UK BRAG
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Research Needs for UK Biodiversity

A summary of the important knowledge gaps, identified by the UK Biodiversity Research Advisory Group, 2003-2006

Edited by Richard Ferris

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Website: www.defra.gov.uk

Published by the Department for Environment, Food and Rural Affairs

Product code PB12708

Front cover photo credits:
Monitoring seabird populations. Paul Glendell, Natural England
A well-connected landscape comprising varied habitat types. Monsal Dale, Derbyshire, Chris Cheffings, JNCC

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Contents

Through its engagement with experts from the scientific research and policymaking communities, the UK Biodiversity Research Advisory Group (UK BRAG) has identified important knowledge gaps associated with a number of cross-cutting biodiversity research themes. Specialist sub-groups were asked to consider these gaps and the research needed to address them. The aim of this process was to identify current biodiversity research priorities and present them to both research funders and providers so that they can assess how best to contribute to resolving current gaps in the evidence base. This report documents the recommendations made by the sub-groups, identifies common themes and sets out the main priorities for biodiversity research in the UK.

Throughout the process, the UK BRAG has adopted an interdisciplinary approach, addressing issues from a social science and economic perspective alongside the natural sciences. This assessment has identified a number of generic priorities for biodiversity research:

- Apply best practice techniques to uncover the values of biodiversity for different stakeholders;
- Understand perceptions about the types of ecosystem society wants;
- Evaluate the effectiveness of current incentives to conserve biodiversity;
- Test the cost-effectiveness and efficiency of existing conservation efforts;
- Increase the capacity of existing decision methods to deal with complex environmental impacts.

The remaining research priorities can be categorised under the four broad headings set out below. These combine topics from the seven cross-cutting themes addressed by the UK BRAG (socio-economic issues; the role of biodiversity in ecosystem function; monitoring and surveillance of biodiversity and evaluation of actions; habitat and ecosystem management; conservation of genetic diversity; the impact of non-native species (NNS); climate change and adaptation).

1. Definition, Distribution and Status of Biodiversity

This incorporates surveillance and monitoring and, whilst not necessarily research, their importance has been recognised across many research themes.

- Improve interdisciplinary use of data in order to make links between changes in the status of biodiversity and the drivers of change;
- Ensure protection for long-term data, since these are vital for identifying the causes of change;
- Make best use of existing monitoring initiatives and ensure that results are ‘fit for purpose’;
- Produce guidance and standards to help make data more comparable and accessible to secondary users;
- Undertake a GB audit of status and trends of terrestrial and aquatic non-native species (NNS), including monitoring of trends in establishment, spread and impact of critical non-native taxa;

- Assess the environmental, economic and social risks and impacts of NNS;
- Identify, quantify and characterise present pathways and vectors for the introduction and spread of NNS into and within GB;
- Define and classify ecosystem functions, including resilience; and develop techniques by which they can be measured;
- Develop and apply a unified system for auditing the distribution of priority habitats within the UK, compatible with existing European schemes;
- Undertake targeted monitoring of climate change and atmospheric pollution impacts on biodiversity, including in marine ecosystems;
- Develop headline indicators of climate change impacts on biodiversity;

2. Ecosystem Management

The need for management to occur at a range of scales (site, habitat, ecosystem, landscape, region etc.) has been recognised. As well as developing and testing new approaches, it is important to evaluate the effectiveness of current management strategies for site maintenance and also, in the face of environmental change (see below), there is a need to understand the effectiveness of implementation of landscape-scale initiatives.

- Strengthen the socio-economic dimensions of an ecosystem approach;
- Appraise the true economic costs and benefits of NNS, including incentives for control;
- Initiate research to address social perceptions, awareness and resolution of NNS conflicts;
- Evaluate the most effective approaches to management of NNS, and the ecosystem consequences of their removal;
- Develop predictive models and decision support systems to improve ecosystem management;
- Establish how ecosystem management, at different scales, can contribute to climate change adaptation strategies for biodiversity;
- Appraise the specific landscape or management conditions over which populations of different species with different life history traits are likely to become genetically isolated, and also establish their abilities to disperse to new sites;
- Undertake genetic and field-based studies to evaluate the fitness consequences of genetic isolation versus population networks in the context of different population sizes, different environmental gradients and different species attributes;
- Undertake further development of conservation programmes aimed at linking the above types of genetic information with targeted management action.

3. Ecosystem Goods and Services

The importance of biodiversity to the functioning of ecosystems, in particular the provision of goods and services, has been recognised in many themes. A number of fundamental research questions remain to be addressed, including:

- Improve understanding of the links between biodiversity and ecosystem function (with reference to resilience and stability);
- Identify the ecosystem processes, or functions, which underpin the provision of ecosystem goods and services, and the strength of the relationship between biodiversity and these processes;
- Improve valuation of the contribution of biodiversity to changes in ecosystem processes and functioning;
- Identify the environmental limits of acceptable change;
- Assess changes in ecosystem function in response to environmental change;
- Evaluate the use of ecosystem function as a surrogate measure for biodiversity and ecosystem health (what is a healthy ecosystem?);
- Identify the impact of climatic changes on soil biodiversity.

