MELTING OF POLAR ICECAPS: IMPACT ON MARINE BIODIVERSITY

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Summary

There is strong evidence that polar ice-caps are, in places, rapidly melting. This is both in response to emergence from the last ice age but also current unprecedented rises in atmospheric carbon dioxide. Melting and the regional warming underlying it, are highly complex and influences on life is debated. In the Arctic and the Antarctic Peninsula the number of glaciers retreating and retreat rates are increasing and there is much consensus on some effects of this on biodiversity. Ice reduction is leading to new sea-ways, and habitat for ice associated organisms is regionally vanishing. Coastlines are changing so more deep areas, shelf, intertidal zones and islands are available for colonisation. More light and heat will enter the water column, increasing primary productivity and sinks for CO_2. Ice-bergs will increase with ice shelf collapses but ultimately decrease as glaciers retreat inland. Lack of ice scouring should increase biodiversity at local scales (less destruction) but greatly decrease it at larger scales as pioneer animals will be smothered by dominant competitors (as mussels do along temperate coastlines). Melt water flow into seas is causing freshening, stratification, and

near-shore sedimentation. These negatively influence on biodiversity by clogging and burying the plankton eaters living on the seabed. Changes in water-mass properties and current dynamics will influence the deeper communities of animals, even the deep sea by, for example, by carrying less oxygen. Such processes will make polar regions more susceptible to invasive (non-indigenous) species. Antarctica has greater marine biodiversity than would be predicted from its coastline length or shelf area and most species there are endemic. Losing Antarctic species is losses to global biodiversity and some evidence suggests particular sensitivity to environmental variability. The future of polar biodiversity and climate change are hard to predict, but considerable (negative) changes are likely in the Arctic and Antarctic Peninsula.

1. Introduction

Throughout most of the last century and currently planet Earth is warming. This warming is very unevenly distributed over the planet and many places are changing little or even cooling. The Polar Regions, in particular the Arctic and the Antarctic Peninsula, are experiencing intense and rapid warming. One of the main effects of the warming has been melting of the ice accumulated in these parts of the Polar Regions. The effects of climate change are many and diverse, and difficult to separate. In this article, we simply discuss melting of polar ice but it is important that it is realised that this melting process is strongly and complexly linked to other processes. That both extreme northern and southern regions currently have ice caps is unusual until recently in geological time. A number of events led to the development of the polar icecaps. The ice masses covering the continent of Antarctica and large areas of the Weddell and Ross seas formed millions of years ago (mya) following a prolonged period of cooling. Following fragmentation of a former super-continent (more than 100 million years ago) other continents drifted away from Antarctica. About 34 mya the Tasman Rise separated and the Drake Passage opened, enabling deep water currents to entirely surround Antarctica. The Antarctic Circumpolar Current (ACC) commenced and Antarctica became oceanographically and geographically isolated. This isolation and the falling atmospheric carbon dioxide (CO_2) levels led to the region’s cooling, development and growth of the huge ice cap and ice shelves. In recent years, to great scientific and public concern, there have been spectacular collapses of floating ice shelves, such as the Larsen B (eastern Antarctic Peninsula).

Following global cooling the ice mass in the Arctic formed mainly to cover the ocean around the north pole. The northern polar icecap also covered Greenland and some of the smaller northern islands such as Ellesmere (in arctic Canada). Many ice masses throughout the Antarctic Peninsula and across the Arctic are retreating and are accelerating in their rate of retreat. It is important to remember that the Polar Regions have been deglaciating for thousands of years since the last glacial maximum. Separation of what, in terms of ice loss, might be expected from the cyclical natural deglaciation and melting in response to rapid warming over the last two centuries is not straightforward. Patterns in seasonal fast ice are changing too. For example the extent, duration and timing of Arctic sea surface freezing in winter is changing rapidly. The consequences of this melting are likely to be increased freshening of surface waters, stratification of the water column, near-shore sedimentation and turbidity, more iceberg scouring, exposing new habitat, and in the case of land-based ice sheets (such as on

Greenland) rising sea level. All of these can drastically influence the biota (living organisms) in the water column, on the seabed and in the lakes and on land in the Polar Regions. Potential effects on biota are further complicated by other changes in the environment such as warming itself, surface water acidification (because of raised atmospheric CO_2) and increased human activity such as bringing in pest species, pollution and fishing.

