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European habitat management strategies for conservation: Current regulations and practices with reference to dynamic ecosystems and ecosystem service provision

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Habitat management for biodiversity conservation in Europe: The established approach

"Starting from the initial venal public reactions against the destruction of beautiful sites or the disappearance of lovely animals, we have ended with devoted professionals trying to apply solid biological conservation science to crude socio-economic development strategies. The gap between is paved with all sorts of intermediate situations. Science is value free, but conservation as an applied science, is heavily value laden. Therefore, cultural and economic differences between the countries, as well as special administrative styles, have generated a varied scenario. The goals may be the same, but the approaches, manifold." (A. Machado, 1997).

The above quote, although now ten years old, is still a fairly accurate reflection of the state of present day conservation biology in Europe and globally.

Biological conservation has its roots in species protection: Traditionally, emphasis was placed primarily upon protecting particular species that were recognised to be somehow ´rare`, mainly birds and furry animals. Protecting nature was equated with protecting beautiful and aesthetically appealing species, in the knowledge that total extinction is irreversible. There was also some interest in protecting aesthetically appealing landscapes – the beginning of what would become National Parks. Then it was recognised that species were becoming extinct because their habitats are being destroyed. Now, the dilemma as to whether to use limited and usually inadequate human and financial resources to pursue the conservation of particular species or whether to invest in the management and protection of habitats that are of notable biological value remains a critical issue in practical conservation strategy. However, it is clear that in the end, both directions are essential for the protection of biological diversity, although now there is a general consensus that habitat protection and ecologically sound management are prerequisite for species conservation (e.g.

Machado, 1997). It is perhaps most useful to regard species and habitat protection as extremes of a continuous and overlapping spectrum of valid conservation strategies, relevant to most organisms but depending upon particular circumstances (Haslett, 2004).

It is hardly surprising, then, that the form and wording of the various legal and other instruments that provide for the conservation of biodiversity in Europe have all been considerably influenced by the species/habitat dilemma, depending to some extent on the fashion at the time. Since 1992, the global Convention on Biodiversity has led the way in promoting an integrated approach by including "diversity within species, between species and of ecosystems" in its definition of biological diversity (CBD, 2001, Article 2: Use of terms) thus implying a spatial (and indeed a temporal) axis.

An overview of international instruments relevant to European conservation is provided in Tables 1 (encompassing species-relevant objectives) and 2 (encompassing ecosystem, habitat or landscape level objectives). An inventory of most of these international instruments, with descriptions and information on objectives, obligations, mechanisms, contacts, etc is provided by Bennett (2002). More recent instruments are referred to in the relevant places within the present text.

It is interesting to note that the species-habitat dilemma is not confined to conservation legislation; active research effort exhibits a similar divide even though most scientists are well aware of the intimate relation between the two. Thus there is a plethora of research that deals with management strategies in the context of conservation of particular species or taxonomic groups such as birds, mammals, higher plants, and some, usually charismatic insects such as butterflies. Other research, equally voluminous, has dealt with management strategies for particular habitat types, including semi-natural grasslands, forests, wetlands, agricultural ecosystems or aquatic ecosystems. It may be speculated that this divide within academic circles may be mainly a result of the availability/applications for funding for research.

Table 1: International instruments with objectives that encompass the conservation of viable populations of species of Pan-European importance across their traditional ranges. After Bennett (2002). Code numbers in the first column refer to those given in the original publication.

	INSTRUMENT	SPECIES	GEOGRAPHICAL SCOPE
A. International agreements			
A.2	Benelux Agreement concerning Hunting and the Protection of Birds	Non-game bird species	Benelux
A.7	Barcelona Convention	Rare, depleted, threatened or endangered wild flora and fauna species	Mediterranean Sea
A.9	EU Birds Directive	All wild bird species, special measures for 255 species	EU
A.10	Bern Convention	119(?) strictly protected wild plant species, 580(?) strictly protected animal species and (?) protected animal species	Pan-Europe

