



MANAGEMENT of Natura 2000 habitats Alpine and subalpine calcareous grasslands 6170

*Directive 92/43/EEC on the conservation of natural habitats and
of wild fauna and flora*

The European Commission (DG ENV B2) commissioned the Management of Natura 2000 habitats. 6170 Alpine and subalpine calcareous grasslands

This document was completed in March 2008 by Ricardo García-González (Instituto Pirenaico de Ecología, CSIC, Spain) on behalf of ATECMA

Comments, data or general information were generously provided by:

Federico Fillat, Instituto Pirenaico de Ecología CSIC, Spain

Daniel Gómez, Instituto Pirenaico de Ecología CSIC, Spain

Mats Eriksson, MK Natur- Och Miljökonsult HB, Sweden

Dobromil Galvánek, Daphne, Slovakia

Guy Beaufoy, EFNCP - European Forum on Nature Conservation and Pastoralism, UK

Gwyn Jones, EFNCP - European Forum on Nature Conservation and Pastoralism, UK

Coordination: Concha Olmeda, ATECMA & Daniela Zaghi, Comunità Ambiente

©2008 European Communities

ISBN 978-92-79-08326-6

Reproduction is authorised provided the source is acknowledged

García-González R. 2008. Management of Natura 2000 habitats. 6170 Alpine and subalpine calcareous grasslands. European Commission

This document, which has been prepared in the framework of a service contract (7030302/2006/453813/MAR/B2 "Natura 2000 preparatory actions: Management Models for Natura 2000 Sites"), is not legally binding.

Contract realized by: ATECMA S.L. (Spain), COMUNITÀ AMBIENTE (Italy), DAPHNE (Slovakia), ECOSYSTEMS (Belgium), ECOSPHERE (France) and MK NATUR- OCH MILJÖKONSULT HB (Sweden).

Contents

Summary	1
1. Description of habitat and related species	2
Distribution.....	2
Alpine and subalpine calcareous grasslands in Natura 2000 sites.....	2
Main habitat features, ecology and variability	3
Ecological requirements.....	3
Main subtypes identified	4
Species that depend on the habitat.....	5
Related habitats	5
Ecological services and benefits of the habitat	6
Trends	6
Threats.....	7
Grazing	7
Ski resorts	7
Other infrastructures (reservoirs, mining, electricity lines, roads).....	7
Tourism	8
Climate change effects	8
2. Conservation management	9
General recommendations	9
Active management	9
Grazing	9
Restoring alpine grasslands damaged by ski trails.....	15
Other relevant measures.....	15
Research and Monitoring.....	15
Special requirements driven by relevant species	16
Cost estimates and potential sources of EU financing.....	16
Acknowledgements.....	17
3. References	18

6170 | Alpine and subalpine calcareous grasslands



61 – Natural grasslands

EUNIS Classification:

E4.4 Calcareous alpine and subalpine grasslands

Alpine grasslands in Somola Alto (ES2410023) in the Western Pyrenees, Spain. Sheep have grazed these grasslands for centuries. Photo: R. García-González.

Summary

Alpine and subalpine calcareous grasslands occur above the timberline on base-rich soils in the high mountains of Europe. Harsh climatic conditions (i.e., low temperatures, prolonged frost, heavy snow accumulation), which limit the vegetative period to a few months, characterize this habitat. It includes many plant communities, mainly in the *Elyno-Seslerietea* and *Ononidetalia striatae* phytosociological classes. Alpine calcareous grasslands are highly diverse, with abundant endemic and rare species, and support alpine birds (e.g., *Charadrius morinellus*, *Lagopus muta*) and Lepidoptera (e.g., *Erebia*, *Glacies*, *Colias*, *Elophos*) that have high conservation value.

Many of those grassland communities are stable, but very sensitive to disturbances. When the vegetative cover is altered or there is significant loss of soil, it is almost impossible to restore the original habitat. Active management is not required for the conservation of habitat 6170. Given the high structural complexity and fragility of the habitat, the best management practice is to leave it alone.

The main threats to these grassland communities are inappropriate grazing practices, the construction of infrastructures (mainly ski resorts), and perturbations caused by changes in land use and global warming. Subalpine and alpine pastures tolerate moderate grazing, and the elimination of grazing can lead to the disappearance of some species; however, overgrazing and overstocking in certain areas, e.g., resting places, profoundly alter the vegetation and cause soil erosion. SICs and SACs that contain habitat 6170 should develop plans for grazing management, particularly including the adjustment of stocking densities (e.g., grazing intensity <25% of net primary production) and regulating grazing practices so that conservation objectives are met; e.g. preventing grazing in high alpine communities until vulnerable species have completed their reproduction.

New ski resorts are one of the main threats to alpine calcareous grasslands. The construction and maintenance of ski trails lead to the deterioration of alpine habitat; therefore, they should not be built in areas where the alpine vegetation has high conservation value.

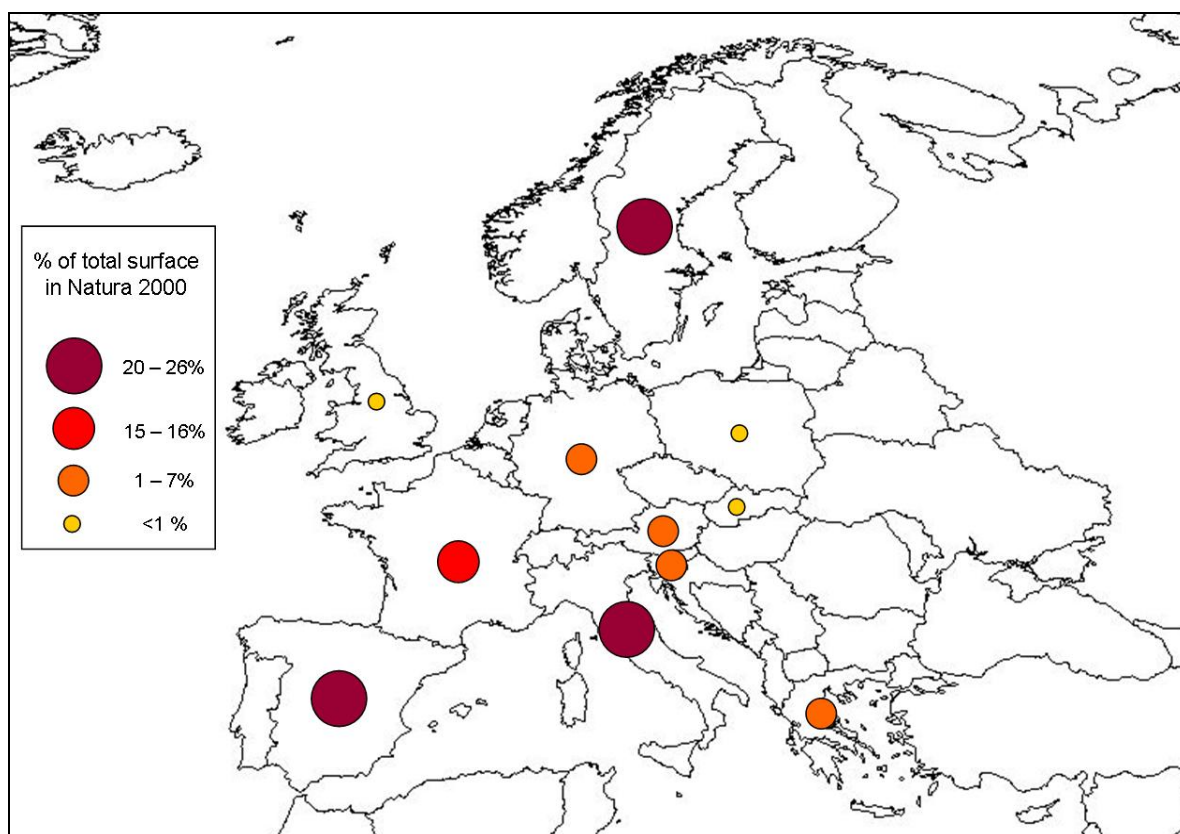
There is strong evidence that global warming is leading to changes in alpine vegetation communities (e.g., the intrusion of alpine species into higher elevations). Currently, beyond the general measures recommended for minimizing the effects of climate change, little more can be done apart from establishing a network of monitoring sites at the most representative points in the alpine mountains.

1. Description of habitat and related species

Calcareous alpine and subalpine grasslands occur on lime-rich soils and consist of short, species-rich mixtures of grasses, arctic-alpine cushion herbs and sedges.

Distribution

This habitat type is found in high calcareous mountains of Europe which have a substantial area above the treeline. It includes alpine and subalpine grasslands on base-rich soils in mountain ranges such as the Alps, Pyrenees, Carpathians, and Scandinavian Mountains, the grasslands of the subalpine (Oro-Mediterranean) and alpine zones of the highest mountains of Corsica, and the mesophile, closed, short turfs of the subalpine and alpine zones of the southern and central Apennines, developed locally above the treeline on calcareous substrates. In addition to the above-mentioned massifs, habitat 6170 occurs in the Betic Sierras, the Iberic System and Cantabrian Mountains in Spain, in the Dinaric Alps, the mountains of Greece, and the Scottish Highlands. It can include associated snow-patch communities (e.g., *Arabidion coeruleae* Braun-Blanquet 1926).



Percentage distribution of the total surface of alpine and subalpine calcareous grasslands in Natura 2000

Alpine and subalpine calcareous grasslands in Natura 2000 sites

The following data have been extracted from the Natura 2000 Network database, elaborated by the European Commission with data updated on December 2006. The surface was estimated on the basis of the habitat cover indicated for each protected site and should be considered only as indicative of the habitat surface included in Natura 2000.

