

UK Biodiversity Research Advisory Group

RESEARCH STRATEGY

for

***Socio-economic and biodiversity research perspectives
relevant to the delivery of the UK Biodiversity Action Plan***

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1. INTRODUCTION

This paper is the result of discussion among a wide range of people, active within the socio-economic fields of biodiversity research and policy. The BRAG socio-economic sub-group to which they have contributed, was charged with undertaking an analysis of the UK Biodiversity Action Plan (UK BAP) and related policy commitments, to identify and prioritise socio-economic research needs.

The socio-economic dimension of biodiversity research addresses the interaction between human behaviour and biodiversity change. It requires the skills of a range of social sciences – psychology, sociology, political science and anthropology as well as economics. It includes an understanding of the ways in which biodiversity supports the production of goods and services. It also includes an understanding of the different ways in which people value biodiversity, and the limitations of current markets and institutions in signalling biodiversity values. These extend along a spectrum from the value of biological resources in direct consumption, through the value of biodiversity in supporting ecosystem functioning and processes, to the cultural, spiritual and aesthetic values people place on different species, communities or habitats. Getting to grips with these values is surely fundamental to implementing the UK BAP (and to broadening/integrating at larger spatial scales, local, UK, Europe, global).

The inaugural meeting of the BRAG socio-economic sub-group in January 2004 was informed by a short report produced for BRAG by *Just Ecology* Consultants (Callaghan 2003), Table 1 of which identifies those high priority research questions regarding socio-economics and nature conservation covered by BRAG. It is somewhat baffling and disappointing (but instructive) that none of the 7 socio-economic topics listed are thought to be relevant to biodiversity and ecosystem functioning! Baffling, because there are clear and obvious links between ecosystem functioning and socio-economic behaviour; disappointing that this was not recognised in the report; and instructive because it demonstrates a clear need to articulate more effectively the importance of socio-economic issues for biodiversity and ecosystem functioning.

The links between socio-economics and biodiversity and ecosystem functioning are very real and clear to us for the following reasons:

- there is compelling evidence that biodiversity change affects the rate of ecosystem processes that underpin the production of goods and services;
- the ultimate driver of biodiversity change is human behaviour, and biodiversity change is thus social, economic and political in origin;
- there are direct and strong feedbacks between human behaviour and changes in the production of goods and services, and these interactions impinge on biodiversity.

These links are encapsulated in Figure 1. While the direct connections between market failures, loss of biodiversity, and the production of foods and fibres is reasonably well understood, the indirect connections through ecosystem process and functioning is not.

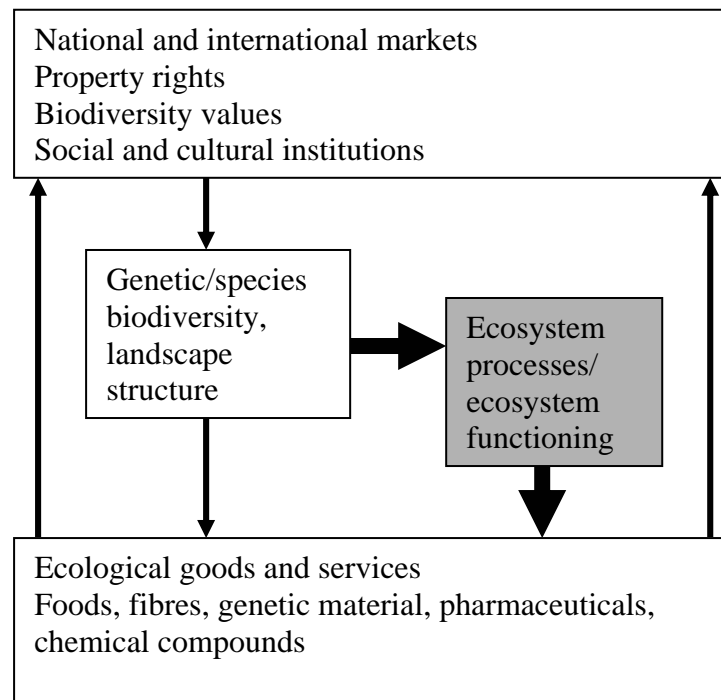


Fig 1: Direct and indirect effects of biodiversity loss on the production of goods and services

It makes no sense to address biodiversity-ecosystem functioning-goods and services linkages without considering socio-economic issues. The following explores some of the major questions still to be addressed, identifies existing relevant research activity in the area and highlights knowledge gaps and research needs. It focuses on all six cross-cutting themes, wherever socio-economic research is thought to be especially important.

2. THE ROLE OF BIODIVERSITY AND ECOSYSTEM FUNCTIONING

Arguments for relationships between biodiversity and ecosystem functioning are compelling, but the evidence available to date is rather limited and patchy. In addition, generalized public statements about such relationships tend to confound different concepts and understanding of both biodiversity and ecosystem processes. It is often not clear whether biodiversity refers to species richness, the number of functionally different taxa, key individual taxa (such as earthworms) or whole assemblages, such as forests. Similarly, the ecosystem processes (previously inappropriately named “functions”) and ecosystem services are often used synonymously.

Much of the current paradigm of the relationship between biodiversity and ecosystem functioning is based on manipulative experiments on grassland systems in Minnesota, USA (Tilman et al., 2001) and the European BIODEPTH project (Hector et al., 1999; www.cpb.bio.ic.ac.uk/biodepth/contents.html), where plant species richness has been manipulated and biomass production measured under the different richness treatments. A large number of similar experiments have now been published (e.g. Pfisterer et al., 2004) measuring a broad range of processes and done in different kinds of ecosystem. For marine systems, the MARBEF programme (www.marbef.org/) specifically addresses socio-economic issues associated with biodiversity and ecosystem function. Furthermore, Covich et al. (In press) have undertaken a review of current evidence and future research needs associated with biodiversity and functioning in freshwater and marine benthic ecosystems.

Preliminary results from a meta-analysis of over 130 such experiments (Pfisterer et al., 2004) reveals that there is evidence that changes in biodiversity do indeed affect a range of ecosystem processes. In addition, the more distant the process (response variable) from the biodiversity (explanatory variable), the smaller the effect size will be. For instance, the primary production of plants whose species richness is manipulated is generally affected strongly, whilst nutrient cycling in the soil is not, probably

because there are more ecological steps (litter formation, microbial action) between plant material and nutrients released in soils. Also, when many different functional groups are present (as opposed to species *per se*), ecosystem functioning is enhanced.

These experiments were prompted by a need to define a relationship between species number and process, in order to validate or falsify alternative graphical representations, such as the rivet hypothesis. Most of the above experiments therefore do not deal with the effects of biodiversity *change*, but with biodiversity *differences* between treatments. They do not specifically address the effects of biodiversity *loss*, in which policy makers have an interest.

Neither do the majority of experiments embrace more than one trophic level. This is a limitation because biodiversity loss scenarios in nature will usually simultaneously affect many trophic levels in a system. The latter consideration matters because of the feedbacks between trophic levels and with ecosystem processes (Fig 2).

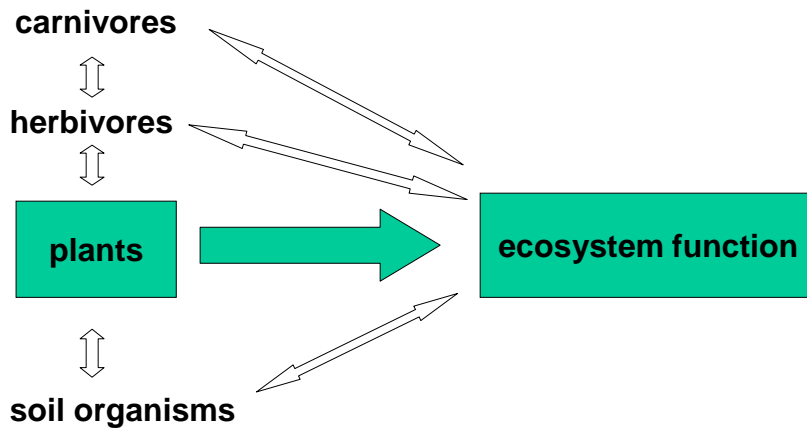


Fig 2. The feedbacks between trophic levels other than those manipulated (plants) and the ecosystem process of interest, here primary production.