4. Environmental Change

This is an important cross-cutting issue, with priority actions required within a number of themes. It is not restricted to climate change, with processes such as atmospheric pollution and eutrophication being important drivers.

- Improve techniques for evaluating the ecological effects of biodiversity change;
- Understand how changes in economic activities and structures of governance affect the vulnerability of ecosystems to biological invasions, the costs of invasions and their control;
- Improve our understanding of how established NNS may respond to future environmental change;
- Assess the likely response of different species and populations to large scale environmental change, from a genetic perspective;
- Investigate the implications of climate change on wetlands;
- Managed retreat: improve understanding of the ecological, social and economic costs and benefits;
- CO_2: improve understanding of feedbacks in natural and anthropogenic systems and their implications for adaptation and mitigation strategies.

Next Steps

Working in a responsive mode, recognising new directions and priorities for the biodiversity research community, both nationally and internationally, the UK BRAG has taken a key role in identifying research across a number of developing areas. There remains a need to maintain an overview of research activity in existing themes, necessitating periodic sub-group updates. In addition, the UK BRAG needs to keep abreast of developing research agendas in the newer, transdisciplinary research themes, e.g. biodiversity and ecosystem function. However, having identified an extensive suite of research needs, the UK BRAG needs to move on to highlight and promote priority biodiversity issues among the research and funding communities. This is recognised in the UK BRAG's new terms of reference, which propose use of 'a variety of mechanisms to take forward its agenda, which might involve organisation of workshops, seminars and conferences, including an annual report and research symposium; providing an opportunity for engagement with a broader constituency, and dealing with specific and cross-cutting issues.'

Underpinning this is a need to ensure that research priorities are promoted more effectively, so that they are more likely to be incorporated within the strategies and programmes of research funders, or taken forward in other ways.

The UK BRAG will be working in partnership with a number of bodies in order to meet these objectives. Activities include an annual science conference as part of the Annual Meeting of the British Ecological Society; engagement with the Environmental Research Funders' Forum (ERFF); and contributing to the BioSTRAT project, which aims to provide support to the European Platform for Biodiversity Research Strategy (EPBRS) and national biodiversity platforms.

Introduction

The Biodiversity Research Advisory Group (UK BRAG) was set up following the publication of *Science in Action for Biodiversity* (Defra, 2001), a report of the Biodiversity Research Working Group (BRWG). During the period 2003-2006, the UK BRAG set two objectives:

- Promote and facilitate biodiversity research that seeks to support the delivery of UK Biodiversity Action Plan (UK BAP) objectives, and hence the Convention on Biological Diversity (CBD), including the needs of species and habitat action plans and cross-cutting issues; and
- Coordinate effective and efficient UK engagement with European and international biodiversity research issues and hence fulfil the role of a national biodiversity research platform.

To fulfil these objectives, a UK BRAG Secretariat, hosted by the Joint Nature Conservation Committee (JNCC), was established under a Service Level Agreement (SLA) with Defra.

In its role as the national biodiversity research platform for the UK, the UK BRAG works closely with the European Platform for Biodiversity Research Strategy (EPBRS). Members from both the policy and science communities take an active role in EPBRS meetings, and the UK BRAG's recommendations are mindful of the priorities identified by the EPBRS. For further information, see Appendix 1. The UK BRAG's members are drawn from a wide variety of organisations, representing the research, policy making and practitioner communities. For a full list of members, see Appendix 2.

The report, *Science in Action for Biodiversity* (Defra, 2001), identified six cross-cutting themes, as a framework for biodiversity research in the UK. Through its engagement with experts from the scientific research and policymaking communities, the UK BRAG has identified important knowledge gaps associated with these research themes. Specialist sub-groups were asked to consider these gaps and the research needed to address them. The aim of this process was to identify current biodiversity research priorities and present them to both research funders and providers so that they can determine how they can best contribute to resolving current gaps in the evidence base. This report documents the recommendations made by the sub-groups, identifies common themes and sets out the main priorities for biodiversity research in the UK.

Climate change poses a threat to UK's biodiversity. However, our understanding of the impacts is incomplete and while some mitigation measures may be possible, there is a need to explore adaptation options. The research needs associated with climate change adaptation have therefore been considered as an additional theme.

Furthermore the UK BRAG recognises the importance of addressing cross-cutting socio-economic issues associated with biodiversity conservation. The UK BRAG adopted an innovative approach in bringing together scientists and policymakers to identify research needs in a truly interdisciplinary exercise.

The UK BRAG has made use of specialist sub-groups to address each of the specific research themes, in order to make use of particular expertise and widen the engagement of the Group. They have reported to the main UK BRAG, and approved reports can be accessed via the UK BRAG webpage at www.ukbrag.org.

