

Biological Response to the Greenhouse Effect

A Conference Report
By Napier Shelton

An Everglades half under the sea. Spruce and fir disappearing from the Great Smokies and Nevada's Wheeler Peak. Tundra ponds becoming forest ponds in the lowlands of Denali. Such were the images conjured up for a Park Service person at the recent conference on Consequences of the Greenhouse Effect for Biological Diversity. Organized by the World Wildlife Fund-U.S. and co-sponsored by the National Park Service and five other organizations, it was held at the National Zoo auditorium in Washington, D.C. Oct. 4-6, 1988.

The conference brought together leading scientists to share their views on biological change under global warming. The picture they presented was complex and sobering. Major ecological dislocations were predicted, and, as the Chinese proverb quoted by George Woodwell goes: "If we continue to go in the direction we're headed, we're likely to get there."

The whole exercise, of course, was predicated on the truth of scientific consensus that rapid global warming, caused by increasing CO₂, methane, and other greenhouse gases in the atmosphere, will indeed happen in the next few decades. Stephen Schneider of the National Center for Atmospheric Research presented ranges of climate changes over the next 50 years or so from "state-of-the-art modeling results": a 2° to 5°C rise in global average annual temperature, a 7 to 15 percent increase in global precipitation, and a 10 to 100 cm rise in sea level. Regional changes, which carry more uncertainty, range from -3 to +10°C, and -20 to +20 percent for precipitation. Warming is expected to be much more pronounced in the temperate and, especially, high latitude zones than in the tropics. Such climatic changes will affect the timing and rates of snowmelt, the frequency of hurricanes and fire, nutrient cycles, oxidation of carbon stored in soil, and many other important environmental processes.

The extremely varied biological effects will be direct and indirect, and will be compounded synergistically by acid rain, stratospheric ozone depletion, deforestation, and other human-caused problems. Most major northern hemisphere plant communities are expected to shift northward and, on mountains, upward, with a reduced areal extent of tundra and boreal forest. Spread of boreal forests into tundra and increase of deciduous species in boreal forests has already been documented over the past 100 years, during which time summer temperatures in these regions of North America have increased by 2°C.

Potential range shifts of four northern hardwood species were investigated by Margaret Davis and Catherine Zabinski of the University of Minnesota. They compared geographical ranges of these species with maps of climatic variables to determine their temperature and moisture limits. Two models were used to generate scenarios of effects on species ranges. Both models predicted a displacement of more than 500 km for all four species. Sugar maple, which now ranges south to Tennessee, was predicted to become extinct in all of its present range except for northern New England and Nova Scotia, and to invade an area of boreal forest to the north. The question arises, however, whether changes in the podzolic soil of the boreal forest could occur fast enough to allow sugar maple to grow there. Another question is whether the four species are capable of migrating 500 km in 100 years or less; fossil records indicate range extensions for most tree species of only 10-40 km per century.

Increased dryness in many parts of North America

could cause additional stress on plants, but greater efficiency in water use can be expected because increased carbon dioxide levels cause plant stomates to close. Some plant species may be able to tolerate climatic change but die out through loss of ability to compete. Scots pine, for instance, ranged throughout the British Isles after the Pleistocene and now can be grown anywhere in the Isles horticulturally, but it can compete under natural conditions only in the north.

Animals, too, will be affected directly and indirectly by climate change. Direct effects should be pronounced on cold-blooded species, for instance, and on embryos of ground-nesting birds, as well as on species such as many turtles and geckos in which sex ratios are temperature-induced.

Animals may be affected indirectly by climate-induced changes in their food supply or their habitat. Migratory shorebirds, for instance, that feed on horseshoe crab eggs in spring in Delaware Bay, might not be able to adjust if climate change altered the timing of horseshoe crab reproduction. Slow migrators such as snails will be losers and fast migrators such as birds will be comparative winners, assuming species comprising their habitats and food can migrate rapidly as well – a large assumption.

Numerous changes in plant-animal interactions are expected. For instance, slug feeding on mint in redwood forests would decrease under drier conditions because the slug is moisture restricted whereas the mint is not. Pollination could be disrupted because of evaporation of volatile pheromone "markers" that tell insects which flowers have already been pollinated.

Much information needs to be collected and analyzed before a basic understanding can be arrived at about how human activities influence global climate, according to a briefing by six U.S. scientists for NASA officials in D.C. recently, but Robert E. Dickinson of the National Academy of Sciences told the administrators: "You should be prepared to [formulate policy] now, so that in 10 years when you do understand the problem, you can do something about it without having to wait another 10 years." *Science News*, Nov. 5, 1988, p. 293.

Soil organisms in general have wide tolerances for temperature and moisture conditions. Taxonomic groups are therefore similar worldwide. Climate change would probably affect soil organisms primarily through effects on vegetation and resulting changes in soil processes. Functional changes rather than much loss of species is expected.

There is bad news on the disease front: tropical parasites probably will invade warm temperate zones. The tsetse fly, for instance, would be displaced northward in Africa, subjecting large new areas to sleeping sickness and livestock mortality, while opening the former range to increased exploitation.