There is considerable evidence that such feedbacks occur in nature (Raffaelli et al., 2002), implying that single trophic level experiments produce outcomes of limited relevance to policy makers.

Linking biodiversity, ecosystem processes and ecological goods and services

Whilst the majority of published² biodiversity experiments indicate some relationship between biodiversity and ecosystem processes, few studies have explicitly linked the latter to goods and services or considered the feedbacks between changes in services and biodiversity. This is partly because the linkages between biodiversity, ecosystem processes and ecological goods and services can be extremely complex (Fig 3). First, linkages between biodiversity and goods and services can be direct. That is, there is not necessarily an intermediate ecological process which is affected. A good example would be the loss of the cultural services which occurs when a

² In all meta-analyses or standard reviews, there remains the problem of the “missing draw” data. That is, those studies that concluded there was no relationship between biodiversity and ecosystem functioning which have not seen publication, possibly because they are inconsistent with the current paradigm.

pristine flora and fauna is degraded. Second, different biodiversity change scenarios (e.g. habitat fragmentation, contamination, over-exploitation) are likely to affect processes (and hence goods and services) in different of ways, because different kinds of taxa (large or small, primary producers or top predators) are lost under the different scenarios. Third, specific goods and services may be underpinned by several different processes.

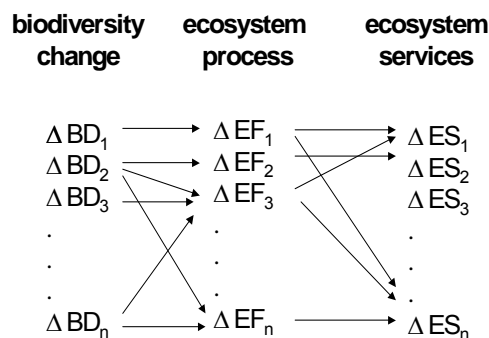


Fig 3. Linkages between changes in biodiversity, processes and goods and services.

The majority of experiments only deal with the left-hand part of Figure 3; they do not attempt to link ecosystem processes to goods and services or goods and services to socio-economic elements. Many experiments measure those processes which are technically straightforward or because the researcher deems the process to be important. In addition only 1 or 2 processes are usually measured. In making biodiversity-ecosystem experiments more relevant to societal interests, it would be sensible to first identify those processes key to underlying particular goods and services and then measure their response to biodiversity change. This will require a change in perspective on behalf of the biodiversity-ecosystem functioning research community. This will be particularly challenging for cultural aspects of biodiversity.

Finally, it is important to distinguish between the production of ecological goods and services and their underlying processes, an issue which confounds many discussions of this area (Fig 4).

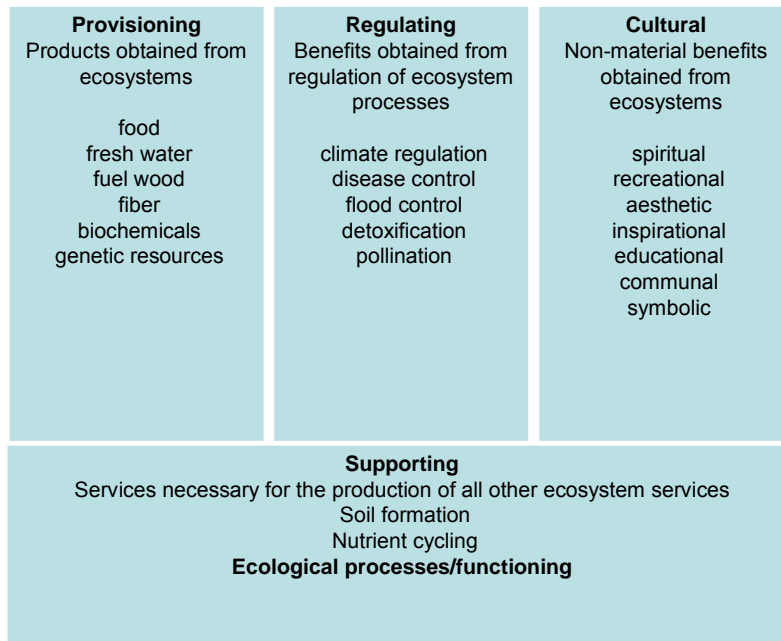


Fig 4. Goods and services and ecosystem processes (source: Millennium Assessment).

BAP and ecosystem functioning

The UK Biodiversity Action Plan has identified taxa and habitats for conservation priority, mainly on the basis of their declining or threatened status. The UKBAP does not explicitly tackle the threat posed to ecosystem processes by biodiversity loss. A case might be made that ecosystem processes should be accorded a similar status as taxa and habitats, although the present lack of information and data about linkages between specific biodiversity elements and processes makes such arguments difficult to mount. Nevertheless, if ecosystem processes were a focus of UKBAP, it is possible

that a much broader range of taxa and habitats would be identified under the plan.

3. THE MANAGEMENT OF HABITATS AND ECOSYSTEMS

Both governments and intergovernmental organisations have taken considerable interest in the use of the ecosystem approach (*sensu* CBD, UNEP/CBD, 2000) for the sustainable management of natural resources and particularly in the context of habitats and ecosystems. There is a priority need to develop practical examples, guidance and operational tools by which to implement the Ecosystem Approach in a fully integrated way. There is a need to assess the extent to which aspects of the Ecosystem Approach are being applied in current habitat & ecosystem management research in the UK. What systems are in place for engaging all stakeholders, i.e. is there an example of best practice, or do we even have a clear view on what constitutes best practice?

Knowledge gaps

There are major deficiencies in our knowledge and information base concerning habitats, ecosystems and biological resources. This is a particular issue in marine systems. The most fundamental problem is the difference in remote sensing capability between terrestrial and marine systems. Our knowledge of the distribution of habitats is severely limited beyond the near coastline and is restricted to maps of very broad habitat categories based on interpolations between sample sites that are widely spread (10s km apart). Thus fine-scale resolution is lacking for the majority of the UK seabed resource. On occasion the data is fine-scale in very site-specific areas in which aggregate or hydrocarbon extraction occurs.

In addition we have limited data on the location of biological resources extracted from the sea. This is not such a problem for hydrocarbon and aggregate extraction as sites are accurately known and revenues generated should be traceable back to a specific location by cross tabulating with time (areas of the seabed are opened up for extraction in succession). Hence mineral value is well known. However fish could be extracted from any part of

the sea. Although we know were a proportion of the fleet fish with high precision, we do not have any information as to what they have extracted (value varies from one species to another and with the quantity landed). Hence every catch landed may be the cumulative effort of 3 weeks fishing across a 1000 km area. Thus it is difficult to make the link between habitat and resources (fish or shellfish). We have some handle on this from fishery independent surveys and several research initiatives.

We have excellent data on temporal trends in fish abundance and biomass. This is only just beginning to be mined (Hinz et al. 2003) and indicates which areas of the seabed are used most consistently by fish and hence might form the basis for attributing 'value' in terms of future food security or necessity for preservation against future unpredictable environmental change. Currently, most resource management takes no consideration of the behaviour of humans (fishermen) in response to management or legislation. This behaviour can undermine the attempts to manage. Hence greater effort needed to model the likely behavioural response of fleets or individuals and likely economic drivers and outcomes. Also of specific importance is what underlies behaviour, for example people may have a strong cultural identity with a particular way of life such as fishing or farming. How landowners and resource managers react to policies and social and political incentives that impact on the rural economy and on land use is also significant.