This report highlights the research topics identified by the UK BRAG under the following themes:

- Socio-economic issues
- The role of biodiversity in ecosystem function
- Monitoring and surveillance of biodiversity and evaluation of actions
- Habitat and ecosystem management
- Conservation of genetic diversity
- The impact of NNS
- Climate change and adaptation

1. Socio-economic issues

Background

Social sciences, including environmental economics, have much to contribute to the process of delivery for the UK BAP and commitments at the European level. Integration of socio-economics with natural sciences will contribute to:

- Articulating the justification for investing resources in biodiversity conservation, for example by the valuation of ecosystem services;
- Developing and formulating policy, for example by systematically comparing the outcomes of different policy scenarios;
- Devising efficient and effective ways of delivering policies, for example by identifying delivery mechanisms that are most likely to find acceptance;
- 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.

A UK BRAG sub-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 research priorities set out below.

Research themes and priorities

Test the role of biodiversity in sustainable development

Biodiversity drives the ecosystem functions that underpin the provisioning of the ecosystem services critical to human wellbeing (Millennium Ecosystem Assessment, 2005). An understanding of these linkages is being established, but the complexity involved requires ongoing work.

- 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);
- Compare these impacts with those of more conventional non-biodiversity based approaches;
- Use case studies to examine the wider policy and governance context in which these examples exist, in order to identify the 'external' conditions needed to better support such approaches and facilitate their wider replication and adoption.

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

Given the limited resources available to meet ambitious and important biodiversity goals, it is essential that conservation efforts are effective and efficient. There is much to be learnt from past experiences but to date there has been little research into the cost-effectiveness of conservation projects and policies. Providing incentives to conserve and use biodiversity in a sustainable manner – incentives that reflect the true value of the natural environment – is

necessary to overcome the numerous market failures that exist. There is much to learn from the various incentive systems that have already been established, such as payments and markets for ecosystem services.

- Evaluate both the cost effectiveness of regulation or other policy instruments designed to achieve a specified level of protection, and the efficiency of resources allocated to the protection of biodiversity;
- Evaluate the incentives to conserve biodiversity offered by existing markets and institutions.

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

Although there is considerable and growing evidence of the value of ecosystem goods and services, there is far less known about the importance of biological diversity *per se* in supporting these services. A more nuanced understanding is needed of the role of biodiversity in supporting ecosystem service provision and ensuring ecosystem resilience against shocks.

- Undertake collaborative research between social and natural scientists, to explore the links between biodiversity changes, ecosystem processes and the production of goods and services. This work should explore the role of biodiversity in protecting the resilience of ecological-economic systems[1] in order to improve our ability to predict the effects of biodiversity change;
- 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.

Improve techniques for valuing the ecological effects of biodiversity change

Valuation of the benefits of changes in biodiversity can be a powerful tool for understanding and advocating the importance of conservation. However, existing valuation techniques have a number of limitations, particularly relating to understanding the role of biodiversity for ecosystem function, and more research is urgently required.

- 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.

Develop the socio-economic dimensions of an ecosystem approach

The ecosystem approach is a useful framework for dealing effectively with complex sustainable development issues. The approach strongly endorses consideration of the social and economic context of biodiversity challenges, but there are limited tools and models available for doing so.

[1] Ecological economics is a transdisciplinary effort to link the natural and social sciences (specifically ecology and economics) in order to develop a deeper scientific understanding of the complex linkages between human and natural systems. See Costanza, R., ed. (1991) *Ecological Economics: The Science and Management of Sustainability*. Columbia University Press, New York.

- Develop predictive models of human systems and ecological systems, similar to the approach advocated under the ecoSERVICES DIVERSITAS science plan (Bulte, Hector and Larigauderie, 2005). 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.

Understand people's perceptions of the value of biodiversity

Participatory and multi-criteria approaches can help to elucidate the complexity of people's perceptions of the value of biodiversity, to resolve environmental conflicts, and to promote public understanding. These approaches have been employed successfully across a range of environmental applications, but there is scope for more work in the biodiversity field.

- 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;
- Use Multi-Criteria Analysis to uncover the trade-offs that people are prepared to make when environmental concerns are one among many. Applications to biodiversity policy should be encouraged.

Improve application of existing decision methods

Cost-Benefit Analyses (CBA) of biodiversity projects still tend to rely on the monetary valuation of all variables, and do not handle variables that cannot be valued in monetary terms in an effective manner. There is a need to increase the capacity of existing decision methods, such as CBA, to deal with complex environmental impacts that are not easily or appropriately monetised.

- Improve applicability of CBA, and test the technique rigorously. While CBA remains the most appropriate way to evaluate public investments in biodiversity conservation, it needs to incorporate all relevant impacts – whether marketed or not.

Develop decision-methods to deal with fundamental uncertainty, irreversibility and threshold effects

In situations of fundamental uncertainty, with the risk of large-scale, irreversible and harmful threshold effects, standard decision methods, such as non-stochastic CBA, are inadequate. Innovative decision methods are required that shape policy to reflect these serious risks.

