The **RUBICODE** Project

Rationalising Biodiversity Conservation in Dynamic Ecosystems

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RUBICODE Review Summaries

Introduction

RUBICODE is a €2m Coordination Action Project funded by the EU to review and develop concepts of dynamic ecosystems and the services they provide. These services include the provision of food, fibre and fuel, regulation of air and water quality, flood protection, erosion control, pollination, pest control, recreation, ecotourism and many others. Those components of biodiversity which provide specific services to society are being defined and evaluated in order to increase our understanding of the value of biodiversity services and, consequently, of the cost of losing them. This will give decision-makers a more rational base for halting biodiversity loss by shaping adequate conservation policies.

This document aims to provide a summary of the review activities in the project, in the form of short, jargon-free summaries of the findings of the full reviews, and an overview of their implications for research and for policy development. The longer review reports can be downloaded from http://www.rubicode.net/rubicode/outputs.html

Seven review summaries are provided in this document as follows:

A RUBICODE Review on:
"Preferences and Economic Values for Ecosystem Goods and Services"

A. Kontogianni, M. Skourtos and P.A. Harrison

There is growing emphasis on ecosystem functions, services and values at all governance levels, especially within state agencies and international organisations. This is a testimony to the importance attached to human benefits from ecosystems in modern nature conservation thinking. The increasing demand for evidence of "good value for money" from public funds used for conservation projects makes reliable monetisation of conservation costs and benefits essential. Although traditionally the costs of environmental externalities (such as climate change, water purity and health impacts) have not been included in national or corporate accounts, monetary reporting on ecosystem health will become more familiar and widespread as ambitious research leads to improved techniques, and as society increasingly demands full accounting.

This review addresses the dynamics of economic values and preferences for ecosystem goods and services. The key questions are "How do human preference and values for ecosystem services change through time?" and "Do we have the methods and data necessary to assess these changes accurately?"

The review highlights empirical evidence of both demand-driven and supply-driven changes in values. Demand-driven changes arise when human preferences change in the short to medium term and thereby alter the value people put on ecosystem services. Review of the evidence reveals considerable differences in the time span examined (2 weeks to 20 years). It is shown that values are stable for time periods of less than a year and certainly change for time periods of twenty years. For periods of four to five years the evidence is mixed.

Over longer periods, changes in cultural parameters can play a key role. This makes the task of modelling the dynamics of preferences very complex. We examine integrated ecology-economy models, and dynamic bioeconomic models, as representative approaches to modelling supply-driven dynamics. The reviewed models are normative, describing in an optimum control fashion how the complex socio-ecological systems should evolve over time in order to fulfill the requirements of efficiency and sustainability. The evolution of values (or 'shadow prices') in such an optimum control frame is described as the time path of state variables indicating how much social welfare is increased if the corresponding variables or restrictions are relaxed by a marginal unit. These approaches have advanced our understanding of complex systems, while also alerting both researchers and policy makers to the dangers of oversimplification. Further improvements in understanding will require mixing of methods and pooling of data. In this respect, the potential of systematic and formalised interdisciplinary research lies in the integration of insights, methods and data drawn from evolutionary and behavioral economics as well as from integrated ecology-economy models in order to portray in a mixed qualitative/quantitative fashion the dynamics of ecosystem values. It remains a task for future research to develop detailed strategies for taking these steps.

Full report: "Review of the dynamics of economic values and preferences for ecosystem goods and services".

A RUBICODE Review of:
"Concepts of Dynamic Ecosystems and their Services"

M. Vandewalle, M.T. Sykes, P.A. Harrison, G.W. Luck, P. Berry, R. Bugter, T.P. Dawson, C.K. Feld, R. Harrington, J.R. Haslett, D. Hering, K.B. Jones, R. Jongman, S. Lavorel, P. Martins da Silva, M. Moora, J. Paterson, M.D.A. Rounsevell, L. Sandin, J. Settele, J.P. Sousa and M. Zobel

Ecosystems and the species living within them undergo change continuously. Ecosystems provide many services to humanity, but the degree of provision changes as ecosystems change, particularly under periods of rapid climate or land use change. Successful conservation of ecosystems, their biodiversity and their services requires conservation measures that take account of the dynamic nature of ecosystems as well as their multiple service provision. This report reviews the state of the art with regard to the assessment of ecosystem services in the context of biodiversity conservation.