Investigation of potential impacts on biodiversity requires background knowledge of the recent richness and actual distributions of organisms in the Polar Regions. A swimmer snorkelling in tropical waters at a Pacific and an Indian Ocean shore would see quite a number of species in common. Doing the same at a site in each of the Polar Regions would be quite different; there are no species in common at all. Famously polar bears live in the Arctic and penguins in the Antarctic, but on the seabed things are even more different. There are a number of reasons why northern and southern polar organisms have so little linkage with each other. This lack of connectivity is important to the nature of polar biodiversity. First, the two Polar Regions are completely separated by thousands of km of warm water and Antarctica has been isolated for so long that most Antarctic species only occur there (they are endemic). Second, the two Polar Regions are also very different. The Antarctic is a large continent surrounded by ocean while the Arctic is sea nearly surrounded by landmasses. The Antarctic Ocean is much deeper, has no rivers flowing into it, is less polluted at its margins, and older. Third, species compositions of temperate and tropical environments have become increasingly more similar. In the last centuries humans have directly or indirectly introduced and established thousands of pest species, such that many particular types now live throughout the world. The Southern Ocean is the only marine environment with no known established invaders. Fourth, the Polar Regions have very different levels of biodiversity. If the numbers of currently known species of each polar region are compared to global averages by length of coastline, continental shelf area or ocean area the Antarctic is rich in marine biodiversity (Figure 1) whilst the Arctic is relatively impoverished. This is, however, a very crude measure and hides some important details. The level of species richness varies considerably with the type of animal, for example the proportion of the world's sea spiders (Pycnogonida) and polychaete worms is very high in the Southern Ocean whereas barnacles, crabs, cartilaginous fish and marine reptiles are very poorly represented. An alternative measure is that amazingly representatives of as many as 15 of 36 phyla (major animal types) can be seen in a single SCUBA dive to about 25 m depth – more than for example could probably be seen in any other environment anywhere-else in the world. Particularly common and abundant seabed animals, apart from sea spiders and polychaete worms are starfish, sea urchins, brittle stars and sea cucumbers (all echinoderms). Other mobile animals which are common are sea slugs, snails and clams (all molluscs), amphipods and isopods (all crustaceans) and nemertean worms. Common sedentary animals include priapulan worms and sipunculan worms. Finally many sessile animals are also abundant such as sponges (poriferans), sea squirts (ascidians), sea anemones, soft corals and hydroids (all cnidarians), lamp shells (Brachiopoda), and bryozoans. In the water column the most famous inhabitants are the whales, seals, penguins and a major component of their food is the crustacean krill (*Euphausia superba*). Other common animals in the water column near the surface include jellyfish (cnidarians), comb jellies (ctenophorans), copepods, amphipods and mysid shrimps (all crustaceans), pteropods (molluscs) and arrow-worms (chaetognathans). Actually, a swimmer or diver would see very little life in the very shallow waters (first 10 m) because of frequent catastrophic impacts of small icebergs. Also on most polar shores any intertidal fauna present is cryptic, and so they appear fairly barren of life. Biodiversity is dynamic in space and time, as are the icecaps, so to be able to consider the influence of one over the other, knowledge of more than just the current state of both is needed. For example despite the famous adage about penguins, the Arctic did have a northern equivalent, the Great Auk, but it was hunted to extinction by humans.

