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Myxomycetes in the Antarctic: A review

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Abstract

This work summarize the results of Myxomycetes collections carried out by European and South American researchers on Antarctic ice free areas during the last fifty years. An annotated list and an identification key for the nine species with confirmed occurrence on the continent are presented.

Introduction

Expeditions to the south polar region began in 18th century, but it was only in the following century that lichens, mosses, algae and phanerogams began to be collected, which were the basis for the first scientific studies, such as those carried out by J. Torrey and J. Eights (Pereira & Putzke 2013). The Antarctic biota consists mostly by organisms capable of surviving extreme conditions, characteristic of the coldest and driest continent of the planet, and home to many phylogenetically unique species (Rogers 2007, Convey *et al.* 2014). According to Vyverman *et al.* (2010), the microbial biota in Antarctica is largely the result of geographic isolation and not just a subset of globally distributed taxa, adapted to the extreme environments that characterize the continent.

Considered the second smallest of the continents, less than 0.5% of its little more than 14 million km^2 offers conditions for the development of vegetation, where bryophytes and lichens predominate, with ca. 116 and 500 species already recorded, respectively; only the native *Colobanthus quitensis* (Kunth) Bartl. (Caryophyllaceae) and *Deschampsia antarctica* E. Desv. (Poaceae), and the introduced *Poa annua* L. (Poaceae), represent the phanerogams (Pereira & Putzke 2013, Mundim *et al.* 2021). The South Shetland Islands archipelago and the Antarctic Peninsula are the areas with the highest concentration of mosses and lichens (Pereira & Putzke 2013, Mundim *et al.* 2021).

Bringing together 54 works published in an interval of more than 100 years, Thompson *et al.* (2019) compiled a list of terrestrial heterotrophic protists from Antarctica; cited the occurrence of 539 taxa for the continent, with 84 belonging to the Amoebozoa, of which the myxomycetes are part, an exceptionally diverse lineage within the supergroup. The class includes phagotrophic eukaryotic microorganisms that commonly occur in association with decomposing plant material in terrestrial ecosystems (Stephenson *et al.* 2000, Lara *et al.* 2020); approximately 1000 species are currently accepted, found in the most different ecosystems on the planet and about 80 of them, known as nivicolous, withstand very low temperatures, sporulating in association with snow banks, on different continents (Lado 2005-2022, Poulain *et al.* 2011, Ronikier & Lado 2015).

Myxomycetes are distributed on all continents, with Antarctica presenting the least known myxobiota (Schnittler *et al.* 2022). The most intensive research on myxomycetes in a high latitude region of the Southern Hemisphere was carried out on the subantarctic Macquarie Island (Stephenson *et al.* 2007), with 13 genera and 25 species, 22 from field collections and three that appeared in moist chamber cultures, whose results, associated with those obtained in research on the subantarctic islands of Campbell and Auckland, were discussed by Stephenson (2011). The present work analyzes the current state of knowledge about the Antarctic myxobiota, generated through sporadic collections carried out by European and South American researchers in the last 50 years, and presents a dichotomous key for the identification of species with recorded occurrence on the continent.

Material and Methods

A survey of publications that mention the occurrence of myxomycetes in Antarctica was carried out, excluding studies made on subantarctic islands, recording data on the location of collection, sporulation substrate and, when available, herbarium where the exsiccate is deposited and number of the collection. A dichotomous identification key was constructed for the species with known occurrence for the continent so far.

Results

Six publications were located that report species of myxomycetes species to the Antarctica, published between 1966-2020 by European and South American researchers and indicate the occurrence of representatives of the orders Physarales (Didymiaceae), Stemonitales (Stemonitaceae) and Trichiales (Dianemataceae, Trichiaceae), distributed in seven genera and nine species (**Table 1**). The greatest number of records was made in the continental part, with seven species from the Antarctic Peninsula (Horak 1966, Ing & Smith 1983, Arambarri & Spinedi 1989). In maritime Antarctica two species were found in the South Shetland archipelago, one on Nelson Island (Putzke *et al.* 2004), and another on Elephant Island (Velloso *et al.* 2020); located

Table 1. Myxomycetes found in Antarctica, with locality of the collection and substrate. 1. Horak (1966); 2. Ing and Smith (1983); 3. Arambarri & Spinedi (1989); 4. Putzke *et al*. (2004); 5. Thompson et al. (2019); 6. Velloso *et al*. (2020).

