



Rediscovering *Andreaea subulata* Harv., a critically endangered moss in Brazil

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ABSTRACT

Andreaea subulata is a moss species that occurs throughout the Southern Hemisphere. In Brazil, it is restricted to high-altitude fields in the state of Rio de Janeiro. The last recorded collection of this species in the country was made 95 years ago in the Itatiaia National Park (INP). It was never seen or collected again since then and it was, therefore, considered 'probably extinct' in Brazil. Here we report the rediscovery of this species in the INP and provide information on its ecology and conservation status in Brazil (Critically Endangered) as well as conservation recommendations. The newly found population is very small and grows on granitic rocks in humid areas. The principal threat to the species in Brazil is habitat loss.

Keywords: bryophytes, high-altitude fields, conservation, ecology, moss, rediscovery.

The genus *Andreaea* Hedw. is cosmopolitan but restricted to temperate regions and mountain tops in tropical regions, exclusively on granite outcrops (Schultze-Motel 1970; Peralta 2020). Few localities in Brazil have been found to provide favorable conditions for the occurrence of the genus, namely, the Serra da Mantiqueira and Serra do Mar mountain chains at elevations between 1,000 and 2,880 m a.s.l. within the Atlantic Forest phytogeographic domain (Peralta 2020).

In Brazil, *Andreaea subulata* Harv. was known only from three collections made ca. 100 years ago in the state of Rio de Janeiro (Flora do Brasil 2020). The first collection was made by Dusén in Itatiaia in 1902 and is deposited in R Herbarium. Then, it was collected by Lützelburg in 1916 in Serra dos Órgãos (Serra do Mar) mountains and by Maria do Carmo Vaughan Bandeira in 1925 in Itatiaia National

Park (INP) (Serra da Mantiqueira mountains). The latter two collections were analyzed by Schultze-Motel (1970).

Due to its rare occurrence, Costa et al. (2005) classified *A. subulata* as vulnerable (VU) in Rio de Janeiro State (RJ). As it was never collected again after 1925 despite numerous recent floristic studies of bryophytes in and around the INP, Peralta (2020) considered it as probably regionally extinct.

While surveying the endemic and threatened moss species from high-altitude fields in the INP, we rediscovered *A. subulata*. The species is, thus, not extinct as previously assumed.

The methodological procedures of collection and herborization followed Glime & Wagner (2017) and the identification followed Peralta (2020). The map was elaborated using QGIS software (QGIS Development Team 2020).

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The analysis of the conservation status of *A. subulata* in Brazil followed the guidelines of the International Union for Conservation of Nature (IUCN) (2003) adapted for bryophytes (Hallingbäck *et al.* 1998; Hodgetts 2015; Hodgetts *et al.* 2019). The Extent of Occurrence (EOO) and Area of Occupancy (AOO) were calculated using GeoCat Kew software (<http://geocat.kew.org/>).

Andreaea subulata Harv. in Hook., *Icon. Pl. Rar.* 3: 201. 1840.

Description and illustration by Roth (1911), Magill (1981); Churchill & Linares (1995), and Peralta (2020).

Examined specimens: BRAZIL. Rio de Janeiro, Serra do Itatiaia, 1902, Dusén [566] (R), Agulhas Negras, sobre rochas úmidas, 16-I-1925, M.C. Vaughan Bandeira [480] (R, RB, SP); *idem*, trilha para o Pico Agulhas Negras, afloramentos rochosos (-4466316, -2237965), 2700 m alt., 31-X-2020, Peralta, D.F. *et al.* [26934, 26953] (SP); *idem*, trilha para o Pico Agulhas Negras, afloramentos rochosos (-4466316, -2237965), 2700 m alt., 31-X-2020, Gonçalves, M.T.A. [159] (R); Serra dos Órgãos (Serra do Mar), 1916, Lützelburg [*s.n.* - foto] (B).

Populations of *A. subulata* were searched out in rock outcrops in the region of the INP (Agulhas Negras, Prateleiras, Morro do Couto, and Pedra do Altar) but the species was only found in Agulhas Negras (-44.66316, -22.37965) (Fig. 1). These rock outcrops are formed by a granitic complex (Ribeiro Filho 1963), the preferred substrate of the genus *Andreaea*.

According to information provided by our field guide, the newly found population in Agulhas Negras is exactly in the course of a small intermittent stream, which is the only one along the trail that provides access to the Agulhas Negras peak. This stream is used by alpinists to obtain potable water during the dry season (May through September, when fires in the region are more frequent [personal information]). There was no evidence of recent wildfires in the locality.