A.11	Bonn Convention	76 species of endangered migratory animal species and about 150 migratory animal species or groups of species which have an unfavourable conservation status	Global
A.11.1	MOU concerning Conservation Measures for the Slender-Billed Curlew	Slender-billed curlew	Pan-Europe, North Africa and Middle East
A.11.2	MOU concerning Conservation Measures for the Siberian Crane	Siberian Crane	Asia
A.11.3	Agreement on the Conservation of African-Eurasian Migratory Waterbirds	170 migratory waterbird species	Eurasia, Africa, Greenland and Canada
A.11.4	Agreement on the Conservation of Bats in Europe	30 European bat species	Europe
A.11.5	Agreement on the Conservation of Cetaceans of the Black Sea, the Mediterranean Sea and the Contiguous Atlantic Area	18 cetacean species and other cetacean species that frequent the Agreement area	Black Sea, Mediterranean Sea and contiguous Atlantic area
A.11.6	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas	5 cetacean species	Baltic and North Seas
A.11.7	Agreement on the Conservation of Seals in the Wadden Sea	Common/harbour seal	Wadden Sea
A.20	Convention on Biological Diversity	Not specified	Global
A.22	EU Habitats Directive	200 wild animal species and 434 wild plant species	EU
B. International programmes			
B.3	Mediterranean Action Plan	Monk seal, 6 marine turtle species, 2 marine turtle species and 18 cetacean species	Mediterranean basin
B.14	EU LIFE Programme	Support for EU environmental policy	EU
B.22	EU Biodiversity Strategy	Not specified	EU
C. Other initiatives			
C.4	European Coastal and Marine Ecological Network	Coastal and marine species	Europe
C.9	EECONET	Species of European importance	Europe
C.11	Large Carnivore Initiative	Brown bear, wolf, wolverine, Iberian lynx and Eurasian lynx	Europe

Table 2: International instruments with objectives that encompass the conservation, restoration or sustainable use of characteristic ecosystems, habitats or landscapes of European importance across their traditional ranges. After Bennett (2002). Code numbers in the first column refer to those given in the original publication.

	INSTRUMENT	OBJECT	GEOGRAPHICAL SCOPE
A. International agreements			
A.1	European Cultural Convention	European cultural heritage	Pan-Europe
A.3	Ramsar Convention	Wetlands of international importance	Global
A.4	World Heritage Convention	Outstanding natural areas	Global
A.7	Barcelona Convention	Marine and coastal habitats	Mediterranean Sea
A.9	EU Birds Directive	Habitats of all wild bird species, special measures for 255 species	EU
A.10	Bern Convention, including the Emerald Network	Habitats of wild flora and fauna	Pan-Europe
A.11	Bonn Convention	Habitats of 76 migratory animal species and about 150 migratory animal species or groups of species which have an unfavourable conservation status	Global
A.11.1	MOU concerning Conservation Measures for the Slender-Billed Curlew	Habitat of the slender-billed curlew	Pan-Europe, North Africa and Middle East
A.11.2	MOU concerning Conservation Measures for the Siberian Crane	Habitat of the Siberian Crane	Asia
A.11.3	Agreement on the Conservation of African-Eurasian Migratory Waterbirds	Habitats of 170 migratory waterbird species	Eurasia, Africa, Greenland and Canada
A.11.4	Agreement on the Conservation of Bats in Europe	Important sites for 30 European bat species	Europe
A.11.5	Agreement on the Conservation of Cetaceans of the Black Sea, the Mediterranean Sea and the Contiguous Atlantic Area	Important sites for 18 cetacean species and other cetacean species that frequent the Agreement area	Black Sea, Mediterranean Sea and contiguous Atlantic area
A.11.6	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas	Habitats of 2 cetacean species	Baltic and North Seas
A.11.7	Agreement on the Conservation of Seals in the Wadden Sea	Important sites for the common/harbour seal	Wadden Sea
A.12	European Outline Convention on Transfrontier Cooperation between Territorial Communities or Authorities	Transfrontier parks	Pan-Europe
A.13	Benelux Agreement concerning Nature Conservation and Landscape Protection	Valuable natural areas and landscapes, including transboundary areas	Benelux

