are the lead authors of the volume 'Alpine Biodiversity in Europe', Ecological Studies vol. 167, Springer Verlag.

Alpine Biodiversity in Europe: an Introduction

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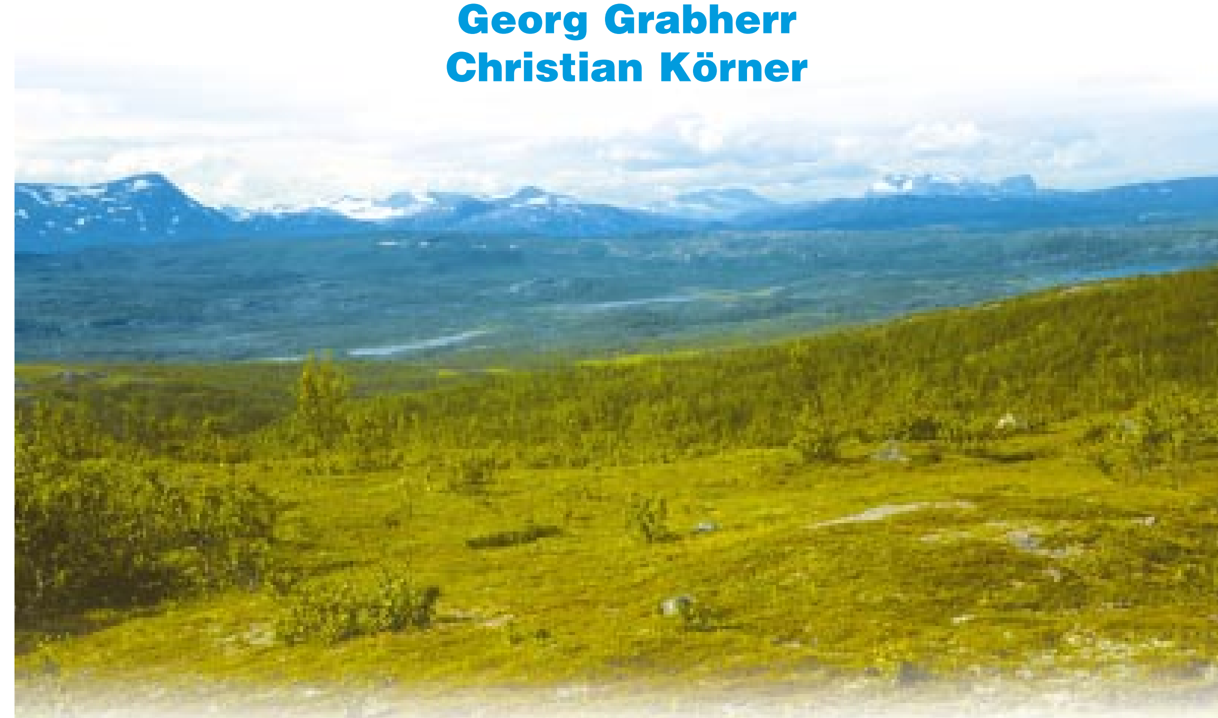

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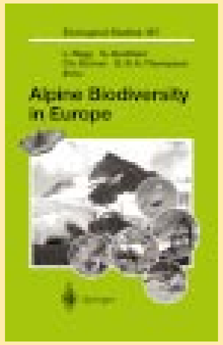

This is the first ever European-wide overview of biodiversity in alpine areas... to develop a holistic understanding of biodiversity at and above the treeline.

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"...a benchmark publication."
Martin Price, *Mountain Research and Development.*

Contents

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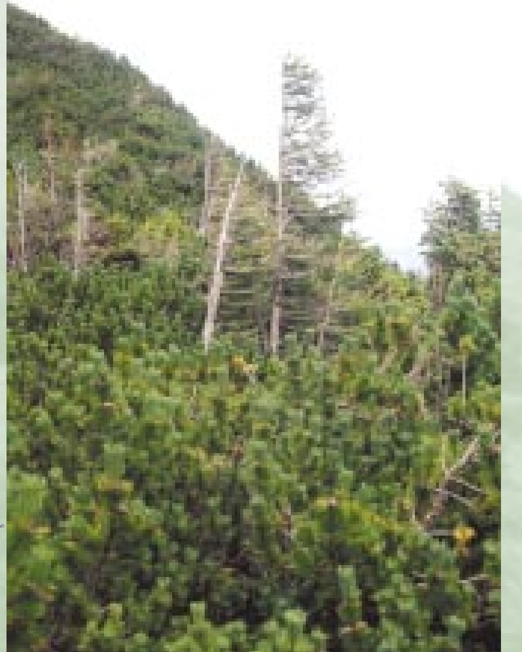
Introduction - alpine biodiversity in Europe