The gametophytes of *A. subulata* are small (from 1 to 4 cm long) and have a reddish brown color in the field; the apices of the gametophytes are greenish (Fig. 2). It differs from *A. rupestris* - the most common species of the genus in high-altitude fields in the INP - by having falcate, costate leaves with a subulate base. *A. subulata* also resembles young individuals of other genera,

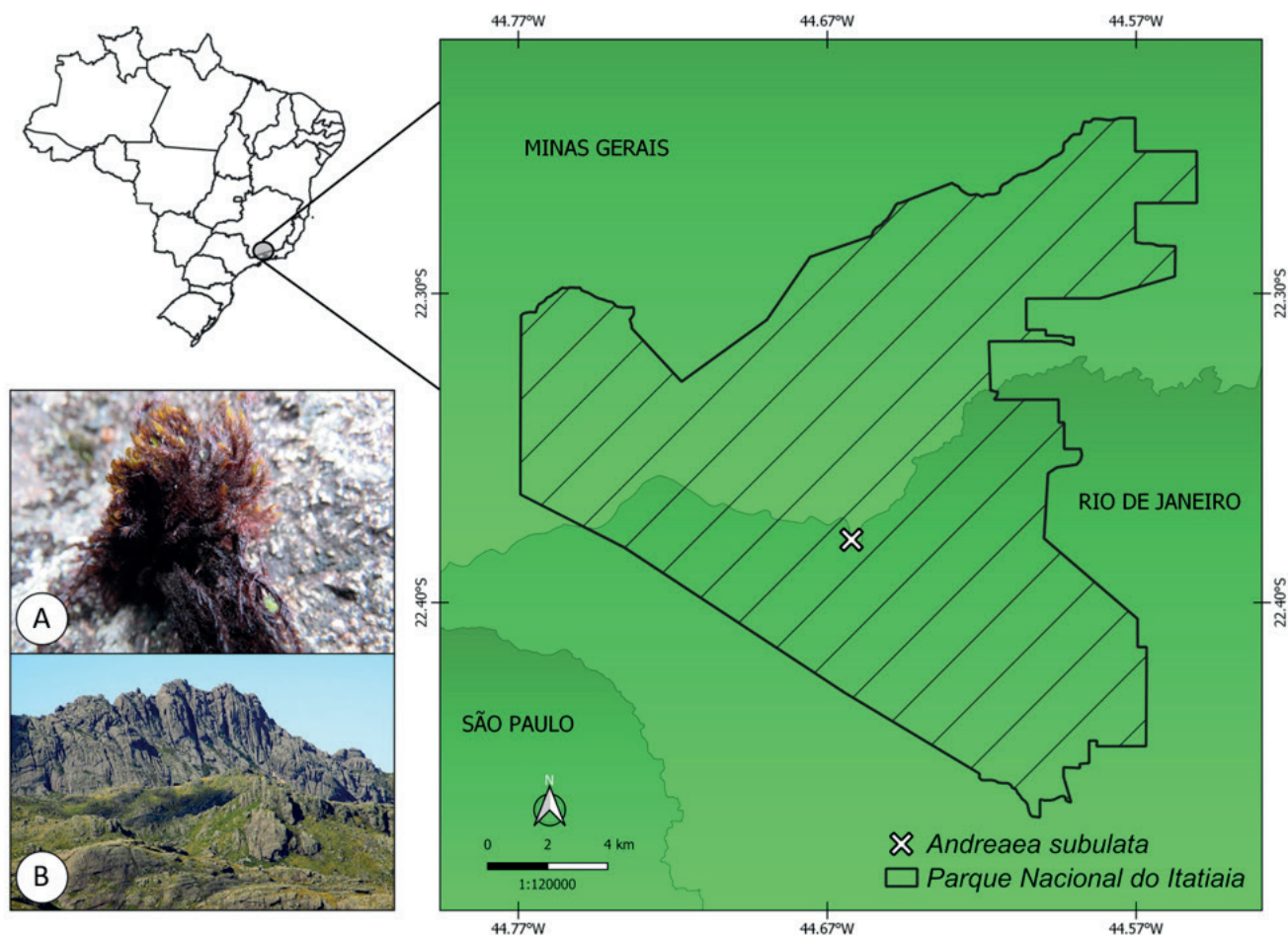


Figure 1. Location of the new record of *A. subulata* in the Itatiaia National Park, Rio de Janeiro State, Brazil. (A) Gametophytes of *A. subulata*. (B) Agulhas Negras peak.

such as *Campylopus* Brid. and *Atractylocarpus* Mitt. The species has a dioicous or autoicous sexual system (Peralta 2020). We found no evidence of sporophytes or sexual reproductive structures in the population seen in the field, nor among herbarium specimens, only the fragmentation of leaves that could constitute an asexual reproductive strategy. The absence of sporophytes in the population is likely related to the highly restricted distribution of *A. subulata* in high-altitude fields in the INP, because if sporophytes were frequent, there should be several other populations due to the ability of moss spores to disperse over long distances. Future phenological studies will greatly contribute to the understanding of the reproductive biology of *A. subulata*.

