LAND USE CHANGE AND BIODIVERSITY CONSERVATION IN THE ALPS

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Abstract - Human activities are changing the Planet, inducing high rates of extinction and a worldwide depletion of biological diversity at genetic, species, and ecosystem level. Biodiversity not only has an ethical and cultural value, but also plays a role in ecosystem function and, thus, ecosystem services, which are essential to civilization, economic production, and human wellbeing. The functional role of biodiversity is still poorly known; a minimum level of biodiversity is required for sustainable preservation of ecosystem functions, and as an insurance for future environmental changes. A large part of the biodiversity of the Alps is linked to an interaction between the natural environment and traditional human practices. At present, the change in land-use, with both intensification and abandonment, and other environmental and socioeconomic processes at different scales (urbanization, tourism, pollution, global change, etc.) are important forces of environmental change. Mowing and livestock grazing are primary factors inhibiting woody plant succession in many areas of the Alps. Abandonment and fragmentation has resulted in an expansion of ecotones and edge, with increase in tick-hosts and possibly changes in host-parasite interactions resulting from species concentration. The abandonment of mountain fields and meadows with a consequent expansion of shrubs and forests has caused a decrease of several grassland species, such as rock partridge *Alectoris graeca*; some arthropod communities of grassland have also been affected. Many forest species should find new opportunities, but in several cases the forests have become too dense for some species, such as for capercaille *Tetrao urogallus*. In the low altitude belts, a high species diversity co-occurs with human disturbance. Biodiversity studies require an interdisciplinary approach by the life sciences, and an interface to socioeconomic sciences. Preservation of species and landscape diversity cannot prescind from a dialogue between different actors and interests.

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1. Introduction

The Convention on Biological Diversity (CBD), output of the UNCED (Rio) summit of June 1992, signalled global recognition of the alarming loss of biodiversity, as well as the awareness of its values. The Convention came into force in December 1993, and was signed by the European Union (EU) and its member states. CBD affirms that conservation of biodiversity is a common concern of humankind, and gives the following definition: "Biological diversity (or biodiversity) means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the complexes of which they are part; this includes diversity within species, between species and of ecosystems".

On the follow up to the CBD, and in order to implement its principles and international engagements, the EU created a series of initiatives and agreements aimed at reversing the depletion of diversity in Europe, setting up several legal instruments (e.g., the Habitats Directive) and undertaking some actions. Particular relevance for research are the recent "EU Strategy on Biodiversity" (approved on 4 February 1998) and "Understanding Biodiversity", the Agenda for research into biodiversity prepared by the European Working Group on Research and Biodiversity (Catizzone *et al.*, 1998). The Agenda stressed the fact that most concern for biodiversity results from the evidence of a huge increase in the risk of plant and animal extinction occurred over the last two centuries, with an acceleration in the last few decades. Extinctions are a natural phenomenon, but they now occur at an overwhelming rate due to human activity: recent and ongoing rates of species loss exceed background levels by two to three orders of magnitude (Balmford, 1996). In addition, domesticated species have suffered a depletion of genetic diversity, with extinction of many breeds.

Biodiversity results from the combined interactions and relationships between natural circumstances and human influence. Historically, the single most important factor generating reduction in biodiversity is human land use, and thus change in land use practices (Catizzone *et al.*, 1998). During the last few decades, man has emerged as an impressive new force of nature, not only mechanically transforming the land, and adding and removing species, but also altering the major biogeochemical cycles (Lubchenco, 1998). The types, rates and the spatial scales of the changes are increasing, resulting in an alteration of the functioning of the Earth systems and irreversible losses of biological diversity. These changes in pattern and processes are rarely under human control.

2. Why defend biodiversity

Biodiversity is not only an ethical and aesthetic inheritance for future generations. It provides a genetic bank that is essential to medical, agricultural and other scientific progress; most importantly, it plays a basic role in the ecosystem functions. Ecosystem functions provide, directly or indirectly, the ecosystem services to the human population, such as climate and water regulation, waste treatment, nutrient cycling, food production, genetic resources, and recreation. Ecosystem services are critical to the functioning of the Planet's life-support systems, provide a basic contribution to human welfare, and are part of the total economic value of the planet (Costanza *et al.*, 1997).