High mountains have long fascinated people. The ancient Greeks made Mount Olympus the seat of many of their gods, and the people of the Alps populated their austere mountaintops with dragons. Today, scientists, nature lovers, and of course casual walkers find alpine environments equally fascinating. Their open landscape, dominated by scrub, heaths and grasslands, and their specialist animal life has a special allure. This publication introduces alpine environments. The alpine zone begins where low temperatures limit tree growth, and it stretches high to the permanent snow line; at northerly latitudes it grades into tundra. Worldwide, about 3% of the earth's surface lies in the alpine zone; glaciers and snow hold about two-thirds of all the planet's freshwater.

Compared with the lowlands, alpine vegetation and wildlife have been less modified by human activities. In most of the mountains of Europe one still finds some of the wilderness long lost in the lowlands. However, given the pressures of agriculture, tourism and other forms of development, and the nature of climate change, there is wide concern for the fragile state of these alpine environments. The delicate relationships between the landscape, soils, plants and animals render these areas highly sensitive to environmental change.

This booklet is an introductory companion to the book '*Alpine Biodiversity in Europe*' (2003). The book has arisen from the efforts of a network of scientists working on biodiversity throughout the alpine areas of Europe (ALPNET 1998-2000), sponsored by the European Science Foundation.

Alpine areas in Europe from the Atlantic edge to the Urals



Alpine areas occupy around 3% of Europe's land surface

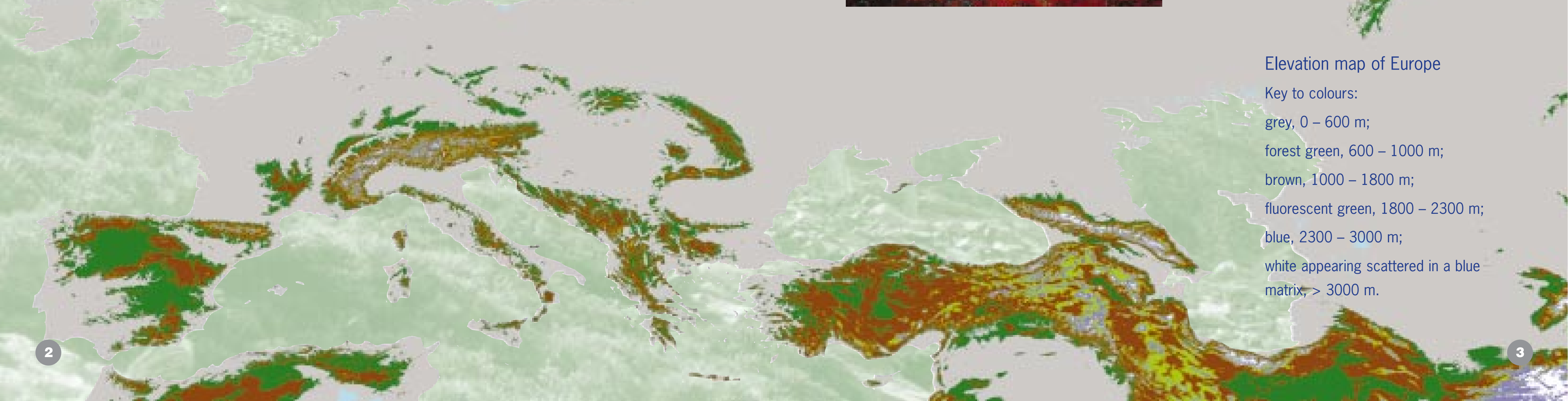
The alpine zone lies above the treeline, where trees become stunted and give way to scrub and dwarf shrubs. Treelines are determined by climatic conditions, but have been modified and lowered by as much as several hundred metres in some areas because much of the upper montane forest zone has been burnt and grazed.

At what elevation do alpine areas occur?

The distance from the North Pole and from the Atlantic Ocean, as well as elevation, determine climate. The coloured areas of the elevation map below lie over 600 m above sea level (the approximate lower limit of the montane forest zone in central Europe). At the Arctic Circle, however, the same elevation marks the upper limit of tree growth. The treeline in the Alps varies from about 1800 m to about 2300 m; it is at 2300 m in the Pyrenees; and in the Polar Urals it is between 200 – 300 m. An oceanic or arid climate can suppress the potential climatic treeline, such as in Scotland or in some Mediterranean mountains.

Alpine habitats often occur as scattered and isolated 'islands'

As in most areas of the world, Europe's high mountains do not form a continuous landscape. Rather, alpine habitats mostly occur as sporadic and isolated 'islands'. The largest expanses of the alpine zone are found in the Alps, Caucasus, Pyrenees and the Scandes; smaller areas occur in the Urals, Carpathians, the Rhodope-Rila massif, the Dinarids, Apennines, Sierra Nevada, Corsica and Scotland.



