to a mountain climate. Species arriving with tourist infrastructure, in contrast, have often been selected for their cold-hardiness. Many horticultural introductions are relatively recent (e.g. from the very species-rich mountain region of Yunnan in China; Mack and Sun 2002), and their potential to become invasive is not known. The safest approach for mountain managers is therefore to restrict the deliberate introduction of all novel non-native species to mountains.

An inventory of non-native plants is an important resource for managers of any biodiversity reserve and should be a priority for mountain areas, which face a growing threat from invasions. MIREN is developing an online database of mountain invasive plant species that will allow managers to evaluate the threat that such species may pose in their regions. It is also important to monitor populations of non-native plants as some will be benign or transient and some will be deleterious. Such a monitoring programme needs to include contingency plans for the event that a highly invasive non-native species is discovered. Eradication is possible only in a very early phase of an invasion and this is particularly true in the complex topography of mountains. In the Australian Alps, MIREN has worked with local land managers on the eradication of two Hieracium species (*H. aurantiacum and H. praealtum*) (Figure 2). Both species are thought to have been introduced through tourist infrastructure in recent decades (Williams and Holland 2007). They have spread rapidly, aggressively competing with natural vegetation, and, although only discovered in the last decade, are now the most costly non-native species being managed in the Alps and one of the greatest threats to these mountain ecosystems. In Australia, at least, the old notion that mountains are somehow resistant to serious plant invasions has been destroyed.

A comprehensive strategy against plant invasions may include more than prevention of novel introductions, monitoring and eradication. For instance, codes of conduct on cleaning clothes, tools and machines before entering natural areas may reduce the risk of spreading non-native species by visitors and managers of natural areas. More generally, awareness building and networking with stakeholders (e.g. the horticultural and tourism industries and the general public) are vital. In the European Alps, MIREN has begun collaboration with the Alpine Network of Protected Area *(www.alparc.org/)* and with the EU Alpine Space project ECONNECT on developing a comprehensive strategy for dealing with the risk of invasive plants. Experiences from this pilot project will later be tested and adapted in other mountain areas. MIREN welcomes inputs about best-practice approaches from managers who already have experience with managing invasive plants in mountains.

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Changes in Biodiversity Patterns in the High Andes - Understanding the Consequences and Seeking Adaptation to Global Change

Anton Seimon, Karina Yager, Tracie Seimon, Steve Schmidt, Alfredo Grau, Stephan Beck, Carolina García, Alfredo Tupayachi, Preston Sowell, Jerry Touval and Stephan Halloy

Over the past decade, a multinational group of investigators has been working in concert to observe, understand and develop adaptations to climate change and its impacts on species, habitats and people in the uppermost reaches of the biosphere at high alpine field sites along the central Andes of Peru, Bolivia and Argentina.

Global context

As infrared radiation is captured by greenhouse gases in the higher atmosphere, there is a faster rate of temperature increases at higher altitudes, with consequent destabilisation and changes in other high altitude climate parameters. Whole regions will develop entirely new (no-analog) climate suites, to which only certain more ruderal (opportunistic) species will be able to adapt. With the speed of change, plant and animal species may not be able to migrate fast enough. In addition to invasive exotics, disease advances are already being documented (Seimon et al., 2007; UNFCCC, 2007).

In the high Andes, changes in physical environments impinge on a complex and intricately interrelated mosaic of human land use and biodiversity with different degrees of impacts. The usual temporal variability of climate is superimposed in these landscapes on a fine grain spatial variability; cloud forest can give way to dry shrublands or grasslands within tens of metres.

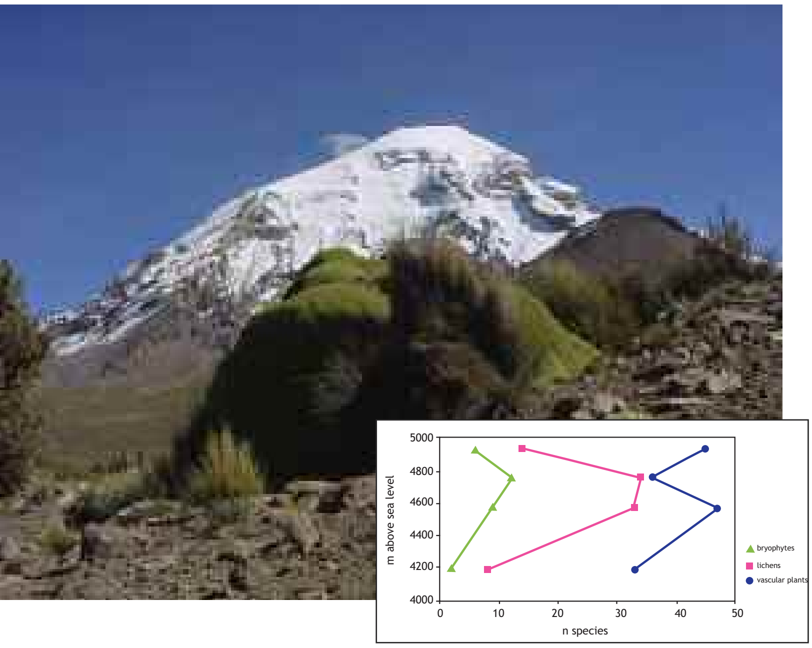

Figure 1: Species richness along an altitudinal gradient in Sajama volcano (background) national park, Bolivia. Photo: Stephan Halloy.