Various methods have been used to estimate the value of ecosystem services; moreover, biodiversity can be assigned an economic value. This exercise is obviously difficult, both theoretically and in practice, but it has the advantage of making the role of biodiversity more understandable to policy makers, and more visible to the public at large (Bengtsson *et al.*, 1997; Catizzone *et al.*, 1998).

In fact, it is becoming increasingly obvious that also the economic systems are intrinsically interlinked with the environment and its diversity. The assumption that society must choose between jobs and environment is false: the real choice is between short-term gain and long-term sustained prosperity and development (Lubchenco, 1998).

3. Biodiversity in action

How does biodiversity work, and how is it related to ecosystem function? We can reasonably argue the existence of a relationship between the composition and structure of natural communities and ecosystem function, although we know surprisingly little about it (Huenneke, 1994; Bengtsson *et al.*, 1997).

An unresolved issue is how the diversity of organisms influences ecosystem processes. Species may differ within and between communities in properties that affect ecosystem and global processes such as productivity, nutrient cycling and fluxes of carbon, water, energy and trace gases between the ecosystem and the atmosphere. The early axiom that more diverse ecological communities are the most stable (MacArthur, 1955) has been challenged by some recent field studies and theoretical approaches. Several hypotheses about the relationship between biodiversity and ecosystem function have been proposed, and we now know that an increase in species richness with the productivity is not universal (Johnson *et al.*, 1996; Bengtsson *et al.*, 1997). In any case, there is a growing appreciation that species diversity can influence the stability and productivity of ecosystems. A synthetic theory of species diversity that predicts relationships between diversity and productivity, taking into consideration the spatial scaling of resource use by species of different body size was recently proposed by Ritchie & Olff (1999). Most theoretical and empirical evidence supports the idea that species number, and especially the nature of species interactions, influence the behavior and function of ecological systems (Johnson *et al.*, 1996).

Biodiversity plays a role in the two main components of the stability: ecosystem resistance, *i.e.* the ability to maintain an ecosystem function, and ecosystem resilience, *i.e.* the ability to recover to normal function levels after disturbance. Ecosystems host many species, but a large part of the work is performed by a few keystone species. Apparently, many species are of minor or no importance to ecosystem processes. To evaluate their role, we must consider changing environments, and not average conditions; diversity can provide insurance for the future, and rare species can also play an important role in ecosystem resistance and resilience under unusual conditions (Schulze and Mooney, 1993; Bengtsson *et al.*, 1997). Schulze & Mooney (1993) compared an ecosystem to a car: some parts are needed for the continuous function, such as the fuel line, others only for emergency (*e.g.* the bumpers), others are used occasionally but are of basic importance, as the brakes.

Four main hypotheses on the relationships between biodiversity and functioning are summarized by Johnson *et al.* (1996): *i.* every species in the system increases the productivity and stability of ecological communities, and so that the deletion of any one species will decrease the ecosystem process rate; *ii.* a number of redundant species can be removed without consequences, as with the rivets of an airplane: beyond a certain threshold number, the airplane (ecosystem) crashes; *iii.* the species are grouped in functional groups, and within each group the species going extinct are substituted by other species of the same functional group; *iv*. there is no determinate relationship between species composition and ecosystem function.

The simplest definition of biodiversity is the number of species living in an area. The set up of local faunas results from a series of processes that were summarized by Schluter & Ricklefs (1993). The classic diversity theory refers to local interactions of species within reduced areas, including predation and competition. But these local processes are interlinked with regional processes. In fact, there is a movement of individuals between the patches of the same fragmented habitat, and a dispersal of individual between habitats, which reflects the variety of habitats within a larger region; in this way, the communities may reach an equilibrium at a larger scale. In addition, the historical and biogeographical perspectives play a crucial role. For example, the long evolutionary history of taxa that requires defined ecological conditions to colonize a habitat; allopatric speciation within a region; large exchanges of taxa between regions; unique events that cause massive extinctions and replacements of communities.

The key role of parasites and diseases in structuring the diversity of ecological communities and in ecosystem function has been recently highlighted (see Dobson, 1999), and the importance of parasites and diseases in population dynamics is increasingly acknowledged worldwide (McCallum & Dobson, 1995). Epidemics could have a dramatic effect on small and fragmented populations causing their extinction, while endemic parasites play a basic role in population regulation and to maintain the diversity of natural communities.