A.16	Convention concerning the Protection of the Alps	Alpine ecosystems, habitats, species and landscapes	Alps
A.18	Convention on the Protection and Use of Transboundary Watercourses and International Lakes	Ecosystems in transboundary watercourses and international lakes	Global
A.20	Convention on Biological Diversity	Ecosystems and habitats	Global
A.21	OSPAR Convention	Marine ecosystems	North-East Atlantic
A.22	EU Habitats Directive	253 habitat types	EU
A.23	EU Agri-Environment Regulation	Agricultural land	EU
A.24	Convention on Cooperation for the Protection and Sustainable Use of the Danube River	Wetlands habitats and landscapes	River Danube
B. International programmes			
B.1	European Diploma	Important natural areas	Pan-Europe
B.2	Man and Biosphere Programme	Areas that are representative of major biogeographical regions and that support human activities	Global
B.4	European Network of Biogenetic Reserves	Representative natural areas	Pan-Europe
B.6	Nicosia Charter	Vulnerable areas	Mediterranean basin
B.11	Charter of Seville	Characteristic Mediterranean landscapes	Andalusia, Languedoc-Roussilon and Tuscany
B.12	Agenda 21	Sustainable development	Global
B.14	EU LIFE Programme	Support for EU environmental policy	EU
B.16	MedWet	Wetlands	Mediterranean region
B.17	Environmental Action Programme for Central and Eastern Europe	Regional environmental problems	Central and Eastern Europe
B.19	Danube Delta Biodiversity Project	Aquatic and terrestrial environment	Danube delta
B.20	Environmental Programme for Europe	European environmental policy priorities	Pan-Europe
B.21	European Spatial Development Perspective	Spatial planning	EU
B.22	EU Biodiversity	Ecosystems	EU
C. Other initiatives			
C.2	Important Bird Areas in Europe	Important sites for migratory, threatened and characteristic European bird species	Europe
C.4	European Coastal and Marine Ecological Network	Coastal and marine biodiversity of European importance	Europe
C.9	EECONET	Habitats of European importance	Europe
C.10	Parks for Life	Protected areas	Europe
C.11	Large Carnivore Initiative	Habitats of the brown bear, wolf, wolverine, Iberian lynx and Eurasian lynx	Europe
C.12	Important Plant Areas in Europe	Habitats of wild plant species	Europe

Managing habitats for conservation in European landscapes

Protected Areas

In planned and intensively used landscapes as are typical of many parts of Europe, establishing and managing Protected Areas (PAs) is an obvious and important tool central to biodiversity conservation. The formal recognition of this, globally and within Europe, has been clearly expressed by the IUCN, specifically within its subsidiary the World Commission for Protected Areas (WCPA). The IUCN defines six categories of protected area, depending on objectives and the degree and type of management they require. The categories are important because they exhibit a gradient of management intervention and in doing so emphasise that habitat management needs are different in different situations. Thus there is management to provide strict protection and the dominance of natural processes (Category I); management to combine this with the needs of visitors (Categories II and III); management intervention to actively conserve and/or restore habitats or species populations (Category IV); management to protect cultural, lived-in landscapes (Category V) and most recently also management to protect the sustainable use of natural resources(Category VI). Full details are available on the WCPA web site (http://wcpa.iucn.org).

With such an organised management framework in place it is tempting to think that, particularly in Europe, where scientific information is plentiful and conservation effort can be supported by a good political and economic infrastructure, protected areas must form an efficient contribution to biodiversity conservation. Unfortunately, as recently as 2002, the WCPA itself recognised that we are failing to protect biological and landscape diversity in Europe and the whole issue is in disarray at the pan-European level (Haslett, 2002). A major cause appears to be a recent major shift of conservation emphasis worldwide. During the 20th century effort was concentrated on designing protected areas and inventorising the species within them, but now there is much more orientation to effective management of protected areas for sustainable development. The WCPA is presently engaged in activities to ensure improved science and management effectiveness (and see Hockings & Phillips, 1999; Hockings *et al*, 2000), more effective involvement of local communities in and around protected areas, and strengthening on ground management capacity (http://wcpa.iucn.org).

Non-protected areas and ecological networks

Protected areas certainly form the essential backbone of biodiversity conservation, but this notwithstanding, it is equally important to recognise that most of the land in Europe is not protected and vast areas are covered by often heavily human-influenced habitats. Organisms naturally disperse across landscapes and such dispersal and the resulting patterns of distribution are of intrinsic importance to ecosystem function and to species and genetic heterogeneity (see, for example, the relevant chapters in Begon *et al*, 2006 and Bacles *et al*, 2007). That much of Europe´s biodiversity is thus to be found outside the borders of designated protected areas is an important point, and one that can hopefully begin to be addressed within the recently created European Landscape Convention of the Council of Europe (Council of Europe, 2000b and see Council of Europe, 2002). Specifically, this Convention covers natural, rural, urban and peri-urban areas (Article 2) and therefore includes "workaday" landscapes lacking any special or remarkable features (Council of Europe, 2002). Although it promotes the protection, management and planning of all these types of landscape (Article 3), conservation of biodiversity is not explicitly mentioned.

