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Biodiversity in the Antarctic

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Note: this paper was presented as IP 85 at XXVIII ATCM, in Stockholm, as the document accompanying the SCAR Lecture. Delegates requested that it be brought back to the ATCM in Edinburgh as a Working Paper, so as to allow substantive discussion of the points raised. The text below remains unchanged from XXVIII ATCM IP 85.

1. According to the Convention on Biological Diversity, biological diversity (or biodiversity) means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.
2. Although biodiversity includes all levels in the genealogical (genes to higher groups) and ecological (individuals to ecosystems) hierarchies, there are significant relationships between various components of biodiversity. Much present knowledge of biodiversity concerns patterns in species richness (numbers of species) variation across space and through time. Therefore, the relationships between species richness and other components of biodiversity mean that at least the fundamental patterns of this variation, if not the mechanisms underlying them, are reasonably well understood.
3. Spatial patterns in biodiversity are complex and three-dimensional. Species richness in marine, terrestrial and freshwater systems varies with both latitude and longitude. Arguably the best known pattern in species richness variation is the latitudinal gradient in diversity which encompasses a decline in richness from the tropics to the poles. It was first documented by Alexander von Humboldt (in 1804), and has been the subject of intense debate ever since.
4. Ultimately, the species richness of an area depends on four main processes: speciation, extinction, immigration and emigration. The relative importance of these processes depends on both the spatial and temporal scale of interest. More proximate determinants of richness variation include available energy, area, and the effects of history of an area which might substantially influence present diversity.
5. From a terrestrial and freshwater perspective, the low energy environment and isolation of Antarctica mean that it is species poor. Indeed, terrestrial and freshwater systems of Antarctica represent the endpoint of the global gradient in diversity. Where life can exist, richness is typically low, and continental Antarctic systems represent some of the simplest in the world. For example, some endolithic (within rock) communities are restricted to a few species of algae, fungi and bacteria. In Ellsworth Land (75°–77°S) the simplest faunal system comprises only microscopical animals with five tardigrade and two rotifer species. Nonetheless, gradients in diversity exist on the continent in terrestrial and freshwater systems and are especially pronounced along the Antarctic Peninsula.
6. Richness variation in continental Antarctica is spatially complex, reflecting regional and local variation in conditions as much as it does the declining energy and increasingly isolated environment towards the pole. This variation is poorly understood owing to limited sampling in many areas especially of East Antarctica. Nonetheless, it is apparent that in many important groups (e.g. nematode worms) the species are wholly endemic (i.e. restricted to the region) to Antarctica or nearly so.
7. Molecular techniques are now starting to reveal that the diversity of microbes in the Antarctic is both complex and rich. Just how diverse it is by comparison with other systems is difficult to ascertain at present given that the techniques used for studying such diversity are novel. However, it seems likely that the microbes of Antarctica will prove to be extraordinary from a variety of perspectives.
8. Terrestrial and freshwater diversity increases rapidly from the maritime Antarctic to the sub-Antarctic islands. On the latter, variation in richness is comparatively well understood, especially in the case of vascular plants and insects, and to some extent in the bryophytes (mosses). Richness variation of the indigenous flowering plants and ferns and in insects is a consequence of energy availability, island area, and to a lesser extent isolation. Thus, the largest and most northerly islands generally have the highest plant and insect species richness.

9. In marine systems the picture is much more complex. In some groups, such as the decapod and stomatopod crustaceans and bivalves, diversity is low, and brachyuran crabs (i.e. typical crabs) are entirely absent from the region. However, in other groups there seems to be almost no decline in Antarctic waters or even an unusual diversity pattern. Thus, the pycnogonids (sea spiders), echinoderms (sea-urchins and their relatives) and polychaetes (segmented worms) are especially rich in the Antarctic region. Indeed, in the case of the sea spiders the Antarctic region may be the area of highest species richness globally.

10. Other groups, such as the notothenioid fish have also diversified dramatically in the Antarctic. Although the Antarctic fish fauna in general is notably species poor, this is not true of the notothenioids group. Of the 174 benthic or demersal fish species known from the Southern Ocean, 55% are notonethioids, and these fish commonly represent more than 90% of the individuals collected. These fish are endemic to the Antarctic region, although recently a Patagonian toothfish was discovered off Greenland, lending support to the idea that trans-equatorial dispersal events can take place in deep, cold water.

11. Although the distribution of benthic and pelagic diversity across the Southern Ocean is poorly understood for most groups, owing to the paucity of information especially for East Antarctica, one group is especially well known. The seabirds, which are essentially pelagic species that return to land to breed, have been well-documented both in terms of their breeding populations and their at-sea distributions thanks to SCAR activities.

12. In terms of functioning, terrestrial ecosystems are influenced predominantly by temperature and water availability, though nutrient availability is also important. In freshwater ecosystems, food webs tend to be simple, and connections may span several levels. Marine systems in the Southern Ocean are complex and incorporate a wide range of ecological processes ranging from disturbance such as ice-scour in shallow-water environments, to considerable food web complexity associated with pelagic top predators such as whales, seals and penguins. The sea ice environment plays an especially important role in ecosystem dynamics in the Southern Ocean, and recent changes to sea ice are having far reaching biodiversity consequences.