Biogeographical region	Nº of sites	Estimated surface in Natura 2000 (ha)	% of total surface in Natura 2000
Alpine	308	303,273	56,31
Mediterranean	212	182,181	33,82
Atlantic	38	19,967	3,71
Boreal	4	17,368	3,22
Continental	41	15,828	2,94
Countries	Nº of sites	Estimated surface in Natura 2000 (ha)	% of total surface in Natura 2000
Spain	169	137,157	25.46
Italy	208	125,845	23.36
Sweden	26	108,618	20.17
France	92	82,460	15.31
Greece	16	33,421	6.20
Germany	25	20,036	3.72
Austria	30	18,820	3.49
Slovenia	10	7,712	1.43
Slovakia	9	2,371	0.45
Poland	3	1,502	0.28
United Kingdom	15	675	0.13
TOTAL	603	538,617	100

Main habitat features, ecology and variability

The large diversity of plant communities that are included in this habitat is the result of a high variability in ecological conditions, especially in terms of plant cover, topography, edaphic conditions, and climate. The brief definition of this habitat in the Interpretation Manual of EU Habitats (EC 2007) is insufficient to describe its ecological characteristics.

Firstly, it is important to agree upon the definitions of the terms “alpine” and “subalpine.” One of the most widely used definitions is that of Körner (1999) and adopted by Grabherr *et al* (2003). According to that definition, the alpine zone extends up from the treeline as far as the beginning of the snow zone, where plant cover drops below 20%. The treeline is the imaginary line linking the highest elevations where trees at least 3m tall are found in distinct patches. The subalpine zone extends from the timberline (the upper limit of the dense mountain forests) to the tree-species line (the limit of isolated trees), which implies that there can be some overlap between alpine and subalpine zones. For that reason, the term “subalpine” is avoided by many authors. Thus, habitat 6170 includes those calcareous grasslands of the European mountains which lie above the timberline.

The elevation of the timberline varies because of environmental and anthropogenic factors, and it is not always easy to distinguish these factors. The treeline and timberline are influenced by climate (Körner, 1999); at high latitudes, they are at lower elevations than they are elsewhere (Ozenda 1983). Altitude is not therefore a good criterion on the basis of which to characterize habitat 6170. In addition, in the mountains of Europe, the ecotone between alpine grasslands and the timberline has been modified by anthropogenic activities in summer pastures, which has lowered both the natural treeline and timberline. In most of the main European mountains, this practice has been important since the Middle Ages (Chocarro *et al.* 1990, Cruise 1991, Olsson *et al.* 2000, Coldea 2003). Consequently, present-day subalpine zones are characterised by a patchy mosaic of scattered trees and a wide diversity of pastures typical of the alpine and montane zones (Ellenberg 1988).

Ecological requirements

Pastures in high calcareous mountains are composed of mesophilous and xero-mesophilous grasslands, and are associated with carbonates in the soil, mainly those of calcium or magnesium. In some places,

they grow in humid, rich soils and are fertilized by wild and domesticated ungulates (e.g., in *Caricion ferrugineae* G. Braun-Blanquet et Braun-Blanquet 1931 and some *Primulion intricatae* Braun-Blanquet ex Vigo 1972 communities). In other locations, the soils are shallow and nutrient-poor (e.g. *Oxytropido-Elynon myosuroidis* Braun-Blanquet 1949, *Seslerion caeruleae* Braun-Blanquet in Braun-Blanquet et H. Jenny 1926).

The wide distribution of alpine pastures in Europe leads to a variety of geographic and climatic conditions. Grabherr *et al.* (2003) defined four major alpine life-zones (Mediterranean, Temperate, Boreal, and Arctic) and the intermediate states between them. Boreal and Arctic alpine environments receive moderate snowfall in winter and experience severe frosts. In summer, the long photoperiod can compensate for the short period of vegetative growth. Mountains in temperate zones often experience large accumulations of snow, which protect against deep-soil frost. Snow-covered and snow-free communities are dramatically different. In the high mountains of the Mediterranean region, summers are relatively dry and warm. The growing period is relatively long and the alpine zone contains tussock-like grasslands (*Stipa* spp., *Festuca* spp.) and xerophytic, thorny-cushion communities (e.g. *Ononidetalia striatae* Braun-Blanquet 1950).

Körner *et al.* (2003) identified the common climate of alpine areas by analyzing the data from 23 stations within the main alpine mountains in Europe. The average duration of the vegetative growth period was 155 days and the average temperature 10 cm below ground was 7-12 °C across the latitudinal range (except in mountains in the extreme south). The average low and high temperatures were -5 °C and 17 °C, respectively. With the exceptions of the Sierra Nevada (Spain) and Etna (Italy), rainfall does not limit the life of the alpine plants, but it influences the length of the period of vegetative growth through its effects on snow cover, which is reflected in the temperature of the ground.

Main subtypes identified

Many communities (alliances and associations) can be ascribed to the alpine and subalpine calcareous grasslands, but practical limits preclude a thorough description of all of the phytosociological units that characterize this complex habitat.

From a biogeographical point of view, it is possible to distinguish the grasslands of the alpine and subalpine zones of the Eurosiberian region from those in the Oro-Mediterranean region of the mountains of southern Europe. Those in the Eurosiberian region belong to the Class *Elyno-Seslerietea* Braun-Blanquet 1948, which extends over a large portion of the mountains of Europe, has a reduced presence in the Mediterranean region, but extends as far east as the mountain ranges of the Far East. Those in the oro-Mediterranean region are included in the order *Ononidetalia striatae* Braun-Blanquet 1950. Both types of grasslands are included in habitat 6170, even though they are very distinct ecologically and floristically.

According to the Interpretation Manual of European Union Habitats EUR27 (July 2007 version), there are five major sub-types within the 6170 habitat (codes refer to the Palaeartic Habitat 1995 classification):

36.41. Closed calciphile alpine grasslands. Mesophile, mostly closed, vigorous, often grazed or mowed, grasslands on deep soils of the subalpine and lower alpine levels of the Alps, the Pyrenees, the mountains of the Balkan Peninsula, and, locally, of the Apennines and the Jura Mountains.

36.42. Wind-edge naked-rush swards. Meso-xerophile, relatively closed and unsculptured swards of *Kobresia myosuroides* (*Elyna myosuroides*) forming on deep, fine soils of protruding ridges and edges exposed to strong winds in the alpine and snow levels of the Alps, the Carpathians, the Pyrenees, the Cantabrian Mountains, the Scandinavian Mountains and, very locally, the Abruzzi and the mountains of the Balkan Peninsula, with *Oxytropis jacquini* (*Oxytropis montana*), *Oxytropis pyrenaica*, *Oxytropis carinthiaca*, *Oxytropis foucaudii*, *Oxytropis halleri*, *Antennaria carpatica*, *Dryas octopetala*, *Draba carinthiaca*, *Draba siliquosa*, *Draba fladnizensis*, *Draba aizoides*, *Gentiana tenella*, *Erigeron uniflorus*, *Dianthus glacialis*, *Dianthus monspessulanus* ssp. *sternbergii*, *Potentilla nivea*, *Saussurea alpina*, *Geranium argenteum*, *Sesleria sphaerocephala*, *Carex atrata*, *Carex brevicollis*, *Carex foetida*, *Carex capillaris*, *Carex nigra*, *Carex curvula* ssp. *rosae* and *Carex rupestris*. Scandinavian *Kobresia* grasslands with *Carex rupestris* are included.

36.43. Calciphilous stepped and garland grasslands. Xero-thermophile, open, sculptured, stepped or garland grasslands of the Alps, the Carpathians, the Pyrenees, the mountains of the Balkan Peninsula, and the Mediterranean mountains, with local outposts in the Jura.

36.37. Oro-Corsican grasslands. Grasslands of the subalpine (Oro-Mediterranean) and alpine levels of the highest mountains of Corsica.

36.38. Oro-Apennine closed grasslands. Mesophile, closed, short turfs of the subalpine and alpine levels of the southern and central Apennines, developed locally above treeline on calcareous substrates. Xerophytic Oro-Mediterranean pastures of the mountains in Greece and central Spain might be included with the last subtypes.

Plants: 36.41 to 36.43 - *Dryas octopetala*, *Gentiana nivalis*, *Gentiana campestris*, *Alchemilla hoppeana*, *Alchemilla conjuncta*, *Alchemilla flabellata*, *Anthyllis vulneraria*, *Astragalus alpinus*, *Aster alpinus*, *Draba aizoides*, *Globularia nudicaulis*, *Helianthemum nummularium* ssp. *grandiflorum*, *Helianthemum oelandicum* ssp. *alpestre*, *Pulsatilla alpina* ssp. *alpina*, *Phyteuma orbiculare*, *Astrantia major*, *Polygala alpestris*; 36.37 - *Plantago subulata* ssp. *insularis*, *Sagina pilifera*, *Armeria multiceps*, *Paronychia polygonifolia*, *Bellardiochloa violacea*, *Phleum brachyrachyum*, *Geum montanum*, *Sibbaldia procumbens*, *Veronica alpina*; 36.38 – *Festuca violacea* ssp. *macrathera*, *Trifolium thalii*.

Species that depend on the habitat

None of the animal species in the Habitats Directive depend exclusively on habitat 6170, but there are alpine species of interest that frequently use this habitat for food and shelter. Among the mammals are *Rupicapra rupicapra* (chamois), *R. pyrenaica* (isard), *Capra ibex* (ibex), *Capra pyrenaica* (Spanish wild goat), *Marmota marmota* (marmot), and *Chionomys nivalis* (snow vole).

Among birds listed in Annex I of the EU Birds Directive, breeding locations of *Charadrius morinellus* (Eurasian dotterel) are closely linked to alpine and subalpine grasslands (habitats 6150 and 6170) in Sweden, Finland and UK and the majority of the breeding pairs (more than 90%) in Europe (outside Russia) are found in these countries plus Norway. Further, *Lagopus mutus* (ptarmigan) can be highly dependent on this habitat in some areas because they feed preferentially in some of its communities (e.g. *Dryado octopetalae* - *Salicetum pyrenaicae* Chouard 1943 in the Pyrenees).

In alpine habitats, the diversity of invertebrates is not high, but the typical species are usually of conservation interest because of their adaptations to alpine environments. Among the Lepidoptera, there are several species in the Genera *Erebia*, *Glacies*, *Colias* and *Elophos* that are endemic to alpine habitats. The diversity of Lepidoptera is greater in alpine calcareous grasslands than it is in siliceous grasslands (Varga and Varga-Sipos 2001).