- Initiate socio-economic research to identify decision-rules for problems involving the uncertain and irreversible consequences of biodiversity change. This involves the implementation of the precautionary principle.

Understand the consequences of changes in regional and global trading systems on the movement of species

NNS have severe detrimental impacts on biodiversity worldwide (Millennium Ecosystem Assessment, 2005), and yet there is still only a limited understanding of the costs of NNS and likely future trends in these costs.

- Improve understanding of the effect of changes in international and national markets on the introduction and spread of potentially NNS. In particular, it is important (a) to explore how changes in 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;
- Investigate how changes in economic activities and structures of governance affect the vulnerability of ecosystems to biological invasions, the costs of invasions and their control;
- 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.

Understand the spatial dimension of interactions between human activities and ecosystem change

Social and natural systems are intricately linked, and this dimension requires further exploration.

- 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.

Assessing the impact of offshore windfarms on Common Scoter. EIS Rees, University of Wales, Bangor.

Identify the social rate of return on environmental investments

Research is needed to understand which environmental investments yield the highest social rates of return.

- Assess which public investments yield the highest benefits in order to prioritise biodiversity conservation efforts. Where there are alternative conservation projects that may be established, these should apply appropriate project appraisal (e.g. CBA) techniques;
- Undertake a more general analysis, in order to evaluate investments in conservation and sustainable use of biodiversity relative to other investments. 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.

Develop natural resource accounts for biodiversity as a portfolio of natural assets so as to assure the resilience of ecosystems

In order to provide a comprehensive picture of a country's assets, it is vital to have information on the state of natural capital as well as physical and social capital. Natural resource accounts for biodiversity would help to monitor changes over time and space.

- Develop natural resource accounts for biodiversity as a portfolio of natural assets.

2. The role of biodiversity in ecosystem function

Background

This theme seeks to understand the mechanisms and processes that underpin ecosystem function, in order to gain a fuller understanding of the role that biodiversity may play in maintaining such processes. A number of specific research objectives have been identified, within a series of broad themes. These objectives are not exhaustive but should be considered as examples of research required to meet the headline messages.

Prior to addressing any new research, the need for two reviews was identified:

- A summary of what is currently known regarding the interactions between biodiversity and ecosystem goods and services with the aim of identifying the main gaps and target areas;
- An investigation to identify those ecosystems whose goods and services are most under threat.

Research themes and priorities

Linking biodiversity with ecosystem function

There is a lack of knowledge regarding how ecosystems function and how biodiversity contributes to that function, across a range of scales. The behaviours of systems following biodiversity loss and thresholds for breakdowns in functioning have yet to be identified. Key issues are the definition of thresholds of functioning, redundancy, resilience and stability.

- Develop a classification scheme of ecosystem functions, to provide a common currency understood across different ecosystems;
- Undertake research regarding the effect of biodiversity changes or species loss on ecosystem function and the resilience and stability of ecosystem function (the difficulty of formulating a testable hypothesis needs to be recognised. It may prove impossible to answer this question, due to the many definitions of ecosystem functionality, and the large number of species in an ecosystem). Inconsistencies highlighted in previous studies require that example protocols are put forward, in order to contribute more robust evidence;
- Establish a better understanding of the metabolic processes of various species at different stages of their life cycles and how these are expressed at the ecosystem level. In order to address this topic, focused projects need to be developed;
- Address the interaction effects of redundancy and resilience;
- Examine the decomposition function: how resilient is the decomposer community in various ecosystems (especially different soils and marine/freshwater sediments). Examine plant/fungal/microbial interactions and the effects of changes in microbial assemblages. Can composition of functional groups be assessed as opposed to species?

Soil sampling on the Stiperstones, Shropshire. Richard Pywell, CEH.

- Develop models to assess the importance of factors in gas regulation and primary production, genetic exchange and dispersal, nutrient cycling, and the roles of different taxa in the delivery of these processes in marine ecosystems. In particular, issues regarding biodiversity and water column (pelagic) processes should be examined;
- Assess microbial community structure and function in a range of ecosystems, especially including scaling up from the laboratory scale to the field and landscape scales.

Linking biodiversity, ecosystem function and the provision of services

Loss of biodiversity is likely to have a variety of effects on ecosystem function, resilience to change, the provision of goods and services and human well-being.

