

THE NATURE AND IMPORTANCE OF THE SUB-ANTARCTIC

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Sub-Antarctic land is a rare resource in world terms. It is appropriate to recognise the sub-Antarctic as a region distinct from the cool temperate zone to its north and the Antarctic zone to its south, a region with its own characteristics, and with significant intrinsic value and scientific importance. Appropriate protection from anthropogenic change and exploitation must be ensured for the sub-Antarctic.

Key Words: sub-Antarctic, islands, environmental change, anthropogenic change.

NATURE AND LOCATION OF THE SUB-ANTARCTIC

From the vantage point of a plant biologist, the nature and location of the sub-Antarctic is very simple: it is the region south of the south temperate zone and north of the Antarctic zone. The sub-Antarctic is a region of much ocean and little land, a region where herbaceous flowering plants and bryophytes grow well, but where trees and shrubs are absent. It is a region where the tiny specks of land are strongly influenced by the vast ocean and where there are strong connections between marine and terrestrial ecosystems (Smith 1984, Selkirk *et al.* 1990, Erskine *et al.* 1998, Smith *et al.* 2001, Smith 2007).

The sub-Antarctic is a region where temperatures are low and vary little throughout the year (Jacka *et al.* 2004), and where there is abundant moisture. Winter days are short and summer days are long, and although all days are likely to be cloudy (Bureau of Meteorology 2007), there is ample daylight throughout the year, and plant productivity is high (Jenkin & Ashton 1970, Jenkin 1972, Hnatiuk 1979, Smith 1984).

Sub-Antarctic islands, where tussock grasses and lush megaherbs are the tallest plants, contrast very strongly with the cool temperate region to the north, where shrubs or trees are the tallest plants around, forming the dominant vegetation layer. With their oceanic climate, the sub-Antarctic islands contrast equally strongly with continental Antarctica to the south, where temperatures differ markedly between summer and winter (Jacka *et al.* 2004), where daylight and liquid water are available to organisms in the summer but not the winter, where vegetation is dominated by mosses and lichens, growing close to the limits of their physiological tolerance. Just two species of flowering plants, *Deschampsia antarctica* E.Desv. and *Colobanthus quitensis* (Kunth) Bartl., grow in the maritime Antarctic, also at the limits of their physiological tolerance (Smith 1984, Holderegger *et al.* 2003, Robinson *et al.* 2003).

There are different conceptions of what constitutes the sub-Antarctic. Meteorologists define the sub-Antarctic one way (Pendlebury & Barnes-Keoghan 2007), oceanographers another (Ansorge & Lutjeharms 2007). Some confine their idea of the sub-Antarctic to the islands close to the Antarctic Polar Frontal Zone (APFZ); others include a wider range of islands and southern Patagonia. This paper, written by a terrestrial plant biologist, concentrates on the islands of the sub-Antarctic, and particularly the terrestrial biota. However, what is said about the sub-Antarctic will still be pertinent, whatever the reader's circumscription.

By many criteria, the sub-Antarctic is different from other parts of the world. The analogous region in the northern hemisphere is commonly taken to be the vast area of tundra-covered continental land bordering the Arctic Ocean to its north — northern parts of Canada, Greenland, Europe and Siberia, an environment quite different from the ocean-dominated sub-Antarctic (Alexandrova 1980).

It is clear that sub-Antarctic land is a rare resource in world terms, and is discussed here in terms of its importance, distinctive characteristics, intrinsic interest and value.

IMPORTANCE OF THE SUB-ANTARCTIC

The sub-Antarctic region is important as a component of world circulation systems: oceanic systems such as the Antarctic Circumpolar Current (Ansorge & Lutjeharms 2007) and atmospheric circulation such as the Southern Annular Mode (Pendlebury & Barnes-Keoghan 2007).

Sub-Antarctic lands are important to the terrestrial organisms — plants, animals, micro-organisms — that live on the islands, and to the marine mammals and birds that breed there. To humans, the sub-Antarctic is important to scientists — to biologists interested in biogeography, to meteorologists recording land-based data for weather forecasting, to climatologists interested in teleconnections and in climate change, to geologists interested in tectonics and vulcanism, to oceanographers interested in the Southern Ocean — and it is important to the interested tourist visitors now in increasing numbers.