13. Antarctica was not always glaciated. Indeed, the first continental ice sheets appeared in Antarctica about 34 million years ago. In consequence, the fact that prior to that time Antarctica supported a diverse terrestrial biota, including plants, insects, and even dinosaurs is not surprising. However, the extent of this fossil biota is only beginning to be explored, and remains poorly known for many groups. For example, the first Cretaceous fossil that can definitely be placed within modern bird groups hails from Antarctica.

14. Subsequent to the development of the Antarctic Circumpolar Current, the continent has remained frigid and relatively isolated. However, this isolation is not complete and organisms have migrated both into and out of the region. Wind transport of propagules (cysts, eggs, larvae, seeds, spores, plant parts) from South America to the Peninsula region is not uncommon, especially in the storm tracks generated by low pressure weather systems, and kelp rafts (and more recently floating plastic debris) may form another source of transport of colonists across the Southern Ocean. In addition, a wide range of pelagic mammal and seabird species regularly migrate into and out of the region, so overcoming the isolation barrier. However, even for those propagules that can cross the barriers which separate Antarctica from the other continents, the low temperature and low productivity environment (in the winter in marine systems) represent a significant challenge to survival.

15. More recently, the routes for colonization have increased substantially thanks to human traffic to Antarctica, first by ship, and now by aircraft too. Thus, humans have introduced a wide range of alien, and in many cases invasive, species to Antarctica and the sub-Antarctic islands. These include microbes, algae, fungi, bryophytes, vascular plants, invertebrates, fish, birds and mammals. These species have come to survive, and in some cases dominate, terrestrial, freshwater, and marine habitats, and in the sub-Antarctic are causing considerable damage by way of local species extinctions and wholesale alteration of ecosystems.

16. On the sub-Antarctic islands the effects of invasive species are well known. For example, rats and cats have caused the disappearance of seabird species from several islands, whilst eradication of the alien species has seen the return of the birds. Alien plants reduce local diversity by as much as 40%, and invasive rodents (both rats and mice) have caused wholesale alterations to ecosystem functioning.

17. Alien species arrive in a multitude of ways: in clothing and personal baggage, attached to fresh vegetables, in vehicles, affixed to the hulls of ships and inflatable rubber boats, and as unwanted passengers on anchor chains, in sea chests and in ballast water.

18. Across the Southern Ocean islands there is a strong relationship between the numbers of humans that visit an island and the numbers of species that have successfully been introduced to an island. This relationship between visitor frequency and numbers of alien and invasive species has been established elsewhere and seems to be a general rule.

19. Recent increases in human activity in the Antarctic have been considerable. For example, in the 2001–02 season, Treaty Nations deployed 4 390 personnel at 67 stations or field camps in Antarctica. They also made use of some 60 ships, departing from c. 30 cities around the world, to offload personnel and cargo. Tourist numbers doubled from approximately 6 000 in 1992 to c. 13 600 ten years later and last season reached over 24 000, most of whom visited the Antarctic Peninsula region. Over the past 10 years, the numbers of ships and passengers visiting South Georgia have increased 3–4 fold. In 2004–05 over 9 400 people visited one small site: Port Lockroy.

20. In the Antarctic Peninsula region, and at many sub-Antarctic sites, climates have warmed dramatically over the past 50 years, making these environments more benign than they once were. Thus, both the isolation and climatic barriers that long meant low colonization rates of Antarctica, are being influenced by human activities.

21. In consequence, the chances of successful colonization of the Antarctic by alien species are likely to increase substantially unless appropriate mitigation measures are put in place. In this instance, prevention is more economically viable than eradication programmes, which are usually expensive, often long-term and may prove inadequate.

22. A formal, spatially explicit conservation assessment of the Southern Ocean islands has shown that by strictly conserving 15 of the Southern Ocean Islands, 90% of species richness can be captured, whilst only 50% of the alien species are included. This formal analysis has demonstrated that using spatially explicit data and modern analytical methods provides a more robust approach than expert consultation, which in this particular case rarely proved better than simply picking islands at random.

23. Whilst there is a wide range of measures in place for the conservation and sustainable use of biodiversity in the region, rational, spatially explicit conservation planning, which has been undertaken for many other parts of the globe, lags far behind in the Antarctic realm. In some cases, such as for marine benthic and pelagic diversity, this is a consequence of data deficiency, and only a sustained survey effort is likely to alter the situation. However, there are spatially explicit data for some groups, such as the seabirds and increasingly for the seals, and much local scale data on terrestrial biodiversity is available as a consequence of the requirements for the establishment of Antarctic Specially Protected Areas (ASPAs) and Antarctic Specially Managed Areas (ASMAs). However, these data are yet to be used to develop a formal, spatially explicit conservation planning framework for Antarctica.

24. SCAR has been making information available for explicit conservation planning and has been exploring best international practice for conservation that is directly applicable to the region in order to develop a new spatially explicit strategy for Antarctic conservation in the 21st century.

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