Climate Change's Pressures on Biodiversity

Thomas Lovejoy

The last 10,000 years has been a period of unusually stable climate very favorable to the development of human civilization. The world's ecosystems also adjusted to the stability. Now that is beginning to change. Nature is responding to the climate change that has taken place on a planet 0.75 degrees Celsius warmer than preindustrial levels. Some of the change is physical in nature, most notably the phase change between ice and water. Northern hemisphere lakes are freezing later in the year and ice is breaking up earlier in the spring.[1]

Glaciers are in retreat in most of the world, with those in the tropics due to disappear in 12–15 years. Some of these are important water sources for cities like La Paz and Quito. Others are important for the major rivers of China and the Ganges. This hydrological shift obviously has implications not only for human populations but also for the ecosystems that depend on them.[2]

The most dramatic changes are those taking place in the Arctic: the summer retreat of the sea ice of the Arctic Ocean has been accelerating, as might have been anticipated with more dark water exposed and absorbing heat from the sun. The biodiversity poster child for this situation is the Polar Bear, now listed as threatened under the U.S. Endangered Species Act because the critical habitat these huge animals need in order to survive is literally disappearing beneath them.[3]

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Beyond the Arctic, the timing of the life cycles of many plant species is changing, plant and animal species ranges are shifting, and the rising temperature is having numerous other unexpected effects. (See Table.) These changes are no longer single examples. They constitute statistically robust documentation that nature is on the move all over the planet.[4]

Yet all these changes are relatively minor ripples in nature. The more important question is, What is in store? There is at least an additional 0.5 degrees Celsius of warming already implicit in the current atmospheric concentrations of greenhouse gases (GHGs) because of the lag time in the buildup of heat.[5]

Climate change is, of course, nothing new in the history of life on Earth. Clearly, glaciers came and went in the past hundreds of thousands of years without major biodiversity loss. But today's landscapes—highly modified by human activities—present obstacle courses to species as they attempt to follow the habitat conditions they need to survive. The obvious policy response to this is to restore natural connections in the landscapes in order to ease species dispersal.

A more difficult complication is that ecosystems and biological communities do not move as a unit. Rather, studies of past responses to climate change (for instance, after the retreat of the last glacier in Europe)

Selected Examples of Climate Change's Effects on Biodiversity

Indicator	Changes to Date
Flowers	Blooming earlier at Kew Gardens in London
Tree swallows	Migrating, nesting, and laying eggs earlier
Butterflies	Ranges shifting for Edith's Checkerspot Butterfly in western United States and for many species in Europe
Golden Toad of Monteverde	Formerly found in Costa Rica, first species to become extinct due to climate change
Eel grass	Southern limit in U.S. Chesapeake Bay moving northward every year
American ash tree	Warmer and longer summers allowed Emerald Ash Borer to produce one more generation than before, producing massive tree death
Coral reefs	Algae expelled from reefs due to warming water, leading to coral "bleaching events"

Source: See endnote 4.

reveal that individual species each move in their own direction and in their own way. In essence, ecosystems will disassemble. After tracking their required conditions, the surviving species will assemble into novel ecosystems the likes of which are difficult to anticipate.[6]

Another complication is that change will not be linear and gradual. Much as there will be abrupt change in the climate system itself, there will also be abrupt change in ecosystems. In fact, such threshold changes are already being observed. In southern Alaska, British Columbia, the U.S. Northwest, and Colorado, as well as in Scandinavia and Germany, the longer and warmer summers and less severe winters are tipping the balance in favor of the native pine bark beetle, for example. With one more generation able to reproduce, there are now tens of millions of hectares where up to 70 percent of the trees are dead, creating an enormous timber and fire management problem and, through the loss of trees, adding yet more carbon dioxide (CO_2) to the atmosphere. It will be difficult to anticipate all such threshold changes; indeed, the world can expect a lot of surprises.[7]

In addition, change at an even greater scale—namely, system change—can be expected, such as with the hydrological cycle of the Amazon. It has been known for 30 years that the Amazon forest has the remarkable feature of generating an important fraction of its own rain. Windborne moisture from the Atlantic Ocean drops as rain, and most of it evaporates from the complex surfaces of the forest or is transpired by the trees, thus returning to the westward moving air mass to become rain and to then recycle again farther to the west. This is important in maintaining the forest and providing precipitation farther south on the continent.[8]

In 2005, the Amazon "rain machine" system failed, creating the greatest drought in recorded history in Amazonian Brazil. This was traced to changes in the Atlantic circulation—and believed to be a preview of what climate change could bring. Indeed, most of the major climate models, particularly that of Britain's Hadley Centre, predict "Amazon dieback" at somewhere around a temperature change of plus 2.5 degrees Celsius.[9]