DISTINCTIVE CHARACTERISTICS OF THE SUB-ANTARCTIC

Sub-Antarctic land is entirely made up of small oceanic islands. The islands here considered to be sub-Antarctic all lie close to the APFZ — Macquarie Island, Marion and Prince Edward islands, Crozet Archipelago to the north of the APFZ; Îles Kerguelen within the APFZ; Heard and McDonald islands and South Georgia to the south.

Sub-Antarctic islands have varying geological origins (Quilty 2007), but much in common biologically. They are breeding sites to multitudes of marine mammals and birds that depend on the Southern Ocean for their food, but depend on the sub-Antarctic islands when it comes to their reproduction. Fur seals, elephant seals, albatrosses, prions, petrels, cormorants and other marine birds all are part of the interconnections between marine and terrestrial ecosystems

in the sub-Antarctic: they feed at sea but breed and excrete ashore, transferring nutrients as they do so (Croxall 1984, Laws 1984, Erskine *et al.* 1998, Smith 2007).

The islands are fringed by similar marine algae including dense vegetation of brown algae (Lüning 1990), so that the bull kelp *Durvillaea antarctica* (Chamisso) Hariot could be said to be the dominant plant species of the sub-Antarctic islands (Klemm & Hallam 1988). On the islands vegetation includes tussock grasslands, mires, lakes, fellfields with cushion plants and many bryophytes (Aubert de la Rue 1964, Smith 1988, Duchêne 1989, Selkirk *et al.* 1990, McIntosh & Walton 2000). Terrestrial and freshwater invertebrates found within all these vegetation types include cosmopolitan species as well as characteristically sub-Antarctic ones (Dartnall 2005, Dartnall *et al.* 2005, Chown *et al.* 2006, Greenslade 2006).

Indigenous biota of the sub-Antarctic islands is distinct from that of both the cool temperate and Antarctic regions. A number of species of plants and invertebrates occur on several sub-Antarctic islands but nowhere else in the world: for example, *Pringlea antiscorbutica* R.Br. ex Hook.f., known as Kerguelen cabbage, occurs on Îles Kerguelen, Heard and Marion islands (Telford *et al.* 1993); *Poa kerguelensis* (Hook.f.) Steud., a small tussock grass, is found on Îles Kerguelen and Heard Island (Du Puy *et al.* 1993); *Poa cookii* (Hook.f.) Hook.f., an often larger tussock grass, is found on Îles Kerguelen and Crozet, and Heard, McDonald, Marion, Prince Edward and Macquarie islands (Du Puy *et al.* 1993); the spider *Myro kerguelensis* O.P.-Cambridge, 1876 occurs on Macquarie and Heard islands, Îles Kerguelen and Crozet (Greenslade 2006).

Some plants and invertebrates are endemic to particular sub-Antarctic islands: for example the small cushion plant *Lyallia kerguelensis* Hook.f. is endemic to Îles Kerguelen (Greene & Walton 1975); the large cushion plant *Azorella macquariensis* Orchard is endemic to Macquarie Island (Orchard 1989); there are two species of orchid, *Nematoceras dienemum* (D.L.Jones) D.L.Jones, M.A.Clem et Molloy and *N. sulcatum* M.A.Clem et D.L.Jones, endemic to Macquarie Island (Jones 1993, Clements & Jones 2007, Clements *et al.* 2007); the waterflea *Daphnia gelida* (Brady, 1918) is endemic to Macquarie Island (Dartnall *et al.* 2005); the flightless moth *Pringleophaga marioni* Viette, 1968 and the weevil *Bothrometopus elongatus* (Jeannel, 1953) are endemic to Marion Island (Barendse & Chown 2001).

The islands are relatively small, relatively young, and have generally evolved in isolation from other landmasses (Quilty 2007). Terrestrial and freshwater organisms have reached the islands by long-distance over-ocean transport — in other words, “via airmail” (Bergstrom & Selkirk 1987, Hennion & Walton 1997, Greenslade *et al.* 1999, Dartnall *et al.* 2005). On-island evolution from an ancestor that arrived by “airmail” is the most likely mechanism for the development of their terrestrial and freshwater endemic species (Clements *et al.* 2007).