Valuing habitat and ecosystem functioning.

Rigorous studies are required to value the end-points of habitat management and ecosystem functions e.g. health, food, water quality, tourist visitation. The need in particular is for more integrated case studies, which link natural science with social and economic methodologies. From an economic perspective there is a lack of good studies valuing the endpoints of ecosystem services, whatever they may be (health, food, tourist visitation, other indirect use outputs apart from carbon). There are a few case studies - the best are probably the few mangrove-fishery stories - but even these are far from rigorous. Part of the problem is the difficulty in translating ecologists'

understanding of ecosystem functioning and processes into economically relevant terms. This requires a more sustained interdisciplinary collaboration than we have yet seen. From a sociological and psychological perspective there are a number of studies exploring the ways in which people construct meaning and understanding out of their experiences of natural environments (Henwood and Pidgeon, 2001; Schroeder, 1991; Twigger-Ross and Uzzell, 1996). These studies provide insights into the ways in which people value their surrounding environment which often underlies the social demand for use of land. Yet there are difficulties with incorporating these findings and giving them weight alongside economic studies and this needs to be explored in more detail.

Governance

Many habitats and ecosystems are used for a variety of activities and might be described as multifunctional. This raises governance issues in relation to multifunctionality. What is the institutional capacity to deliver multifunctionality? Existing institutions in a lot of countries will struggle to implement multifunctionality. New forms of governance include negotiated outcomes at a local level.

Participatory processes: The Århus Convention (UNECE, 1998; <http://www.unece.org/env/pp/>) highlights the need for access to information, public participation in decision-making and access to justice in environmental matters. The convention establishes that sustainable development can be achieved only through the involvement of all stakeholders in decision-making. How do we involve people in decision-making about biodiversity ?

It is necessary to gather more information on people's perceptions and the social and economic value of alternative countryside habitat and ecosystem management approaches; as well as exploring what motivates land managers to positively manage habitats for biodiversity. Related to this, we should investigate how land managers find out what habitat management approaches they should adopt and how better advice could be provided to them.

The role of communities in maintaining biodiversity: Conservationists in recent years view local people's support for protected areas as an important element of biodiversity conservation. Voluntary work and citizen science is especially important e.g. RSPB asking members to identify birds in their gardens can provide important means of support and help in managing biodiversity (e.g. the Big Garden Birdwatch, see *later information:* www.rspb.org.uk/birdwatch/index.asp). What is the extent of this and can it be harnessed more effectively?

Conflicts over management

Social science research can enhance organisations ability to anticipate and understand conflicting interests and concerns. It might be argued that it could be a cost effective approach to reducing potential controversy. Different conflicts will arise in trying to incorporate biodiversity into landscapes that are used in a variety of ways. Spash and Carter (2001) emphasise the importance of value conflict and argue that our desire for consensus is not always possible. They outline how moral and ethical issues, within society which make decisions difficult should be accepted as complex and not reduced to simplistic solutions.

We should research ways of linking national and local biodiversity habitat management policy by investigating how mechanisms could be put in place that would identify which areas are particularly important for which habitats.

At a local level, we should evaluate the economic and ecological role of green-spaces in the urban environment (including agricultural land and woodland on the urban fringe), and how to increase their potential to contribute to both habitat provision and the quality of urban life via better management. This might include exploring how best to encourage and facilitate the management of urban habitats as habitat networks (green corridors for wildlife) as well as networks for people (e.g. walkers and cyclists).

Mainstreaming biodiversity objectives into development and economic cooperation strategies/, and policy dialogue with partner organisations, is as much a political as a technical challenge - without high level political support progress will be slow and difficult. Those concerned with developing cooperation strategies across different sectors, and those who negotiate cooperation agreements at the highest political level, need to be convinced of the value of biodiversity for achieving poverty reduction and economic objectives.

The research process should itself be used as a means to enhance political support for biodiversity and promote change by engaging with many stakeholders, including current 'power brokers' and 'agents of change', seizing political opportunities, and strengthening the negotiating capacity of local representative organisations. In other words, it should be highly participatory, both in terms of the community level assessment, and the policy analysis process. It should also be tailored to inform key economic and development processes in partner countries such as Poverty Reduction Strategies, macro-economic reforms and agricultural modernisation policies.

Climate change and habitat management

Since climate change is expected to have different impacts on the ranges of different species, it will affect both the objectives and the costs of the UKBAP. For example, we will need to have to reconsider the efficiency of conservation policies where climate change moves species closer to or further away from the margins of their natural ranges. In particular, it will be important to estimate the changes in Estimate the costs of additional habitat management that will be required as a result of climate change.

4. MONITORING OF BIODIVERSITY AND EVALUATION OF ACTIONS

The economic equivalent of ecological monitoring involves the development of a system of natural resource accounts. These measure changes in the value

of physical stocks (populations of particular species, for example) and therefore presume that mechanisms to value those stocks exist. At present there are no serious attempts to develop resource accounts for biodiversity. Accounts have been developed for a few biological resources, usually a grouped set of exploited species (fish, forests etc), but there have been no attempts to develop accounts for the diversity of species. Biodiversity can be thought about in terms similar to those applying to asset portfolios. That is, the mix of species has value in providing society with insurances against fluctuating environmental conditions. In this sense the value of the mix is related to the management of environmental risks.

Risk assessment involves a sequence of actions: hazard identification, dose-response assessment, exposure assessment and risk characterisation. These steps give rise to an estimate of risk that is the product of (a) the probability of an outcome that causes harm and (b) the damage associated with that outcome. Implicitly, risk evaluation procedures characterise environmental risks in terms of the mathematical expectation of the value of the damage they cause. This maps into the conventional approach to decision-making under uncertainty in economics, which evaluates a risky action involving a set of outcomes with known probabilities by the expected effect on well-being associated with those outcomes.

There are three main sources of uncertainty about the causes and consequences of biodiversity change:

- uncertainty about the evolution of the main drivers of biodiversity change – climate and the global economic system;
- uncertainty about the dynamic effects of biodiversity change on ecosystem functioning and processes;
- uncertainty about the impact of changes in ecosystem functioning and processes on economic activities.

Socio-economic research is needed to deepen our understanding of the first

and third of these. It requires the calculation of the value of ecological systems in different states of nature both for use in monitoring (natural resource accounting), and for decision-making under uncertainty. Value estimates are needed in order to make the social cost-benefit analysis of different management regimes feasible in the presence of uncertainty; and the application of such approximation methods to the development of instruments and policies for biodiversity conservation.

Socio-economic research is also required to identify the decision-rules to be applied to resource management where the outcomes of our actions include potentially very high and irreversible costs. This includes, for example, the use of robust control or minimax approaches to decision-making under uncertainty. It also involves the development of risk assessment methods for biodiversity change (e.g. Defra-funded research on the development of a generic risk assessment methodology for non-native species). Risk assessment techniques developed for specific plant, animal and human health risks need to be adapted if they are to be applied to biodiversity-related ecosystem service risks.

Finally, socio-economic research is needed to identify the role of institutions such as intellectual property rights (IPRs) and liability rules in the management of diffuse biological risks. The proposed Directive on Environmental Liability with Regard to the Prevention and Restoration of Environmental Damage will establish legal liability (a) for damage to environments harmed by soil and water pollution, and (b) for damage to biodiversity in protected areas. We need to understand how such institutions are likely to change environmental risks.