- Identify the ecosystem processes, or functions, which underpin the provision of ecosystem goods and services, and the strength of the relationship between biodiversity and these processes. A range of appropriate scales and ecosystem services should be considered, while recognising that we cannot address everything;
- Identify the environmental limits of acceptable change, i.e. to determine how much change in biodiversity will affect function of an ecosystem (and adjoining ecosystems) and their ability to provide services. This needs to consider continual and episodic degradation of habitats and the roles of species, including keystone species. Identify thresholds, where possible. Establishment of thresholds for ecosystems must be coupled with safety margins against unpredictable catastrophic events, while recognising that these events may be partly responsible for driving evolution. It is necessary to consider whether this is best tackled as a modelling exercise, or whether it is feasible to establish a large, enclosed experiment in which we alter environmental conditions across a large number of replicated plots (over a long timescale);
- Develop tools which allow ecosystem goods and services to be valued in a meaningful way that reflects the total economic value of ecosystems, including the direct, indirect and non-use values of not only provisioning, but also regulating, supporting and cultural services;
- Increase understanding of the links between resilience and the provision of services at a variety of scales. The effects of changes at small local and short temporal scales may be very different to those at large spatial scales and long term perturbations: the effects are likely to be scale dependent;
- Create predictive models and test these through empirical experimentation;
- Investigate the importance of biodiversity to the provision of ecosystem goods and services in agriculture, forestry, fisheries and the social uses of land and water;
- Investigate the importance of soils, in particular peat, in CO_2 sequestration. What are the processes in soils that provide important functions in land use management?
- Identify and assess the importance of processes associated with wetlands. These may include carbon sequestration, pollution control, hydrology and water returns, flood energy absorption, primary productivity, biomass production, numbers of genera/species supported, cultural interest, genetic interchange and sedimentation;
- Improve public understanding of biodiversity science. Perceptions of biodiversity by wider stakeholders may be quite different from those of natural and socio-economic scientists. Stakeholders who are better informed are likely to make better judgments.

Evaluating changes in ecosystem function in response to environmental change

There is a lack of data and knowledge regarding the effect of changes on ecosystem function and the role of biodiversity in the resilience of ecological-economic systems. Disturbance can, in some situations, act as a source of diversity.

- Assess the impact of climate and land use change, NNS, overexploitation and pollution on ecosystem functions through changes in biodiversity. This needs to include the impacts of gradual versus catastrophic biodiversity loss (species and genetic variability) on the ecosystem's ability to function;
- Quantify tolerance of major drivers/pressures on biodiversity, processes, services and relationships;
- Establish the likely effect of loss of species from systems, as opposed to variation in assemblage composition, and provide empirical evidence to investigate whether 'redundancy' is an appropriate concept. Test hypotheses to attempt to identify thresholds under different environmental conditions, and to test whether a different suite of species or genotypes will play similar functional roles. Does redundancy act as an 'insurance policy' so that an ecosystem will function under a variety of environmental conditions?
- Investigate the threshold of tolerance for extreme conditions under different climate change scenarios, and their potential effects on ecosystem function, e.g. rates of soil processes such as nutrient cycling or shifts in dominant ecosystem processes of primary production and decomposition;
- Model the potential impacts of NNS with response to changing ecosystem function. This needs to include what makes a community/habitat prone to invasion and the ecosystem consequences of successful removal;
- Evaluate the full economic costs and benefits of the introduction of selected critical NNS, including the indirect effects on ecosystem services;
- Establish the different sources of disturbance and determine their impacts on ecosystem function;
- Investigate the importance of connectivity and landscape permeability for dispersal and genetic processes such as speciation and adaptation at larger scales;
- Develop decision-methods for uncertain and irreversible effects;
- Research and model the effects of changes in ocean carbonate chemistry on the function of marine ecosystems. Develop understanding of how interactions between marine biogeochemical cycles and ecosystems respond to and force global change. This should include effects on calcitic and aragonitic organisms;
- Model combined effects and interactions of higher atmospheric CO_2 levels, higher temperatures and lower O_2 concentrations.

The impact of changing ecosystem function on human well being

There is a lack of understanding of the impact of changing ecosystem function on human well being.

- Determine if an ecosystem is fully functional and establish the degrees of functionality;
- Explore general whole community metrics, such as body size spectra, for application in monitoring;
- Investigate how we can manage environmental change in terms of ecosystem function;
- Undertake a formal sub-regional assessment for the UK following procedures outlined in the Millennium Ecosystem Assessment;
- Develop interdisciplinary tools for assessing the impact of changes in ecosystem function on human well being, at a range of scales.

Development of adaptive management strategies

How can we manage or influence ecosystem function in the face of environmental change?

- Test different (experimental) management regimes to assess which performs best;
- Build models to allow exploration of effects of environmental changes and/or management changes on ecosystem function;
- Review the extent to which current information will allow us to quantify ecosystem function and identify pathological states;
- Review the effectiveness of different kinds of policy instruments – what works, what doesn't, when and why?
- Construct spatially explicit meta-community models that allow phase transitions and multiple equilibria to be explored (trophic models).

Issues of scale

To date, much research has focused on relatively short temporal and spatial scales. We need to understand how studies at one scale can be interpreted at another scale.

- Research the relationship between biodiversity loss and ecosystem function across a range of scales, considering multiple land and water use patterns;
- Investigate how results from one scale map onto another scale, to maximise the value of existing and future research results;
- Overcome the mismatch between policy (often macro) and research scales (frequently micro).