Elevation map of Europe

Key to colours:

grey, 0 – 600 m;

forest green, 600 – 1000 m;

brown, 1000 – 1800 m;

fluorescent green, 1800 – 2300 m;

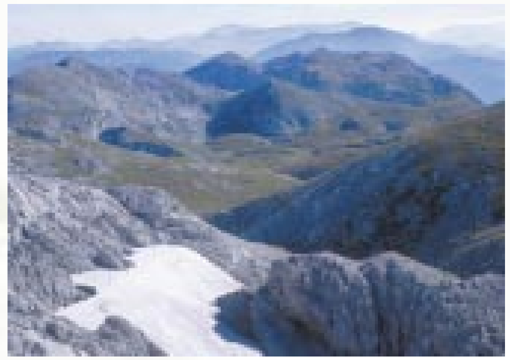
blue, 2300 – 3000 m;

white appearing scattered in a blue matrix, > 3000 m.

Alpine landscapes and climate

A highly diverse landscape results in diverse alpine floras and faunas

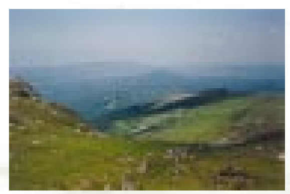
Mountain landforms, sculpted by weathering, rock falls, and glacial and fluvial action give rise to a diverse landscape. There is a rich mosaic of habitat conditions which result from the interplay of microclimate, parent rock, hydrology, the main determinants of biological richness of alpine areas. Today's diversity reflects both historical and recent imprints of climate and human land use.


Karstic landscape, Hochschwab, Austrian Alps

Alpine environments of arctic, boreal, temperate and Mediterranean areas


Cairngorms, Scotland

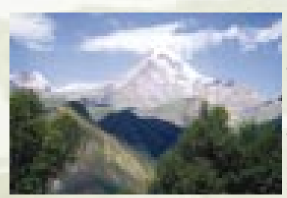

Latnjajaure, Scandes. Sweden


Nurgush, Urals, Russia

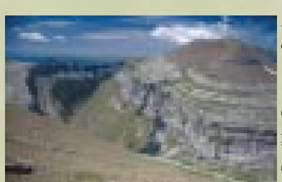
Boreal and arctic alpine environments receive moderate snow in winter and have severe frosts that churn up the soil. This may cause patterned ground over large areas.

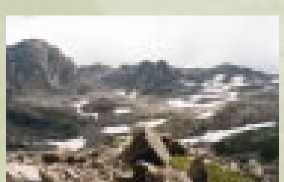

Piz Linard, Switzerland

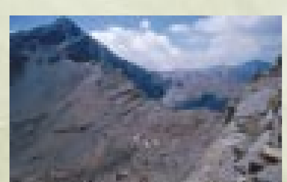

Giant Mts., Czech Republic


Kazbeg, Caucasus, Georgia

In temperate mountains, snow cover provides protection from deep frost, but late-lying snow shortens the growing season, resulting in a distinctive mosaic of plant communities.


Mte Perdido, Pyrenees, Spain


Monte Cintu, Corsica

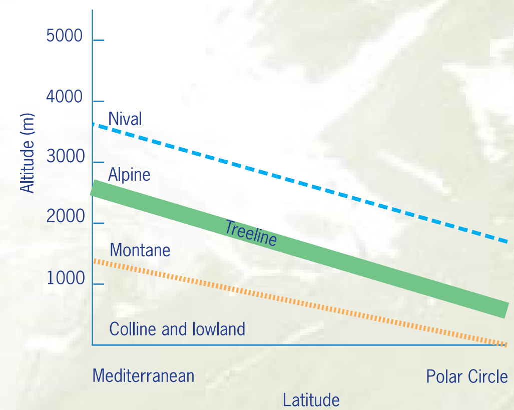

Sierra Nevada, Spain

Sub-Mediterranean mountains, such as the Pyrenees and the Corsican ranges share features between temperate and Mediterranean mountains. The latter are characterised by thorny hemispherical dwarf-shrub cushions, sometimes called 'hedgehog' vegetation.

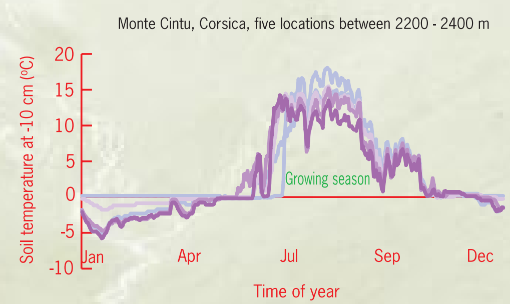
Mountains have steep ecological gradients

Every 100 m increase in elevation is equivalent to c. 100 km distance north. The gradients are largely determined by temperature, which is why they are used in modelling ecosystem responses to climate warming scenarios.