Recording schemes

In addition to the necessity to develop mechanisms for monitoring the value of biodiversity change, it is worth exploring the role of social groups in recording activities (e.g. an ESRC-funded project « *Amateurs as Experts : Harnessing New Knowledge Networks for Biodiversity* »

www.lancs.ac.uk/depts/ieppp/amateurs/) . Whether this is linked to formal monitoring schemes or simply individuals submitting sightings of particular species of interest, it can be invaluable in engaging society with biodiversity conservation initiatives. For example, County Wildlife Trusts and Environmental Records Centres can act as coordination points for such activities. See, for example, <http://www.cornwallwildlifetrust.org.uk/record/index.htm>

With the demographic profile of the UK becoming skewed towards increasing numbers of older, retired people, is it possible to make better use of this resource in biodiversity monitoring schemes ? If so, and this is a general comment applicable to all ages, do we need research to decide on the most suitable format/mechanism for recording and submitting information – to take account of social background, practical experience ? (e.g. online systems).

Habitat and species action plans at the local and regional level have often been based on information about the biodiversity generated by a great many amateur and professional naturalists over many years. When the plans are implemented, we will need to be able to measure whether we are on the right track. We will need to know what is declining and what is doing well. Up to date accessible records will be essential to the biodiversity process.

Local and national recording schemes for species and habitats have existed in various forms for decades. The production of Biodiversity, the UK Action Plan in 1994 gave added impetus to the search for a Country-wide system of recording biodiversity information that was responsive to local needs. The result is the National Biodiversity Network (NBN: <http://www.nbn.org.uk/>). The NBN is a partnership of statutory agencies and voluntary bodies with interests in a wide variety of biodiversity issues.

Problems

- Many organisations and individuals gather and hold biological data.

- Both national and local data-sets exist but there are not always links between the two.
- Much data is difficult to access and use and there is no central point for biodiversity enquiries.
- Much data may be old and of limited value to many potential data users.
- There is little co-ordination of recording and probable duplication of effort.
- Not all data gathered is validated to the same standards.

Involving people in recording activities

Example 1 : Seasearch

Recreational activities, such as diving, can be utilised for the collection of biodiversity data. See <http://www.seasearch.org.uk/> for further details. This is a particularly good example of how to structure the recording process, with clear instruction on what and how to record, as well as providing training for those who require it (essential if a recording scheme is to be consistent and reliable, minimising – as far as is possible – observer error and variability).

Example 2: the RSPB Big Garden Birdwatch

A record breaking 409,000 people watched their gardens and local parks during the RSPB's Big Garden Birdwatch on 24-25 January. A staggering 8.6 million birds were recorded and 247,000 gardens surveyed. It is thought that the key to *Big Garden Birdwatch's* success is the minimal time commitment necessary for people to take part - just one hour. Although this 'snapshot' may mean some of the regular birds are not present during the hour, the fact that so many people are watching means the results from individual gardens do not affect the overall figures. There is just as much chance of another garden recording more birds than usual. For further details see www.rspb.org.uk/birdwatch/index.asp.

The details are analysed using the combined records from many thousands of gardens. The results from *Big Garden Birdwatch* reflect those from other monitoring schemes. Other details provided enable the RSPB to look at how birds are faring in different geographical areas. This is important since some species, declining across the UK, may actually be stable or increasing in certain parts. The house sparrow is for example, doing much better in Wales than in England. However, despite their value, are such recording schemes unbiased? Are these activities undertaken with equal intensity across the UK, among all social groups? What are the barriers to involving people in the monitoring and evaluation of biodiversity?

5. IMPACTS OF INTRODUCED SPECIES

Aesthetic and intellectual values attach to species which have become associated with a place—part of its natural and human history. These species, however, need not have evolved in situ; they need only have settled in for a long enough time. Many of the non-native species among us have become an integral part of our community and our cuisine. The importance of shared history does not favour the native over the non-native, but settled denizens of both types over the most recent arrivals. We need not be ashamed of our loyalty to the flora and fauna who have become our neighbours over those that aspire to do so; nothing compels us to treat newcomers on equal terms. But many or most of the once- non-native species we encounter are not newcomers, and we have as much reason to be partial to the long-resident non-native as to the truly native (Sagoff, 1999)

Most work on the economics of invasive species has focused on the damage or control costs of plant and animal pests and pathogens. However, socio-economic analysis of the problem can offer much more than an evaluation of the cost effectiveness, efficiency or equity implications of alternative solutions. It can provide an understanding of the relationship between human behaviour and the introduction, establishment and spread of invasive species, and using this it can help to find institutional and economic solutions

to what is recognised to be amongst the fastest growing and least tractable environmental problems.

It is our view that biological invasions (other than agricultural pests and pathogens and human diseases) have been under-researched relative to many of the other UKBRAG cross-cutting themes. The SCOPE Global Invasive Species Programme (GISP; <http://www.gisp.org/>) and the Millennium Ecosystem Assessment (MEA; <http://www.millenniumassessment.org/en/index.aspx>) have summarised our understanding of the extent of the problem. GISP has also elaborated the direct control and management options open to us. But both programmes show that there is still much to be done to improve our understanding of what is driving the introduction of new invaders, and the spread of established invaders. There is also much to be done to improve understanding of the economic consequences of invasions, and hence of the payoff to different control strategies. In particular, we need a better understanding of the international dimensions of the problem.

Biological invasions typically involve a number of countries. One country within the home range of a species is linked to others within the invaded range by pathways involving the movement of goods or people. But unless those responsible face the costs of their actions they have no incentive to take those costs into account. Because of this, the level of control exercised by one country has implications for the risks faced by others. Typically, if control is left to the uncoordinated efforts of individual countries, there will be insufficient control to protect the public interest.

There are 5 main areas where socio-economic research into the problem should be supported:

1. Human factors in the introduction of new species
2. Human factors in the spread of 'established' species
3. The external costs of biological invasions
4. The public good in the control of invasions (including human health)
5. Socio-economic policies for the management of biological invasions

The social and economic causes of biological invasions

There has been comparatively little research into the social and economic causes of biological invasions aside from a selected set of agricultural pests. Invasions may be a consequence of decisions involving the use of exotic species in production and consumption, the conversion and fragmentation of habitat, or the movement of goods and people (Mack et al 2000). Such decisions reflect social customs and norms, as well as the incentive effects of existing institutions, property rights, trade rules and regulations, relative prices and wealth (Perrings et al, 2000; Ruiz and Carlton, 2003). Understanding invasion risks accordingly requires that we understand the factors driving both the invasiveness of species and the invisibility of ecosystems.

Understanding invasiveness involves – in part – understanding the operation of markets involving animal and plant material as traded commodities or as adjuncts. This requires not only that we know how the movement of goods or people is associated with the movement of potentially invasive species (the focus of conventional risk analysis), but also that we understand changes in the pattern and structure of markets, and in the volume and direction of trade.

An introduction is provided by McNeeley (2002) “An introduction to the human dimensions of invasive alien species”, www.iucn.org/biodiversityday/causes.html.

- The importance of propagule pressure in invasion risks is generally accepted. To predict the pressure or particular propagules we need to predict the movement of goods and people associated with those propagules. This requires research into the international markets that provide invasion pathways. Horizon scanning activities are a key area in this respect.

Human factors in the spread of ‘established’ species

Understanding invasibility similarly requires an understanding of the way that human activities affect the vulnerability of ecosystems, and this in turn requires an understanding of the incentives to land users. We need research into the changing patterns of land use, and the consequences this has for the vulnerability of managed and impacted landscapes to biological invasions. While this may be addressed by the jointly-funded Research Councils' Rural Economy and Land Use programme (RELU: <http://www.esrc.ac.uk/relu/>), the programme is in its infancy and hence its success cannot be judged.

- To predict the vulnerability of ecosystems in changing environmental conditions we need to be able to predict changes in land use as a function of changes in regional (EU) and global market conditions.
- The importance of dispersal to the spread of invasive species is also accepted. To predict the dispersal of 'trade' species within an ecosystem we need to predict their distribution within a set of national markets. This requires research into the incentives provided by those markets to move goods and services through an ecosystem.