Gradients and patterns

Simplified concepts of altitudinal gradients help us to understand the gradual decrease in temperature and atmospheric pressure with altitude. Such concepts lead to the idea of creating altitudinal corridors to allow species to migrate to cooler altitudes as the climate warms. However, spatial heterogeneity means such gradients must be studied case by case and cannot be generalised. Cloud forest species faced with rising temperatures may not be able to climb into dry valleys separating them from new potentially similar climates. Climate patches may disappear entirely, leaving whole ecosystems cut off from suitable habitats. Given the complex and environmentally determined mosaic of habitats, even minor changes and shift of boundaries will have potentially large impacts on the persistence of ecological communities.

Satellite image analysis has permitted an understanding of coarse grained features of the Andean environment and change scenarios. Given our scant understanding of population biology and physiology of Andean plants (with some notable exceptions), we currently rely on modeling exercises to forecast potential movements and impacts. Although modeling provides novel and valuable insights into predicting species adaptation, there are major gaps in essential land-based verification.

Interdisciplinary research on the ground

Researchers from a wide range of disciplines are collaborating to fill in the gaps in ground-based data by exchanging information and designing research in alliance with local people. Here we describe briefly some aspects of interdisciplinary work that is providing exciting new avenues of research on adaptation to climate change along the central Andes. Research on adaptation to climate change along the central Andes includes analysis and interpretation of ice core data to peer into the past as well as working cooperation with indigenous communities to understand their perceptions of recent socio-ecological changes. Rates of deglaciation and microbial ecology of recently deglaciated and extremophile soils are being measured (Schmidt et al., 2008a; Schmidt et al., 2008b; Costello et al., 2009). Plant succession is also being monitored under variable year to year cycles (Yager et al., 2007), and the impact of change on standardised biodiversity monitoring sites (GLORIA network, *www.gloria.ac.at*) includes documenting the rising altitudinal limits of plants, vertebrates, invertebrates and human productive activities (agriculture and grazing) (Halloy et al., 2008).

Linking these research strands has provoked challenging new questions and has led to a broader awareness of the multiple relationships between various fields. For example, instead of merely documenting amphibians climbing to extreme elevations in deglaciating valleys, researchers have quantified and explained how this apparent expansion is simultaneously impacted by a rapid dieback due to a concurrent advance of the deadly chytrid fungus (Seimon et al., 2007). Likewise, GLORIA baseline studies have shown (Figure 1) unexpected diversity gradients in vascular plants, bryophytes and lichens, with hump-shaped curves (i.e. rise in diversity with altitude then decline) rather than gradual declines with altitude (Halloy et al., 2008). These trends may be linked with changes in microbial, invertebrate and vertebrate diversity. Importantly, these studies are bridging the gap between research and field application with local people (Figure 2). Adaptation action requires understanding the issues (research) and knowing what to do (technology); resources (material and energy, finance); and institutional support (community or government). Each of these dimensions raises a long list of additional interrelations, obstacles and opportunities.

The northern tropical Andes where páramos (wet grasslands) occur are more conical, leading to a gradual reduction of area available for species to colonise upwards. This phenomenon, observed in the Alps and other mountains, has been modeled following species-areas relationships. In contrast, the dry puna grasslands have developed over the large altiplano mountain plains with a more abrupt reduction of area available towards the small summits, entailing a much greater risk of species extinctions for puna species. Conversely, species living below the puna, unlike most mountains in the world, will have an abrupt increase in the area available to them, sometimes more than ten-fold, leading to a 'Noah's Arc' phenomenon where the altiplano could be managed as refuges for biota which is threatened by rising temperatures.

Figure 2: Workshops with local people in the Andes establish an open flow of information between scientists and indigenous people. Inset: booklet presenting the results of perception and adaptation workshops with local herders of Sajama, Bolivia, in a user-friendly and illustrated format (Ulloa and Yager, 2008). Photo: Stephan Halloy.

There are also considerable ethical issues regarding the impact of change and movements on humans and land use conflicts. Approaching these complex and interrelated issues from a wide range of different perspectives is a start to understanding and acting upon climate change adaptation.

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Protection of the Cloud Forests and Their Biodiversity in the Coastal Cordillera of Venezuela

Winfried Meier

Avla National Park seen from the south east of Caracas (900-1,000 metres). The highest peak is about 2,600 metres. Photo: W. Meier.

The Coastal Cordillera of Venezuela stretches from east to west in a narrow band alongside the Caribbean Sea. The Cordillera principally consists of two mountain chains separated by high valleys, of which the best known is the Caracas valley. Generally the mountains are between 1,000 and 2,500 m.a.s.l. high. Moisture laden winds allow the growth of evergreen cloud forest islands within a mainly dryer vegetation. Additionally, more than half of the total precipitation may be caused by the cloud interception of the vegetation. Depending on the local conditions, cloud forests can be encountered between 600 and 2,200 m.a.s.l. The coastal mountains are among the most populated areas of the country.

The cloud forests of the Coastal Cordillera harbour an interesting mixture of plant species with different phytogeographical affinities (Andean, Caribbean, Amazonian and Guayanan elements). The mountain peaks with cloud forest are the major centres of endemism in northern Venezuela.

We are far from knowing all the species of this area, as the investigations of the author over the last years have shown. For instance the description of the tree species *Ampelozizyphus guaquirensis (Rhamnaceae)* showed that the genus was not monotypic but that the *liana A. amazonicus* of the coastal area of Venezuela has a sister species in the Coastal Cordillera (Meier and Berry 2008).

The Avila mountain region with the Avila national park, separated from the urban area of Caracas by a four-lane highway, is one of the floristically best known areas of Venezuela. In the "Flora del Avila" by Steyermark and Huber (1979) there are listed 1,892 vascular plant species. Approximately twenty years later, an additional 370 species have been registered, of which nearly 120