Related habitats

At most mountain sites, alpine and subalpine calcareous grasslands form intimate mosaics with other upland habitats in Annex I, and there are complex transitions to a range of montane communities. They are often associated with 4080 Sub-Arctic *Salix* spp. scrub and other shrub habitats. In the subalpine zone, some of the edaphic and climatic characteristics and management of the alpine and subalpine calcareous grasslands are shared by the grasslands of the class *Festuco-Brometea* Braun-Blanquet & Tx. 1943 (e.g., *Bromion erecti* W. Koch 1926 which are integrated into habitat 6210).

In some high mountain areas, high precipitation leads to the leaching of bases and progressive acidification of the soil. Leaching can give rise to the appearance of acidophilous grasslands on calcareous substrates (e.g., *Nardion strictae* Braun-Blanquet 1926), which are excluded from habitat 6170, even though they can lead to transition communities.

In the Scandinavian mountains, the occurrence of calcicolous plant species is decisive for distinction from siliceous alpine grasslands (habitat 6150), and if there is more than 50% scrub coverage, the land is classified as alpine heath (habitat 4060).

At snow-covered sites, the communities included in habitat 6170 meet those of the *Arabidion coeruleae*, which can form a mosaic. Where the slope is steep, the calciphilous stepped and garland grasslands (sub-type 36.43) meet those of the calcareous scree communities (*Thlaspietea rotundifolii* Braun-Blanquet 1947 class – habitat 8130), replacing them where mobile screes are fixed. In the Carpathians there is also a possible relation to habitat 6190 Rupicolous pannonic grasslands (*Stipo-Festucetalia pallentis*) which is a vicariant of the 6170 habitat at lower altitudes

Ecological services and benefits of the habitat

Alpine and subalpine calcareous grasslands are rich in species and communities, which is why they are reservoirs of biodiversity. Väre *et al* (2003) estimated that alpine habitats comprise about 20% of the European flora, but cover only 3% of the area. Typically, diversity is higher in these grasslands than it is in the siliceous grasslands (Coldea and Cristea 1998, Virtanen *et al.* 2003). Endemics, rarities, and species of high biogeographical value are abundant (Pawłowsky 1970).

The communities that constitute this habitat contribute to the formation and protection of the soil, which is very scarce and unstable in subalpine and alpine environments, by reducing or slowing soil erosion. In Central and Western Europe, one of the main benefits that comes from this habitat is its usefulness as pasture for livestock. Mesophilous grasslands of subtype 36.41, which have high plant cover and rich soils, are good for sheep grazing even though productivity is low (García-González *et al.* 2002, 2005). Those grasslands may cover only small areas, but sheep can take advantage of them between July and September, when the accessible pastures at the lower elevations are already dry or over-used by livestock (García-González *et al.* 1990). Swards of sub-type 36.42 (*Elyno-Seslerietea*) are of limited pastoral value and occupy small areas, but goats and wild herbivores can use them. Garland grasslands of moderate slopes of the subtype 36.43 (e.g. *Festucion scopariae* Braun-Blanquet 1948 in the Pyrenees) occupy wide areas in the mountains and, although their pastoral value is low, they are used moderately by sheep (Marinas *et al.* 2002).

In the Scandes of Sweden and Finland, reindeer grazing has a very long tradition, linked to the Sámi culture. The alpine heaths and grasslands above the tree-line are the main grazing habitats for domestic reindeer, and it is obvious that reindeer grazing has been a key factor affecting the composition of the vegetation and the abundance of species (Suominen & Olofsson 2000, Olofsson & Oksanen 2003).

Alpine grasslands are the most important habitats for alpine herbivores such as chamois, ibex, and marmot. Predatory birds such as the golden eagle depend on this open terrain for hunting, e.g., marmots. Habitat 6170 has substantial societal value. The flora, fauna, and scenery of the high calcareous mountains provide aesthetics that are increasingly valued by society. This habitat and others that define alpine zones support a variety of sports and recreational activities (mountaineering, cross-country skiing, hiking or mountain climbing).

Trends

Alpine and subalpine calcareous grasslands are one of the habitats that cover large areas and have been relatively less affected by anthropogenic forces. Usually, the extreme harshness and inaccessibility of the environment have prevented the widespread exploitation of this habitat. Only when the potential economic benefits are high (mining, forestry, hydro) are human societies motivated to act and, when they do, they often have a significant negative impact on the native habitat. An exception is the use of these grasslands for livestock grazing in summer, which has occurred for hundreds and probably thousands of years (Bahn 1983). However, the negative effects of grazing on this habitat generally are moderate or low, while this activity is also considered to play a positive role in maintenance of the habitat in certain areas.

In response to natural forces after the post-glacial period in Central Europe, the elevation of the timberline has varied by 200 to 300 m (Wick and Tinner 1997). More significant are the changes caused by human activities, including the use of grasslands as pastures and the harvesting of timber. In the Eastern Carpathians, 50-60% of the treeline ecotone was destroyed in the 19th century, which caused erosion and flooding (Caldea 2003). In western Carpathians most of deforestation was done in 16th-17th century during Valachian colonisation. In the western Pyrenees, it is common to find lowering of the timberline of up to

500 m, which has led to the disappearance of substantial part of the subalpine forests of *Pinus uncinata* (Vigo & Ninot 1987). In other alpine mountains, the situation is similar (Ellenberg 1988, Olsson *et al.* 2000).

Not all of the anthropogenic activities are always harmful to alpine and subalpine grasslands. The disappearance of woody species in the subalpine zone has permitted the expansion of alpine grasslands, which has occurred at the expense of other habitats (e.g. 4060, 4090, 9420, 9430). Some of the mammals in the subalpine zone have benefited indirectly from those changes; e.g., chamois (Loison *et al.* 2003) and marmots (Herrero *et al.* 1994).

Threats

Grazing

Livestock grazing in alpine and subalpine grasslands is not a significant threat. It is very likely that the ecosystem has coexisted with grazing by large wild herbivores for millennia (Bahn 1983, Ellenberg 1988, Cruise 1991, Ozenda and Borel 2003). In certain areas, the activities of large herbivores are beneficial to the maintenance of the habitat and there is evidence that the cessation of grazing can lead to the loss of some communities and species (Lomnicki 1971, Miller *et al.* 1999).

The effect of livestock grazing on alpine grasslands is a complex, interactive process. The response of the vegetation depends on the initial conditions; e.g. vegetation composition, grazing season, grazing pressure, animal species, topography, and management practices (Stewart and Eno 1998). Generally, the effect of defoliation on the vegetation is minor, especially at low grazing intensities, and in communities dominated by graminoids. Other indirect effects of the animals, such as trampling and fertilization, are more important. The accumulation of excrement in rest areas or other locations frequented by the animals often causes significant changes in the vegetation (Erschbamer *et al.* 2003).

Several of the grasslands associated with this habitat, especially those at the highest elevations, are mature or end-stage communities (Ellenberg 1988). Nevertheless, the effects of human activity (fire and grazing) favour others, especially alpine grasslands in the subalpine zone. In general, the numbers of livestock in European alpine summer pasturelands have declined (with some exceptions, e.g. in Switzerland). The decrease in grazing pressure has permitted the invasion by shrubs and reforestation in those zones, which is why the extent of this habitat is predicted to decline.

In Scandinavia, the potential negative impact of grazing (or overgrazing) by domestic reindeer on natural values has been under debate for a long time, especially with reference to lichens (Bernes 1996). However, results from field surveys and research are not clear-cut but suggest a more nuanced picture. There seems nowadays to be a consensus that grazing impact is very complex: it has been a factor determining the composition of plant communities for a very long time, and while it appears to have little influence on the diversity of species present, the impact on their relative abundance is high.

Ski resorts

The establishment of ski resorts is one of the main threats to alpine calcareous grasslands. The vegetation is destroyed merely by the occupation of the ground in the construction of facilities, buildings, and other infrastructures. On the ski trails, soil erodes, the snow layer is compacted, and the phenology of plants is delayed, which alters the composition of the vegetation. To restore plant cover, areas often are reseeded with introduced species, which can modify drastically the structure of the vegetation.

Other infrastructures (reservoirs, mining, electricity lines, roads)

As indicated, above, inaccessibility and the harsh climate of the alpine environment have limited the area impacted by infrastructures. However, technological advances might cause an increase in the frequency of these types of negative impact. As in the case of ski trails, disturbances affect the cover, composition, biomass, and diversity of the plant communities, and it can take decades for the vegetation to recover (Curtin 1995).

Tourism

Alpine areas are experiencing an increase in the influx of visitors. Most of the impact of winter tourism is related to skiing. In the snow-free period, tourism can cause localized erosion through trampling and by disturbing the alpine fauna (unnecessary energy costs, destruction of nests) (DPN 2007, Pepin *et al.* 1996).

Climate change effects

Changes in the vegetation of alpine environments in response to increasing temperatures have been predicted by numerous models. One of the predictions is a progressive invasion of the subalpine grasslands by shrubs and colonizing arboreal species, such as *Pinus mugo* in the Alps (Dullinger *et al.* 2003). In addition, higher temperatures will lead to a raising of the treeline and a loss of subalpine grasslands and the process will mainly affect calcareous habitats (Dirnböck *et al.* 2003). Some alpine plant species might disappear (Coldea 2003, Paulsch *et al.* 2003, Lesica and McCune 2004) and the survival of some invertebrate species that depend on this habitat might be threatened (Brandmayr *et al.* 2003). Species at lower elevations will be able to invade high alpine communities (Grabherr *et al.* 1994). The predicted changes are more likely to occur because of invasions by species, rather than because of the internal breakdown of communities, which usually are quite stable (Grabherr 2003). Alpine grasslands have a large inertia and can tolerate increases in temperature of up to 1-2 °C, but drastic changes are predicted to occur if the increase is greater than 3 °C (Theurillat and Guisan 2001).

Alpine grasslands are ideal places to permanently monitor the changes that might result from climate change because, generally, anthropogenic impacts are less in alpine habitats than they are elsewhere (Körner 1999). Currently, in alpine grasslands, beyond the general measures for minimizing the effects of climate change, little more can be done beyond establishing a network of monitoring sites at the most representative points in the alpine mountains. The experiences of ALPNET might be a good example (<http://www.iccr-international.org/alp-net/>).