The external costs of biological invasions

Available estimates of the control and damage costs of biological invasions are quite limited. Pimentel et al. (2000) estimated the annual damage costs from a much wider set of invasive species to be \$137 billion, but this excluded the cost of many important human pathogens such as HIV or SARS. There are estimates of control costs for particular species (screw worm fly, knapweed, leafy spurge, the green crab, the zebra mussel, and the comb-jelly), but little work has been done on the damage costs of species that have indirect impacts on the capacity of ecosystems to deliver valuable ecological services. Nor are there any good estimates of the cost of interspecific interactions, and the way that different species support economic activities.

- To estimate the full external costs of biological invasions requires identification of the changes in ecosystem services that they induce. The value of these services may be derived from the value of marketed goods and services they support.

The control of invasive species is a public good

There is a strong 'public good' element in the control of the risks of biological invasions (e.g. a national quarantine policy to protect against invasive pathogens reduces the risk to all people in the country concerned. If one person benefits from the protection offered by a quarantine policy it does not affect the cost of quarantine. Nor does it reduce the benefits of quarantine to others. However, everyone has an incentive to free-ride on the efforts of others. This is why quarantine is a public service (even if the providers of quarantine facilities are private).

We need to understand the nature of the public good. For example, the commitment of resources to exclusion, control, or mitigation in many cases is sensitive to income. Poor people and poor countries may not be able to commit resources to pest and pathogen control, so increasing the risk to others. If the public good is a 'weakest link' public good, this means that the risk to all depends on the resources available to the weakest.

- To predict the effectiveness of mitigation and adaptation strategies requires research into the incentives associated with different strategies.

Socio-economic policies for the management of biological invasions

The most important point to make is that the science of biological invasions should recognise the fact that invasions are a human problem, with human causes and consequences. The point has frequently been made that invasive species which inflict appreciable harm often (but not always) do so by affecting processes and functions in heavily impacted ecosystems. Agricultural practices that simplify ecosystems by focusing on a small number of crops or livestock, and eliminating predators and competitors, generally make those systems more vulnerable to invasion, less resilient to invasion shocks. Understanding the problem requires understanding of the interactions between social and natural processes (Perrings et al, 2002).

Socio-economic research is needed to uncover:

- anthropogenic factors in the invasiveness of species and the vulnerability of ecosystems,
- the effect of integration and changes in trade, transport and travel on propagule pressure,
- the economic consequences of invasive species impacts on ecological goods and services,
- the cost effectiveness or efficiency of alternative control strategies

The dominant policy options involve either mitigation or adaptation. Mitigation includes pathway measures and actions to prevent the spread of invasive species. It has the effect of reducing the likelihood that a potentially invasive species will be introduced, or that an introduced species will spread.

Adaptation, on the other hand, implies actions that reduce the impact of invasions, but have no impact on the likelihood that they will occur. An evaluation of both options is necessary for the management of the risks of biological invasions.

6. CONSERVATION OF GENETIC AND NATIVE SPECIES DIVERSITY

Where species populations are severely threatened, necessitating the introduction of controls which have direct, tangible societal impacts, do we know enough about:

- how these measures should be introduced/publicised/promoted ?
- socially acceptable alternatives (in particular, for food products) ?
- the effects on dependent communities, and measures to mitigate against negative socio-economic impacts ?

Public understanding and preferences

Conservation of genetic and species diversity also raises questions about public understanding of the issues involved. Much of the media coverage of

genetics concerns GMOs and the associated environmental and health risks (perceived or genuine), and there is still an element of “brave new world” about any mention of the word. Conservation of species is possibly better understood, but also raises questions about native vs non-native species. While general public support could be expected for the conservation of characteristic or flagship species such as English oak trees, the red squirrel, or golden eagles; how do we deal with public perceptions of the importance of (or lack of concern for) species such as the stag beetle or an apparently dull-looking liverwort.

The UKBAP approach relies upon targeted action for 436 priority Species and Habitats. These species and action plans were selected between 1995 and 1998 and are currently being reviewed. What is to say that the review will select the species and habitats that the general public would have selected, if given the choice? Does the public have a preference? Should they have a say in deciding what constitute priority species or habitats? If so, how should we account for this within our planning for biodiversity conservation? An alternative view is to accept that professionals decide the priorities in an open, published way and encourage the selection from this list of species and habitats to carry the conservation message (flagships).

This Research Programme is linked very closely to research theme 5, *Impacts of introduced species*, as many believe that non-indigenous species are one of the main causes of global biodiversity loss and environmental change (Mack et al. 2000; Lodge 2001) and that habitats and communities are more susceptible to invaders if their biodiversity is fragmented or disturbed (e.g. Williamson 1996). Similarly, this Programme also has intimate links with research theme 2, *The role of biodiversity in ecosystem function*, since genetic and native species diversity forms much of the biodiversity that underpins ecosystem processes.

The links between socio-economics and the conservation of genetic and species diversity are very real (see ‘biodiversity’ within Figure 1). Callaghan’s

(2003) review noted a disappointing lack of recognition for the importance of socio-economic issues in the conservation of genetic and native species diversity. Only modelling, of the 7 socio-economic topics listed, was considered relevant, and then was only covered to an inadequate extent. This is disappointing but instructive: there is a clear need to articulate more effectively the importance of socio-economic issues for the conservation of genetics and native species diversity. Similarly, there is a clear need to address the research inadequacies suggested by Callaghan's (2003) preliminary assessment.

Identification of research needs to facilitate delivery of UK BAP

There may be two ways of approaching socio-economic research in relation to genetic and native species conservation:

- Firstly, socio-economic studies of nature conservation should include broad concepts of environmental variety and diversity in their analysis. Connecting general environmental variety with biological diversity requires the (generally reasonable) assumption that more biodiversity will result in a more varied environment (at least on a large enough scale). An example of this is some evidence that environmental variety motivates people to exercise (walk) outdoors. It is difficult to connect the general public to biodiversity (as Defra's valuation study shows, Christie et al., 2004b) but this general recognition of variety is important evidence for supporting the UKBAP. Emphasis can be placed on variety in individual site/habitat cases, and on maintaining the variety of species and their interactions in cases investigating preferences to conserve ecosystems and looking at the environment as a whole.
- Secondly, and more difficult, are studies to specifically examine the value of species diversity over just species. Such an approach needs very carefully designed studies looking at a change in the measured level of diversity, which needs to be distinct from the general concept of variety.

Genetics: an example

Farming and rare breeds: the reduction in genetic diversity brought about by farming methods is another area that might lend itself to socio-economic research. Concerns over the loss of traditional breeds of cattle, sheep and pigs; coupled with an increased interest in organic farming, smaller-scale farm units and local farmers' markets; make this an important area for research.

Species: two examples

Although impossible to be precise, commercial extinction of North Sea cod could occur in two years, or three, or five. This is one example of the socio-economic impacts associated with the collapse of stocks of a native species that is exploited for food. Measures to conserve populations, as proposed by the restrictions (some argue for an outright ban), are also seen as undesirable by some fishermen, their representatives, the fishing communities, and some consumers. This raises a number of important socio-economic issues, including:

- how to conserve diversity in fish stocks (and dependent marine communities), while ensuring economic survival and social cohesion in dependent fishing communities ?
- how to diversify activities following the introduction of restrictions or outright bans ?
- Financial instruments (subsidies/support) to aid fishing communities
- how to encourage changes in consumer preferences ? (the role of the Marine Stewardship Council in promoting responsible management)

There are also clear cases where the conservation of native species (once considered scarce, e.g. the Great Cormorant) is thought to have facilitated large population increases. The increased number and expansion of this species' range has caused great concern to many people who make their living from (or undertake recreation in) aquatic habitats. Representatives from sectors such as fish farming, sports-fishing and commercial fisheries, in

natural and semi-natural water bodies, have expressed their displeasure, continually stressing the harmful effects cormorants have on their business and way of life.