The steep gradient, stretching from the lowlands to the nival zone, represents compressed latitudinal life zones and results in a high species richness in mountain areas.

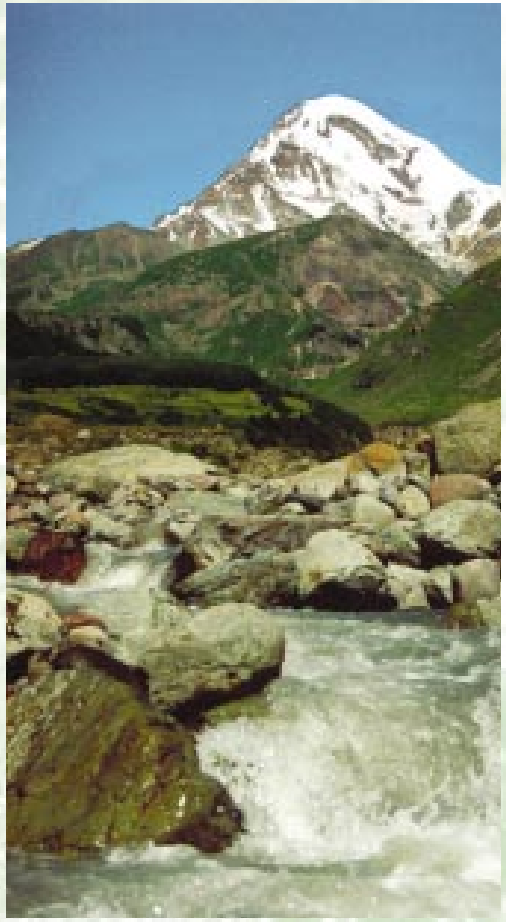


Ecosystem altitude zones largely correspond to temperature isolines. The 6 °C ground temperature isoline for the growing season shows a good agreement with the position of the natural, low temperature treeline, which is the lower limit of the alpine zone.



The length of the growing season is controlled by temperature. A comparison of soil temperatures about 250 m above the potential climatic treeline has shown much in common among alpine areas from the subarctic to the Mediterranean.

Plant diversity



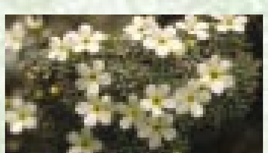
The diversity of today's alpine plant life has been influenced by past climate changes and human land use

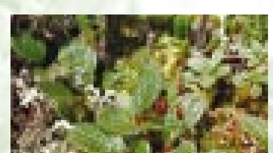
Advancing and retreating ice has contracted and expanded the available space for plant survival and colonisation. Many high peaks have developed specialised floras as a result of their isolation.

Alpine floras in the various regions of Europe share common characteristics in life form, morphology and taxonomy. However, local species composition is related to biogeography, the length and degree of isolation and speciation.

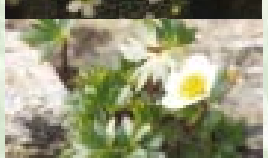
Mountain range	Proportion of the species of the Swiss Alps occurring
Carpathians	55
Caucasus	29
Pyrenees	66
Scandes	46
Sierra Nevada	35
Urals	24

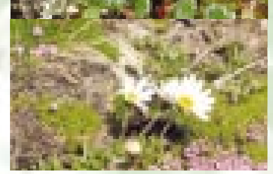
Plants display a variety of adaptations to alpine conditions





Short stature, as displayed by cushion plants or prostrate shrubs such as *Androsacea vandellii* (left) and *Salix reticulata* (right) results in an improved heat balance.





Parabolic flower shape concentrates heat in the middle of the flowers of *Ranunculus glacialis* (left) and *Leucanthemopsis alpinum* (right).

Pubescence protects *Plantago nivalis* against temperature and water stress in the Sierra Nevada.

