Impacts of Global Warming on Polar Ecosystems

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Offprint of Chapter

INTRODUCTION: GLOBAL WARMING AND POLAR ECOSYSTEMS

by

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THE POLAR REGIONS are the remotest on the planet, explored for the first time less than a century ago when expeditions led by Norwegian Roald Amundsen reached the geographic poles (South Pole, 1911; North Pole, 1926). But not even their isolation has saved them from ranking, in our days, among the zones worst threatened by human activity.

The dangers confronting polar ecosystems are especially disturbing, because these regions play a vital role in the Earth System. Not only do they intervene in the circulation of the atmosphere and oceans, they also help regulate the planet's climate and have a high ecological value.

Despite this, our understanding of how the polar climate operates and about the functioning of its ecosystems is in many respects still primitive. To fill some of these gaps, the International Council for Science and the World Meteorological Organisation have called the International Polar Year 2007-2008 (*www.ipy.org*); the fourth declared to date after polar years 1882-3, 1932-3 and 1957-8, with the peculiarity that the present initiative is not about exploring polar systems, but about the need to investigate the impacts and rapid changes that they are currently undergoing. To this end, thousands of scientists from over 60 countries will engage up to 1 March, 2009 in more than 200 research projects on the Arctic and Antarctic under international coordination. This is the first time Spain has participated in an International Polar Year, and it has done so with an array of research projects funded under the Ministry of Education and Science's National R&D Plan (*www.api-spain.es*). Besides scientific research, International Polar Year numbers among its main objectives to train a new generation of experts in the polar sciences and to raise social awareness around the problems facing the polar regions. This book aims to contribute to the achievement of these two objectives.

◀ **Photo 1: Polar bear (*Ursus maritimus*).** The largest of the terrestrial carnivores hunts its main prey, seals, on the pack ice of the Arctic. The acceleration of the ice melt due to global warming, and losses of the ice masses that it hunts on, have impaired its predation success and currently threaten its survival.

Photos 2 and 3: Researchers at work in the Arctic during the Spanish research expedition ATOS-Ártico

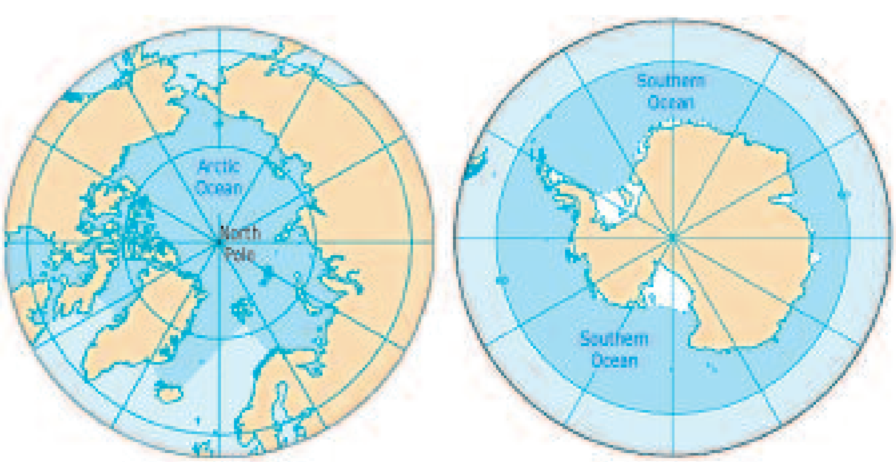
Polar ocean ecosystems are still dominated by a megafauna that has been decimated in other seas. The prevalence of large animals (cetaceans, pinnipeds, birds, etc.) in this kind of environment is due to a number of factors. These include the scant pressure of human activity (contrasting with the intense pressure exerted a few decades back by intensive whaling in the Antarctic, now regulated, and seal hunting in the Arctic, which still goes on), the short length of food chains, due to the presence of relatively large-sized primary producers and planktonic grazers compared to those dominating other oceans, their elevated summer production and the presence of large ice shelves that serve as a habitat for some of the native species. Polar ecosystems can be considered the planet's most inhospitable deserts. Their terrestrial primary production is minimal, meaning they rely almost entirely on the primary production of marine communities. Polar megafauna depend largely on the existence of large ice floes that serve as breeding grounds for key ecosystem organisms (for instance, the krill in the Antarctic), or as hunting, resting or transport platforms for penguins, fur seals and leopard seals in Antarctica and bears, seals, walruses and other animals, including humans, in the Arctic.

