Antarctica may be one of the most remote and inhospitable places on earth, but bryophytes are to be found in its icy wastes. **Rod Seppelt** and **Ryszard Ochyra** introduce us to the mosses of this great continent.

Moss amongst the ice – the forests of Antarctica

In stark contrast to the northern polar regions, the Antarctic continent is a vast expanse of ice-covered land and adjacent ice shelves, centred on the South Pole. It is surrounded by the Southern Ocean and separated by great distances from the southern continental land masses. At its closest, the distance from the northern Antarctic Peninsula to Cape Horn is about 850 km.

Only about 2 % of the 14 million km^2 area of Antarctica is ice-free, with the ice plateau up to 4 km thick and reaching elevations of 3,800 m above sea level. The vegetation of continental Antarctica is restricted to lichens, bryophytes (including 24 species of mosses and 1 liverwort),

▽ *Bryum argenteum* emerging from a cover of ice with numerous propagules on the ice, Cape Hallett (72°S, 170°E), Northern Victoria Land. *Catherine Beard*

mostly microscopic algae, cyanobacteria, and fungi. The milder and wetter maritime Antarctic region (Antarctic Peninsula to latitude about 70°S and 64°S on the western and eastern coast, respectively, and adjacent archipelagos of the South Sandwich Islands, South Orkney Islands and South Shetland Islands, as well as the isolated Bouvetøya) possesses considerably more bryophytes than continental Antarctica (107 species), and there are also two flowering plants.

In the most recent treatment of the Antarctic moss flora, 111 species and two varieties in 55 genera from 17 families are represented (Ochyra *et al.*, 2008). The majority of these are either restricted to or predominantly found in the maritime Antarctic region. In continental Antarctica, with the perimeter of the continent at around 66°S, mosses and associated invertebrates have been found as far south as 84°S in the southern part of the Transantarctic Mountains in the Ross Sea sector. Specimens with mature capsules are, in continental regions, rarely found, although often antheridia or archegonia may be seen on dissection. The majority of the moss genera are now known to be cosmopolitan, or Holarctic (Laurasian) taxa with a bipolar distribution pattern.

History

The earliest collections of Antarctic plants were made from the maritime Antarctic region in early 1820 (see Seppelt *et al.*, 1998). The earliest extant moss collection, comprising *Polytrichum alpinum* and *Sanionia uncinata* which are now preserved at NY and US, was made by James Eights during the US sealing voyage of 1829–1831 in the South Shetland Islands (S. Greene, 1967; Ochyra, 1998). In January 1843, J.D. Hooker collected five mosses, seven algae and six lichens from Cockburn Island off Trinity Peninsula on the north-east coast of the Antarctic Peninsula (Wilson & Hooker, 1847), but it was not until 1899–1900 that the first collections were made from the Antarctic continent, from northern Victoria Land at the east side of the Ross Sea (Newness Glacier, Geikie Ridge and Mount Melbourne at latitude 71°41′S–74°35′S) (Gepp, 1902; Bryhn, 1902). The first attempt at an Antarctic bryophyte checklist was that of Steere (1961), updated by D. Greene (1968). A more detailed


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compilation was undertaken by Greene (1986). A further checklist incorporating the latest taxonomic advances and floristic exploration of the whole Antarctic biome was compiled by Ochyra *et al.* (1998). D. Greene (1986) stressed the need to consider the bryophyte floras of southern South America and Australasia in interpreting the taxonomy of the Antarctic species. This challenge has been comprehensively taken up by Bednarek-Ochyra *et al.* (2000) for the 27 species of liverworts and by Ochyra *et al.* (2008) for the mosses.

The majority of taxonomic work carried out on the Antarctic bryoflora has been ancillary to phytogeographic and biodiversity studies and to ecological surveys. Until recently (Ochyra *et al.*, 2008), there has been little attempt to compare the often environmentally modified and sterile Antarctic plants with southern and worldwide species. Logistic constraints and the lack of specialist field workers have also severely hampered phytogeographic and taxonomic studies.