Family/Species	Locality	Substrate where it sporulates	Reference
Dianemataceae			
Calomyxa metallica (Berk.) Nieuwl.	Base Primavera, Punta Cierva (64°09'00"S and 60°57'50"W)	Mosses not identified.	3 and 5
Dianema nivale (Meyl) G. Lister Meyl.	Elephant Island, Stinker Point (61 13' 21,0" S and 55 21' 35,5" W)	Moss cushions of *Bryum, Chorisodontium, Polytrichastrum, Sanionia* and *Warnsdorfia*.	6
Didymiaceae			
Diderma antarcticola Horak	Baía Paraíso, Estação Científica Almirante Brown (64º53'S and 62º53'W)	Mosses not identified.	1 and 5
Diderma crustaceum Peck	Base Primavera, Punta Cierva (64°09'00"S and 60°57'50"W)	Mosses not identified.	3 and 5
Diderma niveum (Rostaf.) T. Macbr.	Cape Tuxen, Graham Coast (65°16'S and 64°8'W)	*Polytrichum alpestre* Hoppe	2 and 5
Semonitaceae			
Leptoderma megaspora Aramb. & Spinedi	Base Primavera, Punta Cierva (64°09'00"S and 60°57'50"W)	Mosses not identified.	3 and 5
Trichiaceae			
Oligonema dancoii Aramb. & Spinedi	Base Primavera, Punta Cierva (64°09'00"S and 60°57'50"W)	Mosses not identified.	3 and 5
Trichia antarctica Aramb. & Spinedi	Base Primavera, Punta Cierva (64°09'00"S and 60°57'50"W)	Mosses not identified.	3 and 5
Trichia varia (Pers.) Pers.	Nelson Island, South Shetland Archipelago (62°17'01"S and 59°05'27"W)	Mosses not identified.	4 and 5

about 160 km north of the Antarctic Peninsula, the archipelago is situated in the geobotanical zone of the Northern Maritime Antarctic (Figure 1); the climate is cold and dry, with annual rainfall between 350 and 550 mm, but in summer the temperature is milder and the rains are concentrated in this season (Pereira & Putzke 2013, Mundim *et al.* 2021).

Key to Myxomycetes species known to occur in Antarctica:

1.1. Spore dark, in shades of brown............................. 2

1.2. Spore clear, in shades of yellow, never brown 5

2.1. Calcium carbonate absent; columella absent; sessile or occasionally substipitate sporocarp, violet-brown or gray; spore globose to subglobose, 12-21 µm diam...*Leptoderma megaspora*

2.2. Calcium carbonate present; columella present; sessile sporocarp, brown, white or ocher; spore up to 15 µm diam., if larger, then oval to ellipsoid 3

3.1. Peridium simple; capillitial filaments with nodules, flattened and often twisted into a helical shape, tapering towards the ends; spore oval to ellipsoid, (15-) 17-26 µm x (14-) 16-22 µm diam. ....*Diderma antarcticola*

3.2. Peridium double; capillitial filaments without nodules, cylindrical, never twisted into a helical shape, diameter uniform; spore globose, 9-15 µm diam. 4

4.1. Columella globose, ochraceous to strongly orange; spore minutely rough, 9-11 µm diam. .... *Diderma niveum*

4.2. Columella globose to clavate, white; spore spinulose, sometimes appearing sub-reticulate, (11) 12-14 (15) µm diam. .... *Diderma crustaceum*

5.1. Capillitial filaments with 2-6 spiral bands. 6

5.2. Capillitial filaments smooth or with small spines or warts arranged in a spiral 7

6.1. Spore ochraceous yellow, minutely punctured; elaters 5.5-6.4 µm diam., tapered at the ends, with 5 to 6 spiral bands ....*Trichia antarctica*

6.2. Spore yellow to yellowish-orange, warty; elaters 3-5 µm diam., apices often swollen after a conical tip, with 2 (-3) irregular spiral bands, giving a somewhat serrated appearance under oil immersion .... *Trichia varia*

7.1. Peridium evanescent; spore cross-linked, 15.5-29 µm diam. .... *Oligonema dancoii*

7.2. Peridium persistent; spore spinulose or verrucous, < 15 µm diam. 8

8.1. Sporocarp beige or iridescent yellow, green or blue-green; capillitial filaments with few connections to the peridium, 0.5-1.0 µm diam., with small spines or warts arranged in a spiral; spore always free, hyaline, warty, 9-12 µm diam..*Calomyxa metallica*

8.2. Sporocarp brown or ochre-brown; capillitial filaments tightly adhered to peridium, 1.0–2.45 µm diam., smooth; spore free or in groups of 2–14, pale ochraceous, verrucous, sometimes with short spines, 11.22–13.26 µm diam. .... *Dianema nivale*

Discussion

The papers reporting the presence of myxomycetes in Antarctica were published over a long interval of time, between 1966 and 2020; with the exception of Arambarri & Spinedi (1989), they all report only a single species for a given location. Horak (1966) described *Diderma antarcticola* Horak, based on a sample collected in January 1963, near the Almirante Brown Scientific Station, whose type (EC 50.281) is deposited in the scientific collection of the Instituto Antártico Argentino. The author observed that the

