Climate Change Impacts

ANTICIPATING THE FUTURE UNDER THE INFLUENCE OF CLIMATE CHANGE IS ONE OF THE MOST important challenges of our time, and the topic of the special section in this issue of Science (see p. 472). The natural systems that provide oxygen, clean water, food, storm and erosion protection, natural products, and the potential for future resources, such as new genetic stocks for cultivation, must be protected, not just because it is part of good stewardship but also so that they can take care of us. But even the first step of modeling the effects of greenhouse gas sources and sinks on future temperatures requires input from atmospheric scientists, oceanographers, ecologists, economists, policy analysts, and others. The problem is even more difficult because the very factors that influence temperature changes, such as ocean circulation and terrestrial ecosystem responses, will themselves be altered as the climate changes. With so many potential climate-sensitive factors to consider, scientists need ways to narrow down the range of possible environmental outcomes so that they know what specific problems to tackle.

Researchers have turned to the geologic record to obtain ground truth about patterns of change for use in climate models. Information from prior epochs reveals evidence for conditions on Earth that might be analogs to a future world with more CO$_2$. Projections based on such previous evidence are still uncertain, because there is no perfect analog to current events in previous geologic epochs; however, even the most optimistic predictions are dire. For example, environmental changes brought on by climate changes will be too rapid for many species to adapt to, leading to widespread extinctions. Even species that might tolerate the new environment could nevertheless decline as the ecosystems on which they depend collapse. The oceans will become more stratified and less productive. If such ecosystem problems come to pass, the changes will affect humans in profound ways. The loss in ocean productivity will be detrimental for the 20% of the population that depends on the seas for nutrition. Crops will fail more regularly, especially on land at lower latitudes where food is in shortest supply. This unfavorable environmental state could last for many thousands of years as geologic processes slowly respond to the imbalances created by the release of the fossil carbon reservoir. The time scale for biodiversity to be restored, with all the benefits that it brings, will be even longer.

Unfortunately, I view these predicted outcomes as overly optimistic. We are not just experiencing increases in greenhouse gas emissions but also eutrophication, pollution of the air and water, massive land conversion, and many other insults, all of which will have interacting and accumulating effects. The real problem we need to solve in order to truly understand how Earth’s environment may change is that of cumulative impacts. Although the Paleocene-Eocene Thermal Maximum (about 55 million years ago) is the time period considered to be a reasonable analog to a higher-CO$_2$ future, the planet was not experiencing these other stressors and climate change simultaneously. So terrestrial species that survive a climate impact alone may face extinction if reduced to a fraction of their natural range through deforestation and habitat fragmentation. Marine species that are mildly susceptible to ocean acidification may not be able to tolerate this condition plus low oxygen levels.

Sometimes the science of cumulative impacts is straightforward—for example, connecting habitats to provide migration corridors in response to sea-level rise brought on by climate change. But even “clear-cut” cases require extra work, more partnerships, and more time to address. Tackling problems of cumulative dimensions is a priority if we are to find viable solutions to the real environmental crises of the coming decades. There is a need for all scientists to rise to this challenge.

— Marcia McNutt

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