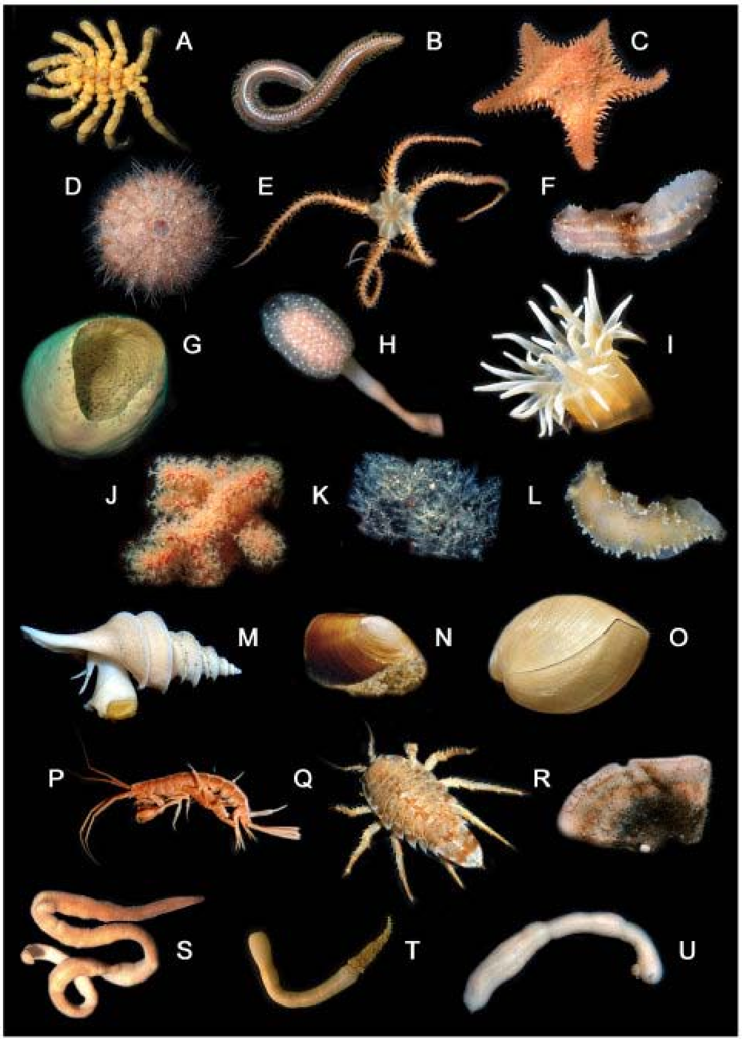

Figure 1. Biodiversity of the Antarctic continental shelf. The benthic animals are a pycnogonan or sea spider (A), polychaete (B), asteroid or sea star (C), echinoid or sea urchin (D), ophiuroid or brittle star (E), holothuroid or sea cucumber (F), demosponge (G), ascidian or sea squirt (H), actinian or sea anemone (I), anthozoan or soft coral (J), hydroid (K), nudibranch or sea slug (L), gastropod or sea snail (M), bivalve or clam (N), brachiopod or lampshell (O), amphipod crustacean (P), isopod crustacean (Q), bryozoan (R) and three types of worm: nemertean (S), priapulan (T) and sipunculan (U).

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Biographical Sketches

David K A Barnes graduated from the Open University in conjunction with the British Antarctic Survey with a PhD on the ecology of Antarctic bryozoans. He taught at the Department of Zoology, Animal Ecology and Plant Sciences at University College Cork, Ireland for five years. Since his PhD he has worked on Indian Ocean coastal biodiversity and ecology in Mozambique, Madagascar and the Seychelles and now heads the nearshore marine section at the British Antarctic Survey and teaches in the Department of Zoology at the University of Cambridge. He and his PhD students are investigating biodiversity and biogeography from the intertidal to deep-continental shelf depths in West Antarctica and Arctic Norway.

Stefanie Kaiser studied zoology, hydrobiology and nature conservation at the Universities of Hannover and Hamburg in Germany. For her PhD at the Zoological Museum, University of Hamburg she is working on the systematic, biodiversity and biogeography of deep-sea isopod crustaceans in the Southern Ocean. In cooperation with the British Antarctic Survey she is studying patterns of colonisation and distribution in macrofauna from the deep sea to the continental slope. She and the team she is part of are trying to find out how biodiversity and abundance of taxa change across spatial scales and so investigating key speciation concepts.