Exotic species are expected to profit everywhere, taking advantage of the widespread habitat disturbance and die-offs caused by climate change. It was suggested that this is not all bad: exotics might thus play a stabilizing role during the climatic transition. Furthermore, what is "exotic" might have to be redefined under a changing climate.

In the sea, said Carleton Ray of the University of

Virginia, the effects should be greatest in coastal and continental shelf waters, which are the most productive. The rich fisheries of temperate to boreal waters can be expected to decline, whereas coral reefs might expand poleward. Species loss may not be great because of typically wide ranges, reproductive capacities, and dispersal mechanisms.

Barrier island landward migration rates, now averaging 1.5 m per year on the U.S. east coast, could increase by 50-600 percent under a projected sea level rise of 10-100 cm in the next 50 years. Estuarine habitats for many marine species would almost assuredly be affected, Ray said. Larry Harris (University of Florida) pointed out that a one-foot rise – about 30 cm – would bring the sea 10 miles farther into the Everglades.

The effects of climate change were brought home most forcefully when specific regions were considered. Marine organisms of the Arctic Ocean would be profoundly affected if warming resulted in melting of sea ice. The food chain depends heavily on algae that grow on the bottom of sea ice and fall to the ocean floor, and on seasonal algal blooms in low salinity meltwaters. Furthermore, polar bears and other animals rely on sea ice for transportation.

Dwight Billings of Duke University foresaw drastic changes in the arctic tundra on Alaska's North Slope if global warming led to disturbance of the sedge-grass cover. "... the ecological effects could lead to loss of system integrity due to decomposition of peat and the loss of the upper permafrost. It is the upper permafrost that binds this ecosystem together as it has for at least the last 10,000 years. If the upper 2 to 3 meters of permafrost is lost, the wet coastal tundra is lost."

Boreal and Pacific Northwest forests would be transformed as well. Using the JABOWA model of forest growth, Daniel Botkin of UC-Santa Barbara projected replacement of the boreal forests of the Boundary Waters Canoe Area by northern hardwoods between the year 2010 and 2040. Jerry Franklin, assuming a 2-5°C temperature increase and little or no change in precipitation in the Pacific Northwest, predicted changes there due mainly to increased wildfire, storms, and pests and pathogens that would result from the drier conditions. Among the overall effects of these disturbances could be loss of diversity as species fail in "tracking" suitable habitat, and a shift from forest to nonforest cover, such as chaparral, because of failure of forest trees to reproduce on disturbed areas.

Less alteration was expected in the Mediterranean ecosystems of California/Baja California and in tropical rain forests. The predicted warmer and wetter climate for the California Floristic Province would result in greater evapotranspiratory stress. Expected vegetation responses are an expansion of chaparral at the expense of southern oak woodland, and an upward extension of pine and red fir forests in the Sierra Nevada. Thorn scrub, now in Mexico, might invade California for the first time since the Miocene.

Responses of humid tropical forest were inferred from observations of ecological change at a few neotropical sites. Global warming, per se, was not expected to have serious effects on tropical forest biodiversity, except near the latitudinal and altitudinal limits of these forests. But changes in the seasonality of rainfall could alter the species composition and population structure of communities, and could affect plant phenology, frequency of reproduction, and altitudinal migration, as well as susceptibility to natural disasters. The lack of a dry season,

for instance, could inhibit flowering of keystone fruit trees, leading to famine among frugivores.

How can we lessen the loss of biodiversity that seems imminent? First, improve knowledge, emphasizing processes rather than species. More refined models of climate change are an obvious requirement. Much interdisciplinary research is needed, and institutional adjustments and professional rewards to encourage this now unpopular activity. We need to expand development of integrated models, and increase long-term research. Boyd Evison stressed the need for basic data about current conditions, so biological effects of climate change can be better detected.

More active management of natural communities will also be required. "We will have to become ecological engineers of the first order," said Jerry Franklin. What this would entail was not the focus of this conference, but someone facetiously suggested moving trees rather than MX missiles northward on railroad flatcars. More seriously, Margaret Davis urged research on procedures necessary to artificially recreate natural forest communities in new locations farther north. Forest management should be directed toward reducing fragmentation and providing a landscape matrix that nurtures biological diversity. Such a landscape would be more

resilient to climate change and would ease the passage of migrating species. Natural reserves, it was stated, should be very large to minimize effects of random disturbance.

Besides seeking management mitigation practices, the underlying economic and political bases of the problem must be attacked. Congresswoman Claudine Schneider eloquently addressed this side of the issue while describing a bill she recently introduced to reduce emissions of greenhouse gases. She concluded by urging scientists to become lobbyists. "You must not sit by the sick bed," she said.

I found this conference extremely informative. It told us in some detail about the kinds of biological responses to expect. Future conferences no doubt will address the next questions: how species migrate, how we can assist in that process, and how we can maintain biological diversity until the long-term problem of atmospheric pollution is resolved. Papers from this conference will be published by Yale University Press in late 1989. If you wish to obtain them contact Stacey Roberts, Conference Coordinator, World Wildlife Fund-U.S., 1250 - 24th Street NW, Washington, D.C. 20037. Phone: (202) 778-9572.

Shelton is a writer-editor in the NPS Washington office.