Arctic and Antarctic ecosystems have important differences between them, deriving from their geographical configuration, which entails striking contrasts in their functioning and their vulnerability to anthropogenic impact. The Antarctic ecosystem occupies a continent extending from the South Pole to 60º-80º south latitude, isolated from remaining continents by the Southern Ocean (map 1). It is accordingly remote from any territory with significant industrial activity. The Arctic, conversely, consists of a central ocean stretching from the North Pole to 70º-80º north latitude, mostly ice covered and encircled by continents with wide continental shelves, close to zones of intense industrial activity (for example, Canada, the United States, Russia, Norway; see map 1).

Antarctica then is surrounded by ice-free waters for most of the summer, while most of the Arctic polar ecosystem unfolds under a vast platform of ice. Further, periods of light and dark vary from the Arctic to the Southern oceans given the almost 20º difference in their latitude ranges in the corresponding hemispheres. And their connection with the global ocean is also different. The Southern Ocean connects with the Pacific, Atlantic and Indian oceans, whereas Arctic waters only mix significantly with the Atlantic Ocean through the Fram Strait, since exchanges with the Pacific through the Bering Strait are hindered by shallow-lying shelves (map 1).

Moreover, many populated cities with major industrial and commercial activities are found within the Arctic Polar Circle, which is not the case with the Antarctic. This proximity to inhabited continents and industrial centres is

Map 1: Area occupied by the polar oceans



Arctic **Antarctic**

important to remember, because it determines the pressure brought to bear on polar environments.

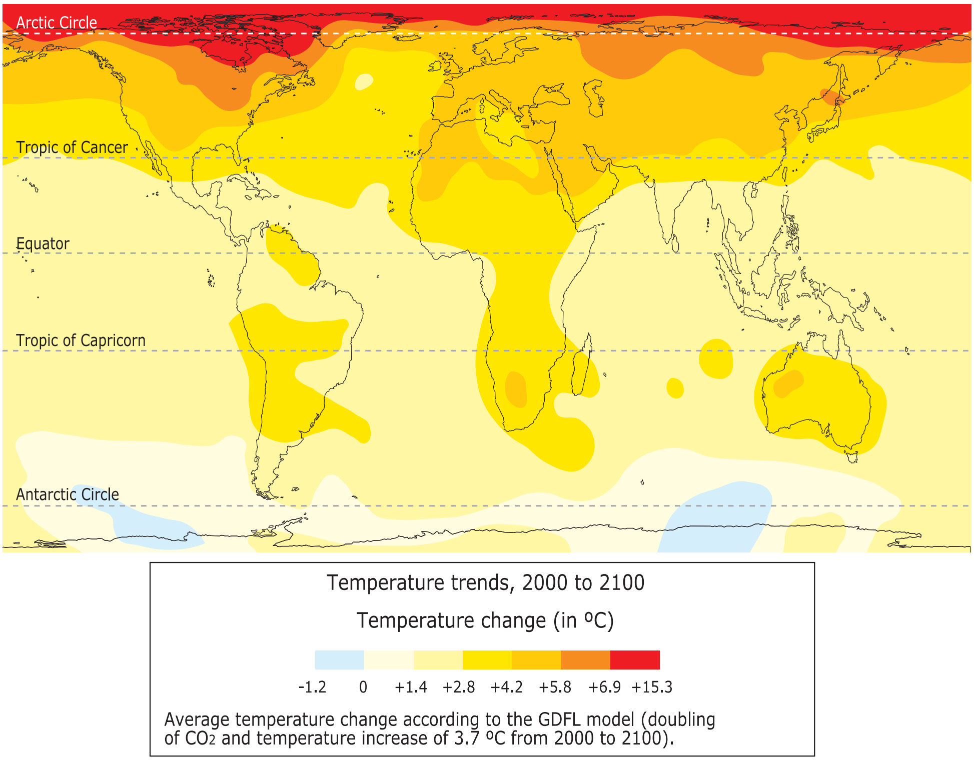
Polar ecosystems are currently experiencing a marked warming trend. This process has reached spectacular proportions in the case of the Arctic, where ice loss is rapid (Vinnikov et al. 1999; Serreze, Holland and Stroeve 2007) and apparently accelerating, to the extent that we can seriously posit an Arctic Ocean without its summer ice cover in the not too distant future (Serreze, Holland and Stroeve 2007). The Antarctic Peninsula is also experiencing significant warming and the disappearance of sea-ice masses (Rignot et al. 2004), albeit with losses much smaller and patchier than in the Arctic.