Public understanding (of science)

Genetic variability establishes the primary form of evolution, the adaptability of wild species to human-induced change, including cultivation and domestication, and the basis of special breeds of animals and plants that provide the fundamental basis for modern food production. This is part of natural protective functions that need to be protected. Reducing biodiversity further will mean that additional alterations to ecosystems, especially in unpredictable combinations, could result in a much more devastating weakening of ecological absorptive capabilities. Decreased biodiversity interferes with all manner of essential ecosystem functions.

Conservation of genetic and species diversity also raises questions about public understanding of the issues involved. Much of the media coverage of genetics concerns GMOs and the associated environmental and health risks (perceived or genuine), and there is still an element of “brave new world” about any mention of the word. Conservation of species is possibly better understood, but also raises questions about native vs non-native species. While general public support could be expected for the conservation of characteristic or flagship species such as English oak trees, the red squirrel, or golden eagles; how do we deal with public perceptions of the importance of (or lack of concern for) lesser known (or appreciated) groups.

An overall, holistic approach

There is a need to increase the centrality of biodiversity in social and economic development. In broad terms this may require a livelihoods approach to the conservation of genetics and native species: to incorporate participatory assessments into planning and programme design, to strengthen civil society and to unite environmental assessment into sustainable development strategies.

There would be benefits from a review of the literature associated with the sustainable livelihoods framework and associated critiques. We should perhaps be asking whether there is any potential for learning from work undertaken over the past decade and/or transferring techniques from elsewhere and applying them in a European context? For example, see: Institute of Development Studies: <http://www.ids.ac.uk/ids>; and Livelihoods Connect: <http://www.livelihoods.org>.

The process also requires collaborative and participatory decision making, to include local citizens, key stakeholder groups, and government agencies. O’Riordan & Stoll-Kleemann (2002) consider that a mix of strict protection, inclusive involvement of people inside/adjacent to reserves should be combined with livelihoods and social well-being in all future biodiversity management. There is a need to consider Grass Roots Environmental Management (GREM). This emphasises the integrated management of entire catchments and ecosystems.

7. DEVELOPING TOOLS TO OPTIMISE POLICIES TO FAVOUR BIODIVERSITY

The aim of this theme is to develop the tools to enable society to make decisions and put in place actions and policies based on good science, to optimise biodiversity in the context of sustainable development objectives.

The drivers for this originate from the *Modernising Government* agenda (1999), which seeks to improve the quality, transparency and accountability of the policy-making process at different levels of local, regional and national government; and to enable more joined-up decision-making within the overall objectives of sustainable development. Guidelines on scientific advice in policy-making recommend forward thinking and anticipation of issues that may arise. Such procedures may include surveillance, forecasting and foresight activities. The Millennium Biodiversity Report, *Sustaining the variety of life: 5 years of the UK Biodiversity Action Plan* (UK Biodiversity Group, 2001), emphasises the need to increase efforts to make biodiversity a mainstream consideration in the policies and practices of all sectors. Further,

it calls for “better access to and application of existing information and scientific knowledge, technology transfer and decision support”.

The research required to make biodiversity a mainstream consideration in policies and practices includes:

i. Quantification of the costs and benefits of actions that affect biodiversity :

This includes the application of existing techniques and the further development of those techniques to quantify the costs and benefits (and/or cost-effectiveness) of alternative policy options. This includes the development of measures to uncover peoples’ interest in and preferences for biodiversity, and extends from stakeholder analysis, multicriteria analysis to both stated and revealed preference methods for the valuation of biodiversity change.

ii. Evidence-based decision support:

It is important to improve the evidence-base and techniques for objective decisions in order to ensure that we are optimising the use of our resources, and balancing conflicting interests in an equitable, transparent and sustainable way. All decision methods – cost-benefit techniques, multi-criteria analysis, risk management, etc – depend on estimates of the value of alternative actions. This supposes that we have both an adequate understanding of peoples’ preferences over different outcomes and of the physical consequences of those outcomes. The evidence base for decision-making requires an understanding of the interdependence between the preferences that inform human choices, changes in biodiversity, ecosystem processes and functioning, and the production of goods and services. A growing interest in evidence-based decision making in conservation is reflected in the establishment of the Centre for Evidence Based Conservation (CEBC) at the University of Birmingham (<http://www.cert.bham.ac.uk/research/cebc.htm>).

iii. Evaluation of the efficiency and effectiveness of biodiversity actions:

Achievement of UKBAP objectives and biodiversity policies at least cost requires that we understand how regulations, institutional structures, markets, incentives and advice work. What are the incentives to conserve biodiversity offered by existing markets and institutions? Alternative mechanisms for delivering biodiversity conservation should also be evaluated for their efficiency or cost-effectiveness as appropriate. We need techniques for linking and integrating across sectors (e.g. the correspondence between biodiversity and conservation of landscape and cultural heritage), and the measurement of environmental capital. How do we design policy instruments which interface with large-scale processes and dynamic systems ?

iv. Development of predictive models:

The assessment and management of risk depends on our ability to develop predictive models of the consequences of current actions. Since the risks associated with any actions depend both on human and natural responses, predictive models should have both a socio-economic and an ecological dimension. There is an urgent and important need to stimulate collaborative interdisciplinary cooperation in the development of predictive models. There is scope to achieve this through the National Institute for Environmental e-Science (<http://www.niees.ac.uk/>). The development of GIS-based tools and decision support systems will enable analysis of ecological and socio-economic interactions at large and small spatial scales, including forecasting techniques. It is important to develop methods and share best practice in awareness raising, communications and conflict resolution.

8. CURRENT RESEARCH PROGRAMMES ADDRESSING THESE ISSUES

There are several national and international programmes which include activities relevant to a number of cross-cutting themes. This list is not intended to be exhaustive. Rather, it presents a range of initiatives from different sectors of the biodiversity research community.

DIVERSITAS is a major international science programme comprising three core projects, all of which are highly relevant to BRAG. Core project 1, *bioDISCOVERY*, deals with the identification of existing taxa and the sources of pressure on those taxa. Core project 2, *ecoSERVICES*, deals explicitly with the relationships between biodiversity and ecosystem functioning and the links to the provision of services. There is a strong emphasis on socio-economic feedbacks. Core project 3, *bioSUSTAINABILITY*, specifically addresses the underlying socio-economic reasons for changes in human behaviour that drive biodiversity change and hence changes in processes, goods and services. It also addresses the development of appropriate policy instruments for the sustainable use of biodiversity, especially where there is uncertainty either about the causes or the effects of biodiversity change. DIVERSITAS has an international focus, but since much of the context of the UKBAP involves change at the international level this is relevant to BRAG.

EuroBiodiversity

http://www.esf.org/esf_article.php?language=0&article=435&domain=3&activity=7 is a new European Science Foundation (ESF) EUROCORES initiative that shares many of the aims and features of the DIVERSITAS science plan, described above. Relevant elements include *Understanding impacts of biodiversity change on ecosystem services* and *Exploring the interface between biological and social systems*. The EUROCORES scheme provides a flexible framework which allows national basic research funding organisations to support top class European research. EuroBiodiversity is expected to start funding European Collaborative Research Projects (CRPs) from the end of 2005 onwards.

