Article

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Mountains: Top Down

MOUNTAINS: STARTING AT THE TOP

Most people live far from mountains and only rarely recognize them as an essential element in contemporary civilization. Yet the mountainous uplands of all continents have ruled on virtually all aspects of human welfare including food and water and climate and the place and politics of nations.

The history of the land can not be viewed separately from that of the mountain ranges. All of which are closely tied to the evolution of life, the geological transitions over four billion years, the break up of Gondwanaland, the drifting of the continents, and the glaciations of the Pleistocene, and present global climates. Major fractions of all the continents are mountains and as much as 10% of the global human population lives in them. The world's oceans also contains vast mountains. In fact, the largest mountain range in the world is entirely submerged at this moment in the two Atlantic oceans, the contemporary product of continental drift and seafloor spreading as the continents move apart at millimeters to centimeters per year. The mid-Atlantic Ridge extends almost pole to pole and rises from abyssmal depths to emerge as Iceland, the Azores, and Ascension Island among others. These islands are tiny samples of a massif larger than the Himalayan or the Andean massifs, all hidden from view from all but the most superficial human experience. However, what is the most important attribute of mountains in the contemporary human equation?

Despite the fact that most people consider mountains as remote extremes, about a quarter of the earth's continental surface is mountainous and these regions provide dwelling places for about 600 million people. And of the other 5.4 billion people in the world who live in the lowlands more than half depend on the mountainous regions for water. All of the world's major rivers are fed in whole or in part from mountains, many from glaciers of ancient origins. Orographic precipitation, largely as snow, is the primary source of the water that feeds cities such as San Francisco, Sacramento, Los Angeles, Phoenix, Seattle, and many others. This is true also true for whole nations such as Bangladesh, Norway, Sweden, Chile, Argentina, Peru and regions such as central Europe and much of Asia. Mountains are not only a human habitat but an essential human resource which, through their influence on water flows, substantially define the limits of human habitation over vast areas globally.

The status of mountains as a segment of the human habitat was examined in detail in November 2002 in a major United Nations conference in Bishkek, Kyrgyzstan. The product of this conference was a report to the UN General Assembly which responded with a resolution (57/245) designed to encourage sustainable development in mountain regions, to correct the wide range of regional and local problems identified during 2002, The Year of the Mountains.

Contemporary environmental issues are virtually all defined by the emergence of human dominance as a global factor. That dominance is defined in many ways but the most conspicuous evidence is the global climatic change that the use of fossil fuels for energy has triggered. Prior to the emergence of human dominance during the last century, the global human environment was under the control of (dominated by) natural plant and animal communities, primarily forests. Although their influence remains large, it is obviously not large enough to counter contemporary human influences and the earth is warming rapidly, disrupting climates globally. This global disruption of the human environment is by far the most important environmental problem the world has faced short of nuclear war, and mountains are affected.

Two aspects of the climatic disruption in mountains reach human interests immediately. Changes in the water regimes in mountains reach into every river basin in the world, and have the potential to wreak havoc in all those extensive regions for which the mountains provide water both as a primary resource and as a source of energy. Such montane reserves of water include the glaciers, seasonal snow fields, ponds and extensive forested areas. Closely coupled to the water resources is the series of changes in the vegetation of mountain regions as the environment erodes with progressive climatic disruption. These changes affect forests in particular and appear predictably as increments of biotic impoverishment that affect the land, the water flows, and the global carbon balance by releasing more carbon dioxide (CO_2) to the atmosphere from soils and trees. All are major effects of climatic disruption and all are well underway globally.

Hydrology: Water Flows Downhill

Climatic disruption has reached the point where glaciers are melting globally. One of the most spectacular changes is the retreat of the glacial cap of Kilimanjaro, Kenya. This has been reduced by about 80% since the first maps were published in 1912 according to Lonnie Thompson of Ohio State University (E. Douglas, New Scientist, Nov. 2002 (1)). The rate of melting is such that current estimates suggest that the ice will disappear between 2010 and 2020. But virtually all glacial ice around the globe is melting rapidly, and water supplies and water power are both clearly threatened. The problem is not hypothetical or potential for some a long-term future; it is with us now and the evidence is overwhelming. The evidence has several forms but the most telling is the obvious retreat of glacial ice throughout both hemispheres.