2. Conservation management

General recommendations

Alpine grasslands are very stable communities. Most of the dominant species are long-lived, clonal perennials that can live for hundreds of years (Körner 1999). Nevertheless, they are very sensitive to drastic perturbations (e.g., soil loss). Once the plant cover is altered or there is a significant loss of soil, it is very difficult if not impossible to restore the native habitat (Grabherr 2003). Generally, the conservation of permanent or near-climax communities of this habitat does not require active management. Given the fragile nature and structural complexity of the habitat, the best management practice is to leave it as undisturbed as possible.

However, a variety of disturbances affect this habitat. Among the most important are grazing (one of the few uses that, in moderation, are compatible with the maintenance of the habitat) and ski trails (the use that has the most negative impact). Most of the attempts to restore this type of habitat by reseeding and fertilization of the soil have failed. The introduction of machinery at high elevations and on unstable slopes makes the problem worse.

The best management advice is not to alter the plant cover or the edaphic conditions of the habitat (Bensettiti *et al.* 2005). If the construction of large infrastructures is permitted, the managers responsible will have to be prepared to accept the almost assured destruction of the habitat, particularly if there is a loss of soil.

Active management

Grazing

In several European countries, socioeconomic changes have led to the abandonment of the practice of extensive grazing in the mountains. In most of the alpine mountains, the number of livestock has declined. A variety of studies suggest that this process will lead to the progressive invasion of the subalpine zone by woody species, possibly aided by the predicted increase in the temperature. The extent to which this process will affect the communities of habitat 6170 will depend on the expansion into the subalpine zone, which varies locally; however, it is likely that the highest alpine communities will be largely unaffected, at least in terms of the amount of area involved.

It seems that the absence of grazing has led to local losses of some species and communities (Lomnicki 1971, Miller *et al.* 1999). It is necessary to study these processes in detail, to identify the degree of the threats to species and communities, and the degree of dependency on grazing. It does not clear whether this problem is significant for habitat 6170. Possibly, the foraging by wild ungulates, whose numbers have increased (Loison *et al.* 2003), will be sufficient to guarantee an adequate level of grazing. Management plans for particular sites (as discussed below) should indicate whether and where grazing by livestock should be maintained, and if certain areas are to be allowed to scrub over.

Reindeer grazing in the Scandes Mountains

In Scandinavia, control of reindeer herding has been discussed but is rarely applied. The key is to find a balance between high and low grazing pressure over a larger area in order to allow for a variation in vegetation and plant species which are dependant upon, or affected by, various degrees of impact from reindeer. This is also likely to have an indirect impact on the abundance of different species of butterflies and other insects that are dependent on various plant species grazed by reindeer (CBM 2006).

Controlling shrub encroachment.

Management tools for controlling shrub encroachment usually include mechanical clearing and burning. Mechanical clearing is not advisable because of the disturbances that it can provoke in the soil. Typically, fire causes a loss of nutrients, but moderate, controlled use followed by grazing is supported by some studies (Metailie 1981, Hope *et al.* 1996). Before undertaking those measures, which can have a significant impact, the environmental authorities have to decide whether they will undertake the clearing and assume the associated problems, or permit the woody vegetation to colonize a space that it very likely occupied in the past. In addition, some of the communities of the colonizing woody species can belong to habitats of Community interest (e.g., 4070, 9420, 9430), which might create conflicts between opposing conservation interests.

Estimating carrying capacity

The overgrazing of alpine grasslands can lead to significant changes in biomass, floristic composition, diversity, and the recycling of nutrients in the community (Erschbamer *et al.* 2003). In some areas of Southern Carpathians grazing has been forbidden in zones where 6170 and other alpine habitats are present (projects LIFE 03 NAT/000032 "Natura 2000 sites in Piatra Craiului National Park"). Nevertheless, in the communities of the highest alpine zone, grazing pressure is usually not very high and the plant communities are adapted to grazing by ibex and chamois (Körner 1999). Some alpine species are tolerant to high levels of herbivory (Diemer 1996, Lee *et al.* 2000). In addition, the impacts of herbivores on mountain grasslands are more a consequence of the spatial distribution of fertilization and trampling than an effect of defoliation (Erschbamer *et al.* 2003).

To avoid the possible pernicious effects of under- and overgrazing, often it is helpful to quantify the carrying capacity of a specific area. Carrying capacity is the maximum density of herbivores that an area can support which still allows the persistence of the ecosystem. Management objectives can dictate which approach is used to meet that objective (Myrsterud 2006). However, overgrazing can occur below the carrying capacity, e.g. the excessive depredation of the species preferred by generalist herbivores. Some have argued that the concept of carrying capacity is of no use in highly variable environments (McLeod 1997). Others suggest that species of herbivores are not equivalent in their grazing impact and that concepts such as the Livestock Unit (LU) can be inappropriate (Farnsworth *et al.* 2002).

The concept of carrying capacity has many criticisms and is a crude tool for the pastoral regulation of an area. In management plans, it can provide a first approximation, but it must be accompanied by other measures. Typically, alpine grasslands form a mosaic with other alpine communities, and usually they all shape a pastoral unit, which often is the management unit. For that reason, the carrying capacity is calculated for an area in which the proportion of alpine grasslands varies.

Usually, the number of animals is expressed in terms of LU, which is equivalent to a 500 kg, non-lactating cow (although the definition varies among countries). It is important to establish a criterion of equivalency among species of ungulates. An accurate equivalence is based on the metabolic weight of the animal ($W^{0.75}$) because forage consumption is significantly correlated with it. Following that criterion, a 40 kg sheep is equivalent to 0.15 LU and a 500 kg cow is equivalent to 6.6 sheep (Stewart and Eno 1998). A widely used expression for carrying capacity is the following:

$$\text{Carrying Capacity} = (\text{Forage Supply} - \text{Costs}) / \text{Herbivore Requirements}$$

Typically, Forage Supply and Herbivore Requirements are expressed in units of dry matter or energy. It is best if they are expressed as metabolizable energy because it incorporates quality and quantity of the forage, and the energy directly usable by the herbivore. In addition to the energetic costs of the protection and support of the ecosystem, "Costs" include the portion of herbaceous production that is unavailable to the herbivore because of the effects of trampling, defecation, and the inaccessibility of certain components of the plants.

Precise estimates of the costs require detailed and expensive studies of the structure and functioning of the grassland ecosystem (Biondini *et al.* 1998). One indirect method of calculating the cost is to estimate its complement, the level of the use of a pasture for known stocking rates using exclusion fences to prevent grazing by large herbivores. The calculation is the following:

$$\text{Use} = 1 - (\text{Biomass grazed} / \text{Biomass excluded}) \text{ (McNaughton 1985)}$$

Studies have shown that the estimates of use (utilization rate) vary from 20% to 60% of the above-ground production in moderately and intensively grazed areas, respectively (Milchunas and Laurenth 1993). In alpine pastures, it is recommended that the utilization rate of the key plant species should not exceed 20-30%, and the limits should be reduced further in areas where the slope is high or the distance to water points is long (Holecheck and Pieper 1992).

Estimates from several calcareous summer pasturelands in the Pyrenees indicate that moderate grazing (25% utilization rate) and a conservative estimate of herbaceous production (i.e., the lower limit of the 95% confidence limit of the mean) are compatible with conservation objectives (García-González and Marinas 2008).

In England, it is recommended that the stocking rate should not exceed 0.4 LU ha⁻¹ yr⁻¹ in pastures that can be included within habitat 6170. The rate should be 0.14 LU ha⁻¹ yr⁻¹ on limestone pavements (Backshall *et al.* 2001). The definition of LU can differ from the one described above.

Information about the production of the grasslands included in habitat 6170 is limited. In Table 1 are data from the Alps and Pyrenees.

Table 1. Production and value (ecological and pastoral) of some of the grassland communities of habitat 6170 in the Alps and Pyrenees

Community	Peak biomass (g DM m ⁻²)	Reference	Ecological Value**	Pastoral Value***
<i>Sesleria</i> heath	260	Rehder 1976 in Körner 1999		
<i>Elynon myosuroidis</i>	210	Labroué & Tosca 1977	8.8	2.9
<i>Primulion intricatae</i>	297*	García-González <i>et al.</i> 2002	11.1	4.9
<i>Festucion gautieri</i>	116	Marinas <i>et al.</i> 2002	7.8	1.2
<i>Ononidion striate</i>	483	Canals 1992	16.7	

* mean of six studies.

** ecological value is an index combining distribution, rarity, diversity and conservation interest of the community in a qualitative scale. It ranges from 3.5 to 16.7 with a mean \pm s.e of 8.4 ± 0.5 in 39 Pyrenean pasture communities (according to Gómez-García *et al.* 2002).

*** pastoral value is estimated as a product of mean values of production, nitrogen content and digestibility of the community. Its unit has no measurable sense. It ranges from 0 to 16.5 with a mean \pm s.e. of 5 ± 0.7 in 24 Pyrenean pasture communities (according to Gómez-García *et al.* 2002).

In the extremely harsh climate of Arctic environments, which might be comparable to some of the wind-edge naked-rush swards and cushion-plant alpine communities of habitat 6170, Bliss (1986) estimated a level of use of 3-10% when grazed by wild ungulates. Thus, the suggested maximum carrying capacity was 2-3 caribou or 1-1.5 muskoxen km⁻² (after taking into account disease, predation, hunting, and severe weather).

In several pasturelands in the Alps, the estimated carrying capacity was 1.3-4.0 sheep ha⁻¹ for a 100-day grazing period (Dorée and Jouglet 1979).

