THE IMPACT OF GLOBAL CLIMATE CHANGE ON MARINE ECOSYSTEMS

Jacqueline M. McGlade

Arbeitsgruppe Theoretische Ökologie
Forschungszentrum Jülich
Postfach 1917
D-5170 Jülich, FRG
and
Darwin College
Cambridge CB3 9EU, UK

INTRODUCTION

The world's climate is inextricably bound up with the dynamics of the oceans and their physical, chemical, and biological functioning. Changes in global climate will therefore affect not only the circulation patterns of the oceans, but also, by extension, the role of the oceans as a reservoir for heat and atmospheric gases. Elements such as carbon take approximately 100 years to be exchanged between the surface waters and deeper layers of the ocean: part of this process is intimately tied up with the production of phytoplankton in the surface layers of the ocean and coastal waters. The ocean, therefore, directly affects the rate at which atmospheric gases, such as carbon dioxide (CO_2), adjust to changes in their sources or sinks. To view climate change sensibly, it is therefore essential that the ocean be seen as an integral part of both the geosphere and the biosphere.

Foremost in the debate about climate change is whether or not the data and models currently used to make predictions about increasing atmospheric CO_2 are sufficient to determine the likely response time of the coupled atmosphere-ocean system. It is already known that alterations in certain coastal currents can lead to the catastrophic inundation of deltaic areas, with widespread damage and loss of life. Now there is a growing concern among the population at large that a worldwide ecological disaster awaits us, a concern driven by the apparent increase in severe storm events, excessively severe winters in the Antarctic, and a progression of uncharacteristic seasonal weather patterns across the globe.

In the following chapter, I trace the implications of these changes along several avenues, by first giving an overview of the main biogeographic events and processes in the ocean. In terms of geological time, the ocean basins are very recent and relatively short-lived structures. When the oceans opened up during the last 150 million years, they were invaded by the major extant groups of marine fish, including the modern teleosts. The structure of the continental shelf and littoral zone subsequently gave rise to many new niches, which were progressively colonized by invasions of marine fish. To a large extent, the life cycles of these species were determined by the oceanographic and bathymetric structures that arose during this period.

Next, I examine some of the major patterns of exploitation of marine resources, identifying those species and countries most likely to suffer from climate change,

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either directly through sea level rise, or indirectly through ecological displacement, loss of resources, or product substitution. Because the influence of the sea is felt all along its terrestrial boundaries, the discussion of biological impacts also includes the coastal region, particularly in areas bordered by mangroves, where the biota are intricately adapted to the tidal and sea level regimes. It is argued that fishing patterns along the world's coasts will be affected by changes in circulation such that within the exclusive economic zones (EEZs) established under the 1982 United Nations Law of the Sea Treaty, other biological and social problems will arise. Indeed, many of the artisanal fishing communities depend upon access to and harvesting of local fish and invertebrates for their survival. The unprecedented explosion of aquaculture in developing countries has brought fish products into the agricultural commodity market, where the incipient economic structures are quite different from those of the fishing industry, and rely on a steady product supply. Changes in sea level will therefore have an immediate effect upon these communities, because they often have no alternative sources of food, habitation, or employment, and might lose their aquacultural investments because of intermittent supply.

Beyond the EEZs, the problems of regulation and defining strategies for sustainable use of the oceans increase in the face of climate change. One option is to make the oceans equally accessible to all, but, paradoxically, the distant-water fleets that use the oceans are likely to be among those most affected by climate change because of their dependence on the pelagic resources of upwelling and polar regions. Fishing fleets will have to be controlled in the open ocean, but as yet there are no institutional structures in place to regulate or govern the activities of countries that might destroy these marine resources through climate-induced changes.

In the final section, I examine problems arising from the fact that the geopolitics of conservation and development of maritime ecosystems are generally at odds with each other. Most current management models for ecosystem exploitation are based on biological models of single species, with equilibrium/deterministic assumptions. Change is incorporated in hindsight, so that regulatory measures are constantly being altered. This inconstancy has led to a growing credibility gap between government and those involved in the commercial exploitation of the marine ecosystem. To overcome some of these problems, a management framework is suggested based on a multispecies, multiactor approach. The structure affords the inclusion of some of the issues arising from conflicts between commercial sectors, socio-economic factors, and instabilities within the ecosystem itself, that are all likely to arise as a result of climate change.

MARINE BIOGEOGRAPHY

The historical record of changes in the marine ecosystem in response to climate changes does not provide the level of detail needed to predict the effects of global warming precisely. One can, however, extrapolate probable future responses from past events. Therefore, this section focuses primarily on known alterations that have occurred in the past as guidance to possible future shifts (see Fig. 1).

Wandering Continents and Biological Invasion

Studies of continental drift show that the Pacific Ocean is approximately 175 million years old, that the Atlantic and Indian Oceans opened up 150 myr ago, and that 50 myr ago the structure of the oceans was similar to the present. On the other hand, the evolution of fish follows from the early jawless Agnathans in the Devonian (200 myr ago) and the teleosts in the Tertiary/early Quaternary (100 myr ago). We can conclude that colonization of the oceans by extant families of fish and invertebrates would have occurred as the oceans opened up; thus, the older the ocean basin, the more species it is likely to have. In addition, latitudinal differences exist between species of fish because of generation times and the time taken to switch from somatic to gonadic growth. Longitudinal differences also occur because of Coriolis forces and the physical structuring of the oceans, so that, for example, there are approximately 900 species in the western Atlantic compared to 300 in the east.