INTEREST IN THE SUB-ANTARCTIC

Eighteenth- and nineteenth-century interest in the sub-Antarctic was essentially economic, with the harvesting of marine mammals and birds for economic gain. Seal and penguin populations fell dramatically (Hindell & Burton 1988, McIntosh & Walton 2000), in some places to extinction (Shaughnessy *et al.* 1988). Populations recovered to varying

extents after cessation of harvesting and statutory protection of most of the animals in the early to mid-twentieth century.

In the late nineteenth century there was scientific interest in the wildlife of sub-Antarctic islands, and their natural history (Headland 1984, Bryden 1988, Duchêne 1989). By the twentieth century, sufficient scientific knowledge had accrued for some biological harvesting to be sustainably managed, for example elephant seals at South Georgia until the mid-1960s (McIntosh & Walton 2000).

In the twentieth and twenty-first centuries scientific interest has centred on the intrinsic nature of the sub-Antarctic, and studies are working towards an understanding of geological and tectonic processes, ecological and evolutionary processes, and oceanic and upper atmospheric processes. Different islands are of interest to scientists in particular disciplines: for example Macquarie Island is particularly interesting to geologists and geophysicists studying tectonic processes (Varne *et al.* 2000, Goscombe & Everard 2001, Wertz *et al.* 2002, Rivizzigno & Karson 2004); McDonald Island is of particular interest for its recent active volcanism (Quilty 1995, Kiernan & McConnell 1999); Marion and Heard islands and Îles Kerguelen are of interest to glaciologists, geomorphologists, and biologists studying glacial retreat, its mechanisms and consequences (Scott 1990, Frenot *et al.* 1998, Kiernan & McConnell 1999, Budd 2000, Ruddell 2006).

The sub-Antarctic contains indicators of widespread environmental change, hence is of interest for the observations of change and the interpretation of mechanisms of change. Records from the islands show significant warming over the past 50 years (Thost & Allison 2006, Pendlebury & Barnes-Keoghan 2007), reduced precipitation in some regions and increased windspeed, resulting in somewhat drier conditions, especially in the mires that are significant habitats on sub-Antarctic islands. There has been substantial warming in parts of the Southern Ocean, which is likely to have a flow-around effect on its islands. Glaciers are retreating, new land is becoming ice-free and available for colonisation by organisms already nearby on the islands; there has been reduction in the extent of some species such as *Sphagnum* on Macquarie Island (Whinam & Copson 2006), and an increase in others such as *Acaena* on Heard Island (Scott & Bergstrom 2006). However, there is a great deal not yet known about how organisms will respond to the rapidly changing conditions. Will the colonists of newly deglaciated land all be present residents of the islands? Will the environmental changes allow the establishment of some additional species, yet to arrive by “airmail”, or by human-mediated means? Will the changed environment exert different selective pressures on island biota, allowing the evolution of new, endemic species on the islands?

What about the environment itself? For instance, how will geomorphic processes be affected? Periglaciation is the geomorphic process that leads to patterned ground including stone stripes and polygons. Periglacial processes result from freeze-thaw action on unvegetated ground. If temperatures rise so that fewer freeze-thaw cycles occur, periglacial processes may become much more limited in extent, to become restricted to progressively higher parts of the islands where freeze-thaw cycles continue and, ultimately, be inactive in the sub-Antarctic.

On Macquarie Island, peat slides around the steep coastal slopes are triggered by heavy rainfall events. When rain saturates the peat, it becomes unstable and fails when the combined load of vegetation, peat and water becomes too

great for the slope to support (Selkirk 1996). If precipitation decreases and evaporation increases, the incidence of sub-Antarctic peat slides may diminish.

Clearly the sub-Antarctic is a particularly interesting place, one that is interesting to many people, a place that has the capacity to help us understand a number of fundamental processes.

VALUE OF THE SUB-ANTARCTIC

The intrinsic value of the sub-Antarctic islands has formally been recognised in World Heritage listing for Macquarie Island, Heard Island and the McDonald Islands, and the New Zealand shelf islands, and in the tentative World Heritage listing of Marion and Prince Edward islands.

In the past, the sub-Antarctic had commercial value for its exploitable biota — the myriad seals and penguins whose skins clothed many people, and whose oil lit many houses. Now there is monetary value in tourism, and potentially in future for other purposes, such as the development of sub-Antarctic plants as vegetable or horticultural crops (Dawson 1998), or sub-Antarctic microbiota as sources for biotechnology developments.