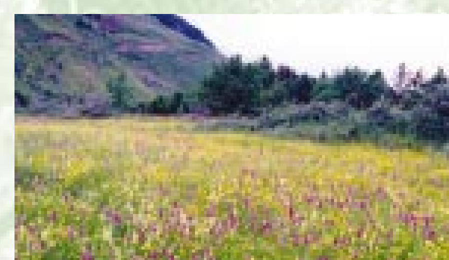
The European alpine flora

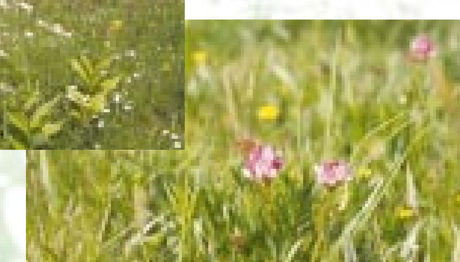
The European alpine flora (i.e. species confined to or predominantly above the treeline) has recently been estimated to be in excess of 2500 species and subspecies, or 20% of Europe's native vascular plants. Species restricted to the alpine zone range from less than 0.5% of the total flora in Corsica to about 17% in the Alps.

Draba sauteri is endemic to the eastern Alps; in Europe, about 10% of all species and subspecies in the alpine zone are endemic (their geographic range is confined to a single mountain or range).

There are very few introduced species in the alpine zone. For example, in Corsica, an island, where about 16% of the total flora is introduced, no non-native species occurs above the treeline. Near the treeline in the Giant Mts. of the Czech Republic, however, about 14.5% of the plants are introduced.

Many species are restricted to alpine habitats, whilst others may occur equally below and above the treeline. In the transition zone between the upper montane forest and the alpine zone (treeline ecotone), where the flora of the forests, man-made grasslands and alpine grass and sedge heaths meet, there is a structurally diverse vegetation, rich in species.





Vegetation

Alpine vegetation occurs in more or less distinct elevation bands, following bioclimatological patterns

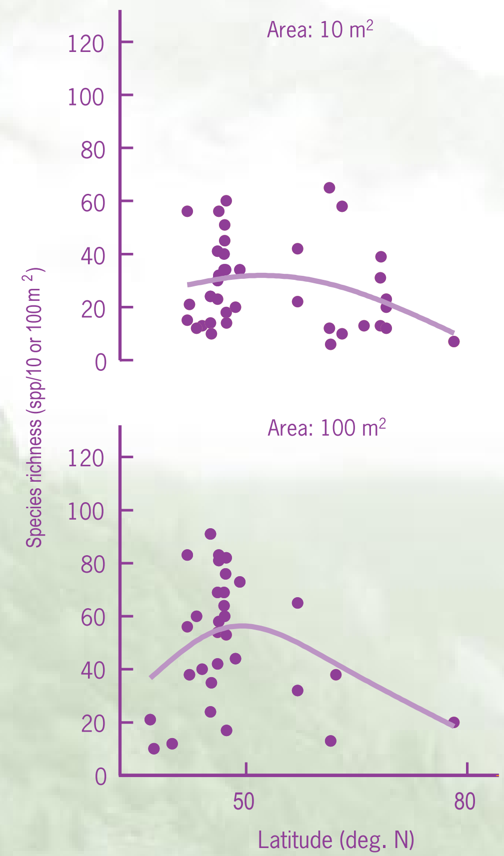
In Europe, most nival summits are found in the Alps and the Caucasus, along with a few peaks in the Pyrenees. Glaciers cover most of the nival zone of the Scandes. Nival plant assemblages of endemic cushion plants and short grasses are found in the Sierra Nevada of Spain above 2800 m.

In the (sub-)nival zone, scattered assemblages of cushion and rosette plants, and grasses grow in favourable sites. Bryophytes and lichens increase in importance with altitude as well as latitude.

In the Scandes, above the dwarf-shrub heath zone, there is a range of sedge and moss heaths grading into fell-fields. In temperate alpine areas, closed grass and sedge heaths (alpine grasslands) dominate.

There is an extensive zone of ericaceous dwarf-shrub heath above the treeline ecotone in north-west Europe. The dwarf-shrub/scrub zone is less developed in temperate alpine areas. In the Mediterranean alpine zone (sometimes called as cry-oromediterranean) the presence of thorny cushion communities is characteristic.

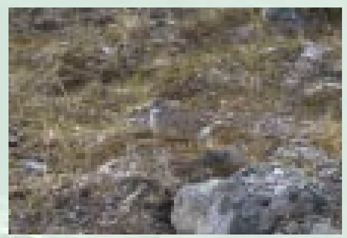
Although locally one or very few tree species form the treeline in Europe, there is much variation in tree species at the continent-wide scale.



In addition to a decrease with elevation, vegetation tends to be less species rich towards the north, especially in wind-blasted habitats with no winter snow protection.