Glaciers now occur in the Northern Hemisphere in Greenland, and elsewhere as montane glaciers in Iceland, Jan Mayen, Svalbard, and to a much more limited extent in mountains across North America and Eurasia. In the Southern Hemisphere, the Antarctic continent is glacial, but for a few dry valleys, and a large area in Patagonia on the Argentine border with Chile is under ice. Elsewhere, glaciers are montane, but all are in retreat. Many are disappearing, causing major physical changes in water flows and thus availability. Their decay and ultimate disappearance has implications for stream flow, for hydroelectric energy production, for water supplies, for irrigation, as well as for the salinity of estuaries and coastal waters. Such rapid changes in a world of 6 billion people who have come to depend on the continuity of virtually all resources are simply another, expensive, destabilizing force related to the more general global climatic disruption. Who is affected? Not only those who dwell in mountain villages and depend on mountain streams for their daily living, but those streams also feed the rivers of the world which are connected to the lives of fully half of the world's population directly or indirectly. This change may be unmeasured, as it is, but it is no minor change if you are one of the tens to hundreds of millions dependent on the stability of climate to assure the flow of the Ganges and the Brahmaputra, for example (Fig. 1).

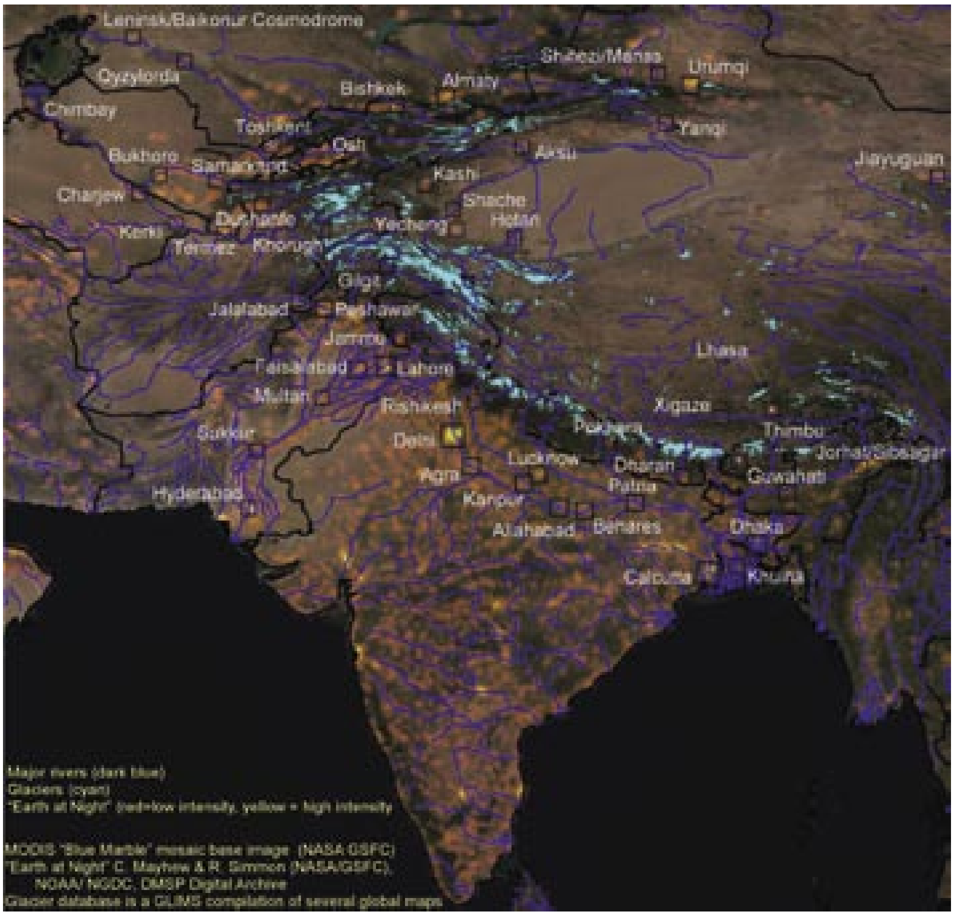

Figure 1. The glaciers of the Himalayas shown here in light blue are an important source of water for tens of millions of people in these cities and towns of Southern Asia. The glaciers are receding. Some are disappearing now.

