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Protected areas and climate change impact research: roles, challenges, needs

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Abstract

Protected areas were originally designated to deal with regionally caused threats. Yet, they increasingly encounter potentially detrimental influences from distant sources and of globally area-covering climate change effects. By forcing organisms to shift in latitude and elevation, anthropogenic climate change may deprive nature reserves of their threatened "biotic goods". The long-lived nature of many mountain species may counter their rapid disappearance and topographically determined habitat and micro-climatic diversity may buffer against climate warming impacts. An ongoing large-scale thermophilisation of alpine vegetation and a decline of narrow-range species in fragmented cold habitats, however, call for joint efforts in observing and studying the changes as well as in developing and implementing suitable conservation measures. Both protected area managers and researchers will mutually depend on and benefit from each other in such an endeavour. High mountains hold an unsurpassed potential for large-scale comparative studies, due to their virtually global distribution and their rather natural environments. Taking advantage of this situation, the Global Observation Research Initiative in Alpine Environments (GLORIA) has started already at the turn of the millennium to build a global research programme and observation network. Rapidly expanding, it is now represented on six continents. The majority of the currently 115 study regions lie within protected areas and, thus, provide a unique opportunity for tracing human-induced impacts on the shrinking natural biosphere.

Keywords

alpine plants, climate change, conservation management, long-term monitoring, mountain protected areas, species migration

Introduction

Protected areas were usually designated in view of locally or regionally generated causes of threats to species, habitats, ecosystem services and landscapes. At least since the 1970s, however, when the dying forests syndrome and rapid lake acidification became apparent in Europe, long-distance effects of pollutants shifted into the focus of conservation concerns. Only one-and-a-half to two decades later, human-induced climate change was recognised as a by far more spatially extensive phenomenon which could have a strong impact on species distributions and survival. Even if climate change may still be outranked by other threats such as forest exploitation, industrial agriculture, construction or land use changes, it could become one of the most powerful factors of change, owing to its virtually global area-covering influence and in the view of its projected continuation or even acceleration (SALA et al. 2000).

Climate warming is expected to force many terrestrial organisms to shift in latitude and elevation. A recent meta-analysis estimated that the distributions of species have already moved to higher elevations at a median rate of 11 m per decade, and to higher latitudes at a median rate of c. 17 km per decade, but species varied greatly in their rates of change (CHEN et al. 2011). Organisms living in cold environments, such as high mountain regions, are considered to be particularly prone to climate warming, because species are adapted to low-temperature conditions (GOTTFRIED et al. 2002). By that way, even this otherwise more remote and anthropogenically undisturbed mountain biome experiences a shift from nature-dominated to human-dominated environmental changes (MESSERLI 2006).

Developing and implementing suitable strategies to protect high-mountain biota from the impacts arising from warmer climates, therefore, appears to be one of the greatest challenges of conservation biology and conservation management.

Mountain protected areas – effective conservation or a hopeless lag behind?

Despite the possibility that protected areas may simply become ineffective, if their threatened "biotic goods" lose their suitable habitats, all may not be lost for the endangered biota. First, most of the plants living in high mountains are slow-growing and long-lived individuals, which can counteract their rapid disappearance. Simulations using a hybrid model suggested persistence of alpine plant species over several decades, at least in form of remnant populations, in spite of the view of projected average range size reductions of 44-50% by the end of the century (DULLINGER et al. 2012). In fact, extinctions or declines of species numbers were by far less commonly reported up to now, than an increase caused by an upward shift of mountain plants (GRABHERR et al.

1994, WALTHER et al. 2005, KULLMAN 2010, PAULI et al. 2012, WIPF et al. 2013). Second, rugged terrain and pronounced microtopography, being typical for many high mountain environments, provide a multitude of habitat situations with marked microclimatic changes over short distances. This would allow for escape routes to nearby colder refuge sites, when temperatures continue to rise (SCHERRER & KÖRNER 2011).