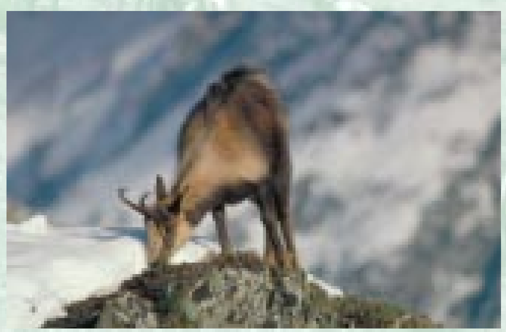
Vertebrates

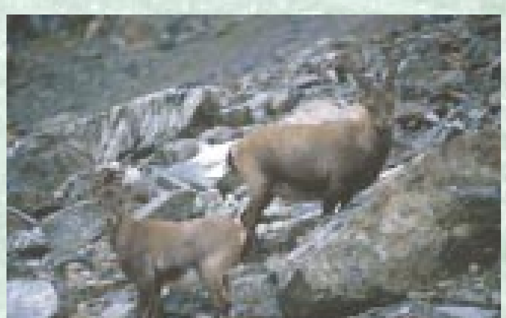
Numerous vertebrate species have been recorded from the alpine zone, however, only few of them are confined to high elevation



Ungulates

The reindeer (*Rangifer tarandus*) is the only large herbivore in the Scandes. In central and southern Europe, there are five alpine specialist species: Alpine ibex (*Capra ibex*), Pyrenean ibex (*Capra pyrenaica*), chamois (*Rupicapra rupicapra*), isard (*Rupicapra pyrenaica*) and mouflon (*Ovis gmelini*).
The impact of these species on the vegetation and their role in ecosystem processes can be important. The interactions between some of the ungulates, and their potential influence on the distribution and abundance of predators is conditioned by land management and its changes.

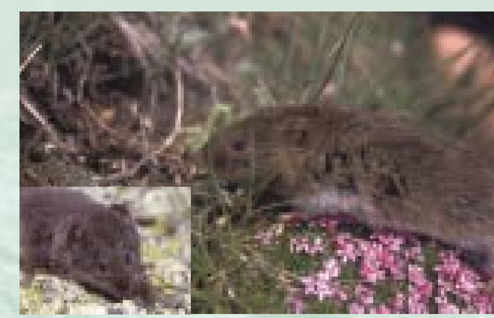




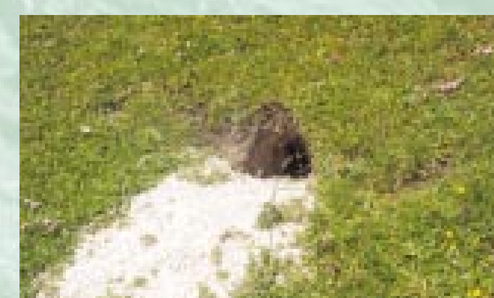
Rodents

The Norwegian lemming (*Lemmus lemmus*) is an important species of the alpine areas in the Scandes and is well-known for its sudden large-scale population fluctuations and long-distance migration. It preferentially grazes in snowbeds, however, during population peaks, it grazes all habitats. Mountain hare (*Lepus timidus*) and a number of vole species are also important grazers in the Scandes.

In the Alps, three rodents live permanently above the treeline: marmot (*Marmota marmota*) in burrows in closed grassland, snow vole (*Chionomys nivalis*) in screes and common vole (*Microtus arvalis*) in closed grasslands. Their populations are far more stable than those of the lemmings in the Scandes.



Lemmings in peak years, voles at high density and marmots around their burrows may have direct local impacts on the vegetation. All rodent species can be an important source of food for predators, such as stoat, red fox and golden eagle.



Invertebrates

The best-studied alpine invertebrates are butterflies, moths, beetles and spiders

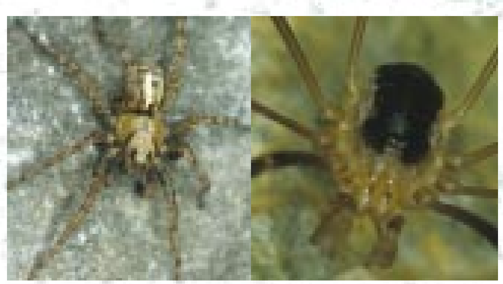
However, this is but a small fraction of the most diverse group of living organisms. In general, total invertebrate species richness increases from north to south, while alpine specialist richness decreases. As arthropod groups differ in mobility, it is difficult to provide figures with regard to the proportion of species occurring in the alpine zone compared with the total.

Insects and other arthropods have adopted a variety of ways of coping with alpine conditions

These include cold hardiness, supercooling or, rarely, tolerance of freezing, anaerobiosis in response to ice crusting, increased rates of metabolism, and resistance to desiccation. Some specialists make use of winter habitat differences resulting from uneven snow cover and associated temperature differences. Morphological adaptations include reductions in size and wing, melanism, thermoregulation, and nocturnal activity (to avoid overheating in melanistic species). Life cycles may be prolonged (Carabids, Acari, *Pardosa* of Arachnida). Alpine aquatic invertebrates, especially those living in glacier-fed waters, represent another example of specialisation.