4. The Alps, changing environments and biodiversity

The Alps exhibit an impressive variety of habitat and climatic conditions along reduced spatial scales, reflecting a complex physical history, and have a long history of human presence and exploitation. The Alps are a centre of biodiversity for the whole of Europe. They host about 4,500 plant species, more than a third of the flora recorded in Europe west of Urals, and almost 400 plants are endemic of the Alps (Theurillat, 1995). The fauna of the Alps might reach 30,000 species.

Human activity has modified the landscape and biodiversity of the Alps into what they are at present. A large part of the biodiversity of the Alps is therefore linked to artificial or semi-natural environments, and to traditional land-use. In the last few decades, changes in society, tourism, and agricultural production methods have led to substantial changes in land-use systems, including both intensification of exploitation in some areas and abandonment of traditional practices.

These changes have led to the disappearance of many traditionally managed grassland areas throughout the Alpine region (Bätzing, 1990), with a loss of landscape diversity.

Abandonment results especially in the expansion of forests and shrubby ecotones in secondary grasslands but also in an expansion of dwarf shrubs in the pastures above the timberline.

Land-use systems affect the pattern and diversity of vegetation (Cernusca *et al.*, 1992; Tappeiner & Cernusca, 1993) and fauna (Tscharntke & Greiler, 1995). Animal species differ widely in their vulnerability to current threats and disturbance, and in their ability to exploit the new opportunities. Communities are more resilient to threats if they have faced similar challenges in the past. Human activity acts as a major extinction filter, and extinction is lowest in the longest settled, most disturbed areas, because losses already occurred in the distant past (Balmford, 1996).

On the Alps, forces of change result from environmental and social events at different scales. At the local scale, urbanization, development of local tourism, agriculture and grazing, intensification, abandonment, habitat fragmentation, introduction or persecution of species, water use and water pollution are the main forces of change. The processes at a global scale are driven by climate change, air pollution, enrichment in CO_2 and nitrogen deposition, but also by economic, social and cultural processes originating outside the Alps (*e.g.* market forces, fluctuation in tourism, traffic, demographic change). These external forces are especially dangerous, because a local feedback response cannot be activated (Chapin & Körner, 1994).

In the mountains, an important role in determining the local occurrence of species is also played by climate heterogeneity resulting from topographical complexity. The great ecological diversification of the Alps, and the adaptation of most species to a variable climate, should counterbalance the increase of 1-2°C foreseen in the minimum scenario of the Intergovernmental Panel on Climate Change (IPCC).

With a greater increase in temperature (3-5°C, maximum IPCC scenario), that is, a temperature range of a whole vegetation belt, many species may need to move to follow their habitats (Theurillat, 1995). The increase in CO_2 could interfere with the relationships between plants and herbivores, since an increase in the C/N ratio in plant tissues results in a decrease of the nutritional value of plants (Körner, 1995).

Mowing and livestock grazing are primary factors inhibiting woody plant succession in many areas of the Alps, where the vegetation structure may reflect the long presence of domestic stock. The effects of grazing on biodiversity are complex and controversial, because they are linked to intensity, local conditions and plant communities, type and number of stock, and water availability. Typically, these effects are mitigated by favorable growing seasons and magnified in unfavorable years. A trophic and sanitary interaction has been recorded between wild bovids, and sheep and goats grazing at high altitude. The spread of infectious diseases with consequences for the dynamics and abundance of wild species is related to the virulence of the pathogen, host susceptibility and immune response (Gauthier *et al.*, 1991).

The perturbation of host-parasite interactions may produce different effects at the population level (Grenfell & Dobson, 1995), but the long-term effects of livestock, wildlife and disease management on ecosystems are still unknown. The ubiquitous use of anthelmintics, for instance, may affect decomposer activities (Spratt, 1997).