At the same time, however, geographically highly restricted alpine species (endemics) often occur in moderately-high mountain ranges, where space above the forestline is limited, e.g. in the marginal ranges of the Alps (DIRNBÖCK et al. 2011) and to a much higher degree in many of the fragmented Mediterranean mountains (KAZAKIS et al. 2007, NOROOZI et al. 2011, FERNANDEZ CALZADO et al. 2012). Looking into the past, the late Quaternary climate displacement rate was high in the north, in NW-Eurasia and NE-North America in particular, when the formation of ice shields caused massive extinctions. Nowadays, these regions are populated mostly with rather widespread and more generalist species. Further south, such as in the Mediterranean, but also in parts of the Pyrenees and the Alps, the climate remained relatively stable and supported survival of many species with small range sizes, narrow ecological niches and expectedly poor dispersal abilities (ESSL et al. 2011, SANDEL et al. 2011). Narrow-range and often less mobile species constitute much if not most of Earth's biodiversity. What if accelerating climate warming pushes these less vigorous species, dwelling in long-term climatically stable habitats, into high velocities of climate change (SANDEL et al. 2011)? Recent local declines of high-mountain vascular plant species were already observed on Mediterranean mountains and were hypothesized as a consequence of decreasing precipitation in spring, combined with climate warming (PAULI et al. 2012).

Protected areas are in a role of Noah's Ark, but leaking and occasionally in heavy sea. The future role of mountain protected areas is expected to significantly gain in importance. On one side, they act as Noah's Ark for upward-moving climate refugee species. Mountains, thus, will harbour many more species than they presently do. The cold-adapted species may remain to be on board, either by re-establishing at nearby sites or in form of weakened remnant populations. A protection status, however, does not ensure that species will survive. Narrowly distributed endemics may drop out from Noah's ark, as will eventually do the shrinking population of cold-adapted species with some delay of probably several decades (ENGLER et al. 2011, DULLINGER et al. 2012). Even though species richness will increase locally on many mountains, mostly due to immigrating wider spread, more thermophilous species (GOTTFRIED et al. 2012), we are going to lose the more special to the benefit of the more common species. The large-scale picture, therefore, would show a drop of species numbers and a homogenization of species compositions (WINTER et al. 2009). Floras would become more similar to each other among mountain ranges and mountain systems.

The mutual needs of conservation management and climate change impact research

Simultaneously with the growing importance of mountain protected areas and effective conservation strategies, internationally comparative ecological research in mountain regions increasingly became a matter of attention since the 1990s, following the UNCED-Conference in Rio 1992. Between 1996 and 1998, the Mountain Research Initiative (MRI; (BECKER & BUGMANN 2001) was launched. A few years later, two research programmes and observation networks targeting on mountain biodiversity emerged: the Global Mountain Biodiversity Assessment (GMBA of DIVERSITAS; (KÖRNER & SPEHN 2002) and the Global Observation Research Initiative in Alpine Environments (GLORIA; (PAULI et al. 2009, GRABHERR et al. 2010). Linking between protected area management and research, the UNESCO MAB programme attempted to develop and/or to incorporate existing global change research and monitoring approaches within its network of mountain Biosphere Reserves (GRABHERR et al. 2005).

The generation of knowledge about past, recent and possible future changes as well as the development and implementation of suitable measures against expected biodiversity losses demands collaboration. Both protected area managers and researchers intrinsically benefit from each other from their different, but mutually dependent perspectives.

<u>The researcher's perspective:</u>

- Areas where a continued "naturalness" can be ensured are invaluable for observing and studying large-scale impacts on the biosphere in absence or at minimised background noise from direct anthropogenic impact. Legally designated protected areas have a greater chance to remain undisturbed from direct human intervention than areas without a conservation status. In an increasingly populated and globalised world, contrasts may further grow between such "set aside" near-natural or pristine areas and the expanding human-shaped land.
- Longer-term time series of semi-natural or natural vegetation from standardised permanent plot designs are still scarce, but would essentially contribute to the evaluation of predictive models and to ecological theory. A co-operation with protected area management will be of much help to filling this urgently demanded gap.
- Protected areas usually have experienced staff knowing the places and often many of the species. Although staff capacity may be limited due to other obligations, a long-lasting management could provide an ideal general setup for ecological climate impact monitoring – in particular, if service costs and expenditure of time can be kept at reasonable levels.
- Records on the recent land use history may be easier obtainable as for unprotected land. This is important information for areas where, e.g. pasturing practices ceased with a protection status, but which may continue to influence the composition of species over decades.

<u>The conservation manager's perspective:</u>

- Knowledge based on local data about recent impacts of climate change is crucial for defining and implementing targeted conservation measures.