Thus it is clear that while there is an essential need to manage protected areas and habitat patches internally, it is also necessary to include the situation outside the patches, with particular consideration of linkages between patches (Arnold, 1995; Harrison & Fahrig, 1995). This makes spatial planning the director of environmental conservation in Europe. In addition to official protected areas, we need ecological corridors and other linkages (Opdam *et al.*, 2003; Opdam & Wascher, 2004). Thus there is an urgent requirement to integrate biodiversity conservation with different sectoral policies, such as transport, tourism, agriculture, forestry, water resources and others (Council of Europe, 2003). To be acceptable, these linkages need to have not only ecological functions, but also aesthetic, educational and recreational functions (Jongman, 2004). The tradition for "greening" the landscape has existed for a long period in many countries in Europe as a tool to prevent and guide urban sprawl with a - not always recognised – side product of ecological coherence (Von Haaren & Reich 2006). Such multifunctional zones need to be developed and maintained to cover all interests.

All this invites the application of a classical "geography" landscape ecology approach to habitat management for conservation purposes – patches within a matrix may be isolated or connected by corridors and the whole is managed as a network. Such networking has become a major paradigm in biodiversity conservation worldwide (Shafer, 1990; Forman, 1995)

However, since the early 1990s conservation and landscape biology research has also recognised that the patch/matrix/corridor approach is not necessarily an accurate reflection of real landscapes. Instead, landscapes should be regarded as an almost endless series of nested mosaics of patches at different spatial scales. These mosaics are perceived and used differently by different organisms (e.g. Wiens, 1995; Haslett, 2001; Vos *et al*, 2001). Thus two distinct schools of thought have arisen, mainly as a result of scientists` tendencies towards geographical or theoretical ecology.

In Europe, also at about the same time, the Pan-European Biodiversity and Landscape Diversity Strategy (PEBLDS) came into being. (Council of Europe & UNEP, 1995, and see http://www.strategyguide.org/fulltext.html). This Strategy is a Pan-European response to support the implementation of the Convention on Biodiversity and has four specific aims: (i) that threats to Europe´s biological and landscape diversity are reduced substantially; (ii) that the resilience of Europe´s biological and landscape diversity is increased; (iii) that the ecological coherence of Europe as a whole is strengthened; and (iv) that full public involvement in the conservation of biological and landscape diversity is assured (Council of Europe, 2000a).

The Strategy also provides a framework for strengthening and building on the range of existing initiatives relating to the conservation of biological and landscape diversity as well as providing a means to integrate ecological considerations more effectively into all relevant socio-economic sectors, among others. The aims are to be achieved by implementing a variety of Action Themes, one of the most significant of which (Action Theme 1) is the establishment of the Pan-European Ecological Network (PEEN). This network aims to ensure that:

- a full range of ecosystems, habitats, species (including their genetic diversity) and landscapes of European importance are conserved;
- habitats are large enough and of sufficient quality to place species in a favourable conservation status;
- there are sufficient opportunities for the dispersal and migration of species;
- damaged elements of the key ecosystems, habitats and landscapes are restored; and
- the systems are buffered from potential threats (Council of Europe, 2000a).

Each of the above aims implies that some sort of appropriate habitat management should be implemented. The broad design principles to achieve the aims at the European level rely on creation and management of core areas, corridors and buffer zones, thus strongly tending towards the “matrix” landscape ecology approach. This is in some ways useful because the different existing instruments (see Tables 1 and 2) all use a similar approach in identifying the landscape components.

Consideration of aquatic (freshwater) habitats within ecological networks presents a further suite of problems that are not explicitly addressed within PEEN, though such habitats are the subject of Action Themes 6 (River ecosystems and related wetlands) and 7 (Inland wetland ecosystems) of PEBLDS. Freshwater systems include not only the surface hydrographic network, but also the groundwater – underground aquifers and the wet spaces between alluvial particles in the substrate and the interface between surface and underground. This complexity is acknowledged by the Water Framework Directive (WFD) of the EU. The Directive recognises that aquatic habitats may be patchy and be linked by above and below ground flows between them, and that they occur within a broader terrestrial matrix. The WFD also seeks to integrate ecological considerations with other sectors by encouraging or requiring that in river basin management plans (RBMPs) management actions that contribute to improving water quality are integrated into other European policies, such as agriculture and fisheries, energy and tourism. As such then the WFD encourages appropriate habitat management within a broad landscape approach to ensure “good status” and this is maintained through six-yearly reviews of the RBMPs. Presently, it seeks to “ensure all aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands meet 'good status' by 2015” (see http://ec.europa.eu/environment/water/water-framework/pdf/objectives.pdf).