Distribution (biogeography)

The range of terrestrial plant communities in the simple cryptogam-dominated tundra vegetation of the Antarctic biome is limited. Terrestrial vegetation is best developed in the Maritime Antarctic (Lewis Smith 1996) and in a few Continental Antarctic localities, the most notable being the Windmill Islands region (66°S, 110°E; Melick *et al.*, 1994), Cape Hallett (72°S, 170°E) (Brabyn *et al.*, 2006) and the aptly named Botany Bay (77°S, 162°E) (Seppelt & Green 1998). Of the 27 species of hepatics known from the Antarctic biome (Bednarek-Ochyra *et al.,* 2000) only *Cephaloziella varians* is found on the Continent, but is known as far south as 77°S at Botany Bay in southern Victoria Land (Seppelt & Green 1998).

◁ 1. *Syntrichia magellanica* from near Luther Lake, Cape Hallett (72°S, 170°E) area, Northern Victoria Land.

◁ 2. Extensive convoluted turf of *Bryum pseudotriquetrum* on an outwash slope at the base of scree slopes, Cape Hallett (72°S, 170°E), Northern Victoria Land.

▽ 3. Collembola foraging on a *Bryum argenteum* turf, Cape Hallett (72°S, 170°E) Northern Victoria Land.

▽ 4. Extensive convoluted turf of *Bryum pseudotriquetrum* emerging from snow (with R.D.S.), Cape Hallett (72°S, 170°E). *All photos Catherine Beard*

Physiology

The dry continental Antarctic climate places severe physiological stresses on terrestrial plants. Within moss colonies the stems and shoots tend to be densely packed, maximizing water retention capacity. Availability of free water has a marked impact on plant abundance and distribution patterns, and in coastal areas, nutrient input from breeding seabirds is also important. Exposure may significantly effect stature and complicate identification of taxa. Diminution of the ozone layer in summer has let to higher levels of potentially damaging UV radiation during the active growing season (Robinson *et al.*, 2005). Despite the environmental hazards, the bryoflora is physiologically well-adapted to life in Antarctica. Pannewitz *et al.* (2005) found that net photosynthesis in mosses was strongly depressed at subzero temperatures but was substantial at 0 °C. Water availability and the limited time during which temperatures are favourable for sexual reproduction, however, combine to make the occurrence of sporophytes very rare in continental localities, although antheridia or archegonia are commonly found on dissection.

Molecular systematics

Molecular techniques have not been comprehensively applied to Antarctic bryological subjects and taxonomy relies heavily on a good understanding of morphology. RAPD studies of a number of mosses (Skotnicki *et al.*, 1997), which indicated a high level of molecular variation, have been recently questioned because of fungal contamination of the extracted DNA (Stevens *et al.*, 2007). Molecular methods have, however, aided in assisting identification of recalcitrant moss protonema (Skotnicki *et al.*, 2001) and in establishing the true identity of *Bryum subrotundifolium* as *B. argenteum* (Stevens *et al.*, unpublished data). The latter data perfectly coincide with results of the taxonomic studies based upon classical morphological methods which showed that this species falls well within the range of variation of the protean *B. argenteum* and may be merely considered as a variety, *B. argenteum* var. *muticum* (Ochyra *et al.*, 2008). Much remains to be done before the apparent age of the flora or its origin can be ascertained.

RAPD – Random Amplified Polymorphic DNA. This is a technique used to study genetic variation between species and is particularly useful for comparisons where no detailed DNA sequence data are available.

Antarctic Moss Flora

After many years of painstaking research and field work we will soon have access to a comprehensive Moss Flora of the Antarctic region (Ochyra *et al.*, 2008), a companion volume to the Hepatic Flora (Bednarek-Ochyra *et al.*, 2000). Researchers undertaking applied and ecological research activities on the terrestrial Antarctic flora will then be able to properly identify the taxa being studied.

The future

Large areas of Antarctica remain unstudied and under-collected. Logistic problems impose severe limitations on field work, and field surveys by specialists are essential. Ecophysiological and molecular genetic research remains a priority. Increasing scientific and tourist activities pose significant threats to the vegetation from physical damage and introduction of alien species. With global warming, careful management and a comprehensive understanding of the terrestrial ecosystem of Antarctica is becoming critical.

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