Ecosystem services were categorised according to the Millennium Ecosystem Assessment into four different classes: provisioning, regulating, cultural and supporting. Six terrestrial (agro-ecosystems, forests, semi-natural grasslands, heaths and shrubs, montane and soils) and three freshwater (wetlands, rivers/floodplains and lakes) ecosystems were assessed. Some services (such as food, fibre, and fuel) are provided by all ecosystems, while others are restricted (for example pollination is only provided by terrestrial ecosystems). Quantification of these ecosystem services is important in understanding their value (both monetary and non-monetary) to humanity.

The concept of "service providing units" (SPU) was explored as a tool to link species populations, functional groups and ecological communities to the quantification of the services provided to humanity. An SPU can be defined simply as the components of biodiversity necessary to deliver a given ecosystem service at the level required by service beneficiaries. This definition makes three assumptions. First, that the [human] need for an ecosystem function has been explicitly identified thereby re-classifying it as a service. Second, that the rate of delivery of the service can vary, but it should meet some base level defined by service beneficiaries (i.e. humans; e.g. financial profits attributable to service provision are above a given threshold). And third, that the components of biodiversity providing the service can be identified and quantified.

The steps that need to be undertaken to identify and quantify an ecosystem service using the SPU concept can be divided into three stages of analysis, which are described in detail in the full review: (i) identify beneficiaries and providers of the ecosystem service; (ii) quantify demand and supply of the service; and (iii) appraise the service value and implications for management and policy. A literature review gathered information on each of these steps for 64 case studies, covering all nine ecosystems, though good examples for montane and lake ecosystems were few. Studies cover a range of scales from local to regional to global, though local examples were more common as it is easier to recognise service provision and usage at this scale.

Ecosystems are in a constant state of flux and ensuring systems have the capacity to cope with likely changes is crucial if desirable ecosystem services are to be maintained. A permanent shift in conditions or an increase of stress (due to anthropogenic pressures such as climate change) can lead to changes in the balance between species, changes in species and/or functional composition and therefore to changes in (the composition of) SPUs, with possibly important consequences for conservation and management. A framework for quantifying and assessing these factors was developed and is discussed in the full review paper.

The review showed that service quantification, particularly in non-monetary terms, is often minimal and that some standardised approach to quantification, and thus to conservation, of ecosystem services is required.

A RUBICODE review of:
"Drivers of Environmental Change"

S. Anastasopoulou, V. Chobotova, T. Dawson, T. Kluvankova-Oravska and M. Rounsevell

Environmental change on earth has been taking place for billions of years, but the scale, the magnitude and the speed at which change has been occurring since the industrial revolution, and especially over the last sixty years, is new and worrying. Human activity has led to greatly increased risks of crossing critical thresholds that could result in abrupt changes to human and ecological systems.

To reduce or prevent further environmental degradation, and to reverse it where possible, it is important to understand how and why change is occurring. The term "driver" is used to describe the underlying causes of environmental change. Drivers are embedded in the way humans live their lives and include characteristics of economic activity, social behaviour and preferences, technological development, policy, politics and governance. Collectively the effects of multiple, interacting drivers leads to the changes that are observed in ecosystems and the broader environment.

The RUBICODE project has set out to research what we know about the drivers of environmental change. The review demonstrates that the majority of studies focus exclusively on one spatial scale, for example global, national or landscape scales, although we know that drivers act differently at different spatial (and temporal) scales. Two types of drivers can be distinguished: indirect and direct. Indirect drivers are the underlying causes of environmental change that do not have a direct influence on the ecosystem in question, e.g. global climate and socio-economic change, national and international policy. Direct drivers are any natural or human-induced factors that cause a change in an ecosystem directly, e.g. temperature, precipitation, land cover, per capita water demand, crop prices or gross margins. Population growth is the most frequently cited indirect driver of environmental change, while land use and land cover change, and climate variability and change, are the most commonly cited direct drivers. Natural, physical and biological phenomena, diseases and wars are the least discussed direct drivers.

The review highlighted the problems that arise from the use of different terminology in describing similar or even identical concepts of change. There is not even a commonly accepted definition of a driver. Better defined and standardised terminology would help to reduce confusion and facilitate the rapid exchange of comparable information.

Full report: "Identifying and assessing socio-economic and environmental drivers that affect ecosystems and their services".