3. Monitoring and surveillance of biodiversity and evaluation of actions

Background

Reliable information is important for biodiversity conservation as a whole, not simply to support the implementation of Habitat and Species Action Plans (HAPs and SAPs). Ideally, we should be able to monitor the biological status of all UK biodiversity, with focus on priority species and habitats. We should also understand the effects of changes on ecosystem support functions such as pollution buffering, flood reduction or climate change responses. This theme aims to develop the best approaches to measuring biodiversity, identifying negative impacts and evaluating the success of the actions we take.

Research themes and priorities

Classification and mapping of habitats

A map of habitats is critically important for assessing the status, and changes in status, of the habitats themselves but also as a tool for stratification of other environmental monitoring, as a layer in environmental GIS systems, as a component of environmental models, and as a means to focus action and policy. Before habitats can be mapped they must be defined. Habitat definitions for mapping must be repeatable, meet needs and facilitate use of as much pre-existing information as possible.

- Develop workable habitat definitions/classifications for meeting obligations, taking actions, and for monitoring/reporting;
- Establish a programme for mapping of seafloor habitats to follow-on from the European MESH project[2].

Survey techniques and monitoring schemes

Many well established survey techniques are available for assessing the status of biodiversity. Choosing the right technique for new survey and monitoring involves ensuring comparability with historic results of importance and other initiatives as well as achieving 'fit for purpose' rigour. In a few cases new techniques might need to be established.

- Review the potential of all types of remote sensing (including acoustic sensing of the seafloor), combined with other techniques, for establishing inventories and monitoring biodiversity;
- Address the monitoring gap for coastal and marine systems;
- Develop monitoring techniques that can be adapted to work in a dynamic environment;
- Consider how Countryside Survey could be used explicitly to inform the UKBAP.

Monitoring seabird populations. Paul Glendell, Natural England.

[2] MESH is an international marine habitat mapping programme, which aims to produce seabed habitat maps for north-west Europe, and develop international standards and protocols for seabed mapping studies. www.searchmesh.net.

Indicators

Given the urgency for information on the state of biodiversity and the long lag-time between starting a new monitoring scheme and producing reliable results, it is essential that interpretations are made based on current effort. Reliable surrogates or proxies of biodiversity status need to be established to assist the identification of biodiversity indicators and to make optimum use of existing information.

- Identify key indicators and surrogates of biodiversity status (considering ecological function, direction and rate of change, and links to socio-economic measures for provision of ecosystem goods and services);
- Identify how best to indicate the health of marine ecosystems through a combination of existing surveys (e.g. marine macrofauna) and new effort;
- Identify and evaluate surrogate indicators of condition at a landscape level.

Analytical techniques, modelling and interdisciplinary synthesis of multiscale datasets for detecting environmental change

Interdisciplinary use of data is essential to make links between changes in the status of biodiversity and the drivers of change. Long-term data are vital for identifying the causes of change and need to be protected for this reason. In the marine environment, the only long-term data sets sufficient for predictions is for the rocky shore and the plankton. The big question is how well performance of these ecosystems will predict other marine assemblages.

- Agree and set a broad framework, linking physical data with biological data;
- Develop approaches for separating the effects of the multiple drivers of biodiversity change, especially climate change, from each other and from natural change;
- Evaluate and, if necessary, develop methods for scaling-up: from single samples to the state of regional seas (and terrestrial equivalents);
- Develop techniques to define secure status or long-term viable status for biodiversity, especially the UK priority habitats.

Ecosystem function

Ecosystem functions are often suggested as the ideal focus of wildlife status assessment effort. This stems from a belief that ecosystem functions represent the combined health of all wildlife components and are directly related to benefits that accrue from use of natural resources (sustainable or otherwise). Unfortunately, ecosystem functions have not been adequately defined and, as yet, there is no commonly agreed technique for measuring them.

- Define and classify ecosystem functions, including resilience;
- Develop techniques by which ecosystem functions can be measured;
- Evaluate the use of ecosystem function as a surrogate for biodiversity and ecosystem health (what is a healthy ecosystem?).

Socio-economics

Socio-economic disciplines offer the only language in which all the inputs we need to fully interpret the changes in status in biodiversity can be compared and modelled. Any monitoring scheme must consider the elements of the biota that drive socio-economic values.

- Evaluate the sustainability of activities in the marine environment, including fisheries, tourism, leisure and land reclamation;
- Evaluate the social perceptions about the type of ecosystem society wants.

Data management

A key challenge for biodiversity monitoring is to make best use of existing initiatives and ensure that results are 'fit for purpose'. Techniques are needed to make the data comparable. There is an important need to review existing data on monitoring and indicators, at all scales and for all purposes; examining issues such as suitability, sensitivity, reliability and cost-effectiveness.

- Produce guidance and standards to help make data more comparable and accessible to secondary users.

4. Habitat and Ecosystem Management

Background

The conservation of biodiversity requires the development of knowledge, best practice and practical tools to enable management at a range of spatial scales. In all cases the aim of such management is to optimise landscapes and habitats for biodiversity. This theme arises from a need to complement the effort within individual species and habitat action plans by focusing on cross-cutting management issues that address the wider landscape and integrate with sustainable development objectives.

