CHAPTER

21

Global Climate Change and Species Interactions

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A major environmental concern of this century is the impact of human activity on the Earth's climate, with prospects of major biological upheaval. The combined effects of deforestation and release of chemicals to the environment are likely to dramatically modify global temperature, and wind and rain patterns within the next century (Schneider 1989; Wetherald, 1991). However, most conservation biology proceeds without reference to climate shifts. This may be because the major threats to biodiversity (e.g., habitat destruction) occur quite independently of climate. Unfortunately, however, many of our solutions to biodiversity threats, such as the creation of national parks and reserves, are designed on the assumption that the climate will stay as it currently is. In this chapter I review the commonly accepted scenarios for climate change, sketch some research regarding impact on different organisms, and focus on two issues: how might climate change threaten the persistence of species and what surprises might await us as a result of climate change.

Since the industrial revolution, gas emissions linked to human activities have resulted in a 25% increase in CO_2 in the atmosphere (Root and Schneider 1993). This elevated CO_2 and other gases "trap heat" in the atmosphere, and an increase in average temperature is expected as "greenhouse gases" continue to accumulate in the atmosphere. The main sources of CO_2 are the combustion of fossil fuels and the destruction of tropical forests, which release 5–6 and 1–3 billion tons of carbon per year, respectively (Tregarthen 1988; Legget 1990; Rubin *et al.* 1992; Skole and Tucker 1993). Most models predict that if the gas release continues at the same rate, there will be an average increase of temperature on Earth between 2.5° and 4.5°C by the middle of next century (Schneider 1989; Davis 1990; Legget 1990; Wetherald 1991). Already in the 20th century there apparently has been a warming trend of 0.5 to 2°C (Root and Schneider 1993). During the Ice Ages in the Pleistocene the average temperature change was 5°C over 10,000 years, and this caused major changes in the distribution and abundance of organisms during that period (Woodward 1987; Schneider 1989). A similar temperature change occurring ten to one hundred times more rapidly could have devastating effects on many species, and will almost certainly change community and ecosystem dynamics.

Of course, climate change will not affect all organisms equally. Some may be able to disperse northward to escape the "heat"; others may possess physiological tolerance to the altered climate; and some may have a greater ability to evolve in response to the

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changing environment. Because species will differ in their responses to climate change, there is certain to be a reshuffling of species associations even if there are not massive extinctions. One then has to wonder whether goals such as preserving selected natural communities are feasible. Perhaps communities and ecosystems as we know them must inevitably cease to exist as a result of climate change.

DIRECT EFFECTS OF GLOBAL CHANGE ON ORGANISMS

Abiotic variables, such as temperature and humidity, largely determine which organisms succeed in a given area. Thus a change in the physical environment is expected to cause changes in survival, reproduction and physiological responses, as well as shifts in the geographic distribution of those organisms. Measuring the response of individual species to changes in abiotic factors should stimulate hypotheses about the effect of global change on different organisms.

Direct Effects of Global Change on Plants

One way plants can respond to climate change is to shift their distributions via dispersal and colonization of new regions. Unfortunately, the capacity of organisms to disperse among habitat fragments may be so poor that this response is not a "real option" (Groom and Schumaker 1993). In fact, limited dispersal abilities apparently caused massive extinction of plant species during previous climate change events (Gates 1993; Knoll 1984). For example, the paleontological data suggest that the taxonomic composition of the temperate forests of Eastern North America and Northwestern Europe were very similar during the Pliocene. However, the present woody flora of Northwestern Europe is very species-poor relative to Eastern North America. This is apparently due to the difference in the topography of the two regions: in America, the Appalachian Mountains run in north-south direction, whereas the Alps run from west to east. During the Ice Ages in the Pleistocene, the Alps constituted a barrier for dispersal to warmer climates, whereas seed dispersal was much more successful in America without such west-east mountain barriers (Knoll 1984).

It is important to realize that the expected climate change in the next 60 years would be at least two orders of magnitude faster than in the Pleistocene. Thus, to avoid massive extinctions, seed dispersal and establishment rates of new populations would have to be much higher than anything known from the past. Assuming that (1) a 1°C temperature increase approximately corresponds to 100 km in latitude (Pacala and Hurtt 1993), (2) temperatures will increase approximately 2.5°C over the next century, and (3) plants disperse at historical rates, it is obvious that the pace of warming will be too fast for natural dispersal of plants to keep up with predicted changes in temperature (see Table 21.1) (Schneider 1989; Gates 1993; Morse *et al.* 1993).

Given the likely inadequacy of dispersal, it is therefore interesting to ask to what extent current distributions of species overlap with predicted future regions of suitable climate. The Nature Conservancy (TNC) has developed a "climate envelope" analysis to address this question. The analysis includes all the native vascular plants of North America north of Mexico: a total of 15,148 species (Morse *et al.* 1993). The "climate envelope" of each species is defined by the range of climates in which the species is currently found. This envelope is then compared to the geographic area that would be within this