A RUBICODE review of:
"Biodiversity Conservation: Going Beyond the Protection of Species Richness"

C.K. Feld, F. de Bello, R. Bugter, U. Grandin, D. Hering, S. Lavorel, O. Mountford, I. Pardo, M. Partel, J. Römbke, P. Martins da Silva, J. Paulo Sousa and K.B. Jones

Land use, land management and changing climate conditions are likely to impact adversely on biodiversity in numerous ecosystems worldwide. In order to detect and monitor such impacts, indicators are needed that reliably reflect these changes. Biodiversity indicators need to be easy to interpret and communicate to decision makers. But they must also have a strong relationship with the biology, structure and function of biological communities.

Within the RUBICODE project, a review compiled about 630 scientific references to compare the development and application of indicators for different purposes in different terrestrial and aquatic ecosystems. The analysis revealed widespread use of plant and animal "richness" (the number of species present) as indicators of biodiversity. A remarkable gap, however, was found for the functional and genetic components of biodiversity. Functional diversity refers to the role a species or community plays in an ecosystem. Soil microbes, for instance, help to decompose and recycle organic material, while algae and bacteria are crucial for the process of self-purification in rivers. Thus, functional diversity is strongly related to ecosystem processes, which finally make the ecosystem services people obtain from the ecosystems.

As a consequence, new biodiversity indicators are needed to account for functions: the process-related component of biodiversity. A potential way to fill this gap is to measure the ecological characteristics of plants and animals. These characteristics ('traits') are attributable to specific ecosystem functions (in a way that individual species names are not) and therefore provide a promising means to indicate the status of functional biodiversity. The ecological characteristics are applicable at various geographical scales, making them useful as indicators at the scale of entire nations and bioregions. At present, such large-scale indication is still approached by rather indirect measures of biodiversity, such as ecosystem area and fragmentation.

The review on indicators showed that much more effort must focus on the development of process-based bioindicators. In order to sustain ecosystem services, such as food and fuel provision, water purification, or nutrient cycling, we also need to know more about the thresholds of biodiversity at which a service is no longer provided or runs the risk of failure.

Finally, little is known about genetic biodiversity indicators across ecosystems. Filling this gap will be crucial to identifying and monitoring genetic resources and, ultimately, to ensuring their sustainable use. The sustainable use of ecosystem services, in general, is likely to be promoted by greater use of ecosystem valuation, where economic (monetary) indicators are linked to ecosystem functioning. Economic indicators, however, are still scarce in the field of indication.

Full report: "Assessing and monitoring ecosystems – indicators, concepts and their linkage to biodiversity and ecosystem services".

A RUBICODE review of:
"Characteristics of Biodiversity that Provide Humankind with Services"

F. de Bello, S. Lavorel, S. Diaz, J. Storkey and R. Harrington

RUBICODE aims to provide a framework for aiding decision making for nature conservation, taking account of the dynamic nature of ecosystems, and the constraints due to limited land and finance. One approach is to identify the importance of biodiversity to the provision of ecosystem services used by humankind. This may help to bring the importance of conservation to the attention of those who are not sufficiently motivated by biodiversity conservation *per se*, and also to justify nature protection over and above the minimum required to avoid species loss.

Most services that biodiversity provides to humankind can potentially be supplied by a variety of organisms. For example, a range of bee species may be capable of pollinating a particular crop, and a range of plant species may be able to filter pollutants and prevent their entry into water-courses. In different years and in different places, under different conditions, the composition of the community providing the service is likely to vary, perhaps substantially.

In order to maintain ecosystem services, therefore, conservation should be directed at the whole range of species that possess the characteristics ('traits') necessary to provide the services. The wider the range of species involved, the more likely it is that at least some of them will possess the traits necessary to survive disturbances such as changing land-use or changing climate. To adopt such an approach effectively, we need a good understanding of how organisms' traits are linked to the services they provide. We reviewed and analysed quantitative evidence for such links: more than 500 examples of links between traits and service provision were found in 247 journal articles. Most of the studies centred on plants and soil invertebrates in grassland, soil or freshwater ecosystems, and considered services resulting from decomposition, productivity, nutrient acquisition and retention, sedimentation and herbivory.

Analysis of the examples showed that particular traits were often associated with the provision of more than one service. Also, particular services were often associated with several traits. Links were identified from groups of traits to groups of services, suggesting that it should be possible to assess the implications for multiple services of conservation strategies aimed at one particular service.