Argynnis aglaja - 119 of the 275 butterfly species in Italy have been recorded from above the timberline.

Arctosa alpigena and *Dicranopalpus gasteinensis* are two of the 90 alpine spider species in the Eastern Alps, Austria, where about 13% of all the spider species are alpine specialist.



In danger of extinction

The high degree of specialisation in many invertebrates confined to the alpine zone may turn to their disadvantage in the event of a rapid, large-scale climate change. The survival of such taxa may be threatened by the disappearance of suitable habitats.

Chrysolina cf. *subcostata*, an endemic leaf beetle and *Anemonastrum biarmiensis*, an endemic plant from the South Urals, represent a yet poorly understood aspect of endemic alpine herbivory specialism.

The carabid beetle *Bembidion bipunctatum nivale* (left) is typically found near melting snow in the Alps, in July. *Carabus creutzeri* (right) is a calcareous alpine grassland dweller.

Natural change and man's impact

Long-term trends

The cover of arctic and alpine vegetation has been decreasing at a low but steady rate in north-western Europe, e.g. Scandes and the Scottish Highlands over the last 15,000 years. In the Alps, over the past c. 8000 years there has been a high stability in plant cover above the treeline, which itself fluctuated within an altitudinal range of 150-200 m.

Climatically determined, long-established alpine vegetation, such as the *Carex curvula*-dominated sedge heaths of the Alps, is rather stable and persists over perhaps thousands of years. However, after heavy perturbation its capacity of recovery is low.

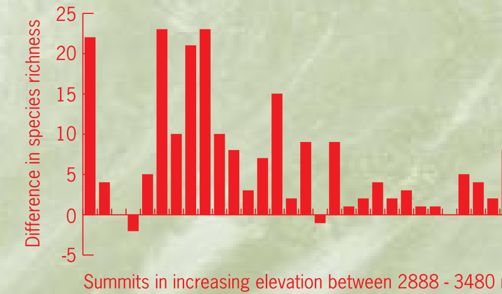
Habitats that become available for plant growth, such as glacier forefields, are colonised rapidly.

What has happened in the last 100 years?

Treeline increases in the Scandes have been explained by warm summers in the 1950s. In the Urals, the treeline ecotones have become denser with trees and this has been attributed to a warming of the climate.

The main summit of Bolshoi Iremel, Urals in 1929 (left) and in 1999 (right)

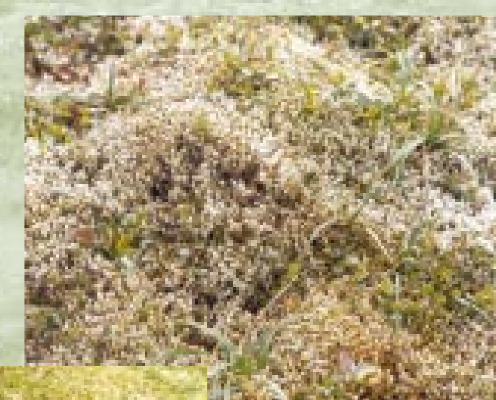
Local studies, using floristic and vegetation data of up to over 100 years old, have recorded changes in species richness and species abundance on nival mountain summits and in snowbeds in the Alps and the Scandes. As the time-scale of these observations has been coincident with an increase in annual air temperatures, the changes in flora and vegetation have largely been attributed to climatic amelioration.



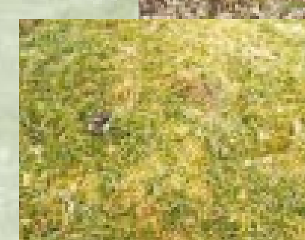
Differences in species richness on 30 nival summits of the Alps between early (1897-1953) and recent (1992 - 1993) recordings (Pauli H, Gottfried M, Grabherr G)

Since the decline of traditional grazing practices, a vigorous regrowth of forest and scrub occured in many previously cleared upper montane forest areas.

Alpine grasslands have long been grazed by livestock, and much of their dynamics and species richness is related to it. In most alpine areas grazing is restricted to a few weeks in the summer and causes little damage. However, locally, in heavily used sheltered areas, distinct new plant communites have formed.



Lichen- and bryophyte-rich vegetation is susceptible to grazing and trampling impacts and in these types of vegetation there has been a loss of lichen and moss cover.