The effects of global warming on polar regions are already so evident and have such alarming consequences that they were the prime motivation behind the organisation of International Polar Year. Among the activities scheduled under its banner are studies of the polar ecosystem in order to more accurately predict its response to environmental changes, especially global warming. Another of its goals is to inform society better about the changes taking place in the polar regions; a goal shared by the authors of the present book.

Emissions of carbon dioxide and other greenhouse gases produced by human activity are causing a build-up of these substances in the atmosphere which threatens to push up the planet's global temperature by around 4 ºC (IPCC 2001) in the course of the 21st century. The global circulation models used to predict future climate variations point to large regional differences in the speed of warming, with some zones suffering a drastic rise in temperature and others getting off relatively lightly. These models suggest that warming will be most intense in the Arctic zone, , where temperatures may rise by as much as 9 ºC (map 2). In fact, records indicate that the Arctic is already heating up at a rate of 0.4 ºC per decade, twice as fast as the rest of the planet (IPCC 2001). The Southern Hemisphere, in contrast, is projected to experience practically zero warming (map 2).

Other impacts deriving from human activity are, however, far greater in the Antarctic. For instance, the effects on the ozonosphere of volatile synthetic chemical compounds are magnified in the Southern Hemisphere, causing the appearance of a seasonal hole in the ozone layer which exposes the region to greatly increased levels of ultraviolet radiation (see chapter 1). Likewise, whaling has had an important aftermath in the world's southern waters, with implications for the Antarctic system that may run a lot deeper than suspected (see chapter 2).

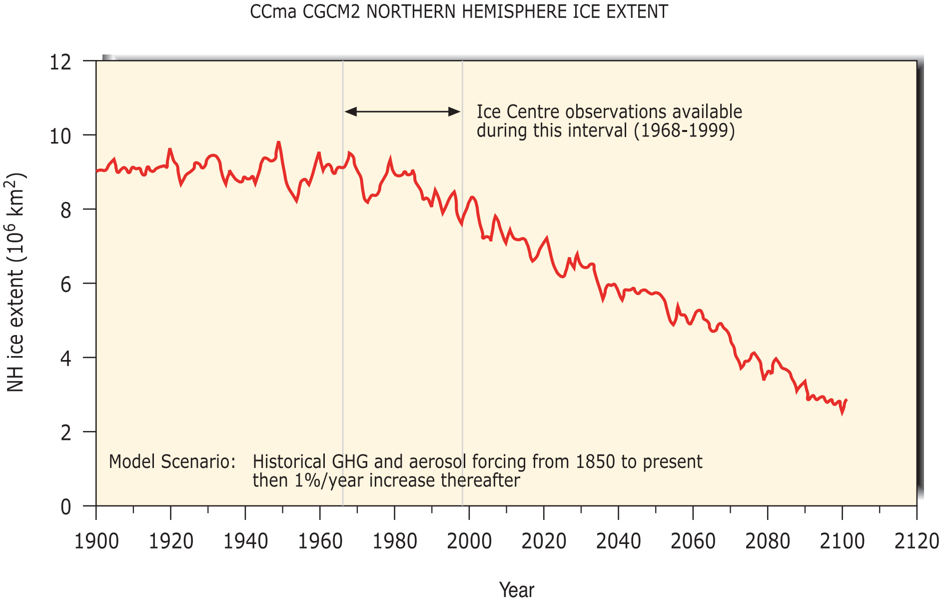
Map 2: Predicted increase in average temperature of all world regions in the 21st century