In one pastureland in the calcareous western Pyrenees (the Collarada summer range), there is a small (22 ha) plateau at 2,600 m that is surrounded by cliffs (Somola Alto, see photograph above). The vegetation is composed of pastures of the alliances *Primulion intricatae* and *Elynon myosuroidis*, which are included in habitat 6170 (subtype 1 and 2). For decades, every summer a flock of 2,900 sheep enters the plateau on its own and remains there grazing freely until it leaves of its own accord. The shepherds do not dare to move them for fear that the sheep will fall over the cliff. That situation made it possible to estimate that the

maximum stocking rate that some pastures of habitat 6170 can support sustainably was 22 sheep (3.3 LU) ha⁻¹ month⁻¹ (García-González *et al.* 2007a).

Procedures and sources of variability in estimates of carrying capacity

To determine the forage supply:

1. Define the area of the study, which can be done using one of several approaches, e.g. assume that the entire area is available to all of the herbivores, or determine through direct observation the areas actually used by each type of livestock (species or identifiable herds and flocks).
2. Stratify the study area using a conventional vegetation map or another type of functional classification of the grasslands, which will be the basis for estimates of production, along with other types of information (phenology, pasture quality, priority habitats, key species). The development of a Geographic Information System (GIS) that incorporates all of the layers of information relevant to pastoral management is highly recommended.
3. Choose the method for calculating plant production. There are numerous methods for calculating production in supraforestral grasslands (Singh *et al.* 1975). Results can vary enormously depending on the method that is used. In addition, it is advisable to estimate production in several years (growing seasons). Telemetry using remote sensors (satellites, small planes) is very useful for estimating production over large areas and in areas that are difficult to access (Goetz 1997).
4. Estimate the total energy supply of the study area, weighted by the area of each community, preferably in terms of metabolizable energy. Usually, correction factors are applied; e.g. to an average gross energy of alpine pastures of 4.7 kcal g⁻¹ DM, apply 60% for the digestibility of grass and 82% for the metabolizability of digestible energy (Robbins 1993).

To determine the nutritional requirements of the herbivores:

5. There are no in situ measures of the metabolic costs for animals grazing in alpine pastures. As a first approximation, the information required to be able to estimate the energetic needs of the herbivores can be obtained by using the regular nutritional standards (INRA 1988, NRC 1996).
6. The level of consumption or the metabolic needs should be estimated for each age and sex class (female and male adults, juveniles, and yearlings) and specific physiological states, e.g. gestation and lactation (Stewart and Eno 1998).
7. Determine the composition of the flock or herd in terms of sex, age, and physiological state. By weighting the composition of the flock or herd by the energetic needs of each class, we can establish the needs of an average individual.
8. It is important to establish the area occupied by each of the flocks and herds, and the time they spend grazing in those areas. One of the significant limitations of the concept of carrying capacity is the irregular distribution of the stocking rate within a pastoral area. In places where the animals concentrate (e.g., water points), the stocking rate can be hundreds of times higher than it can be in other areas.

Complementary surveys

Knowing the carrying capacity of a pastoral unit often is insufficient for detecting under- or overgrazing. An alternative or complementary action is to define a group of key species and to carry out a detailed monitoring of the impact of grazing on them (Du Toit 2000). They can be the indicator species of habitats of Community interest (JNCC 2006, 2007), rare species that have conservation value, or species that are particularly sensitive to grazing. Stewart and Eno (1998) extended the concept by proposing the use of "key features," which can be species (plant or animal) or plant communities, on which the impact of grazing is assessed. Once the key features are identified for a specific area, a survey protocol is developed that specifies the variables to be measured, the frequency of measurements, tolerable limits to herbivory, etc. (see Monitoring Programs, below).

The monitoring programs can expand to include other important factors for the maintenance of the system, such as plant cover, track density (Pringle and Landsberg 2004), and edaphic erosion. An innovative and interesting complement to ground-based surveys is surveys by satellite (Schino *et al.* 2003).

Eco-pastoral indices

Gómez-García *et al.* (2002) developed an index that measures both the ecological and pastoral values of alpine grasslands and assesses the conservation status of one or several pastoral units. From quantified variables of ecological type (rarity of species and communities, distribution, diversity) and forage (production, digestibility, protein content, herbivore preferences), the index calculates separately the eco-pastoral value of each plant community (Table 1).

The calculations are based on plant communities; therefore, a vegetation map of the study area allows an analysis of the spatial distribution of the index (Fig. 1), which can be incorporated into a GIS and combined with other information layers that facilitate the eco-pastoral management of the area. The use of a standardized method permits the use of periodic surveys of the grasslands, to establish the scientific basis for the pastoral use, and promote management measures that are compatible with the conservation of the area.

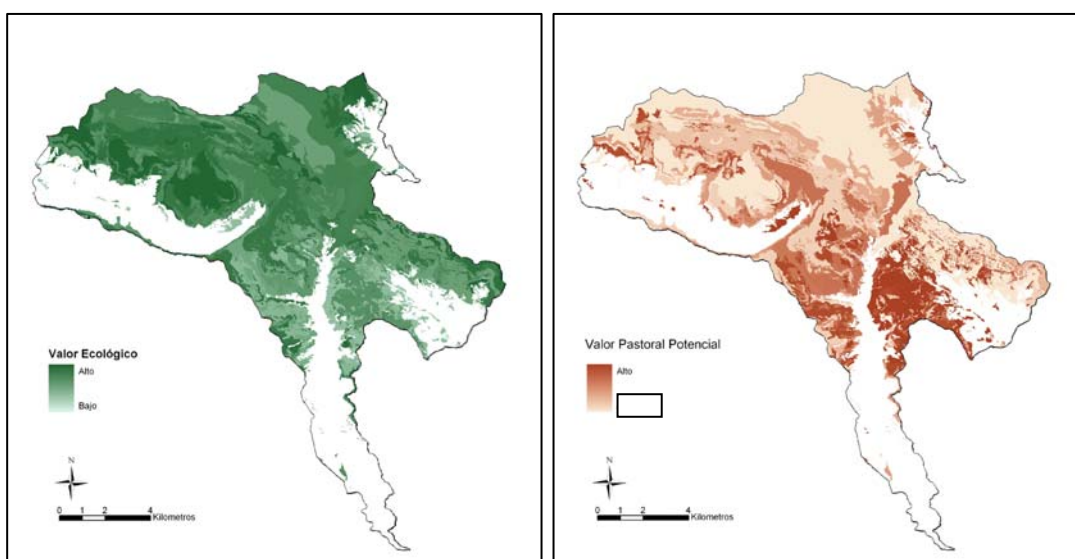


Fig. 1. Distribution of the Ecological and Pastoral Indices in the supraforestral area of Ordesa National Park (Spanish Pyrenees). Ecological value (left) is negatively correlated with pastoral value (right). The high-altitude zones (dark green) have high ecological value and low pastoral value, and vice versa. The areas in white are forest (García-Gonzalez *et al.* 2007b).

In southern Europe, the pastoral index of Daget and Poissonet (1971) has been used widely to evaluate the quality of alpine grasslands and their carrying capacities. The subjectivity introduced into the process of calculation makes the use of this index inadvisable (Al Haj Khaled *et al.* 2006).

Grazing behaviour

In some alpine countries, sheep numbers have increased in recent decades. For example, in Switzerland, the number of sheep has gone from 200,000 to 400,000 in the last 40 years. Half of the flocks graze freely in the alpine summer pasturelands (Troxler and Chatelain 2005). When the sheep graze in the absence of a shepherd, they tend to occupy the highest sections and can damage the communities of the alpine grasslands of habitat 6170. An early ascent by sheep to the highest portions of the summer pasturelands can interrupt the growth and reproduction of the alpine plants of special interest through defoliation and trampling. The reproduction of sensitive bird species such as ptarmigan can be jeopardized. In contrast, the lower portions of the pasturelands are under-grazed, which favours encroachment by shrubs. The spatial distribution of flocks in summer pasturelands should be adapted to the phenologies of the species that are found there and their conservation needs (Fig. 2).

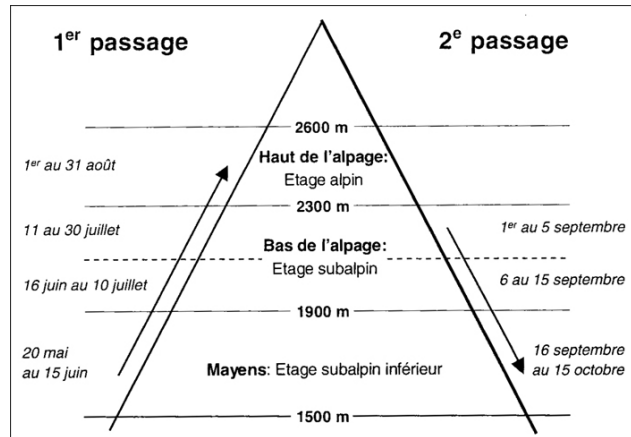


Fig. 2. Periods of ideal grazing in the different areas of a typical pastureland in the Alps that have E, S, or W exposures, and in an average year (after Chatelain and Troxler 2005)

Some changes in grassland management and conservation measures have led to changes in the abundance of animal species, which might have repercussions in alpine calcareous grasslands. For example, wolf populations have expanded in the Western Alps (Breitenmoser 1998) and, consequently, the sheep that once grazed freely and created a more homogenous distribution of the fertilization now leave their excrement in the night paddocks, which has led to changes in the composition of the vegetation and the development of nitrophilous communities (Cugno 2002). When it is necessary to create new night paddocks, special attention should be paid to the location and duration of their use.

Measures that can ameliorate the problems indicated above, include promoting the use of more shepherds and the construction of electric fences for rotational grazing. Troxler and Chatelain (2005) estimated the cost of electric fences in two pasturelands in the Alps to be €174/100 m or €9/sheep. In 2003, Switzerland established subsidies to help to improve the use of summer pasturelands (OFAG 2002), including €200/LU for grazing with a shepherd present or €147/LU for rotational grazing managed with electric fences (LU = 600 kg live weight).

The orography of some of the summer pasturelands prevents the use of fences. In addition, fences can interfere with the movements of large wild mammals. Thus, it appears that guarded grazing is a better option. Shepherding in the mountains of Europe is normally the result of a cultural tradition that has been transmitted orally between generations, and it is a tradition that is disappearing (Pallaruelo 1988). The poor availability and high cost of skilled shepherds is reported as a widespread problem for the maintenance of extensive grazing systems in many regions of southern and eastern Europe (EFNCP, pers. comm.). Policies to support the training and employment of shepherds, combining traditional knowledge and modern techniques, could make an important contribution to the conservation of grazed habitats such as 6170.

