Climate Change in the Mountains – Who Wins and Who Loses?

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Species diversity per unit land area in mountains is often greater than in the lowlands. This is quite amazing considering the limited amount of land area they appear to cover. Topographic richness and steep elevational gradients are the key: climate zones are compressed across elevational gradients over short distances.

As one ascends, one passes through humid jungles in the foothills, and montane cloud forests and alpine heaths, eventually reaching the regions of permafrost and snow where a nival flora can be seen that at low elevation is usually found 8,000 km closer to the poles. The high degree of species richness is also a result of gravity-driven fragmentation of the land surface, yielding a high 'geo-diversity' or habitat diversity offering a multitude of ecological niches. Mountains are 'islands in the sky', but also islands of biodiversity.

Alpine plant diversity in Jigme Dorji National Park in Bhutan

Why conserve mountain biodiversity?

One ever valid foundation of biodiversity conservation is ethics: every species has a right to exist and flourish. This is an argument that receives broad public support and does not need a scientific justification. Human beings also create biodiversity by domesticating plants and animals, adding a 'cultural' element to biological richness. Genetic or species diversity also makes a lot of sense economically, because diverse crop and husbandry systems are less likely to run into complete failure. The state of a region's biodiversity is key to a number of ecosystem processes from which people are drawing benefits. Science is able to identify and quantify these benefits (e.g., certain ecosystem goods and processes).

Mountain biodiversity in a warmer world - where to go?

Mountain organisms were long thought to be seriously constrained by the influence of low temperatures. Today, the same experts are worried that climatic warming will threaten those high elevation biota. It is a paradox that an 'improvement' in conditions which were thought of as 'harsh' before, is suddenly considered dangerous.

This dilemma reflects a basic misconception of 'stress' in nature. A given assemblage of species is nature's response to the local environmental conditions, provided there has been sufficient time for evolutionary processes (selection) and migration to take place. What might seem harsh to the human observer is not harsh for those species that have been selected for the specific local life conditions. Thus, the real issue is that the ongoing and expected climatic changes are much faster than what evolution and migration are commonly able to track.

Mountain areas are an excellent laboratory for studying adaptation to changes in temperature because temperatures decrease rapidly as elevations rise. Mountains provide cool 'escape routes' for those species that cannot stand the 'heat', but species already inhabiting summit regions are in a very difficult situation, because they can go nowhere else. Those that move upslope into already occupied terrain face heavy competition, and the inhabitable land area gets more and more restricted as one ascends.

Finally, it is important to recall that habitat diversity in mountains also offers alternative thermal niches at often very short distances (just think of the micro-climatic

Gentiana sp. growing in a rugged alpine habitat in Sikkim

conditions in front of and behind a rock). Thus, there should be fewer 'hopeless' refugees in mountain areas than anywhere else. On the other hand, the spatial compression of climatic belts allows ongoing biological changes to be tracked more easily, the reason why mountains have been considered early warning systems for climatic change. However, notwithstanding the fact that many plants might adapt or migrate without too much trouble, the increasingly limited land area with elevation will threaten the survival of large territorial animals.

Winners and losers

When environmental conditions change, organismic populations either have to adapt, escape, or become extinct. Competitive exclusion favours species that compete successfully for basic resources such as light, water, space, prey, window of time, and so forth. Physiological limitations are not so much of an issue in the case of climate warming because most organisms can cope with a few degrees of extra heat. What is meant by 'adaptation' can in fact involve rather different processes: organisms can adapt either by acclimatisation or, in the case of animals, by changing their behaviour. Such adaptations differ from evolutionary adaptation which takes place over a very long period of time. Large populations with diverse habitats are more likely to host genotypes that can replace others if environmental conditions change. Over the expected short period it will take for the climate to warm significantly, many species will be unable to evolve new genotypes. Thus, local species that lack genotypic adjustment or acclimative potential will be replaced by species from elsewhere which will then assemble into new 'adapted' communities.

"Local species that lack genotypic adjustment or acclimative potential will be replaced by species from elsewhere"

Spatial fragmentation and diverse habitats commonly result in a high degree of genetic diversity among alpine organisms. Species accustomed to changing conditions from week to week and season to season may be more likely acclimatise to new conditions. When species cannot acclimatise or change their behaviour, and when no selections from the local gene pool match the new conditions, escape or decline are inevitable.

Likely losers	Likely winners
Large territorial animals	Small, highly mobile organisms
Late successional plant species	Ruderal species (species growing on wasteland, weeds)
Species with small, restricted populations	Widespread species with large populations
Species confined to summits or the plains	Mid-slope species

What may happen to organisms that cannot adapt rapidly enough? One example is the European edelweiss (*Leontopodium alpinum*): this charismatic species once populated the cold glacial steppes stretching from central Europe into central Asia (where its relatives still thrive at high elevation). When a 'sudden' arrival of interglacial warmth reached Western Europe the edelweiss took refuge in the colder environment of the nearby Alps and escaped extinction – it is now the flagship plant species of the Alps.

Which species will be lost if change takes place as rapidly as we fear? There is no simple answer, but a few general characteristics may serve as a guideline.

Looking at the possible combinations, small, mobile, widespread ruderals (species growing on wasteland, weeds, and so forth) are likely survivors, and large, slowly-reproducing organisms with small populations will risk extinction. Recent advances of plant species into higher elevations have indeed been observed for the group of 'weedy' plants that are favourably equipped to take advantage of the new situation. Nevertheless, some other plant species are so resilient and adaptive that they have hardly been affected by past climate changes over several thousand years (e.g., clonal plant taxa). Research has shown that some of these species haven't changed position by more than a few metres over the last millennium. There are still other species that overcome climate changes by utilising diverse mosaics of high-elevation micro-habitats. Given the natural inertia of most high-elevation plant species, a few degrees of warming might not bring about much change in alpine vegetation in the short term, but more pronounced warming might. Species respond individualistically, and the formation of new communities is more likely than the migration of communities as a whole. Initially, these movements may only be noticed by experts who are used to examining small changes. Unless some charismatic species are affected, the slow pace of change may escape public notice. Experts may become alarmed, but the public at large will remain insouciant, so there is a communication challenge.