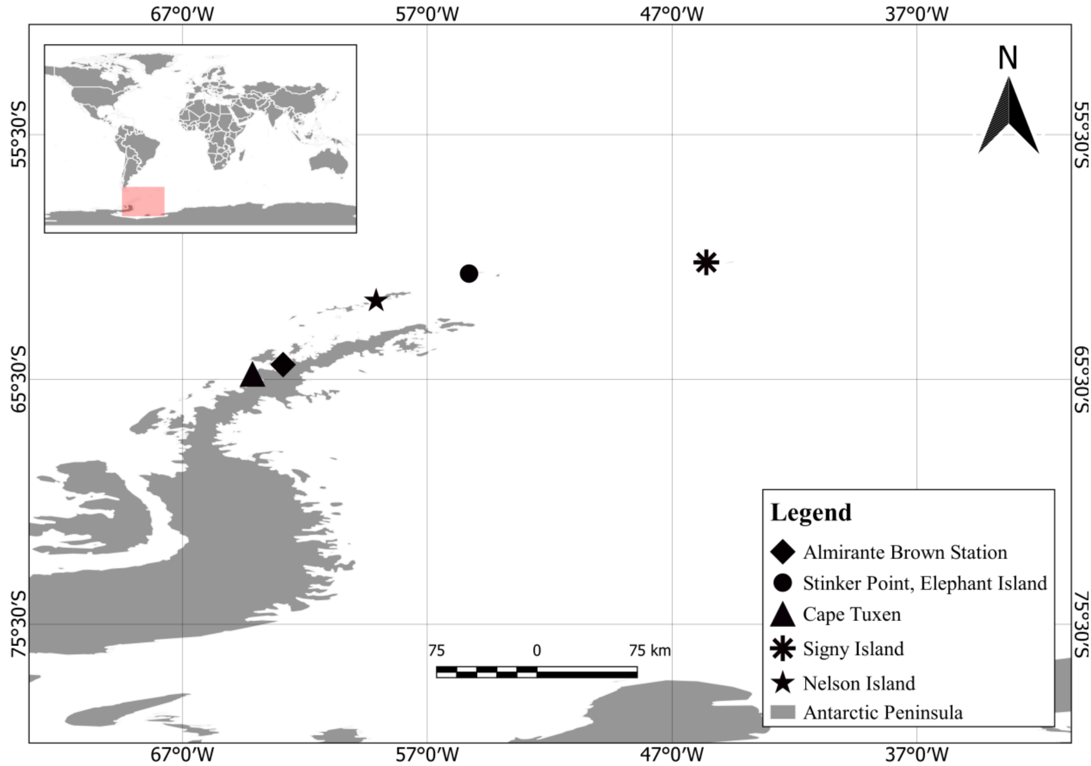

Figure 1. Antarctic localities from which myxomycetes have been recorded.

sporocarps were attached to mosses and had not sporulated directly on the soil surface. In March 1981 R I. L. Smith collected specimens of *Diderma niveum* (Rostaf.) E. Sheld. on *Polytrichum alpestre* Hoppe at Cape Tuxen, on the western coast of the Antarctic Peninsula, whose exsiccate was deposited in the herbarium of the British Antarctic Survey, under number AAS 02964 (Ing & Smith 1983). The species is recorded from sub-Antarctic islands, such as South Georgia and Signy, through collections by R. I. L. Smith and other researchers and is also present in different countries in Africa, the Americas, Asia and Europe. Lister (1925) commented that the plasmodium of *D. niveum* grows and feeds under snow, being extremely abundant in spring in alpine environments, forming large colonies on plants and rocks along the edges of melting snow blocks, a characteristic condition of species currently treated as nivicolous.

Arambarri & Spinedi (1989) reported the occurrence of five species, collected in moss banks in the Antarctic Peninsula during expeditions carried out in the summers of 1985/86 and 1986/87, whose exsiccates are deposited in the herbarium of the Universidad Nacional de la Plata (LPS). Two of them, *Calomyxa metallica* (Berk.) Nieuwl. and *Diderma crustaceum* Peck, have a known distribution in different ecosystems and continents, in both Hemispheres, but the other three were described as species new to science. *Oligonema dancoii* Aramb. & Spinedi (LPS 44,329) and *Trichia antarctica* Aramb. & Spinedi (LPS 44,332) have clear colored spores and belong to the Trichiaceae; the third, with dark spores, was included in the genus *Leptoderma* G. Lister (Stemonitaceae), until then monotypic (*L. megaspora* Aramb. & Spinedi LPS 44.330, 44331). The Primavera Station, where the new taxa were collected in February 1986 and January 1987, is an Argentine scientific station in Antarctica, and the three new species, as well as the one described by Horak (1966), were mistakenly included in the myxobiota of that country in the literature review on neotropical myxomycetes carried out by Lado & Basanta (2008).