MARBEF is a marine Network of Excellence funded under Framework 6. It has substantial elements of interdisciplinary (socio-economic, environmental and ecological) science aimed at exploring the relationship between biodiversity and ecosystem functioning in marine systems. It aims at integrating research efforts by forming a dedicated group of marine scientists and institutes and creating a virtual European institute with a long-term

research programme and dedicated links with industry and the public at large. This involves besides coordination of research the training, exchange and outreach activities in several relevant fields of science, including marine ecology and biogeochemistry, fisheries biology, taxonomy and socio-economic sciences. Better integration of research is also required to support the legal obligations of the EU and its member states and associated states for the Convention for Biological Diversity, the OSPAR and Barcelona conventions as well as several EU directives (Bird Directive, Habitat Directive, Water Framework Directive). The network will also improve links with the large and growing number of industries depending on the sustainable use and exploitation of marine biodiversity. This includes tourism, fisheries and aquaculture but also new industries that explore and commercialise marine genetic and chemical products.

IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) is a marine programme presently being developed by SCOR and IGBP. IMBER focuses on open ocean pelagic systems but includes continental margins and explicitly covers the relationship between biodiversity and ecosystem functioning in these systems. However, there is little socio-economic material apparent in the draft implementation plan.

BIOECON is both a programme of biodiversity research and a network of social scientists concerned with the economics and policy of biodiversity conservation. It is focused on European biodiversity but includes studies of biodiversity change and biodiversity policy in developing countries. Within Europe it includes studies of the implications of changes in the Common Agricultural and Fisheries Policies, and involves evaluation of alternative policy instruments, institutions, property rights and market structures.

RELU has the overall aim to conduct research on the connections between rural economy and land use. The outputs of RELU will inform the achievement of sustainable rural development, encompassing the social and economic vitality of rural areas and the conservation and protection of the rural environment. RELU is funded jointly by the Economic and Social Research

Council, the Biotechnology and Biological Sciences Research Council and the Natural Environment Research Council, with additional funding from the Scottish Executive Environment and Rural Affairs Department and the Department for Environment, Food and Rural Affairs. It has three themes, all relevant to biodiversity: the integration of land and water use; the environmental basis of rural development; and economic and social interactions with the rural environment. Proposals are invited that address at least one of the following research questions:

- i. What are the drivers and processes of change in rural economy and land use, with a focus on understanding the dynamics of and barriers to change (social, economic, technological and environmental) from an integrated perspective?
- ii. How to assess their medium/long-term effects, i.e. predicting and evaluating the consequences within a 20-year horizon. (The time horizon means that the programme will not address the very long-term effects of climate change)
- iii. What are the most appropriate mechanisms for integrating social, economic and environmental goals in the monitoring and management of change over this time frame?

COST-IMPACT (<http://www.cost-impact.org/>): Costing the impact of demersal fishing on marine ecosystem processes and biodiversity. The European Union currently faces potentially conflicting objectives of maintaining sustainable fisheries in European waters with all the economic benefits afforded to the community through the fishing industry, whilst at the same time maintaining biodiversity and avoiding negative effects on the environment. To date the economic arguments controlling fishing effort have focused on costs of fishing per unit catch and maintenance of sustainable fish stocks for the future. The current objectives of the EU are to control the environmental impact of fishing and to strike a balance between economic needs and protection of the environment. This EU funded project uses a multi-criteria analysis to enable managers to balance the benefits of trawl fishing with the losses of marine biodiversity.

SOBIO is a current 6th Framework Programme aimed to stimulate social science research relevant to the management of ecosystems. An overview of current and existing knowledge in this area is being undertaken. The project summary outlines the lack of social (rather than economic) research on biodiversity and ecosystem management. Phase 3 of the work will be to develop a social research programme in the field of ecosystem and biodiversity management and therefore has direct relevance to this theme (ECNC, 2004).

AMATEURS AS EXPERTS is an ESRC project to look at how to improve use of amateurs in meeting recording needs for the UK BAP ('Amateurs as Experts: Harnessing New Knowledge Networks for Biodiversity'). This is a cross-disciplinary research study, involving sociologists, anthropologists (IEPPP, Lancaster University) and natural scientists (Natural History Museum, London). The study has five primary aims: to advance understanding of the social dimensions of effective biodiversity protection policies, in the UK and beyond; to use ethnographic research methods to understand the social practices surrounding scientific knowledge generation and to understand scientist-public interactions; to enrich the self-reflective capacities of the biodiversity community by observing and reporting back on participatory processes underway; to stimulate and contribute to UK debates regarding biodiversity policy and the relationships within it between science and society; and to provide an improved basis for understanding the conditions required for an improved public engagement with science and expert-led policymaking.

9. RESEARCH NEEDS AND KNOWLEDGE GAPS

Defra's expectations of the contribution of socio-economics to the process of delivery for the UKBAP are that it will:

- help to articulate the justification for investing resources in biodiversity conservation, for example by the valuation of ecosystem services;
- assist in developing and formulating policy, for example by

systematically comparing the outcomes of applying different policy scenarios

- help in devising efficient and effective ways of delivering policies, for example identifying delivery mechanisms that are most likely to find acceptance
- help in evaluating policies for their cost-effectiveness and value for money, for example by providing us with indicators, and helping us understand the wider impact of policies for biodiversity conservation.

The group has considered these expectations along with the broader requirements of a programme of socio-economic research into biodiversity change in the UK, and has identified the following research priorities (figures in parentheses indicate the UK BRAG research themes to which each research priority relates):

Key to research themes

1. conservation of genetic and native species diversity
2. impacts of introduced species
3. roles of biodiversity in ecosystem function
4. monitoring of biodiversity and evaluation of actions
5. management of habitats and ecosystems
6. developing tools to optimise policies to favour biodiversity

Socio-economic research priorities

1. Test the role of biodiversity in sustainable development (1,2,3,4,5,6)
2. Test the cost effectiveness/efficiency of existing conservation efforts, and the incentives to conserve biodiversity offered by existing markets and institutions (1,5,6)
3. Understand the relationship between biodiversity change and the production of goods and services (2,3,4,5,6)
4. Develop the socio-economic dimensions of an ecosystem approach (1,2,3,4,5,6)

5. Improve techniques for valuing the ecological effects of biodiversity change (4,5,6)
6. Understand people's perceptions of the value of biodiversity (3, 5, 6)
7. Improve application of existing decision methods (CBA) (3, 5, 6)
8. Develop decision-methods to deal with fundamental uncertainty, irreversibility and threshold effects (1,2,5,6)
9. Understand the consequences for the movement of species of changes in regional and global trading systems (2,3,5,6)
10. Understand the spatial dimension of interactions between human activities and ecosystem change (1,2,3,4,5,6)
11. Identify the social rate of return on environmental investments (1, 2,3,4,5,6)
12. Develop natural resource accounts for biodiversity as a portfolio of natural assets so as to assure the resilience of ecosystems (1,2,3,4,5,6)

We take each of these research priorities in turn:

1. Test the role of biodiversity in sustainable development

We need to identify examples of approaches that integrate biodiversity, livelihoods and economic objectives in each key sector, and conduct a detailed assessment of their impacts on the ground, including their contribution to food, health, income, livelihood security and ecosystem services (as well as cultural and spiritual well-being). These impacts should then be compared with those of more conventional non-biodiversity based approaches. Such case studies would also serve to demonstrate the types of activities and approaches that can be supported to integrate biodiversity, development and economic objectives. The selection of case study examples could be guided by the principles of the Ecosystem Approach.

Furthermore, the case studies should also examine the wider policy and governance context in which these examples exist to identify the 'external' conditions needed to better support such approaches and facilitate their wider replication and adoption - for example, secure land tenure, strong representative local peoples' organisations, democratic local governance,

effective decentralisation, participatory and adaptive policy processes, flexibility to experiment, feedback from local experience, institutional coordination, and so on. Within a given country, such findings could be distilled from case studies in different sectors and regions.

2. Test the cost effectiveness/efficiency of existing conservation efforts, and the incentives to conserve biodiversity offered by existing markets and institutions

It is important to evaluate both the cost effectiveness of regulations/policy instruments designed to achieve a specified level of protection, and the efficiency of resources allocated to the protection of biodiversity.

