la División de Patrimonio Natural—Plantas*. Division of Natural Heritage, Department of Natural and Environmental Resources of the Commonwealth of Puerto Rico, San Juan, 12 pp.
- DNER (2008b) *Procedimiento Para Evaluar y Determinar La Categoría de Un Hábitat Natural de Acuerdo a La Nueva Ley de Vida Silvestre de Puerto Rico*. Department of Natural and Environmental Resources of the Commonwealth of Puerto Rico, San Juan, 38 pp.
- Gao, Q. & Yu, M. (2014) Discerning fragmentation dynamics of tropical forest and wetland during reforestation, urban sprawl, and policy shifts. *PLoS ONE* 9: e113140.  
<https://doi.org/10.1371/journal.pone.0113140>
- GBIF (2026a) Occurrence Download: *Sphagnum perichaetiale*. (7 September 2026) The Global Biodiversity Information Facility.  
<https://doi.org/10.15468/dl.aq9z kf>
- GBIF (2026b) Occurrence Download: *Sphagnum trinitense*. (7 September 2026) The Global Biodiversity Information Facility.  
<https://doi.org/10.15468/dl.frn9r5>
- Gómez-Gómez, F. & Torres-Sierra, H. (1988) *Hydrology and effects of development on the water-table aquifer in the Vega Alta quadrangle, Puerto Rico (No. 87-4105)*. US Geological Survey, 62 pp. [<https://pubs.usgs.gov/wri/1987/4105/report.pdf>]  
<https://doi.org/10.3133/wri874105>
- Google (n.d.) *Map of Puerto Rico's North Coast*. Available from: <https://www.google.com/maps/@18.4433373,-66.403622,12z> (accessed 2020–2022)
- Griffin, D.G. III (1981) El género *Sphagnum* en Los Andes de Colombia y Venezuela. Clave para las especies frecuentes u ocasionales con notas ecológicas y taxonómicas. *Cryptogamie, Bryologie, Lichénologie* 2: 201–211.
- Hampe, G.E.L. (1852) *Linnaea* 25: 359.
- Hampe, G.E.L. (1848) In: Müller, C. (1848) *Synopsis Muscorum Frondosorum omnium hucusque Cognitorum*, Vol. 1. Sumptibus Alb. Foerstner, Berolini, pp. 93.
- Howard, A.R. (1968) The ecology of an elfin forest in Puerto Rico, 1. Introduction and composition studies. *Journal of the Arnold Arboretum* 49: 381–418.  
<https://doi.org/10.5962/p.324699>
- Karlin, E.F. (2006) Update on the distribution and ecology of *Sphagnum portoricense*. *The Bryologist* 109: 541–550.  
[https://doi.org/10.1639/0007-2745\(2006\)109](https://doi.org/10.1639/0007-2745(2006)109)
- Lugo, A.E., Castro, L.M., Vale, A., López, T.d.M., Prieto, E.H., Martínó, A.G., Rolón, A.R.P., Tossas, A.G., McFarlane, D.A., Miller, T., Rodríguez, A., Lundberg, J., Thomlinson, J., Colón, J., Schellekens, J.H., Ramos, O. & Helmer, E. (2001) *Puerto Rican Karst—A Vital Resource*. United States Department of Agriculture Forest Service Gen. Tech. Report WO-65, 101 pp.  
<https://doi.org/10.2737/WO-GTR-65>
- Ma, X.Y., Xu, H., Cao, Z.Y., Shu, L. & Zhu, R.L. (2022) Will climate change cause the global peatland to expand or contract? Evidence from the habitat shift pattern of *Sphagnum* mosses. *Global Change Biology* 28: 6419–6432.  
<https://doi.org/10.1111/gcb.16354>
- Master, L.L., Faber-Langendoen, D., Bittman, R., Hammerson, G.A., Heide, B., Ramsay, L., Snow, K., Teucher, A. & Tomaino, A. (2012) *NatureServe Conservation Status Assessments: Factors for Evaluating Species and Ecosystem Risk*. NatureServe, Arlington, VA.
- Merced, A. (2023) *Monitoring the distribution, ecology and conservation status of Sphagnum in Puerto Rico*. Technical report of the observations, management recommendations and status of *Sphagnum* populations in Puerto Rico. International Institute of Tropical Forestry. [<https://usforestserv.on.worldcat.org/oclc/1593828658>]
- Müller, C. (1848) *Synopsis Muscorum Frondosorum omnium hucusque Cognitorum*, Vol. 1. Sumptibus Alb. Foerstner, Berolini, pp. 102.
- Robinson, S.C., Nieto-Lugilde, M., Duffy, A.M., Martínez Muñoz, K., Aguero, B., Merced, A., Hassel, K., Flatberg, K.I. & Shaw, A.J.

- (2023) The *Sphagnum cuspidatum* complex: phylogeny, species delimitation, and morphology. *Biological Journal of the Linnean Society* 141: 466–492.  
<https://doi.org/10.1093/biolinnean/blad111>
- Sastre-D.J., I. & Buck, W.R. (1993) Annotated checklist of the mosses of Puerto Rico. *Caribbean Journal of Science* 29: 226–234.
- Sastre-D.J., I. & Santiago-Valentín, E. (1996) Bryology in Puerto Rico: knowledge prior to and after the Scientific Survey of Porto Rico and the Virgin Islands. *Annals of the New York Academy of Sciences* 776: 115–122.
- Sastre-D.J., I. & Tan, B. (1995) Problems of bryophyte conservation in the tropics: a discussion, with case example from Puerto Rico and the Philippines. *Caribbean Journal of Science* 31: 200–206.
- Sepúlveda, N. (1999) *Ground-water flow, solute transport, and simulation of remedial alternatives for the water-table aquifer in Vega Alta, Puerto Rico*. Water-Resources Investigations Report 97-4170. U.S. Geological Survey, San Juan, 96 pp.  
<https://doi.org/10.3133/wri974170>
- Veve, T.D. & Taggart, B.E. (Eds.) (1996) *Atlas of ground-water resources in Puerto Rico and the US Virgin Islands*. Water-Resources Investigations Report 94-4198. U.S. Geological Survey, 161 pp. [[https://www.rekursosaguapuertorico.com/GW\\_Atlas\\_of\\_PR\\_USGS.pdf](https://www.rekursosaguapuertorico.com/GW_Atlas_of_PR_USGS.pdf)]  
<https://doi.org/10.3133/wri944198>
- WFO (2024) *Sphagnum sintenisii* Müll.Hal. World Flora Online. Available from: <http://www.worldfloraonline.org/taxon/wfo-0001190196> (accessed 1 September 2024)
- Whitney, B.S., Swindles, G.T., Cameron, I., Galka, M. & Meerman, J.C. (2025) A tropical *Sphagnum* peatland ecosystem in lowland Belize. *Current Biology* 35: 4587–4594.e3.  
<https://doi.org/10.1016/j.cub.2025.08.002>
- Yu, M., Rivera-Ocasio, E., Heartsill-Scalley, T., Davila-Casanova, D., Rios-López, N. & Gao, Q. (2019) Landscape-level consequences of rising sea-level on coastal wetlands: saltwater intrusion drives displacement and mortality in the twenty-first century. *Wetlands* 39: 1343–1355.  
<https://doi.org/10.1007/s13157-019-01138-x>