The problem is, however, much larger and more complicated and it reaches still further into realms that are at or beyond the capacity of contemporary scientific prediction or even research. For example, climatic disruption is not uniform over the whole of the earth. The warming is greater by a factor of two to three or more in the higher latitudes of both hemispheres than it is in the tropics, and greater than the average warming of the earth as a whole by an only slightly smaller factor. An average warming globally of 1 to 2 tenths of a degree C per decade for the earth as a whole as anticipated for the next century becomes 2 to 3 tenths of a degree, possibly as much as ½ a degree in some places in the higher latitudes. Such changes move the world into a realm well beyond systematic prediction into the unknown (2, 3).

The speed of the melting is great enough to add substantial, if unmeasured, quantities of freshwater to the oceans. There is currently enough water locked in ice to raise sea levels by tens of feet. At the peak of the last glacial cycle, sea level was 300 feet (AUTHOR, METERS PLEASE) or more lower than it is now, so a change of 10 feet in sea level is a modest change in global terms. Such a change is probably not in store for tomorrow, but it is certainly a possibility for the 21st century. What is required is the continued substantial further melting of glacial ice globally supplemented by a further increment of glacial ice from the West Antarctic glaciers to slide into the ocean. Melting is progressing and such increments of change are being entrained.

Worse, and perhaps more immediate, is the concern of the physical oceanographers that the accumulation of large amounts of freshwater in the Norwegian Sea will reduce the density of surface water sufficiently to stop the production of deep water in that region and check or stop the flow of the Gulf Stream. Large quantities of freshwater are available from the melting of glacial ice in Greenland combined with freshwater from montane glaciers of Svalbard and northern Europe, and the westward drift of the freshwater from the north-flowing rivers of Asia. The transition has apparently occurred in the immediately post-glacial past. It would reduce greatly the flow of water and energy to northern Europe and Scandinavia, bringing a series of drastic changes in climate to the region (4). Just how serious could such a change be? Could it trigger a reglaciation of segments of the Northern Hemisphere? When and how fast? Such questions lie in the realm of the unanswered, and possibly unanswerable. A similar array of questions surrounds the climatic effects of the Arctic Ocean's changing from ice-covered, white and reflective to open water, dark and absorptive of energy in the long summer days (Fig. 2). Unfortunately, the warming already entrained, opens the world to such awkward questions. But that is not the whole issue.

BIOTIC IMPOVERISHMENT: PREDICTABLE DISRUPTION

Greater attention is neded to the insights we have from mountains as to the current human circumstance, which is increasingly precarious and threatened by what seems to be an inexorable march of political folly. Wars and economic crises often displace environmental concerns temporarily, but the erosion of environment continues, acknowledged or not. One of the largest issues, perhaps the very largest in fact, is biotic impoverishment, the systematic erosion of the biotic systems that have dominated the earth for the whole of human existence and longer. These natural communities of plants and animals still define and maintain the global human habitat. They are the contemporary expression of evolutionary success, in any place they are the survivors of the evolutionary process as modified by succession following local recent disturbance (Fig. 2). They are vulnerable, as we shall see below, to the chronic disruption which now marks the entire globe and puts them in retreat (5). The retreat bodes ill for the future of human life.

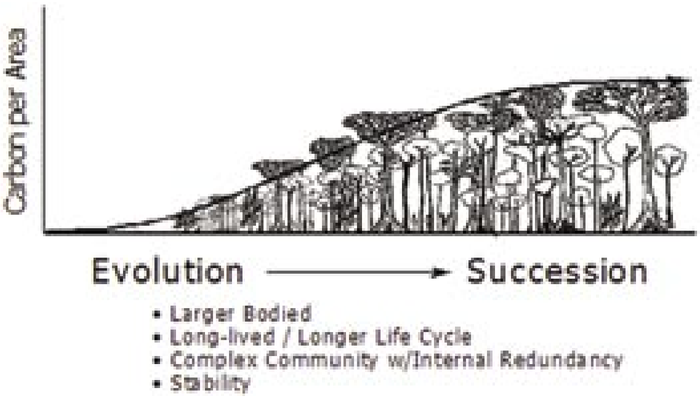

Figure 2. Evolutionary and successional development in climatic regions capable of supporting forests proceed on similar paths toward more complex communities with larger, longer lived species with increasing interdependence.