The risk of damage to the sub-Antarctic should not be overlooked. There is risk of damage to sub-Antarctic islands from alien plants, specifically those that become invasive. Many such plants have arrived on sub-Antarctic islands as hitchhikers on humans and their equipment, from soon after the islands were discovered, through the era of seal and penguin and whale exploitation, through settlement and farming practices, to the present era of scientific investigation and tourism (Whinam *et al.* 2004, Frenot *et al.* 2005, Convey *et al.* 2006, Bergstrom & Selkirk 2007). Similarly, alien animals that become feral pose threats to sub-Antarctic environments. Some, such as mice and rats, travelled on ships and went ashore uninvited; others, such as cats, rabbits and reindeer, were imported for a purpose at a time when the threats they would later pose were not appreciated (Leader-Williams 1988, Convey *et al.* 2006). Recovery programs have achieved the eradication of cats from Marion Island (Bester *et al.* 2002), of weka and cats from Macquarie Island (Copson 1995, 2003), of rabbits and rats from Île Saint Paul and from three small islands in the Îles Kerguelen (Lebouvier & Frenot 2007), and of rats from Campbell Island (McClelland & Tyree 2004, Shepherd 2007). Quarantine measures aim to prevent further introductions (Copson & Whinam 2001, Whinam *et al.* 2006), and management practices are in place for the control of some of the alien species now present (Copson & Whinam 2001, Courchamp *et al.* 2003, Cooke *et al.* 2004). On Macquarie Island, however, management of the feral rabbit population has become ineffective, with deleterious consequences for bird populations and vegetation (Considine 2007, Parks and Wildlife Service 2007). A plan for the eradication of rabbits and rodents has been developed (Parks and Wildlife Service 2007), funding from the Australian and Tasmanian governments has been approved, and the plan is expected to be implemented over the years 2007 to 2012.

Other threats of damage to sub-Antarctic islands come from anthropogenic pollution damage including fuel leaks and waste dumping (Stark *et al.* 2003). Hydrocarbon spills are considered to be more damaging in cold than in warmer climates, and ecosystem recovery slower (Snape *et*

al. in press). Surveys and toxicity testing have shown the need for remediation in some locations (Stark *et al.* 2003, Schafer *et al.* in press, Rayner *et al.* in press). Considerable quantities of derelict building materials have been removed from Heard Island during several clean-up operations (Stark *et al.* 2003, Hull 2002) and plans are in train for remediation at sites on Macquarie Island (Raymond *et al.* 2005). The oil spill associated with the 1987 foundering of M.V. *Nella Dan* killed invertebrates and adversely affected the littoral and sub-littoral environment over several kilometres of Macquarie Island's shoreline for more than a year (Pople *et al.* 1990). Marine plastic rubbish, often dumped thousands of kilometres away, damages birds and seals both at sea and on beaches when washed ashore (Slip & Burton 1991).

There is potential for change in the sub-Antarctic. Climate change, including rising temperatures and falling precipitation, and resultant environmental change including retreating glaciers, have been considered above. These changes in the physical environment will be associated with biological changes; there is the potential for additional biota to arrive naturally and to become established, independent of human agency; and there is the capacity for new biota to evolve.

It is clear that all change is not a bad thing, to be resisted: the world has been a changing place throughout its existence and continues to change. The sub-Antarctic is no exception — Macquarie Island continues to rise as tectonic plates move (Adamson *et al.* 1996), McDonald Island continues to expand following recent volcanic eruptions (Australian Antarctic Division 2005).

It is appropriate to ponder, with better knowledge and understanding than in the past, whether the sub-Antarctic is adequately protected from deleterious exploitation, and indeed from deleterious anthropogenic change, of any nature.

CONCLUSION

I believe that the sub-Antarctic, however defined, must be recognised as a region in its own right, distinct from the Antarctic region to its south and from the cool temperate region to its north. It is time to move away from the long-standing tendency for the sub-Antarctic to be regarded as “not the real Antarctic”, or “less than the Antarctic”.

The characteristics, intrinsic value and scientific importance of the sub-Antarctic must be recognised, and appropriate protection from deleterious anthropogenic change and exploitation ensured. Humans, as custodians of the planet, must recognise and value the unique qualities of, and must care for all parts of, the Earth, including the sub-Antarctic.

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