Taking account of the dynamic nature of ecosystems

Ecosystems are dynamic – they are constantly changing over space and time and over a wide range of scales. The causes of these changes may be biotic or abiotic, natural or anthropogenic, direct or indirect. This dynamic aspect of ecosystems and their components is central to the science of ecology and underlies many ecology text books (e.g. Begon *et al*, 2006). Within ecosystems the dynamics of species activities and abundances dictate whole-ecosystem functioning, stability, resilience and “health” (e.g. due to compensatory effects among species, patches, seasons or years, Tilman, 1996; Cottingham *et al.*, 2001). Thus natural dynamics and their causes need to be maintained and appropriate habitat management is necessary to ensure this (the “balance of nature?” of Pimm, 1991).

But it is the anthropogenic drivers of change (or “pressures”) that are of overriding concern to present biodiversity conservation. The world’s ecosystems are now impacted by humans to a greater or lesser extent and humans play an important role in modifying or regulating the types and rates of ecosystem change, e.g. through land use, climate change, pollution, biotic pressures such as invasive species, pest outbreaks, and more (Lelieveld *et al.*, 2000; Sala *et al.*, 2000; Lepers *et al.*, 2005; Reid *et al.*, 2005). Because of this, habitat management must take into account the effects of environmental pressures to facilitate adaptation, protect against or otherwise mitigate adverse effects or restore habitats after adverse impact (IUCN *et al.*, 2003; Berry *et al.*, 2006). Unfortunately, such implications of ecosystem dynamics for conservation management seem to have been rather forgotten in many situations outside academic circles. Also, there is a recognised disparity between conservation science and practice. Recent academic discussions have highlighted the need for conservation management to be based more firmly on sound science, despite recognition that this may not always be practicable in real situations (Sutherland *et al.*, 2004; Griffiths, 2004).

Climate change is now an omnipresent pressure that has not only direct effects on biodiversity, but also influences the entire variety of anthropogenic pressures and the strengths of their impacts on natural ecosystem processes. A recent important commentary on climate change and the conservation of biodiversity in Europe by Usher (2007) provides an up-to-date overview of the subject. This review and other studies highlight an alarming variety of anticipated changes within Europe (European Environment Agency, 2004), including changes to the geographical ranges of species (Araújo *et al.*, 2006) and of entire ecological communities (Buse *et al.*, 1999), changes to the sizes of these ranges (extent), changes to species abundances and to life-cycle patterns (phenology) (Menzel *et al.*, 2006), changes to genetic diversity and problems caused by non-native (invasive) species.

To consider the necessary management responses to these and other changes, it is useful to return to habitat mosaics and their spatial-temporal dynamics. Scaling is of particular relevance. A mosaic of different habitat patches at the scale of looking out of an aeroplane window – an eagle´s eye view of a woodland, a meadow, a lake – is very different to the habitat mosaic relevant to a beetle that spends its life within a few square metres, but which experiences equally heterogeneous patches of terrain at that scale (Haslett, 2001; Vos *et al.*, 2001). Within habitat mosaics of any scale, a wide variety of mosaic patch parameters are important to conservation, including not only the content of the patches (including topography and microclimatic parameters), but also their border complexity, shape, size, contrast, connectivity, orientation, frequency and more (Wiens, 1995 and see also Verboom *et al.*, 2001; Vos *et al.,* in preparation). All are relevant to how the different plants and animals exist and interact within the mosaics.

Thus habitat management responses need to be linked to the characteristics of the mosaics at the relevant scales (the "organism point of view", Hansson *et al.*, 1995; Haslett, 2001) and how the mosaics change with time, including successional change, whether natural or pressure-driven (Bazzaz, 1996; Schütz *et al.*, 2000) within and outside protected areas.