Grazing management plans

The issues addressed in the subparagraphs above should lead to the development of Grazing Management Plans that are adapted to the characteristics of individual or groups of pastoral units. Those plans should include the following:

1. A thorough description of the fauna, flora, ecology, and the past and present uses of the area.
2. Objectives of the plan and selection of "key features" (species or communities that are of special interest to conservation).
3. Identification of the obligations and policies to which the key features are subject.
4. Impacts of grazing that affect the key features.
5. Recommendations and monitoring for grazing management, and for how to achieve or maintain the required grazing regime (for example, what incentives are required to encourage the appropriate patterns).

Stewart and Eno (1998) provide a good practical manual for the development of plans for managing livestock grazing.

Restoring alpine grasslands damaged by ski trails

Numerous studies have demonstrated the pernicious effects of ski trails on alpine vegetation. On the ski trails, the composition of the vegetation is changed and biodiversity is reduced. The compaction of the snow delays snowmelt and the phenology of the plants, which favours the plants of snowbeds (Rixen *et al.* 2003). The soils of the ski trails lose organic C, and micropore volume and size decrease. The microstructure of the soils suffers a significant loss of organic cement and fungal hyphae, which makes the soil unstable (Delgado *et al.* 2007). Artificial snow poses a serious threat to plant species diversity on low-nutrient and dry grasslands (Kammer 2002). The additives that are used in artificial snow, e.g., ammonium nitrate, can strongly increase biomass and plant cover after a single application, but species richness can decline in previously diverse meadows (Rixen *et al.* 2007). The seed bank and seed rain can be both diminished and less diverse on ski trails (Urbanska & Fattorini 1998a, Urbanska *et al.* 1998b). The establishment of ski trails can diminish the diversity and density of alpine birds (Rolando *et al.* 2007).

Reseeding is good for restoring plant cover, but the original floristic composition does not recover for, at least, 25 years (or maybe never) because of the slow rate of colonization of some of the key species and the snowpack (Bayfield 1996). At one site, the soil microbial community remained very unstable during the early stage of the restoration of the 13-year-old ski trail because of the dominance of opportunist microorganisms (Gross *et al.* 2004).

Given the considerable evidence that the construction and maintenance of ski trails lead to the deterioration of alpine habitat, they should not be established in areas where the alpine vegetation has a high conservation value (Wipf *et al.* 2005). The authorities responsible must be conscious of the destruction that these types of activities cause in alpine environments. In any case, they should apply a policy of compensation for net losses (*no-net-loss policy*), so that the accidental or deliberate degradation of each ecosystem is corrected through restoration or the legal protection of another ecologically equivalent area (Cairns 1995).

Other relevant measures

Research and Monitoring

Research and monitoring are some of the key initiatives that could be implemented in this habitat, where human activities are not expected to have a significant impact because of its inaccessibility. Although we know much about alpine species and habitats (Körner 1998), we need more information about the adaptations to life in the high mountains and the overall response of these ecosystems to the threats posed by global change.

A monitoring network in calcareous alpine and subalpine grasslands should include the following:

- Syntaxonomic clarification of the communities of habitat 6170 (types and subtypes) and their characteristic species.
- Definition of the monitoring objectives and the concept of “favourable condition.”
- Selection of monitoring sites that are representative of the habitat.
- Mapping of types and subtypes using the highest resolution possible.
- Development of a GIS that incorporates the layers of other information relevant to the conservation of the habitat.
- Definitions of the variables, factors and indices to be monitored, which should include the following:
 - Floristic composition, abundance, and diversity of plant species.
 - Area coverage, plant cover, and vertical structure.
 - Presence of disturbances and their intensity.
 - Effects of grazing on the reproduction of species and the structure of the community.Possible use of exclosures.

- Monitoring of the diversity and abundance of animal species associated with the habitat.

The structural and functional variables should be measured annually. The changes in area and plant cover of the community can be surveyed at five-year intervals.

Special requirements driven by relevant species

Some of the types of grasslands that are included in habitat 6170 (e.g., snowbeds, alpine cushion plants, garland grasslands) are favoured by nesting and feeding ptarmigan (*Lagopus mutus*). Very early arrival of flocks of sheep in the nesting areas in the summer pastures (mid June – mid July) can compromise laying success. The effects can include disturbing the hen, trampling the eggs, and the partial elimination of the feeding resources of the chicks. It is recommended that the flocks of sheep be prevented from grazing on the pasturelands in the highest zones (2,600 m) until August in southern European mountain ranges.

The breeding populations of *Charadrius morinellus* (eurasian dotterel) has declined in UK and Finland during the last decades, while it has remained stable in Sweden and Norway. Thus, the conservation status in Europe is provisionally evaluated as “secure” (BirdLife International 2004). However, details in habitat requirements as well as potential problems and threats are poorly understood, and reasons for decline have been linked to changes on the wintering grounds (Whitfield 2002).

Livestock do not pose significant problems for chamois, ibex and marmots. Competition for the forage usually does not occur unless the densities are very high. Indeed, the wild animal species generally benefit from the presence of livestock. For example, chamois and ibex take advantage of the remains of the salt that the farmers provide to their herds *in situ*. Marmots often place their burrows near pastures that are enriched by cattle excrement. The only danger comes from the dogs of the shepherds, which sometimes kill marmots or young chamois. The risk of the exchange of diseases between domesticated and wild animals is usually low.

Cost estimates and potential sources of EU financing

Funds should be mainly devoted to:

- Implementation of local Grazing Management Plans, including measures to maintain or stimulate appropriate grazing systems. This involves providing economic support, the training of new shepherds, introduction of appropriate technology, etc.
- Prompt actions to restore plant cover and retard soil erosion where possible, e.g. some experiences have been developed in LIFE-Nature projects: LIFE05 NAT/RO/000165 and LIFE00 NAT/IT/007239.
- Monitoring.
- Purchase of private lands that contain target habitat to increase its extent, e.g. LIFE00 NAT/IT/007239.

Given the large area covered by and the structural complexity of habitat 6170, each country or local authority should devote the necessary funds based on their conservation priorities in combination with the mechanisms provided by the EU (Miller and Kettunen 2007).

EU funds for Natura 2000 in the period 2007-2013 should come from different existing Community financial instruments aiming to enhance rural, regional, and marine development in the EU. The integrated use of these resources will allow the financing of various management actions for areas with habitats listed in the Habitats Directive and included in the Natura 2000 network.

Each Member State has identified the issues that are of most concern locally and has prioritized EU funds in order to address these issues. National and regional programs, which have been prepared by Member States on the basis of the EU Regulations, determine the concrete funding possibilities for Natura 2000. The funds to be taken into consideration are:

- The Structural Funds: (European Social Fund (ESF) and European Regional Development Fund (ERDF);
- The Cohesion Fund (CF);
- The European Agricultural Fund for Rural Development (EAFRD);
- The Financial Instrument for the Environment (LIFE+);
- The 7th Research Framework Program (FP7).

Among the diversity of sources for EU funding, the following funds might primarily be of interest for the management of the alpine and subalpine calcareous grasslands.

- The European Fund for Rural Development (EARDF): This program has a potential to cover several management activities that might be relevant, although the measures have to be covered in the National Strategy and related Rural Development plans (RDs) in order to be eligible on a national basis. Furthermore Leader+ projects have to be studied on a national basis.
- The European Regional Development Fund (ERDF), The Cohesion Fund and Interreg: These funds might be relevant in single cases although activities related to Natura 2000 sites mostly need to be integrated in a broader development context. However, the Interreg approach is more flexible but requires a European objective and partnership. Different geographical levels were defined and all of them have their specific rules, eligibility criteria and objectives.
- The Financial Instrument for the Environment (LIFE+): The 'Nature' component of LIFE+ supports best practice and demonstration projects contributing to the implementation of the Birds and Habitats Directives but only exceptionally outside Natura 2000 sites. The 'Biodiversity' component is for demonstration and innovation projects contributing to the objectives of the Commission Communication 'Halting the loss of biodiversity by 2010 – and beyond'. Both the 'Nature' and 'Biodiversity' components emphasise on concrete non-recurring management actions (at least 25 % of the budget). Recurring management is not eligible under LIFE+.

Concerning potential sources of EU financing, the European Commission has published a Guidance Handbook that presents the EU funding options for Natura 2000 sites in the period 2007-2013, which are, in principle, available at the national and regional level (Torkler 2007). Furthermore an IT-tool is available on the EC web site (http://ec.europa.eu/environment/nature/natura2000/financing/index_en.htm).

Acknowledgements

This model was prepared by Dr. Ricardo García-González, and Drs. Federico Fillat and Daniel Gómez provided comments and suggestions, all members of the Instituto Pirenaico de Ecología, CSIC (Spanish National Research Council). Additional comments were supplied by Mats Eriksson (MK-Konsult, Sweden) and Dobromil Galvánek (Daphne, Slovakia).

Guy Beaufoy and Gwyn Jones (European Forum on Nature Conservation and Pastoralism) revised the final draft.

3. References

Case studies and practical examples

Bernes, C. 1996. Arktisk miljö i Norden – orörd, exploaterad, förorenad? Naturvårdsverket, Stockholm., 240 pp.

Cairns J. 1995. Rehabilitating damaged ecosystems. Lewis Publishers, Boca Ratón.

Canals R. 1992. Dinàmica de l'herba y qualitat de les pastures subalpines del Plà de Rus (Pirineu Oriental). Projecte Final de Carrera. Esc. Tèc. Sup. d'Enginyeria Agrària. Universitat de Lleida.

CBM – Centrum för biologisk mångfald & Länsstyrelsen i Norrbottens län 2006. Renbete och biologisk mångfald i fjällen. *Länsstyrelsen i Norrbottens län Report Series No. 16/2006*.

Chatelain C. & Troxler J. 2005. Gardiennage permanent des moutons à haute altitude. Analyse de cinq alpages et recommandation de gestion. *Revue suisse Agric* 37: 151-160.

