

Effects of Global Warming on Freshwater Ecosystems

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The idea of global climate change is mostly speculation at this point – a prediction founded on some still fairly shaky evidence. Yet it would be unconscionable not to give the possibility serious consideration. We offer these thoughts on global warming and its effect on freshwater ecosystems while at the same time wishing to avoid proposing dire consequences based on too little data, putting too much faith in preliminary scenarios or failing to consider other plausible alternatives. Our comments are based on a symposium, "Troubled Waters of the Greenhouse Earth: Climate Change, Water Resources and Freshwater Ecosystems," held at Virginia Tech in May 1990, the results of which will be published by fall of 1991.

Estimates predicting a doubling of atmospheric CO₂ levels within the next 100-150 years are today almost universally accepted (Schneider 1989). If this occurs, global average temperatures may increase up to 5.5°C, and precipitation will increase by 7-11 percent. In general, the central parts of the continents will get warmer and drier in summer. The oceans will warm more slowly than the continents, while the polar regions will warm more than the equator. The largest temperature changes will occur in the fall and winter seasons at the high latitudes of both hemispheres.

An initial response to warming will be increased levels of methane derived from bacterial metabolism in tundra and boreal wetland ecosystems during summer months. The huge expanse of Canadian and Siberian tundra will provide large amounts of this greenhouse gas to the atmosphere, compounding the greenhouse effect. As warming proceeds, melting will lower the permafrost layer, further increasing the release of methane. This effect is fairly easy to project because arctic ecosystems are relatively simple. In temperate and tropical areas, effects will be no less significant, just harder to estimate.

All global processes are linked, so terrestrial events will have effects on streams. Streams will then reflect these effects in their transport of materials to the oceans. The River Continuum Concept (Vannote et al. 1980), a basic component of present stream ecology, views rivers as more than simply downstream transporters. Important nutrient materials moving downstream are retained by physical (e.g. leaves in a log jam) or biological means (e.g., aquatic insects) and held in place where they may be further processed or "spiralled." Under the effects of global warming, input and retention of vital materials in streams will be significantly altered. For example, warmer temperatures will increase rates of bacterial respiration in soil, leading to increased consumption of soil organic material. This, in turn, leaves less material to be leached into streams, and hence lower levels of dissolved organic carbon (DOC) available to stream organisms.

Streamwater nitrogen concentrations are tightly linked to microbial transformations in soils, so alterations of temperature probably will affect the amount of nitrate entering streams. Concentrations of phosphorus are also tightly bound and closely regulated in stream ecosystems. Changes in streamflow will have pronounced effect on the net retention of phosphorus by streams and their transport of this vital nutrient to coastal estuaries.

In many parts of the world, leaf litter input is the chief energy source driving stream ecosystems. Invertebrates shred the leaf material and make the resulting fine particulate organic matter available to the rest of the food chain downstream. Changes in terrestrial vegetation are inevitable in most global warming scenarios. Whether by changing growth patterns or community species composition, these alterations will have an effect on stream ecosystems. As trees die, streams will initially receive an increased loading of woody debris. Primary production of algae might increase due to holes in the canopy shading the stream. Thereafter, nutrient inputs to streams will change as the composition, condition, and timing of leaf litter input changes.

Although stream animals are noted for their resistance to frequent disturbances (like flooding), changes on a larger or more frequent scale, will not necessarily fall within the animals' ability to adapt. Individual animals will have to cope with change over unprecedentedly short times. Life cycles of aquatic insects are strongly affected by temperature cues. Populations of lotic species (those that occur in flowing water) in non-optimal thermal habitats are characterized by low population density and small-bodied individuals. Animals faced with sudden exposure to unusual conditions will have only three choices: to move, adapt, or die. Considerations of genetic makeup and phenotypic variation suggest that *in situ* adaptation is more likely than shifts in geographic range. Extinction of some species remains a possibility.

Some predictions say that global warming will favor increased rates of forest disturbance due to forest fires, convective wind storms, coastal flooding, and hurricanes. Alterations in flow can affect storage and transport of DOC, nitrogen, and phosphorus. Present projections conclude that if floodplains are drier and there is less anaerobic activity, there will be a subsequent decrease in denitrification causing an increased pulse of inorganic nitrogen reaching streams. Whether this increase (and a related phosphorus pulse) will continue, or whether the situation will result in rapid soil depletion with dire effect on streamlife, is still not clear.

Flow regime and vegetation of the flood plain will also have a strong influence on the amount and type of sediment washed into streams. Siltation directly influences habitat available to stream insects and the eggs and fry of fish.

There have been 10 major and more than three dozen minor periods of glaciation in the last million years. Yet scientists at the Climatic Research Unit in England reported that 1988 was the hottest year since records have been kept. They further reported that the six hottest years of the century all occurred in the 1980s. Without additional paleoecological research, little additional help will be derived from the past on what might occur in future aquatic environments. Human activities already have stressed natural systems so severely that it becomes difficult to separate these disturbances by discrete causes. An adequate supply of high quality fresh water is essential to our society. We need to be able to predict the effect of different climate change scenarios to protect what we have, to maintain productivity and diversity, and to develop acceptable alternatives for management.

Freilich recently completed a doctorate in aquatic entomology at U/GA; his research focused on behavior of stoneflies at Grand Teton NP.

Minshall, professor of biology at ID/St/U, is a well-known stream ecologist, and was final summation speaker at the Troubled Waters conference mentioned in this article.

Literature Cited

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