It is also important to evaluate the incentives to conserve biodiversity offered by existing markets and institutions.

3. Understand the relationship between biodiversity change and the production of goods and services

Research needs to be undertaken collaboratively between social and natural scientists to explore the links between biodiversity changes, ecosystem processes and the production of valuable goods and services. This work should explore the role of biodiversity in protecting the resilience of ecological-economic systems in order to improve our ability to predict the effects of biodiversity change.

Current research focuses on describing the relationship between levels of biodiversity and ecosystem processes that may or may not underpin the production of goods and services. Future experiments should explore the effects of biodiversity loss across a range of trophic levels on processes known to underpin the production of goods and services. Such experiments need to be carried out at the spatial and temporal scales which are relevant to society.

4. Develop the socio-economic dimensions of an ecosystem approach (1,2,3,4,5,6)

The research needs identified above may best be achieved through predictive models of human systems and ecological systems, similar to the approach advocated under the ecoSERVICES DIVERSITAS science plan (<http://www.diversitas-international.org/scientificprogramme/CP2.html>). This requires a much better understanding both of the interactions between the natural and social dimensions of coupled processes, and of the basis of social choice/decision making in the sustainable use of biodiversity. The ecosystem approach adopted by the CBD is consistent with this, but needs to be strengthened in its socio-economic dimensions.

5. Improve techniques for valuing the ecological effects of biodiversity change (4,5,6)

Methods for valuing some attributes of biodiversity are reasonably well developed. There is much to be done, however, to improve the valuation of biodiversity's contribution to changes in ecosystem processes and functioning. Production function methods need to be extended to include ecological processes and functioning.

6. Understand people's perceptions of the value of biodiversity (3, 5, 6)

Methods for eliciting statements of preference are reasonably well-developed. It is important to apply best practice techniques to uncover stakeholders' perceptions of the value of biodiversity, and of the role of biodiversity in provision of goods and services. In particular, it may be useful to develop appropriate choice experiments to test people's valuation of biodiversity-based ecosystem services (e.g. Christie et al., 2004a: "A valuation of biodiversity in the UK using choice experiments and contingent valuation"; and Eggert and Olsson, 2004: "Heterogenous preferences for marine amenities: a choice experiment applied to water quality").

Multi-Criteria Analysis offers scope for uncovering the tradeoffs that people are prepared to make when environmental concerns are one among many. Applications to biodiversity should be encouraged.

7. Improve application of existing decision methods (CBA) (3, 5, 6)

Cost-Benefit Analyses of biodiversity projects still tend to rely on the monetary valuation of all variables, and do not effectively handle variables that cannot be valued in monetary terms. While this remains the most appropriate way to evaluate public investments in biodiversity conservation, CBA should incorporate all relevant impacts – whether marketed or not. CBA should not be applied if it is inappropriate.

8. Develop decision-methods to deal with fundamental uncertainty, irreversibility and threshold effects (1,2,5,6)

Two aspects of biodiversity loss are especially difficult for decision-making. First, species loss is irreversible. Second there is uncertainty about the effects of biodiversity change both on ecosystem functioning and on the production of economic goods and services. Socio-economic research is needed to identify decision-rules for problems involving the uncertain and irreversible consequences of biodiversity change. This involves the implementation of the precautionary principle.

9. Understand the consequences for the movement of species of changes in regional and global trading systems (2,3,5,6)

One of the most significant effects of globalisation and the growth in world trade is the movement of species between ecosystems. Research is required to understand the effect of changes in international and national markets on the introduction and spread of potentially invasive species. In particular, it is important (a) to explore how changes market conditions affect land use and the vulnerability of ecosystems to biological invasions, (b) to estimate the damage costs of invasions and their control, and (c) to develop appropriate predictive models.

The general question to be answered is how do changes in economic activities and structures of governance affect the vulnerability of ecosystems to biological invasions, the costs of invasions and their control? At a regional level it is important to understand the implications of the accession of Eastern European states for the risks of biological invasions across an expanded European Union. This requires research into the impact of change in land use,

production or consumption on ecosystem characteristics, and an evaluation of the effect of this on vulnerability to biological invasions. We need to understand, for example, the implications of the introduction of decoupled direct payments together with a progressive reduction of such direct payments (degressivity and modulation), increasing cross-compliance measures, the introduction of long-term environmental set-aside and the enhancement of Rural Development measures on land allocation decisions in the EU.

10. Understand the spatial dimension of interactions between human activities and ecosystem change (1,2,3,4,5,6)

The principle of subsidiarity relates to the level at which problems should be addressed. In the case of biodiversity change this depends on the spatial and temporal spread of the causes and effects of that change. It is important to identify a spatially explicit framework for evaluation of appropriate policy responses in order both to be able to apply the principle of subsidiarity in a scientifically robust way, and to coordinate regulations involving different jurisdictions.

11. Identify the social rate of return on environmental investments (1, 2,3,4,5,6)

To prioritise biodiversity conservation efforts we need to know which public investments yield the highest benefits. Where there are alternative conservation projects that may be established, these should apply appropriate project appraisal (CBA) techniques. In order to evaluate investments in conservation and sustainable use of biodiversity relative to other investments a more general analysis is required. It would be useful to establish the social rate of return on environmental investments in the restoration, protection generation, and sustainable use of natural capital.

12. Develop natural resource accounts for biodiversity as a portfolio of natural assets so as to assure the resilience of ecosystems (1,2,3,4,5,6)

The economic equivalent of ecological monitoring involves the construction of natural resource accounts (NRA). Accounts have been developed for a few biological resources (fish and forests, for example) but not for the diversity of

species or habitats, and not for the UK. It would be useful to develop NRA for biodiversity as a portfolio of natural assets.

ANNEX 1

High priority research questions regarding socio-economics and nature conservation, and their coverage within the BRAG Research Programmes (Callaghan, 2003).

Topic	Question ¹	BRAG Research Programmes ²						
		A	B	C	D	E	F	All
Modelling	How can we better integrate economic and ecological models to inform environmental decisions?	●	■		■	■	■	☺
Equity	How does equity between individual people, nations, and over generations relate to sustainability?		○				○	☹
Indicators	Can we redirect development by augmenting traditional indicators with biophysical indicators?		○		■	○	○	☹
Limits	What properties of ecological and social systems act as "limits" to development?				■	○	○	☹
Trade & Development	How do current policies to promote development through capital mobility affect biodiversity?		○		○	○	■	☺
Valuation	What are the non-market services provided by ecosystems, what are they worth and what is the trend in their supply?		■		■	■	■	☺
Policy Instruments	How should systems of tradable environmental permits and environmental tax reform be implemented?		●		○	○	■	☹

¹Priority research questions were adapted from those identified by IIEE (2003).

²The BRAG Research Programmes are: A - Science for the conservation of genetic and native species diversity; B - Addressing the impacts of introduced species; C - Understanding the roles of biodiversity in ecosystem function; D - Science-based monitoring of biodiversity and evaluation of actions; E - Science-based management of habitats and ecosystems; F - Developing tools to optimise policies to favour biodiversity; All – All six research programmes combined. Coverage of the priority socio-economic research questions within these programmes is assessed as follows:

[blank] – socio-economic question largely irrelevant to the programme;

○ – socio-economic question relevant to the programme but seemingly excluded entirely;

● – socio-economic question relevant to the programme and included to a seemingly inadequate extent within the context of the programme;

■ – socio-economic question relevant to the programme and included to a seemingly adequate extent within the context of the programme.

Coverage of socio-economic questions within all six research programmes is assessed as follows:

☹ - following current programmes, socio-economic question could only be answered to a seemingly minor extent;

☺ - following current programmes, socio-economic question could be answered to a seemingly moderate extent;

☺ - following current programmes, socio-economic question could be answered to a seemingly major extent.

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