Mountains offer a telescopic review and sharpen our eyes to some of the more egregious changes in vegetation that have become far advanced without our really having observed it. The biological insights that mountains have offered us are many and rich.

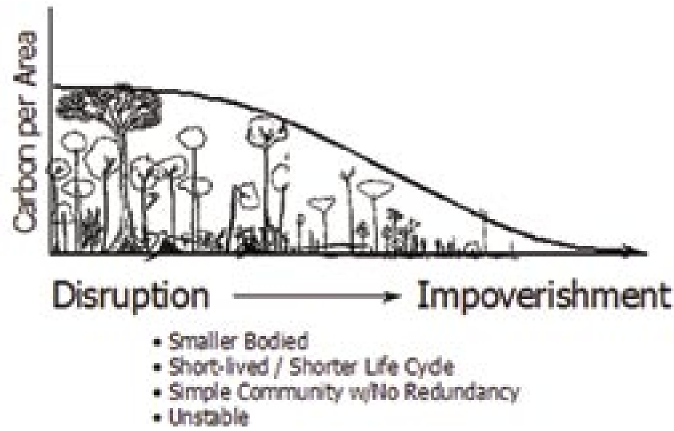

Fig. 3. Chronic disruption in virtually any form causes systematic impoverishment of natural communities that follows predictable patterns and favors small-bodied, rapidly reproducing forms that are, with continued disturbance, displaced by smaller, hardier forms and ultimately lost to barren ground.

Treeline, the altitudinal limit of the distribution of trees, attracts almost universal fascination because it marks the point in the altitudinal gradient of exposure beyond which trees no longer hold ecological dominance. At lower elevations trees define the structure of the community and provide the habitat of other species. Above treeline, climatic extremes dominate and define the structure of the community as it is further reduced in structure and diversity to crustose lichens and other close-growing, hardy plants of the "barren ground" or high tundra.

The pattern of change in life form is as much an evolutionary product as the plants and animals themselves. It is repeated on mountains around the world and conspicuous again in the latitudinal transition to tundra as well. The forest is systematically impoverished until the trees disappear and are replaced by a tall shrub community that yields under greater exposure to low shrubs, often *Vaccinium* spp, and dwarf trees. The shrubs yield to hardy herbs and sedges, mosses and lichens with lower-growing forms more prevalent and hardy than upright or foliose forms.

The changes are not simply changes in form, although they are conspicuous as such. Mountains are islands in a terrestrial sea of other environments and they are populated by plants and animals that are survivors in that particular environment. There is no surprise in the observation that along the gradient of exposure there are ecotypes, genetically selected populations that are peculiar to that place and have a growth form and physiology appropriate to the climate. Transplanted elsewhere they retain the form and physiology of their place in the montane gradient. Thus, selection has worked its magic even here. But there is still more to the observations, superficial as they appear.

The transition in form and physiology from intact forest to barren ground as climatic exposure intensifies on mountain slopes is far from unique. Experience with gradients of exposure to chronic disturbances of various types, including chemical pollution and fire, produces a similar response in the normally naturally forested regions. The changes are most conspicuous, of course, where there are obvious gradients of exposure downwind from smelters such as those at Sudbury, Ontario, and Norilsk in Siberia, and Palmerton, Pennsylvania. In such places, forests have been destroyed over many square miles leaving gradients of change in the vegetation similar to what has been described around the montane and polar limits of trees. Strangely enough, a similar gradient has followed experimental chronic exposure of forests to ionizing radiation. In the latter instance accompanying research showed that the gradient is also associated with chromosomal structures such as polyploidy and small chromosome size that confer resistance to mutations, and the gradients of structure emerge as far from chance responses to particular disturbances but a generalized response to a wide range of chronic disturbances. It becomes obvious once again that chronic disturbance of virtually any type favors incremental changes along this gradient with small-bodied, rapidly reproducing species being favored over large, long-lived, slow reproducers (Fig. 3).

Armed with that insight we have a far better basis for appraising the effects of any chronic disturbance, especially a rapid general change in the earth such as the global climatic disruption now accelerating. The effects appear, not sheltered within some "threshold" or "assimilative capacity", but as a continuum of incremental impoverishment defined overall by the transition we see compressed for us on mountains from rich lowland forest to the barren ground of the tundra.