Chocarro C., Fanlo R., Fillat F. & Marin P. 1990. Historical evolution of natural resource use in the Central Pyrenees of Spain. *Mountain Research and Development* 10: 257-265.

Dorée A. & Jouglet J.P. 1979. Estimation de la capacité de chargement des alpages. Cas des pelouses supraforestières du brianconnais. In: Molénat G. & Jarrige R. (eds.) Utilisation par les Ruminants des Pâturages D'Altitude et Parcours Méditerranéens. INRA, Versailles. 163-176.

García-González R., Hidalgo R. & Montserrat C. 1990. Patterns of time and space use by livestock in the Pyrenean summer ranges: a case study in the Aragon valley. *Mountain Research and Development* 10: 241-255.

García-González R., Marinas A., Gómez-García D., Aldezabal A. & Remón J.L. 2002. Revisión bibliográfica de la producción primaria neta aérea de las principales comunidades pascícolas pirenaicas. In: Chocarro C. et al. (eds.) Producción de pastos, forrajes y céspedes. Ed. Universitat de Lleida, Lleida. 245-250.

García-González R., Aldezabal A., Garin I. & Marinas A. 2005. Valor nutritivo de las principales comunidades de pastos de los Puertos de Góriz (Pirineo Central). *Pastos* 35: 77-103.

García-González R., Reiné R., Pérez S., Gartzia M. & Gómez D. 2007a. Comportamiento de ovinos en pastoreo libre y guiado por pastor en un puerto pirenaico. In: Neiker (eds.) Los sistemas forrajeros: entre la producción y el paisaje. Neiker-SEEP, Vitoria-Gasteiz. 389-396.

García-González R., Alados C.L., Bueno G., Fillat F., Gartzia M., Gómez D., Komac B., Marinas A. & Saint-Jean N. 2007b. Valoración ecológica y productiva de los pastos supraforestales en el Parque Nacional de Ordesa y M.P. In: Ramírez L & Asensio R. (eds.). Investigación en los Parque Nacionales. OAPN Ministerio de Medio Ambiente, Madrid. 105-128.

Herrero J., García-González R. & García-Serrano A. 1994. Altitudinal distribution of Alpine marmot (*Marmota marmota*) in the Pyrenees. *Arctic and Alpine Research* 26: 328-331.

Legg C.J. 2000. Review of published work in relation to monitoring of trampling impacts and change in montane vegetation. Scottish Natural Heritage no. 131. Scottish Natural Heritage. Battleby.

Lomnicki A. 1971. The management of plant and animal communities in the Tatra Mountains National Park. In: Duffey E.W., A. S. (eds.) The scientific management of animals and plant communities for conservation. Blackwell, Oxford. 599-604.

Marinas A., García-González R. & Gómez-García D. 2002. Valoración forrajera de los pastos de *Festuca gautieri* (Hackel) K. Richt en el Pirineo aragonés. In: Chocarro C. et al. (eds.) Producción de pastos, forrajes y céspedes. Ed. Universitat de Lleida, Lleida. 251-256.

Olofsson, J. & Oksanen, L. 2003. Effects of reindeer density on vascular plant diversity on North Scandinavian mountains. *Rangifer* 25(1): 5-18.

Olsson E.G.A., Austrheim G. & Grenne S.v.N. 2000. Landscape change patterns in mountains, land use and environmental diversity, Mid-Norway 1960-1993. *Landscape Ecology* 15: 155-170.

Pepin D., Lamerenx F., Chadelaud H. & Recarte J.M. 1996. Human-related disturbance risk and distance to cover affect use of montane pastures by Pyrenean chamois. *Applied Animal Behaviour Science* 46: 217-228.

Schino G., Borfecchia F., De Cecco L., Dibari C., Iannetta M., Martini S. & Pedrotti F. 2003. Satellite estimate of grass biomass in a mountainous range in central Italy. *Agroforestry Systems* 59: 157-162.

Troxler J. & Chatelain C. 2005. Gestion durable des alpages à moutons dans les Alpes Suisses grâce au pâturage tournant. *Options Méditerranéennes, Series A* 67: 39-43.

Urbanska K.M. & Fattorini M. 1998a. Seed bank studies in the Swiss Alps. I. Un-restored ski run and the adjacent intact grassland at high elevation. *Botanica Helvetica* 108: 93-104.

Urbanska K.M., Erdt S. & Fattorini M. 1998b. Seed Rain in Natural Grassland and Adjacent Ski Run in the Swiss Alps: A Preliminary Report. *Restoration Ecology* 6: 159-165.

European and national guidelines

Backshall J., Manley J.T. & Rebane M. 2001. The upland management handbook. English Nature.

BirdLife International 2004. Birds in Europe: population estimates, trends and conservation status. BirdLife International, Cambridge (BirdLife Conservation Series No. 12).

Bensettiti F., Boulet V., Chavaudret-Laborie C. & Deniaud J. (eds.), 2005: Cahiers d'habitats Natura 2000. Connaissance et gestion des habitats et des espèces d'intérêt communautaire. Tome 4 - Habitats agropastoraux. MEDD/MAAPAR/MNHN. Éd. La Documentation française, Paris, 2 vols. + CD.
<http://natura2000.environnement.gouv.fr/habitats/cahiers.html> (7/11/2007).

DPN. Manuale per Gestione dei Siti Natura 2000. *Ministero dell'Ambiente e della Tutela del Territorio*.
<http://www2.minambiente.it/scn/records/sections/download/files/manuale.pdf>. (15/12/2007).

EC 2007. Interpretation Manual of European Union Habitats - EUR27.
http://biodiversity.eionet.europa.eu/activities/Natura_2000/documentation. (15/12/2007).

JNCC. Common Standards Monitoring Guidance for Upland Habitats, Version October 2006.
<http://www.jncc.gov.uk/default.aspx?page=2237>. (15/12/2007).

JNCC. Joint Nature Conservation Committee. 2007. SAC Interest Features. Alpine and subalpine calcareous grasslands. *Joint Nature Conservation Committee*
<http://www.jncc.gov.uk/ProtectedSites/SACselection/habitat.asp?FeatureIntCode=H6170>. (15/12/2007).

Metallie J.P. 1981. Le feu pastoral dans les Pyrénées Centrales (Barousse, Oueil, Larboust). Editions du C.N.R.S., Paris.

Miller C. & Kettunen M. Financing Natura 2000 Guidance Handbook Revised version, June 07.
http://circa.europa.eu/Public/irc/env/financing_natura/library?l=/contract_management/handbook_upd_ate&vm=detailed&sb=Title. (15/12/2007).

MMAMRM (in preparation). Bases ecológicas para la conservación de los tipos de hábitat de interés comunitario en España. Ministerio de Medio Ambiente y Medio Rural y Marino.

OFAG. 2002. Ordonnance sur la gestion des exploitations d'estivage (RS 910.133.2), État du 24 avril 2002. Office Fédéral de l'Agriculture. Berne.

Paulsch A., Dziedziuch C. & Plän T. 2003. Applying the Ecosystem Approach in High-Mountain Ecosystems in Germany: Experiences with the Alpine Convention. BfN - Skripten 76. Federal Agency for Nature Conservation.

Stewart F.E. & Eno S.G. 1998. Grazing Management Planning for Upland Natura 2000 Sites: A Practical Manual. The National Trust for Scotland, Aberdeen.

Torkler P. (ed.) 2007. Financing Natura 2000 Guidance Handbook. Available at: http://ec.europa.eu/environment/nature/natura2000/financing/index_en.htm.

Articles and other documents

Al Haj Khaled R., Duru M., Decruyenaere V., Jouany C. & Cruz P. 2006. Using leaf traits to rank native grasses according to their nutritive value. *Rangeland Ecology & Manage.* 59: 648-654.

Bahn P.G. 1983. Pyrenean Prehistory: A Paleoeconomic Survey of the French Sites. Aris & Phillips Ltd, Warminster.

Bayfield N.G. 1996. Long-term changes in colonization of bulldozed ski pistes at Cairn Gorm, Scotland. *The Journal of Applied Ecology* 33: 1359-1365.

Biondini M.E., Patton B.D. & Nyren P.E. 1998. Grazing intensity and ecosystem processes in a Northern mixed-grass prairie, USA. *Ecological Applications* 8: 469-479.

Bliss L.C. 1986. Arctic ecosystems: their structure, function and herbivore carrying capacity. In: Gudmundsson O. (eds.) *Grazing Research at Northern Latitudes*. Plenum Press, NATO Series, New York & London. 5-26.

Brandmayr P., Pizzolotto R. & Scalercio S. 2003. Overview: invertebrate diversity in Europe's Alpine regions. In: Nagy L., Grabherr G., Körner C. & Thompson D.B.A. (eds.) *Alpine Biodiversity in Europe*. Springer, Berlin. 233-237.

Breitenmoser U. 1998. Large predators in the Alps: The fall and rise of man's competitors. *Biological Conservation* 83: 279-289.

Coldea G. 2003. The alpine flora and vegetation of the South-Eastern Carpathians. In: Nagy L., Grabherr G., Körner C. & Thompson D.B.A. (eds.) *Alpine Biodiversity in Europe*. Springer, Berlin. 65-72.

Coldea G. & Cristea V. 1998. Floristic and community diversity of sub-alpine and alpine grasslands and grazed dwarf-shrub heaths in the Romanian Carpathians. *Pirineos* 151-152: 73-82.

Cruise G.M. 1991. Environmental change and human impact in the upper mountain zone of the Ligurian Apennines: the last 5000 years. *Rivista di Studi Liguri* 57: 175-194.

Cugno D. 2002. Modifications des pratiques pastorales et mesures de protection contre les prédateurs des canidés sur les alpages à ovins. *Fourrages* 170: 105-122.

Curtin C.G. 1995. Can montane landscapes recover from human disturbance? Long-term evidence from disturbed subalpine communities. *Biological Conservation* 74: 49-55.

Daget P. & Poissonet J. 1971. Une méthode d'analyse phytologique des prairies. Critères d'application. *Annales Agronomiques* 22: 5-41.