The review highlighted types of ecosystem, service and organism for which relationships between traits and service provision have not been adequately studied. It did not look at the impact on services of interactions between organisms, nor at the links between traits, environmental changes and service provision: these will be topics of further reviews.

A traits-based approach can help to take account of trade-offs, where traits that are beneficial to provision of some services may be detrimental to others. But the traits and services approach must be seen as complementary to more traditional species-based approaches to conservation, not as an alternative.

Full report: "Functional traits underlie the delivery of ecosystem services across different trophic levels".

A RUBICODE review of:
"Effectiveness and Appropriateness of Conservation Policies"

R.H.G. Jongman, G. Bela, G. Pataki, L. Scholten, Á. Mérő and C. Mertens

RUBICODE has produced an analysis of institutional structure and responsibilities in the field of biodiversity conservation policy, considering in particular the ways in which ecosystem services are included.

Current European Union and Member State Policies have a common basis in the Birds Directive and the Habitats and Species Directive. These two Directives are the focus of site and species protection in the EU, and the objectives and messages have to be translated into national actions and carried out within national institutional structures. All EU Member States have their own structure for the organisation of biodiversity policy, implementing the European Directives within national and/or regional political structures. In some Member States, NGOs play an important role in land management and policy setting, while in other Member States NGOs have a limited role.

Agriculture is crucial for European biodiversity: roughly 40% of land is agriculturally cultivated, and farmers are perhaps the most important land managers. Farming practices significantly impact all levels of biodiversity: landscape, species and genetic. Farmland that provides habitat for a diverse range of flora and fauna can be called High Nature Value (HNV) farmland; 15-25% of the European countryside can be considered HNV farmland.

The main threats to biodiversity (especially farmland biodiversity) in rural areas are land abandonment, intensification and land use change. Much farmland biodiversity depends on semi-natural grasslands. Extensive farming practices are important to prevent land receding into the succession process, but intensification is a problem in many areas. Often marginal lands with low market value are threatened by afforestation. The Common Agricultural Policy (CAP) strongly influences the agricultural measures and funding in the EU Member States. All EU Member States are obliged to present the subsidy schemes of the second pillar for their country in a Rural Development Programme (RDP). The second pillar consists of four axes, of which Axis 2 concerns "improving the environment and the countryside". Payments for ecosystem services, Natura 2000 and agri-environmental measures can protect farmland biodiversity. Implementation of these measures is very varied throughout the EU. Pillar 1, the Single Farm payments, continues to receive the lion's share of the CAP budget in most countries, except countries that joined the EU since 2004.

In interviews, biodiversity conservation was understood as going beyond species or habitat conservation, covering landscape and genetic diversity as well. Interviewees stated that a very important challenge in the near future is establishing connectivity between protected and designated areas (for example connectivity of the Natura 2000 system) as well as effective management of the Natura 2000 system. Some expressed the need for adapting the traditional concept of area protection to take better account of ecosystem dynamics and other innovative approaches. There is a need for measurable and quantifiable objectives. The Service Providing Unit (SPU) concept could help in setting more quantitative targets, and in categorising systems based on their service-providing 'value'.

At a very general level, current nature conservation policies are assessed as sufficient by most interviewees. However it is hard to make "ecosystem service" ideas come to the fore, because of difficulties in conceptualising complex relationships among biodiversity, ecosystem functions and ecosystem services. When comparing effectiveness in responding to threats, there was concern about lack of action, invasive species and decline of marine systems. Political problems were thought to hamper the effectiveness of decision making and at the level of land use planning – in particular, the lack of political will, as evidenced by the limited availability of financial resources.

A RUBICODE review of:
"Habitat Management Strategies for Conservation in a Changing World"

J.R. Haslett, P.M. Berry and M. Zobel

Nature conservation began with human concerns for the disappearance of particular, usually charismatic species of animals and plants, and the destruction of beautiful scenery. Even now, whether to protect species or the habitats in which they live is still a dilemma in the use of limited financial and human resources. Present European legislation recognises that habitat protection is prerequisite for species survival and provides a broad range of valid species and/or habitat conservation strategies.

However, in addition to our aesthetic concerns about species and habitats, socio-economic values have become a new and major driving force in how we make decisions about managing and protecting biodiversity. We need to acknowledge and protect all that biodiversity does for human well-being – so-called ecosystem services. This may lead us to place economic values on different aspects of nature. We may thus promote the sustainable use of nature and at the same time offer a *value-added strategy* to supplement (but not replace) existing biodiversity conservation efforts. These ideas are not yet explicitly included in European biodiversity conservation Strategy and Policy.