- Large-scale phenomena such as climate change require standardised settings over many sites and across regions. Protected areas being part of such a network would benefit in the way that larger data sets enhance statistical significance and therefore an earlier detection of change.
- Internationally organised, standardised monitoring enables comparison among different protected areas and could stimulate interdisciplinary and trans-disciplinary activities in a conservation and sustainability context.
- Participation in long-term monitoring would enduringly contribute to capacity building for young generations of experienced field workers.
- Presentation to non-experts and visitors of regional results on climate change impacts combined with the large-scale dimension strengthens public awareness of conservation needs.

The Planet's mountains and their unique potential to trace climate change impacts

The world's high mountain areas represent the only terrestrial biome type which is really globally distributed from the tropics to the polar regions: i.e. the "alpine life zone" above the upper treeline. All of the globally scattered alpine areas have one thing in common – and this is low-temperature conditions (KÖRNER 2003). Alpine areas, moreover, are usually by far less influenced by human landuse than many of the lowland areas. More than half of the world's mountains are categorized as not influenced or with low influence from direct human activity. Surprisingly, 34.7 % of these little impacted mountain regions are covered by nationally designated protected areas (RODRIGUEZ-RODRIGUEZ & BOMHARD 2012). Such a worldwide configuration of cold and fairly natural ecosystems, which are legally protected from direct human intervention, offers an unrivalled opportunity for investigating and tracing the ecological and biodiversity impacts of a global human-fuelled phenomenon.

Taking advantage of this unique situation and of the indicative value of alpine organisms was one of the key-considerations in developing a globally applicable long-term monitoring approach. Already in the late 1990s, a world-wide call for participation was replied by many concerned ecologists, expressing their interest to join in. This was the actual starting point of the Global Observation Research Initiative in Alpine Environments (GLORIA; www.gloria.ac.at). GLORIA's basic monitoring approach was designed along three main principles: comparability, simplicity, and economy. Practicality as well as a large number of committed biologists led to the outstandingly fast expansion of the research and observation network, which also includes remote mountain areas. GLORIA comprises currently 115 target regions (study regions) scattered over six continents. Sites are to be established along a series of four mountain summit arranged between the treeline and the limits of plant life. The main requirement for the field observers is a very good knowledge of the regional vascular plant flora, the priority organism group of the basic approach. Dependent on the availability of experts, time, and budget, bryophytes and lichens can be included in the basic approach and suitable designs were developed for other organism groups such as arthropods, reptiles, and amphibians. Further, additional research and monitoring approaches are emerging and are already in operation is some GLORIA study regions, such as on soil variability, complete downslope transects of vascular plants, as well as on socio-economic and cultural aspects.

The world-wide coordination including the central database is located in Vienna, Austria at the Institute for Interdisciplinary Mountain Research of the Austrian Academy of Sciences and the University of Natural Resources and Life Sciences. The majority of GLORIA target regions and active observation sites lie within protected areas. In several cases, protected area authorities take the responsibility of operating the monitoring activity. Examples for the Alps are Berchtesgaden National Park, Swiss National Park (NP) or Gesäuse NP, for the Rocky Mountains, Glacier NP or Yellowstone NP. Many others are organised as joint efforts between national research institutions and the protected area management, e.g. the sites in California's Sierra Nevada national parks Yosemite and Kings Canyon and the White Mountains Reserve, Australia's Kosciuszko NP, and several national reserves in Taiwan. Others, again, are principally operated by research institutions, but supported by protected area authorities, such as many of the sites in the Andes, the Himalaya system and in Europe. A number of intergovernmental unions and organisations (e.g., European Commission, Comunidad Andina, UNESCO MAB), national governments (e.g. Austria, Germany, Taiwan), internationally operating research and development organisations and NGOs such as Missouri Botanical Garden, ICIMOD (Himalaya-Hindu Kush), CONDESAN (Andes) or The Nature Conservancy as well as private foundations such as the Swiss MAVA Foundation for Nature Conservation and the National Geographic Society provided or provide support.
Thus, a fairly large number of different ways of support and cooperation proved to work well and should be successful for a long-term operation. With every monitoring cycle, sites and data sets gain in significance and, thus, of relevance for decisions and development of conservation measures. The GLORIA program and network is continuing to expand in the number of sites as well as in the development of integrating and interdisciplinary activities. Additional sites in protected areas are most welcome and important in order to have a solid network of indicators for an uncertain future of the biota in natural habitats.

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