Delgado R., Sánchez-Marañón M. & Martín-García J.M. 2007. Impact of ski pistes on soil properties: A case study from a mountainous area in the Mediterranean region. *Soil Use and Management* 23: 269-277.

Diemer M. 1996. The incidence of herbivory in high-elevation populations of *Ranunculus glacialis*: a re-evaluation of stress-tolerance in alpine environments. *Oikos* 75: 486-492.

- Dirnböck T., Dullinger S. & Grabherr G. 2003. A regional impact assessment of climate and land-use change on alpine vegetation. *Journal of Biogeography* 30: 401-417.
- Du Toit P.C.V. 2000. Estimating grazing index values for plants from arid regions. *Journal of Range Management* 53: 529-536.
- Dullinger S., Dirnböck T. & Grabherr G. 2003. Patterns of Shrub Invasion into High Mountain Grasslands of the Northern Calcareous Alps, Austria. *Arctic, Antarctic, and Alpine Research* 35: 434-441.
- Ellenberg H. 1988. *Vegetation Ecology of Central Europe*. Cambridge Univ. Press., Cambridge.
- Erschbamer B., Virtanen R. & Nagy L. 2003. The impacts of vertebrate grazers on vegetation in European High Mountains. In: Nagy L., Grabherr G., Körner C. & Thompson D.B.A. (eds.) *Alpine Biodiversity in Europe*. Springer, Berlin. 377-396.
- Farnsworth K.D., Focardi S. & Beecham J.A. 2002. Grassland-Herbivore interactions: how do grazers coexist? *The American Naturalist* 159: 24-29.
- García-González R. & Marinas A. 2008. Bases ecológicas para la ordenación de superficies pastorales. In: Fillat F., García-González R., Gómez D. & Reiné R. (eds.) *Pastos del Pirineo*. CSIC - Diputación Provincial de Huesca, Madrid. 229-253.
- Goetz S.J. 1997. Multi-sensor analysis of NDVI, surface temperature and biophysical variables at a mixed grassland site. *International Journal of Remote Sensing* 18: 71-94.
- Gómez-García D., García-González R., Marinas A. & Aldezabal A. 2002. An eco-pastoral index for evaluating Pyrenean mountain grasslands. In: Durand J.-L. *et al.* (eds.) *Multi-function Grasslands*. Grassland Science in Europe. vol 7. EGF, La Rochelle (Francia). 922-923.
- Grabherr G., Gottfried M. & Pauli H. 1994. Climate effect on mountain plants. *Nature* 369: 448.
- Grabherr G., Nagy L. & Thompson D.B.A. 2003. An outline of Europe's Alpine areas. In: Nagy L., Grabherr G., Körner C. & Thompson D.B.A. (eds.) *Alpine Biodiversity in Europe*. Springer, Berlin. 3-12.
- Gross R., Jocteur Monrozier L., Bartoli F., Chotte J.L. & Faivre P. 2004. Relationships between soil physico-chemical properties and microbial activity along a restoration chronosequence of alpine grasslands following ski run construction. *Applied Soil Ecology* 27: 7-22.
- Holechek J.L. & Pieper R.D. 1992. Estimation of stocking rate on New Mexico rangelands. *J. Soil and Water Cons.* 47: 116-119.
- Hope D., Picozzi N., Catt D.C. & Moss R. 1996. Effects of reducing sheep grazing in the Scottish Highlands. *Journal of Range Management* 49: 301-310.
- INRA. 1988. *Alimentation des bovins, ovins & caprins*. Institut Nationale de la Recherche Agronomique, France.
- Kammer P.M. 2002. Floristic changes in subalpine grasslands after 22 years of artificial snowing. *Journal for Nature Conservation* 10: 109-123.
- Körner C. 1999. *Alpine Plant Life. Functional Plant Ecology of High Mountain Ecosystems*. Springer-Verlag, Berlin.
- Körner C., Paulsen J. & Pelaez-Riedl S. 2003. A bioclimatic characterisation of Europe's alpine areas. In: Nagy L., Grabherr G., Körner C. & Thompson D.B.A. (eds.) *Alpine Biodiversity in Europe*. Springer, Berlin. 13-28.
- Labroué L. & Tosca C. 1977. Dynamique de la matière organique dans les sols alpins. *Bull. Ecol.* 8: 289-298.

- Lee, W.G., Fenner, M., Loughnan, A. & Lloyd, K.M. 2000. Long-term effects of defoliation: incomplete recovery of a New Zealand alpine tussock grass, *Chionochloa pallens*, after 20 years. *Journal of Applied Ecology* 37: 348-355.
- Lesica P. & McCune B. 2004. Decline of arctic-alpine plants at the southern margin of their range following a decade of climatic warming. *Journal of Vegetation Science* 15: 679-690.
- Loison A., Toïgo C. & Gaillard J.M. 2003. Large herbivores in European alpine ecosystems: current status and challenges for the future. In: Nagy L., Grabherr G., Körner C. & Thompson D.B.A. (eds.) *Alpine Biodiversity in Europe*. Springer, Berlin. 351-366.
- McLeod S.R. 1997. Is the concept of carrying capacity useful in variable environments? *Oikos* 79: 529-542.
- McNaughton S.J. 1985. Ecology of a grazing ecosystem: the Serengeti. *Ecological monographs* 55: 259-294.
- Milchunas D.G. & Lauenroth W.K. 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecological Monographs* 63: 327-366.
- Miller G.R., Geddes C. & Mardon D.K. 1999. Response of the alpine gentian *Gentiana nivalis* L. to protection from grazing by sheep. *Biological Conservation* 87: 311-318.
- Mysterud A. 2006. The concept of overgrazing and its role in management of large herbivores. *Wildlife Biology* 12: 129-141.
- NRC. 1996. *Nutrient Requirements of Beef Cattle*. National Academy Press, Washington, D.C.
- Ozenda P. 1983. *The vegetation of the Alps*. Council of Europe, Nature and Environment, Strasbourg.
- Ozenda P. & Borel J.L. 2003. The alpine vegetation of the Alps. In: Nagy L., Grabherr G., Körner C. & Thompson D.B.A. (eds.) *Alpine Biodiversity in Europe*. Springer, Berlin. 53-64.
- Pallaruelo S. 1988. *Pastores del Pirineo*. Ministerio de Cultura, Madrid.
- Pawlowsky B. 1970. Remarques sur l'endémisme dans la flore des Alpes et des Carpates. *Vegetatio* 21: 181-243.
- Pringle H.J.R. & Landsberg J. 2004. Predicting the distribution of livestock grazing pressure in rangelands. *Austral Ecology* 29: 31-39.
- Rixen C., Huovinen C., Huovinen K., Stockli V. & Schmid B. 2007. A plant diversityxwater chemistry experiment in subalpine grassland. *Perspectives in Plant Ecology, Evolution and Systematics* In Press, Corrected Proof.
- Rixen C., Stoeckli V. & Ammann W. 2003. Does artificial snow production affect soil and vegetation of ski pistes? A review. *Perspectives in Plant Ecology, Evolution and Systematics* 5: 219-230.
- Robbins C.T. 1993. *Wildlife feeding and nutrition*. Academic Press. 2nd ed., New York & London.
- Rolando A., Caprio E., Rinaldi E. & Ellena I. 2007. The impact of high-altitude ski-runs on alpine grassland bird communities. *Journal of Applied Ecology* 44: 210-219.
- Singh J.S., Lauenroth W.K. & Steinhorst R.K. 1975. Review and assessment of various techniques for estimating net aerial primary production in grasslands from harvest data. *The Botanical Review* 41: 181-231.
- Suominen, O. & Olofsson, J. 2000. Impacts of semi-domestic reindeer on the structure of tundra and forest communities in Fennoscandia: a review. *Ann. Zool. Fennici* 37: 233-249.
- Theurillat J.-P. & Guisan A. 2001. Potential Impact of Climate Change on Vegetation in the European Alps: A Review. *Climatic Change* 50: 77-109.

Väre H., Lampinen R., Humphries C. & Williams P. 2003. Taxonomic diversity of vascular plants in the European alpine areas. In: Nagy L., Grabherr G., Körner C. & Thompson D.B.A. (eds.) *Alpine Biodiversity in Europe*. Springer, Berlin. 133-148.

Varga Z.S. & Varga-Sipos J.I. 2001. Vertical distribution of the alpine lepidoptera in the Carpathians and in the Balkan peninsula in relation to the zonation of the vegetation. *Pirineos* 156: 69-85.

Vigo J. & Ninot J.M. 1987. Los Pirineos. In: Peinado-Lorca M. & Rivas-Martinez S. (eds.) *La vegetación de España*. Alcalá de Henares Univ, Madrid. 351-384.

Virtanen R., Dirnböck T., Dullinger S., Grabherr G., Pauli H., Staudinger M. & Villar L. 2003. Patterns in the plant species richness of European high mountain vegetation. In: Nagy L., Grabherr G., Körner C. & Thompson D.B.A. (eds.) *Alpine Biodiversity in Europe*. Springer, Berlin. 149-172.

Wick L. & Tinner W. 1997. Vegetation changes and timberline fluctuations in the Central Alps as indicators of Holocene climatic oscillations. *Arctic and Alpine Research* 29: 445-458.

Wipf S., Rixen C., Fischer M., Schmid B. & Stoeckli V. 2005. Effects of ski piste preparation on alpine vegetation. *Journal of Applied Ecology* 42: 306-316.

Whitfield, D. P. 2002. Status of breeding Dotterel *Charadrius morinellus* in Britain 1999. *Bird Study* 49: 237-249.

Projects

LIFE 03 NAT/RO/000032 "Natura 2000 sites in Piatra Craiului National Park".

http://www.pcrai.ro/engleza/proiect02_05.html

LIFE00 NAT/IT/007239 "Conservation of Tuscan Appennines mountain grasslands"

<http://www.rete.toscana.it/sett/agric/foreste/life/life-home.html>

LIFE05 NAT/RO/000165 "Conservative management of alpine habitats as a Natura 2000 site in Retezat National Park" <http://www.retezat.ro/>