Establishing and managing Protected Areas (PAs) is central to modern European Strategies for biodiversity conservation. IUCN, the World Conservation Union, defines six categories of Protected Area, with a gradient of management intervention to meet different needs in different situations. However, even within this organised framework, IUCN stated in 2002 that we are failing to protect biological and landscape diversity in Europe. Also, much of Europe´s biodiversity is to be found outside the borders of designated PAs. Thus we need ecological corridors and other linkages between PAs to form an integrated network across Europe, and biodiversity conservation must be integrated with sectoral policies, such as transport, tourism, agriculture, forestry, water resources, etc. All these issues are being addressed through present instruments such as the European Landscape Convention, the Pan-European Biodiversity and Landscape Diversity Strategy (PEBLDS), the Pan-European Ecological Network (PEEN) within PEBLDS, and the Water Framework Directive (WFD) of the EU.

Even so, present European conservation Strategies remain rather limited in their effectiveness. The nature we wish to protect is inherently dynamic – it is constantly changing over space and time – and human influences are of overriding concern, through changes in land use, climate change, invasive alien species and other drivers. Unfortunately, most present conservation instruments assume a rather unchanging, static situation. Thus a new flexibility is required to allow organisms to adapt to change or to move. This means that we will need to acquire new abilities, for example to enable redefinition of Protected Area boundaries, to forecast efficient placement of future PAs and networking links relevant to future landscapes, or to re-designate the status of existing Protected Areas.

A further limitation is failure to view landscapes over the relevant spectrum of many spatial scales. Heterogeneous habitat mosaics must be understood from the organism point of view and scale, not just from the human perspective, and should be managed accordingly. An eagle´s eye view of a woodland, a meadow or 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. There is indeed at present a major deficit in the extent to which small invertebrate animals and their associated functions are included in habitat management decisions, even though these organisms make up the major part of biodiversity.

In short, future successful habitat management for nature conservation in Europe requires some major changes in emphasis – perhaps even a paradigm shift, to take account of our own needs and the changing needs of the biodiversity that provides the services upon which we so heavily depend.

Summary

R. Tinch and S. van den Hove

The RUBICODE reviews have assessed what we know, and what we still need to discover, about linking science to policy for conserving biodiversity. We understand a great deal, and yet there remain key gaps in knowledge. At a broad level, we know that biodiversity underpins the ecosystem services on which human societies depend, in complex ways that are sometimes difficult to unravel. In particular we need deeper understanding of the following areas:

1. **How drivers of change influence the dynamics of ecosystems.** Some individual drivers, and the combined influence of several drivers, are not sufficiently understood. This is crucial to understanding the dynamics of ecosystems and ecosystem services, and therefore to designing effective policies for ecosystem management and conservation.
2. **How biodiversity relates to ecosystem functions, and how these functions relate to ecosystem services.** We understand a good deal of the basics, but our knowledge is insufficiently quantitative. We need standardised approaches for assessing and measuring the interactions. Concepts such as the "Service Providing Unit" may prove useful in some circumstances.
3. **How traits of organisms relate to performance in ecosystems.** This particular aspect of the biodiversity-function-service chain requires much greater attention: to what extent can the provision of services be assessed by analysis at the level of traits of organisms rather than the population level? Advances here could lead to more efficient assessment methods and policy interventions.
4. **How we can measure ecosystem health, function and service.** Although we have many existing tools for measuring components of ecosystems, methods for measuring process and function require more development. Such measures are crucial for bridging the gap between ecosystem components (species, populations, genes) and the services provided by ecosystems.
5. **How we can measure economic value of services and supporting systems.** Great progress has been made in estimating the economic value of ecosystem services. Various issues remain, notably surrounding the appropriate limits on the uses of such techniques, and in particular the ways in which individual values can be derived and combined in the context of decision / policy support.
6. **How to harness knowledge for effective policy development.** Although these reviews focus on gaps in knowledge, we should not forget that we do know and understand a great deal about how biodiversity provides humans with a great many essential services. Conservation policy, and some other policy areas, are starting to reflect this. But we need better ways for communicating and interpreting the knowledge, and in particular those parts relating to uncertainty, thresholds and ecosystem dynamics, within the context of developing and implementing effective policies for safeguarding biodiversity and optimising our sustainable use of ecosystem services.