It would seem then, that the scientific basis of biodiversity conservation planning, particularly in an era of climate change, argues against procedures designed to maintain a steady state (Usher, 2007). There are four general approaches to habitat management to respond to climate change that have been developed for the Canadian national parks (Scott & Lemieux, 2003). These are:

(i) *Static*: Continuation of management and protection of current habitats and species within current protected area boundaries, using current goals,

(ii) *Passive*: Acceptance of ecological responses to climate change and allowing evolutionary processes to take place unhindered,

(iii) *Adaptive*: Maximisation of the capacity of habitats and species to adapt through active management designed to slow the pace of ecological change or to facilitate ecological change towards a new (climate) adapted state,

(iv) *Hybrid*: Some combination of two or more of the above management types.

Usher (2007) surmises that adaptive management or some form of hybrid management involving the adaptive approach is likely to be the most widely applied in Europe (see also European Environment Agency, 2005). This means that established conservation instruments, both on paper as listed in Tables 1 and 2 and also the practical definition and management of protected areas and networks such as Natura 2000 and the Emerald network sites, need to steer away from their presently rather static approach, and incorporate a new flexibility to reflect ecosystem dynamics to allow populations to adapt to change or to move. This even though some instruments do implicitly acknowledge that the condition of habitats may change. For example, in the Birds Directive of the EU, Member States (http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm) must "preserve, maintain or re-establish a sufficient diversity and area of habitats" for all designated species (Article 2) and must "avoid pollution or deterioration of habitats" (Article 3). Annex 1 species subject to specific changes in their habitat may be subject to special measures

(Article 4). The Habitats Directive (http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm) also requires Member States "to take measures to maintain or restore natural habitats and wild species at a favourable conservation status" (Article 2).

This flexibility means that we will need to acquire new abilities, for example to enable redefinition of protected area boundaries, or to forecast efficient placement of future reserves and networking links relevant to future landscapes or to re-designate the status of existing protected areas. This is not least because generally, it is already clear that under a warming climate in Europe, there is a trend for species to move regionally northwards and/or locally upwards (Usher, 2007). Most worryingly, it is clear that many of the presently designated Protected Areas across Europe are not likely to be in the right place under future climate change scenarios (e.g. for amphibians and reptiles see Araujo *et al.*, 2004).

As a landscape example, nowhere are these issues more apparent than in Europe´s mountains. From their topography, increasing altitude in mountain ranges means less ground area and less area with a particular set of climatic conditions. At the top, this "climate space" simply runs out (Halpin, 1994a,b). Combined with changes in human land use (e.g. no more winter sports, more forestry and agriculture, etc), this dictates major alterations to habitat management strategies for conservation in the directions described above. Existing protected areas and networks will no longer protect what they were designed to, with direct repercussions on their definition, placement and practical management. The entire situation is further exacerbated by the observation that the mobility of species is extremely variable in both space and time, so that although it is already clear that many are rapidly changing their ranges, man-made habitat fragmentation and isolation mean that many organisms cannot move with the climate either with altitude or latitude. The less vagile species (including many invertebrate animals; note that these make up the bulk of species biodiversity in Europe and worldwide) are at greater risk of extinction.

Although the need for a dynamic approach to conservation in the face of climate change is beginning to be acknowledged at the European level (e.g. EEAC, 2005) and in some cases at the national level. In the U.K, for example, the potential changes in species' ranges has led to calls for conservation to embrace adaptation actions (Walmsley *et al.*, 2007), it has not yet been explicitly incorporated into international European instruments.

For the moment, conservation management of habitats throughout Europe remains mostly large scale and over-simplified. This is inappropriate for the conservation of the majority of biodiversity, terrestrial and aquatic.

Habitat management to protect biodiversity and sustain the provision of ecosystem services

Ecosystem service provision is about acknowledging what biodiversity does for humans, and may include placing economic values on different aspects of nature, and the different grounds for being able to do so. The recent United Nations-sponsored Millennium Ecosystem Assessment (MEA) distinguishes four broad groups of services – provisioning, regulating, cultural and supporting, with further categories and subcategories (Hassan *et al.*, 2005). Populations of one or multiple species groups responsible for providing a particular ecosystem service have been referred to as constituting Service Providing Units (SPUs) (Luck *et al.*, 2003).

The idea of ecosystems providing services of economic relevance to us is not new. Indeed the origins can be traced back to the early 1920s (see the commentary by Wiens, 2007). What is new is the recognition that securing the provision of ecosystem services can also provide a means of managing habitats to the benefit of biodiversity protection, thus considerably broadening the scope and relevance of conservation.