Research themes and priorities

Ecological definition (what is it?)

Revisit the appropriateness and utility of Habitat Action Plan (HAP) definitions.

- Identify those HAPs where definition is a limitation to progress;
- Undertake basic ecological research to better understand habitats and thus discriminate between them.

Mapping and surveying (where are they?)

Undertake an audit of the distribution of UK BAP terrestrial, freshwater and marine priority habitats across the UK, using comparable methods.

- Develop and apply a unified system for auditing the distribution of priority habitats within the UK, compatible with existing European schemes.

Ecological dynamics of sites (what's happening?)

Develop an understanding of what is happening to sites, in terms of their condition (with respect to Conservation Status), composition and ecological function. This will require the development and implementation of monitoring and surveillance programmes of sufficient frequency, detail and extent to detect trends.

- Apply effective monitoring, surveillance and evaluation techniques within and between sites;
- Improve understanding of responses to anthropogenic and natural drivers of change;
- Initiate research on ecosystem functioning, and the provision of goods and services;
- Initiate research on the autecology of species of conservation concern, indicator species and "keystones."

Assessing changes in wet meadow vegetation. North Wyke, Devon. Richard Pywell, CEH

Site-based management (how are we doing?)

Develop a clearer understanding of the effectiveness of current interventions for maintenance, restoration and (re)creation. This builds upon the work of the monitoring sub-group, i.e. identification of novel approaches to management, which obviate or mitigate the impacts of change.

- Evaluate the effectiveness of current management strategies for site maintenance;
- Investigate the feasibility/effectiveness of restoration and recreation (in relation to above);
- Apply effective internal (i.e. site-based) monitoring and evaluation techniques;
- Develop predictive models and decision support systems to improve management;
- Assess the appropriate scale (or range of scales) for management.

Landscape scale (what's the big picture?)

Set habitat patches within the context of larger spatial and temporal scales and processes.

- Improve understanding of landscape/ecosystem processes and their impacts on sites, at a range of scales;
- Undertake modelling to explain and predict the impact of exogenous drivers, e.g. socio-economics, environmental change;
- Develop approaches to landscape monitoring and surveillance.

5. Conservation of genetic diversity

Background

There is increasing awareness that the quantity and quality of genetic diversity in populations might influence their long term conservation prospects. However, the importance of genetic factors in species conservation remains only partly understood. This theme seeks to provide a better knowledge of genetic variation, in order to guide policy and practical action for biodiversity conservation and restoration. Faced with environmental change, it is important that consideration is given to managing not only species' populations, but also habitats and ecosystems at an increasing spatial scale.

Research themes and priorities

There are three main areas in which conservation has underlying genetic concerns:

- The maintenance of the adaptive potential of species in the face of environmental change;
- Avoiding the loss of genetic diversity;
- Avoiding inbreeding and outbreeding depression.

In practice conservationists are currently concerned with:

- Identifying situations where genetic constraints limit population viability;
- Learning whether species can be grouped meaningfully according to the level of genetic risk, in order to identify generic conservation policies;
- Conserving habitats and processes to facilitate evolutionary responses to changing environmental conditions;
- Identifying potential conflicts between species and genetic conservation.

Invertebrate sampling in upland heathland. Allan Watt, CEH.

Managing genetic diversity in situ

It is important to provide assessments of when genetic problems are likely to occur, in order to obtain the necessary information to guide management for mitigation. There is a need to provide conditions under which genes, populations and species are able to adapt and survive in a fragmented and changing environment. This issue relates to issues of fragmentation, connectivity and edge-of-range populations. The following research tasks have been identified:

- Provide a realistic appraisal of the specific landscape/management conditions over which populations of different species with different life history traits are likely to become genetically isolated, and also establish their abilities to disperse to new sites;
- Provide combined genetic and field-based studies to evaluate the fitness consequences of genetic isolation versus population networks in the context of different population sizes, different environmental gradients and different species attributes;

- In the context of the above, assess the likely response of different species and populations to large scale environmental change;
- Trial and further develop explicit conservation frameworks aimed at linking the above types of genetic information with targeted management action.

Translocations

It is important to establish the best strategies for active movement of organisms. Managing gene flow through translocations is extremely complex, as many issues need to be addressed. In the face of climate change, these will inevitably become more complex. Although there is a general understanding of how translocations can work, including some individual case studies, robust guidelines need to be developed, based on a more extensive evidence base. Therefore, the following task is identified:

- Undertake further experimentation, meta-analyses and experimental coordination and monitoring of re-introductions, to enable the development of robust conservation guidelines for translocations.

Units to conserve

There is a general requirement to establish and measure the diversity of species or divergent lineages so that we can better understand the meaning of biodiversity. The following tasks have been identified:

- Identify and prioritise conservation of divergent intra-specific endemic lineages;
- Develop protocols and increase use of high throughput genetic tools for species identification and discovery, particularly to increase our understanding of the species-level biodiversity of lower plants/invertebrates;
- Coordinate development of dedicated action plans designed to cope with the challenges for taxonomically complex groups and those undergoing diversification.