The population we encountered was formed by few small clumps along vertical fissures with dripping water. The gametophytes form cushions, a life form tolerant to high solar radiation levels and adapted to conserve water (Glime 2007).

According to Schultze-Motel (1970), *A. subulata* occurs in Brazil at 2,000 m a.s.l. in Serra dos Órgãos mountains and between 2,800 and 2,900 m in Serra da Mantiqueira mountains – INP. Its rediscovery in a single locality at 2,700 m of altitude indicates that its elevational range

in the INP has narrowed over the last 95 years, maybe in response to climate change. Bergamini et al. (2009) demonstrated that climate warming can provoke alterations in the distributions of bryophyte species typical of cooler environments (cryophilous) and that they tend to migrate from mountainous sites to areas more favorable to their establishment and growth.

Concerning the conservation status, *A. subulata* was previously considered Vulnerable (VU) by Costa et al. (2005) in Rio de Janeiro State, but its conservation status in Brazil was not evaluated. In light of the extremely restricted distribution in the country, with only two recent samples (collected in October 31, 2020) from the same population in localities where they went unnoticed in the frequent surveys conducted during the last years, and the decline of habitat quality observed in those localities, we indicate that the conservation status of *A. subulata* in Brazil is Critically Endangered (CR). This classification is suggested on the ground of the small area of occupancy of the species (less than 10,000 km²), its occurrence in areas intensely visited by tourists, and the fact that it is only known from two localities (Serra dos Órgãos and Serra da Mantiqueira mountains) in high-altitude fields (fragile ecosystems threatened by climate change).



Figure 2. Rock fissures on the Agulhas Negras peak, where *A. subulata* was collected.



The criteria utilized were: *Andreaea subulata*. Status: CR (Brazil). Criteria: B1bi,ii,iii,iv; B1ci,ii,iii. Extent of Occurrence < 100 km² and Area of Occupancy < 10 km². The species has a restricted area of occupancy, few localities of occurrence, and declining populations. Its populations are severely fragmented into small subpopulations, occurring in limited humid microhabitats. Recent collections undertaken in Serra da Mantiqueira located only a single population at 2,700 m a.s.l. in Agulhas Negras. Schultze-Motel (1970) indicated the occurrence of two populations in Agulhas Negras and one population in Serra dos Órgãos.

High-altitude fields in the INP harbor a high diversity of species, with elevated numbers of endemic and/or threatened liverwort and moss species (Costa & Santos 2009; Rezende 2015; Gonçalves & Santos 2018). Wildfires, predatory tourism, areas of pastures, the introduction of exotic species, and climate change constitute the principal threats in the region (Aximoff 2011). More specifically in the case of *A. subulata*, habitat loss due to climate change is the main factor that makes it critically endangered, as this species has unique environmental requirements, that is, it depends on humid rocky microenvironments for its establishment. According to predictions for the coming decades (Marengo 2014), drought events should become more frequent, intense, and persistent, increasing the likelihood of the disappearance of the humid microenvironments required by *A. subulata*, with direct consequences for its survival. Uncontrolled tourism also represents a threat to the species, as the sites where it is found are intensely visited by tourists.

As proposed by Gradstein & Raeymaekers (2000) and Hodgetts et al. (2019), we put forward the following recommendations for the conservation of *A. subulata* in Brazil:

1. Recognition of high-altitude fields ecosystems (within the phytogeographic domain of the Atlantic Forest) as a priority and critical area for conservation.
2. Protection of the microhabitats formed by small watercourses on the Agulhas Negras peak to ensure the survival of *A. subulata* because this species has a niche restricted to humid environments, and only a single population was found along an intermittent stream.
3. Elaboration of informative material (manuals, folders, websites, videos, etc.) for dissemination of information about bryophytes and the rare and/or threatened species of this group present in the INP among the public visiting the park.
4. Promotion of the sustainable use of trails within the park focusing on the conservation of bryophyte species occurring on rock surfaces that are often not noticed by visitors, avoiding losses of entire populations of bryophytes that can be removed or damaged during the use of hiking trails and climbing pitches.

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