Previously, nature conservation was undertaken solely for reasons of moral, ethical, or aesthetic issues, - the "cultural values" of the MEA. Now, however, there is also a strong interplay between conservation and economics in all of the other MEA service groups.

Managing habitats to protect service provision, while at the same time encompassing the needs of biodiversity conservation, may offer a potentially highly effective means of improving present habitat management strategies for biodiversity maintenance. Perhaps the greatest difference between this and more conventional approaches to conservation arises from the definitions of the target units to be conserved. Where conventional conservation strategies tend to oscillate between protecting single species populations or entire habitats (see above), strategies to conserve service provision involve a spectrum of types and sizes of target units, from single populations to functional groups (guilds) to entire species assemblages, and how they change in space and time. Thus the approach is intrinsically dynamic, particularly as it is not always spatially fixed – service provision must follow environmental change.

It is not expected that the ecosystem service provision approach could replace present conservation management strategies. Rather it should build upon and complement the traditional compositional (evolutionary, entity oriented) and functional (system and process oriented) ways of viewing conservation (Callicott *et al.*, 1999). Thus, for conservation purposes the service provisioning approach can be regarded as a *value-added* strategy to support and complement existing strategies. It also can provide an important "early warning system" when appropriately monitored because the services will cease to be delivered before the providing units, or their components, become extinct. Management of habitats and their linkages within the Pan-European Ecological Network presently relates to ensuring that populations and/or habitats are maintained at a sufficient size to prevent extinctions (Council of Europe, 2000a), whereas management to ensure that SPUs are large enough to provide ecological services would normally exert influences at levels prior to exposure to high extinction risk.

Interest in ecosystem service provision is recent, so it is hardly surprising that existing instruments for conservation in Europe acknowledge its importance in a chronological progression. The earlier instruments may be interpreted, in certain places, as implying involvement of services, while the most recent instruments are more direct. For example, within the Birds Directive of the EU, ecosystem service provision is not explicitly included, but under the Obligations, conservation is seen as being "aimed at the long-term protection and management of natural resources".

Similarly, Article 2 of the Bern Convention states that "Contracting Parties shall take requisite measures to maintain the population of wild flora and fauna …..while taking account of economic and recreational requirements and the needs of sub-species, varieties or forms at risk locally" (Council of Europe, 1979).

Recent instruments are often more specific. For example, the European Plant Conservation Strategy devotes a section to the sustainable use of plant diversity, including the specific recognition of the economic value of wild plants, with extra mention to the value of medicinal plant species (Planta Europa & Council of Europe, 2002). This document also points out that while sustainable use of biodiversity is one of the three major objectives of the CBD (Article 1), the subject has received less attention in Europe than in areas of the world that rely more heavily on wild species. This comment may be taken as valid for most groups of organisms. The European Strategy for the Conservation of Invertebrates also clearly states the importance of these animals in providing ecological services (Haslett, 2007). The Strategy´s Key Action 2.6 is to "Collate existing information and undertake focussed new research on the provision of ecological services by invertebrates and the economic values of those services". Other parts of the Strategy aim to stimulate awareness of the significance of invertebrate animals to biodiversity and ecosystem function (insects alone are about 65% of all known species of organisms, including plants and micro-organisms. A major deficit is identified in the extent to which invertebrates are included in habitat management decisions and also in the amount of expertise available relative to other groups of organisms (May, 2007). The importance of invertebrates in providing vital ecosystem services is certainly not to be underestimated, as recently demonstrated by Losey & Vaughan (2006) using selected examples of insects in the USA.

A further recent instrument, the European Strategy on Invasive Alien Species, does not refer explicitly to ecosystem service provision, but accentuates the consequences of invasions and their control from an economic perspective by acknowledging the losses to the European economy, particularly in agriculture, forestry and fisheries. Public health issues and negative effects on biodiversity are also noted. The Strategy lists key actions for the prevention and mitigation of the effects of alien invasive species and outlines restoration measures within the ecosystems and habitats affected (Genovesi & Shine, 2004). However, it has become clear that from a conservation perspective, the interactions between species invasions, habitat modifications and other variables will have complex effects on native species survival (Didham *et al.*, 2007).

