Part IV: Ecological changes

Ecological processes that affect mountain ecosystems and have an influence on their ability to provide goods and services occur over a wide range of temporal and spatial scales. Accordingly, a variety of methods and approaches is required to assess Global Change impacts on ecological processes in mountain regions. The following section of this book reflects this diversity, but it also documents that considerable progress has been made over the past years both with respect to 'sectoral' research activities as well as with respect to the integration of research across scales and disciplines.

In the first two contributions, *Körner* and *Bowman* provide an overall rationale for studying ecological processes under the impact of drivers of Global Change in mountain regions. Both papers emphasize the importance of species-specific responses and the fact that numerous feedbacks exist that complicate the analysis and often make it impossible to identify simple cause-effect relationships.

In view of such complex responses, which may also differ from one region to the other, it is highly useful to develop networks that foster collaborative research on mountain issues and allow for cross-site comparisons. *Pauli et al.* document the concept, approach, and future aims of the GLORIA (GLobal Observation Research Initiative in Alpine environments) project, which focuses on documenting and understanding the widespread upward shift of mountain vegetation using a set of sophisticated observational as well as modeling procedures. *Spehn & Körner* then introduce GMBA, the Global Mountain Biodiversity Assessment; this is an observational effort that also includes research on the relationship between biodiversity and ecosystem function, with a special emphasis on slope stability.

"Global Change" is sometimes mistaken as a synonym of "Global Warming". However, it is almost certain that at least over the coming few decades changes of land-use and bio–diversity (through extinctions and invasions) will have larger effects on mountain ecosystems than changes of climate or atmospheric chemistry. *Williams & Wahren* document the effects of the various drivers of Global Change in their case study of Australian mountain vegetation, and the contribution by *Tasser et al.* deals with land-use changes and their implications for ecological processes in the European Alps.

Understanding change at the ecosystem level needs to be based on an understanding of processes at finer scales to elucidate response patterns and potential feedback mechanisms. *Harte et al.* (as well as *Körner*, *Bowman* and *Baron et al.*) focus on such process studies, using montane meadows as a case study. *Harte et al.* also address the question whether observational altitudinal gradient studies might be used as a substitute for in-situ experimental manipulations.

Due to gravitational forces, the various terrestrial and aquatic ecosystems are tightly linked in mountain regions, and ecological assessments of Global Change impacts therefore need to go beyond the consideration of terrestrial ecosystems. *Baron et al.* discuss the implications of N fertilization for both terrestrial and aquatic systems in the Rocky Mountains and the linkages between these two sub-systems. *Vinebrooke & Leavitt* focus on high mountain aquatic biota, the likely impacts of Global Changes on these systems, and their suitability as indicators.

The need for considerations across classical system boundaries is paralleled by the need to transgress spatial and temporal scales in our attempts to understand and predict Global Change impacts. In their contribution, *Schimel & Braswell* emphasize that to understand mountain system dynamics with respect to carbon relationships, we need to consider the watershed (or, as they call it, the "carbonshed") scale. Along the same line, *Shugart* provides a review of the potential of remote sensing methods for better understanding large-scale patterns and processes in mountain regions.

Many of these contributions mention the need for the integration of observational and experimental work with modeling studies. *Guisan et al.* review the state of modeling vegetation distribution above treeline, and make proposals towards long-term monitoring networks that would serve to integrate across disciplinary boundaries. *Bugmann et al.* review modeling efforts with a focus on forested systems, and discuss the problems and potentials for integration of modeling efforts across various disciplines. *Fagre* presents a case study of integrated modeling that is facing significant challenges, but that has gone a long way towards the ultimate goal of integrated assessments of Global Change in mountain regions.

Finally, *Graumlich et al.* review treeline dynamics as inferred from paleo-ecological studies and landscape ecological analyses, thus reminding ecologists who focus on the analysis of contemporary data that the link from the past across the present into the future is a very important one that should not be forgotten (see also the section on paleo changes in this book).