Source: Geophysical Fluid Dynamics Laboratory, Princeton University.

The first effect of global warming on polar ecosystems is the melting of the polar ice caps. Results published in 2006 reveal a sizeable loss of the planet's ice. On the one hand, the Antarctic ice sheet is losing 152 km^2 of ice a year. This equates to an annual increase in the global sea level of 0.4 ± 0.2 mm, and has also lost the Antarctic Peninsula around 8,000 km^2 of its ice shelves in the last 50 years, coinciding with an approximately 2 ºC rise in regional temperatures. On the other, the retreat of the Arctic ice sheet is accelerating, with recent data showing seasonal ice-cover losses up to 18 times higher than in past decades. This has been accompanied by an unprecedented decline in the Arctic ice, provoking an all-time low in winter ice cover in March 2006 (figure 1), followed by an abrupt melting event in the summer of 2007. Also, in August 2006, large cracks were observed, running hundreds of kilometres, in what was till now the Arctic's permanent ice cover, suggesting that the loss of mass may be about to quicken. In Greenland, meantime, the glaciers are melting at twice the rate of five years ago. The decline in the Greenland ice sheet

Figure 1: Changes observed over the 20th century in the Northern Hemisphere sea ice extent and predictions based on expected Arctic warming rates in the 21st century



Source: National Snow and Ice Data Centre, United States.

has increased fivefold to 239 ± 23 km^3 of ice a year, contributing a further 0.6 mm to the annual worldwide rise in sea level. And modellers are predicting a further jump in the warming rate, which in the Arctic, for instance, will increase to 1.2 ºC per decade over the first part of the century, accelerating to 3 ºC in the second half. Projections for global warming-induced changes in the Arctic ice sheet augur a rapid retreat to less than 3 million km^2 by the end of the 21st century (figure 1); three times less than its extension in the opening years of the 20th (see discussions in Rignot and Thomas 2002; Rignot et al. 2004; and Serreze, Holland and Stroeve, 2007). These estimates are being rapidly revised in the light of the abrupt ice loss of summer 2007.

All these losses have major climatic and geopolitical consequences, but they also threaten a unique "habitat"; the ice surface of the polar oceans. This publication sets out to examine the effects of global warming on polar ecosystems, until now only poorly investigated. In its pages, leading world experts in polar ecosystems discuss the impact of their waters being exposed to solar radiation—associated to loss of ice cover, with particular attention to the levels of ultraviolet radiation reaching the Antarctic ecosystem, and analyse how the marine ecosystem is responding to global warming along with the rich megafauna it sustains.

This book brings together the presentations delivered in the second cycle of debates organised by the Spanish Council for Scientific Research (CSIC) and the BBVA Foundation at the Cap Salines Lighthouse Coastal Research Station (Mallorca), in order to stimulate reflection on the latest scientific challenges and discoveries in marine biodiversity and to alert society to the need to conserve our oceans and coasts.

In its chapters, reputed international experts offer a prospective vision of the impact of climate change on polar ecosystems.

I wish, in closing, to thank the BBVA Foundation for its support and financial assistance in organising the event that gave rise to this book and facilitating its publication. My thanks also to José Manuel Reyero and his associates for their work on preparing the texts. This introductory text benefited from discussions to plan the Arctic Tipping Points project, funded by the European Commission.

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