Land use change, including widespread abandonment of traditional activities in the mountains, has allowed the expansion of forests and related shrubby ecotones, resulting in an increase in suitable habitat both for the ticks and their main hosts, as rodents, shrews, and deer. The incidence of human cases of tick-borne diseases (TBE and Lyme borreliosis) recently recorded in the Italian Alps has been correlated with an increase in the frequency of occurrence and local abundances of *Ixodes ricinus*. A remarkable increase in Roe deer *Capreolus capreolus* density and diffusion has been recorded in most of the Alps in recent years; for example, Roe deer had an impressive resurgence in the Province of Trento, with an increase from 5,350 counted in 1965 to 25,210 in 1994 (Merler *et al.*, 1996; Chemini *et al.*, 1997). In the presence of a relatively small number of reservoir hosts, the large vertebrates can play an important role in maintaining tick populations and amplifying infections even when they play no part in pathogens multiplication (see Hudson *et al.*, 1995). In fact, results from samples of Roe deer and questing ticks in several game districts of the province of Trento showed a large overlapping of the habitat preference of *I. ricinus* and Roe deer, and a high prevalence of adult tick infestation on Roe deer (75.7% in the altitudinal belt from 600 to 1100 m); (Merler *et al.*, 1996; Chemini *et al.*, 1997). Therefore we can expect changes in density of roe deer to influence tick abundance and perhaps the incidence of some tick-borne diseases. In the Provinces of Trento and Belluno, where most recent cases of TBE in Italy have been detected (Caruso *et al.*, 1997) we found significantly more ticks on bagged Roe deer, and more ticks on standardized drags in the areas where TBE had been positively identified compared with areas where TBE was probable or absent. In addition, more Roe deer were shot in areas where TBE has been recorded compared with areas where TBE was either suspected or has not been recorded (Hudson *et al.*, 2001).

Land use change may also directly influence host-parasite interactions. The increase in ecotonal areas, and habitat fragmentation and shrinking may result in concentration of both individuals and species into restricted areas, promoting transmission and exchange of parasites. Therefore, the importance of disease could increase in shrinking ecosystems, with the emergence of new diseases and increasing numbers of epidemics. Increased pathogenicity of generalist parasites may pose a threat to species with restricted distributions or small populations (Holmes, 1996).

The abandonment of mountain fields and meadows, and the expansion of shrubs and forests with an accompanying reduction of clearings, as well as the intensification of tourism and human presence have caused a decrease in the distribution and abundance of several grassland species, such as Rock partridge *Alectoris graeca*. The actual consistence of this species in the province of Trento is 20% of the estimated potential number (Meriggi *et al.*, 1998), and a tendency to cyclic fluctuations in abundance have been recorded in the dryer part of the province (Cattadori *et al.*, 1999).

Intensity of infection with the nematode parasites *Ascaridia compar* and *Heterakis tenuicauda* was higher in female rock partridge of cyclic populations and studies are now on course to determine whether such parasites may act as destabilizing factors (Rizzoli *et al.*, 1997; 1999).

Reforestation should provide suitable habitats for forest species, but in several cases these forests have become too dense and uniform for some species. The most charismatic and endangered species, the Capercaille *Tetrao urogallus*, needs a structural diversity in forests (Storch, 1993). In the province of Trento, mathematical modelling of forests has shown the relevance of the spatial structure of the canopy, small scale environmental diversity, and underlayer richness for the forest colonization and lek selection by capercaille (Cescatti, 1996). The Provincial forest rangers confront this situation by establishing land-use intervention priorities that meet the needs of the species (Pedrolli, 1996).

The ecological effects of different land-uses on mountain biodiversity were studied within the EU project ECOMONT (Cernusca *et al.*, 1996). A special topic "Plant-Animal Interactions" was integrated into the project to assess the relationships between functional diversity and the different types of land-use, with particular reference to the consequences of grassland abandonment (Bonavita *et al.*, 1999; Guido *et al.*, 1999). Ground- and plant-dwelling arthropods were sampled on three ECOMONT study sites situated along a transect from the Italian to the Austrian Alps: Mount Bondone, Passiria Valley, and Stubai Valley. At each site, sampling was carried out on plots with different land-use practices: intensively managed hay meadows, extensively managed hay meadows, pastures, abandoned grassland with different successional stages, and forests. The land-use affected the local occurrence of arthropods both directly, through the disturbance of mowing and grazing, and indirectly by modifying microclimate, vegetation structure, and above-ground phytomass. Intensive management of hay meadows, consisting of fertilization and mowing, resulted in a higher diversity of primary consumers (Orthoptera). It is possible that the periodic disturbance of mowing resets the system discouraging the establishment of a strong dominance structure. Abandonment fosters a vegetation succession of the meadows, with an increase in the height of the turf, arrival of shrubs, and finally re-colonization by forest. The increase in tree and shrub canopy, and the occurrence of forest patches affected the assemblages of orthopteran and carabid insects, with a decrease in species diversity. Other species receive short-term benefit from abandonment, but in the long-term the re-colonization by forest causes the almost complete disappearance of the recorded species (Guido *et al.*, *in press*). Therefore, the maintenance of the current extensive management system of meadows has particular importance for the conservation of orthopteran assemblages from the Mount Bondone plateau.