Some ongoing programmes on alpine biodiversity

Since ALPNET, a number of worldwide initiatives have developed work on alpine biological diversity. These include the Global Mountain Biodiversity Assessment (www.unibas.ch/gmba) of Diversitas (www.diversitas-international.org), the Global Observation Research Initiative in Alpine Environments (www.gloria.ac.at) and the forthcoming mountain biological diversity work programme of the Convention on Biological Diversity (www.biodiv.org).

GMBA, the Global Mountain Biodiversity Assessment of DIVERSITAS was established to co-ordinate an assessment of the biological richness of upper montane and alpine biota worldwide. Stocktaking and the explanation of the causes of biological diversity, as well as how and why these patterns change, are the main foci for GMBA. After its launch in 2000, GMBA has concentrated on land use related issues, especially sustainable use and biodiversity in the highlands of the tropics and subtropics. The results from two workshops, in Africa (Moshi, Tanzania, 19-24 August 2002) and in the Andes (La Paz, Bolivia, 20-23 August 2003) have recently been reported (http://www.diversitas-international.org/publications/newsletter5.pdf).

GLORIA, the Global Observation Research Initiative in Alpine Environments has established a Europe-wide monitoring network to assess climate change-induced impacts on alpine vegetation and plant diversity. In 20 regions of Europe, from the Sierra Nevada, Spain to the Polar Urals, Russia, plant species were censused and vegetation recorded in permanently marked plots on 80 mountain summits. It is planned that this network will be extended world-wide with 30 new target regions outside Europe. An additional global network of so-called master sites is planned for detailed investigations and experimentation (for more details see www.gloria.ac.at).

CBD Mountain Work Programme. The Convention on Biological Diversity (CBD) was agreed at the Rio Earth Summit in 1992. The United Nations Environment Programme (UNEP) oversees this. Recently, the Mountain Work Programme was adopted by the 7th meeting of the Conference of Parties to the CBD. This is a major, global programme of work which seeks to reduce the loss of biological diversity in mountain areas. Its three objectives cover conservation, sustainable use and benefit sharing (www.biodiv.org).

Further reading

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Front cover: View from the treeline on Mt Njunjis, Scandes towards the west (U. Molau). Background images: Landscape, Eastern Limestone Alps, Austria (inside cover and page 1), *Pinus nigra* ssp. *laricio* treeline in Corsica (pp. 2-3), Glacial landscape, Tyrolean Alps, Austria (pp. 4-5), Vegetation patch in the sub-nival zone with *Leucanthemopsis alpinum*, Mount Schrangkogel, Tyrolean Alps (pp. 6-7), Upper montane landscape, Tyrolean Alps (pp. 8-9), Alpine landscape, Monte Cintu, Corsica (pp. 12-13), Alpine valley, Tyrolean Alps (pp. 14-15 L. Nagy), Chamois, Austrian Alps (pp. 10-11, H. Pauli), *Pinus nigra* ssp. *laricio* treeline in Corsica (p. 16 and inside back cover). Photographs on each page from top to bottom and left to right: Alpine-nival landscape, Tyrolean Alps (p. 1, L. Nagy) ;pp. 2-3, *Picea excelsa* treeline trees with *Pinus mugo* scrub, eastern Limestone Alps (L. Nagy), *Betula pubescens* treeline, Scandes (R. Virtanen), p. 4, Landscape images, T. Dirnböck, L. Nagy, U. Molau, Y. Mikhailov, H. Pauli, J. Jenik, G. Nakhutsrishvili, H. Pauli, H. Pauli, L. Nagy; pp. 6-7, O. Abdaladze, J.-P. Theurillat, R. Virtanen, L. Nagy, L. Nagy, H. Pauli, H. Pauli, G. Nakhutsrishvili, L. Nagy, L. Nagy; pp. 8-9, Bioclimatological vegetation zones: second row left, R. Virtanen, all others, L. Nagy; pp. 10-11, J.P. Martinez Rica, J.P. Martinez Rica, U. Molau, J.P. Martinez Rica, H. Pauli, C. Gower, R. Virtanen, hand-drawn graph (after original by H.Henttonen), D. Allainé, N. Yoccoz, N. Yoccoz, L. Nagy; pp. 12-13, E. Balletto, K. Thaler, Y. Mikhailov, P. Brandmayr; pp. 14-15, G. Grabherr, G. Grabherr, L.N. Tyulina, P. Moiseev, L. Nagy, L. Nagy.

Dedication

Fundamental to the establishment of ALPNET was the unstinting enthusiasm, drive and commitment of Jennifer Nagy (née McConnell, right), who died shortly before the first workshop in 1998. Our bryologist, Patricia Geissler (left), was killed in a traffic accident in Geneva in 1999. This booklet is dedicated to the memory of these two excellent scientists, friends and colleagues.