An even more devastating system change is already taking place: the acidification of the oceans. This is change driven by the increased concentrations of carbon dioxide in the atmosphere. So much attention had been paid to the CO_2 absorbed by the oceans (which has kept climate change from being even greater) that the portion of the CO_2 converted to carbonic acid was largely overlooked. The oceans are today 0.1 pH unit more acid than in preindustrial times. That may seem inconsequential, but because pH is a logarithmic scale, this is equivalent to 30 percent more acid.[10]

Increasing acidity is a matter of great consequence because tens of thousands of marine species build shells and skeletons from calcium carbonate. They depend on a calcium carbonate equilibrium that is sensitive to both temperature and pH: the colder and more acid the water is, the harder it is for organisms to mobilize calcium carbonate. This includes species like corals or Giant Clams. It also includes tiny planktonic organisms that exist in huge profusion at the base of marine food chains. Change is already being detected at the base of food chains off Alaska and in the North Atlantic.[11]

What can be done to diminish as much additional climate change as possible and to simultaneously buffer natural systems against the change that is all but inevitable? The former involves producing a new energy basis for civilization. One component of that is reducing CO_2 emissions from the destruction of modern biomass, principally tropical forests. At the moment that accounts for roughly one fifth of the annual increase in GHG concentrations. This makes Indonesia and Brazil the third and four largest CO_2-emitting nations even though their fossil-fuel-derived emissions are relatively low.[12]

But forest carbon (other than reforestation and afforestation, and to a large extent plantation forests) was left out of the current arrangements for carbon trading through the Clean Development Mechanism established in the Kyoto Protocol. Its status is currently being explored in hopes of negotiating a system to reward countries for reducing emissions from deforestation and degradation. Finding a solution to lower and eliminate this source of CO_2 emissions is good for the forest, good for biodiversity, good for forest peoples, and good for the climate.

At the same time, a great deal of attention needs to be paid to "adaptation," to making biodiversity and ecosystems resilient in the face of climate change. Natural connections urgently need to be reestablished in landscapes to facilitate the dispersal of individual species as they follow the conditions they need to survive. Basically, the opposite of the current situation of patches of nature in human-dominated landscapes needs to be created, so that human needs and aspirations are embedded in a natural matrix.

A second obvious measure is to reduce other stresses on ecosystems so that they do not reinforce the changes taking place in a warming world—by reducing siltation, for instance, on coral reefs. Biodiversity and ecosystems basically integrate all environmental stress, so this aspect makes the existing conservation and environment agenda even more important.

A lot of the potential management and adaptation measures are hard to design using the extremely coarse scale of global climate models. Managers need a much more precise idea of what kind of change is likely to take place within a square kilometer and over the next few decades. This can be greatly facilitated by "downscaling," which can be done quickly and cheaply using laptops instead of supercomputers. There will undoubtedly be a succession of downscaled projections, each refining scientists' understanding of what is likely to happen in small units of landscape. One of the most useful things that can be done quickly is to produce a first set of downscaled projections that can highlight the challenges that managers need to address.

www.emeraldashborer.info

Emerald Ash Borer larva in fall

In particular situations, adaptation options can be illuminated through modeling projected range shifts of individual species, as has been done for some of the flowering plant species of the Cape Floral Kingdom in South Africa. And in very special situations management can actually "assist" migration. Unfortunately, the cold, hard reality is that the number of species in the world is far too large for these options to be used extensively.[13]

Adaptation to sea level rise, although virtually nonexistent for low-lying islands, is possible in coastal areas. The Nature Conservancy has a valuable experiment on this in Albemarle Sound in North Carolina that anticipates sea level rise and will facilitate the development of new freshwater wetlands as current ones become tidal. But such adaptation is useful only with gradual sea level rise, not the rapid rise likely to occur following major changes in the Greenland ice sheet, for example.[14]

The world's protected areas are certainly not being invalidated because the species for which many were established will move away. Indeed, they have a new conservation role: to be the safe havens from which species will move to new locations. Without the existing protected areas, there will be nowhere for the new biogeographical pattern to emerge from. Species will of course need safe havens once they have moved and will need natural connections in the landscape to facilitate the movement to those areas.

The most important conclusion is that ecosystems and biodiversity are extremely sensitive to climate change and represent one of the most urgent reasons to limit additional change. The warming inherent in current GHG levels will bring the planet's average temperature increase to 1.3 degrees Celsius. This is just a bit more than half a degree short of the level at which many conservation organizations anticipate ecosystems will be in serious trouble. Yet since there are already threshold changes in ecosystems and ocean acidification at current levels of climate change and greenhouse gas concentrations, dangerous change is likely to appear before 2.0 degrees Celsius. In essence, biodiversity is indicating climate change needs to be treated with unprecedented immediacy and urgency.[15]

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