Relationships between land use and diversity patterns of plants, fungi and arthropods were studied in four forest sites on the Provinces of Bolzano and Trento (Italian Alps) within the International Cooperative Programme on Integrated Monitoring ICP/IM (Bonavita *et al.*, 1998). A total of 2,351 species were identified. The species richness was far greater (77% of identified species) in the lower and more stressed belt (stands at 560 and 680 m a.s.l.) subject to a series of disturbances and changes in land use, related to grazing, clear-cutting, reforestation, and tourism. The natural decline in species richness with increasing altitude is a general pattern well known in the Alps (Meyer and Thaler, 1995), and these data confirm that a large part of species diversity co-occur with a heavy human presence and land management.

5. The future: a chance for research

The conservation and the sustainable use of biodiversity - creating the conditions of its continuity for the future generations - is indicated as one of the major challenges for humankind in the next millennium (Catizzone *et al.*, 1998). The functioning of ecosystems, production of food for all human beings, use of genetic resources, economic productions, and human wellbeing, would be dramatically affected by a loss of diversity below a minimum threshold. We know that ecosystem services are essential to civilization, and that very large numbers of plant and animal species and populations are required to sustain ecosystem services (Lubchenco, 1998). At the same time, we know embarrassingly little about the relationship between species diversity and ecosystem function (Huenneke, 1994).

Diversity will be a challenge (and a chance) for research too. Biodiversity needs and fosters a scientific synthesis of ecological, evolutionary, systematic, biogeographical, genetic, and paleontological studies.

Biodiversity provides a common ground for all these disciplines, from which a better understanding of the natural world will develop (Schluter & Ricklefs, 1993). Ecological research should consider and value the existing large body of biodiversity inventory data, provide indices and indicators, look for general diversity patterns, and consider diversity in ecosystem function modelling. In addition, it should disseminate the results to respond also to the need of end users, such as conservationists, educators, farmers and planners (Chemini, 1999). Also the study of infectious diseases in wildlife and domestic livestock cannot prescind from an integrated ecological approach (Dobson, 1999).

Many authors underline the need for a new paradigm for research, based on an interdisciplinary approach and taking into consideration ecological economics and a dialogue between different interests and different actors (scientists, end-users, decision-makers) that often have conflicting interests with regard to biodiversity (Catizzone *et al.*, 1998).

The Alps are a symbolic territory to implement this new research paradigm. Human activity will continue to be the one of the greatest forces of change in the mountains of Europe in the coming decades (Chapin & Körner, 1994; Backmeroff *et al.*, 1997). In the Alps, the long traditional integration of the human dimensions with the physical-chemical-biological dimensions needs to find a new equilibrium. Preservation of biodiversity cannot be pursued only with the protection of single species, or habitats, or foundation of reserves. Biodiversity is interlinked with human land use. The maintenance of cultural landscapes and their biodiversity also depends on keeping humans in the mountains and on appropriate management practices, resulting from an integrated and multiple-use management of the territory. Preservation plans should consider also the "quality" of diversity, with particular attention to rare and endangered species and habitats, and endemism.

Laws and regulations, economic instruments and incentives, education and training, should all enhance the social and economic incentives to preserve biodiversity, identify and reduce conflicts at different scales, and build up a large consensus on the value of biological diversity, taking into account the ecosystem services provided by Alpine areas to the entire national community (Backmeroff *et al.*, 1997), and ensuring the sustainability of present levels of life and landscape heterogeneity.

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