More than just the changes in life forms is the compelling evidence that each population along the gradient is a genetically defined entity, an ecotype, selected over generations for survival in that site. Our interest in preserving the integrity of function of landscapes now takes on a new dimension and the climatic disruption has an even more sinister side. While a species may have a wide range *in toto* and the climatic changes may appear to be minor relative to the apparent ecological amplitude of the overall species, each population within the species is in fact an ecotype, selected over generations for survival in that place and with that climate. Changing the climate out from under the ecotype suddenly makes the organism, plant or animal, maladapted to that place. There should be no surprise in the sudden discovery that as the earth warms, plant and animal diseases become more prevalent. The morbidity and mortality of trees spreads as insects and disease become prevalent in the weakened tree populations, especially those close to the edges of the ranges of the species. Again, the cost is difficult to appraise, but it is the certain product of the global climatic disruption. The problem is especially acute in the forested regions of the Northern Hemisphere where it has far-reaching implications for both forest products and for municipal water supplies that depend, as many do, on forested uplands.

CONCLUSIONS

The details of the status of mountain communities around the globe have been reviewed in detail at the Bishkek Conference of 2002. A major feature of the changes taking place in these communities is the global climatic disruption and its effects, not only on mountain communities, but through effects on mountain communities, on the rest of the world, especially the roughly 50% of the world dependent on mountains for water supplies and for power. These sources of water are diminishing and will diminish rapidly over the next years affecting directly hundreds, perhaps thousands, of communities and municipalities and the lives of as many as 2–3 billion people around the world.

The important inferences ecologists are making about the role of natural plant communities in maintaining an earth that is habitable need to be monitored carefully. Experience from extensive studies of mountain areas shows the vulnerability of those communities to disruption by only modest disruptions of climate. These changes are especially critical in forested regions and affect forest resources and water supplies as well as local climates and, through the accelerated decay of organic matter in soils and forests, the carbon dioxide balance of the atmosphere.

Both realms reveal large costs accruing to the public from the climatic disruptions already underway and larger costs from those effects entrained by heat trapping gases recently released whose effects will be realized over the next few years.

Is There a Correction for Current Trends?

There is no correction short of following the purpose the world has accepted in universal ratification of the Framework Convention on Climate Change, namely stabilizing the heat trapping gas content of the atmosphere at a level that will protect “human interests and nature”. Unfortunately, US leadership is key and has been exercised, not to solve the problem, but to extend the era of fossil fuel use as much as possible, thereby aggravating the problem worse. The 1997 Protocol to the Treaty, negotiated in Kyoto to suit US demands at the time, was a small step toward stabilizing emissions from the industrialized nations, not stabilizing the atmosphere. Even such a small step has not yet recieved approval from the US administration. So far, the US has flatly rejected the protocol. There are many areas of the world which will suffer the consequences of climate change even more severely than the wealthy industrialized nations who carry primary responsibility for causing the problem. Meanwhile, the Kyoto Protocol will go into effect even without the US when the Russians ratify it. The protocol will then be greatly strengthened in efforts to halt the further accumulation of heat trapping gases in the atmosphere, certainly before we move from the current 370 ppm CO_2 in air to 450 ppm. It can be done.

Within the US many efforts are being made to shift away from the use of fossil fuels. The Woods Hole Research Center, for instance, has one new building that burns no fossil fuels at all, and which has been designed and built to use less than half the energy similar large buildings use. This building currently generates, through the use of solar panels, more energy than it uses in cooling the building at mid-day on one of summer’s hottest days. A wind turbine, will enable the building to generate more energy annually than it now uses and to produce enough hydrogen to run an institutional automobile.

A proposal has been put forward for the installation of 130 wind turbines on a shoal in Nantucket Sound which will provide power equivalent to about 75% of the base load of electricity for Cape Cod, the southeastern Massachusetts peninsula that embraces 15 towns. Solar panels and wind turbines can make up the difference and make the entire region free of fossil fuels for electricity.

Using mountains as our starting point we can show just how much further we need to go to rise above the smog of a faltering and unsustainable contemporary civilization to obtain a clear view of what could be a peaceful and sustainable future.

References and Notes

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