Although the above indicates that the role of service provision in conservation is beginning to be recognised, this role remains, for the moment, hypothetical. Putting the theory into practice will be far from simple. The entire concept of SPUs is new and continues to develop rapidly. There are many additional factors, such as the effects of interactions between organisms that may be antagonistic to service provision, or the requirement for secondary services at other levels in the system that may be necessary to support the provision of the particular primary service in question, or the provision of multiple services by a single SPU and many other such parameters and interactions. All of these need to elucidated and their effects taken into account.

It is combinations of such factors that are likely to be responsible for one general difficulty with the service provision approach that has already become apparent: Conflicts in interest may often arise between the requirements necessary for providing different services. The management aims for one type of service provision may indeed be antagonistic to the provision of a different service, and these may indeed also prove contrary to the interests of biodiversity conservation. In such circumstances, more often than not it is management for conservation that suffers most.

For example, management of forest trees in order to maximize the production of fibre may conflict with management targeted to increase biodiversity or for cultural services such as ecotourism. In other words, a forester will happily manage for sustainable forestry, but this is not at all the same as a sustainable forest ecosystem! Similarly, managing mountain ecosystems for the provision of winter recreational activities such as skiing causes severe degradation of the landscape and is thus a major pressure on the biodiversity and health of the very ecosystems that provide the service. The future lies in creating a satisfactory balance between such conflicting interests.

In conclusion

One of the main purposes of the present paper is to stimulate discussion about the efficiency of present habitat management strategies for conservation and how this could be enhanced. We have provided an overview of the established approach to habitat management for biodiversity conservation in Europe and the main legislative instruments involved. This information was then placed against a background of ecosystem dynamics and of the provision of ecosystem services. In doing so, we have begun to build the basis for a new outlook on biodiversity conservation relevant to habitat management in the 21st Century. In the light of the information provided, it is now possible to identify some gaps in knowledge and practice that would need to be addressed for future successful habitat management for biodiversity conservation in Europe.

In general, there is a need for a more dynamic approach to habitat management that takes account of ecosystem change in space and time instead of the present rather static approach. This entails viewing habitats and landscapes as continuous mosaics of patches at different spatial scales instead of maintaining the traditional patch-matrix-corridor interpretation, as well as recognition that changes are occurring quickly under a changing climate and because of other drivers of environmental change.

There is also a need to include the sustainable provision of ecological services within the bounds of management for conservation. Here the SPU approach offers novel new insights. In addition to focussing on the maintenance of services, the concept has the benefit of acting as an “early warning system” for biodiversity loss – service provision will cease before the service providers become extinct. In this way, management of habitats for SPUs becomes a “value-added strategy” for biodiversity conservation, supplementing and strengthening those instruments already in place.

Some specific gaps that need to be filled in these directions (in no particular order of importance) include the following:

- Issues of spatial scale need to be more closely addressed. Habitat mosaics need to be viewed from the organism point of view, not just from the human perspective and managed accordingly. This applies to both the definition and content of patches in any given mosaic and to the allowances for networking to allow linkages and exchange of organisms across the mosaic.
- Spatial mosaic heterogeneity needs to be more closely bound to temporal change, particularly in recognition of climate change. Habitat mosaics at any spatial scale can alter rapidly, so it is necessary to be able to apply measures to protect biodiversity in the future. This requires a new flexibility in land planning and management, particularly in the definitions of borders of protected areas and in the siting of future reserves (lines on maps need to be changeable). Management of habitat mosaics must adapt to take account of this, with particular reference to general trends of movement of species populations and communities latitudinally northwards and altitudinally upwards in Europe.
- Although successional changes in communities and ecosystems occur naturally, they are also the consequence of any anthropogenic disturbance or change. Climate change will continue to drive ecological succession, so acceptance and working with these changes is preferable to management that tries to maintain a static state.
- There remains a major lack of inclusion of invertebrate animals in habitat management decisions and legislation, even though these organisms contribute more to biodiversity than any other group of organisms and have many essential ecosystem functions, in Europe and worldwide.

- Despite the advantages of including the ecosystem service provision approach, much more information is required on how to balance the conflicts between economic service provision and biodiversity conservation. This involves finding a compromise in theory and practice between management for SPUs, service antagonisers and conservation interests.

It is likely that a fundamental cause of most of the above-listed gaps lies in the differences between the present levels of scientific understanding and the design and implementation of the instruments and legislation relevant to habitat management – there is still a need to go "up-market". Many of the formal instruments have been, and continue to be updated, but considerable time delays may still occur at all levels. Accepting such delays, in cases of uncertainty it is best that the Precautionary Principle be implemented.

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