Putzke *et al.* (2004) reported the occurrence of *Trichia varia* (Pers.) Pers., collected in moss fields on Nelson Island, with exsiccate deposited in the herbarium HCB. After almost 20 years without new citations for the Antarctic myxobiota, Velloso *et al.* (2020) recorded the occurrence of *Dianema nivale* (Meyl.) G. Lister, collected during the austral summer of 2018 on Elephant Island, Stinker Point, 15 meters south of Goeldi Refuge; the exsiccate was listed under the number UFP 87,395 in the myxomycete collection of the Geraldo Mariz herbarium, Universidade Federal de Pernambuco, Brazil.

The reduced number of myxomycetes species that manage to occupy environments where the temperature is very low in almost all seasons of the year make up a taxonomically heterogeneous group of nivicolous species, proposed by Meylan (1908, 1914). According to Gorris *et al.* (1999), the snow acts as a brake on the development of myxomycetes, but in the nivicolous ones the metabolism is not totally interrupted, because the ice layer works as a thermal insulator and provides protection to amoeboflagellates and plasmodia; sporulation occurs during the period when the snow melts. Studies on nivicolous species are concentrated in the Northern Hemisphere, where they occur more frequently in mountainous regions, sporulating in melting snow at certain times of the year (Mitchel *et al.* 1986, Poulain *et al.* 2002, Poulain & Meyer 2005, Ronikier & Ronikier 2009, Ronikier *et al.* 2010). However, Novozhilov *et al.* (2013) commented that, although they are often found in typically very cold locations, sporulating in melting snow, nivicolous myxomycetes can occur in any habitat where the combination of microclimatic conditions is suitable.

In Antarctica, although the phanerogamic flora is extremely limited, the bryoflora is rich and diverse, both in the continental and maritime islands. Mosses and liverworts grow directly on rocky outcrops, usually at sites above 100 m, but can spread to lower bare ground and become available for colonization by lichens and other organisms such as myxomycetes (Albuquerque *et al.* 2012). According to Mundim *et al.* (2021), the following species of mosses are widely distributed and very common in Antarctica: *Bryum pseudotriquetrum* (Hedw.) G. Gaertn., B. Mey. & Scherb.; *Brachythecium austroglareosum* (Müll. Hal.) Kindb.; *B. austrosalebrosum* (Müll. Hal.) Kindb. and *Sanionia uncinata* (Hedw.) Loeske. *Andreaea regularis* Müll. Hal. is also very common, especially in the South Shetland Islands archipelago, *Bartramia patens* Brid. and *Pohlia cruda* (Hedw.) Lindb., as well as species of *Polytrichastrum* [*P. alpinum* (Hedw.) G.L. Mr.; *P. piliferum* Hedw.], *Syntrichia* [*S. filaris* (Müll. Hal.) R.H. Zander; *S. magellanica* (Mont.) R.H. Zander; *S. saxicola* (Cardot) R.H. Zander] and *Warnstorfia* [*W. fontinaliopsis* (Müll. Hal.) Ochyra; *W. sarmentosa* (Wahlenb.) Hedenäs].

On Elephant (Stinker Point) and Nelson (Rip Point) Islands, where *D. nivale* and *T. varia* were recorded, the human impact is minimal, with only a few small buildings sporadically occupied. In the first, formations of *Bryum argenteum* and *Chorisodontium acyphyllum* stand out, reduced in the other islands, while in the second, several species of mosses are dispersed in groups throughout the entire area of the island, forming small spots, rarely in carpets (Pereira & Putzke 2013). Samples of the two species collected on the islands, as well as the seven recorded in the Antarctic Peninsula, were found on moss beds, in the austral summer, during studies on other organisms that occupy similar microhabitats; in this way, the Antarctic myxobiota is classified as muscicolous, although it also presents some characteristics of the nivicolous ones, as they develop in high altitude environments, with the presence of snow and ice at almost all around the year.

Myxomycetes with known occurrence so far for Antarctica are distributed almost equitably between species with dark spores (45.5%), belonging to Didymiaceae and Stemonitaceae, and species with clear colored spores (55.5%), belonging to Dianemataceae and Trichiaceae. In addition to showing that the knowledge about the myxomycetes that occur in Antarctica is still incipient, the analysis of the literature indicated a regionalization of the myxobiota, since 80% of the species found were still unknown to science, indicating the need to better explore the diversity and the ecology of these microorganisms on this continent.

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