6. The impact of non-native species

Background

Research issues concerned with NNS have been addressed under a series of ten broad themes, structured in order to provide a logical transition from understanding status and trends, identifying drivers and pressures, and initiating management and legislative responses.

Research themes and priorities

Audit

An audit is required of status and trends of terrestrial and aquatic NNS, comparable across Great Britain (rather than on a country-by-country basis).

- Develop unambiguous guidance regarding what is considered native/non-native;
- Undertake an audit of all NNS and subspecies present in GB (including the Crown Dependencies);
- Identify priority taxa for further investigation of status and trends;
- Undertake an audit of habitats to identify the extent to which they support or are threatened by NNS.

Risk assessment

Assessment of environmental, economic and social risks and impacts is needed in order that appropriate measures can be adopted to address NNS problems.

- Undertake risk assessments for a priority list of NNS;
- Undertake vulnerability analysis, selecting particularly vulnerable species or habitats from earlier audits;
- Develop models to forecast changes in socio-economic variables that may affect future invasion risks (there is a need to emphasise the link between trade and biodiversity).

Pathways and vectors

There is a need to identify, quantify and characterise present pathways and vectors for the introduction of NNS into and within Great Britain.

- Quantify and evaluate current pathways and vectors, based on various resumés (there is no requirement for a detailed review, as a large body of information already exists);
- Analyse the potential changes in socio-political and environmental conditions (including climate change) required to forecast impacts on pathways and vectors;
- Further develop novel techniques (e.g. DNA bar-coding) for tracing the origin of introductions.

Ecological research and modelling

Autecological and demographic studies of critical non-native taxa are needed to develop and validate models of population dynamics, impacts and management.

- Identify what makes a species invasive (e.g. release from competitive interactions and natural enemies, effective dispersal mechanisms, high propagule production, rapid growth rates, ability to withstand high levels of disturbance, and susceptibility of the invaded environment);
- Undertake specific research into key aspects of the ecology and life history of high risk/high impact (priority) NNS;
- Undertake research into what makes a community/habitat prone to invasion by NNS;
- Incorporate this knowledge into models of invasiveness of species and invasibility of habitats;
- Undertake forecasting and horizon scanning of future threats. A key attribute associated with invasiveness is that the species is invasive in a similar climate zone. Assess major NNS in similar climate zones e.g. eastern North America, Atlantic areas of Europe, Japan.

Environmental change

There are likely to be important interactions between species invasion and environmental change, including facilitating the establishment of new NNS. It is important to improve our understanding of how established NNS may respond to future environmental change.

- Carry out an assessment of selected NNS under various environmental change scenarios;
- Improve understanding of the relationship between land- and water-use changes caused by climate change and the introduction of NNS species.

Economic costs

It is important to understand the socio-economic dimensions of NNS, including appraisal of true economic costs and benefits, and understand incentives for their control.

- Review the overall economic costs and benefits associated with NNS in GB;
- Evaluate the full economic costs and benefits of the introduction of selected critical NNS, including the indirect effects on ecosystem services;
- Evaluate the cost-effectiveness and social acceptability of alternative prevention and control strategies for critical species;
- Explore the alternatives to use of NNS in trade (developing new market opportunities, use of economic incentives).

Social perceptions

Research is needed to address social perceptions, awareness and resolution of NNS conflicts.

- Undertake a study to establish a baseline and to monitor changes in public attitudes (and consumer behaviour);
- Investigate the most effective range of measures to raise public awareness and change public attitudes;
- Explore methods for resolving different attitudes to NNS.

Management

Research is required to identify the most effective approaches to management, including prevention, control and eradication strategies; and evaluation of the ecosystem consequences of NNS removal.

- Identify the species that are high risk or for which there is a high likelihood of success, in terms of control or eradication (i.e. demonstrable "quick wins");
- Research into ecosystem management to improve habitat resilience to NNS;
- Identify the pathways that are high risk or for which there is a high likelihood of success. What is the most effective way of closing (specific) pathways?
- Development of decision support tools so that practitioners can gain help in deciding whether to prevent, control or eradicate NNS;
- Review the practicalities of existing prevention, control or eradication methods (i.e. is there an adequate, appropriate method?);
- Develop new systems for management where methodological gaps exist[3];
- Contingency planning: review and identify potential future arrivals, and assess whether we have systems in place for rapid and effective control;
- Monitor control programmes, with a view to generating generic advice, including ways of detecting successful eradication;
- Develop predictive modelling and monitoring of ecosystem consequences of removal, particularly where a NNS has become established and significantly altered the environment (e.g. vegetation responses to a removal of or reduction in grazing pressure).

[3] Specific areas for consideration:
– biological control;
– control of invasive water plants, for which no effective herbicide is permitted;
– immunocontraception/sterilisation;
– chemical/electrical methods for treating ballast water;
– selective delivery systems for eradication of vertebrates.

Biological surveillance and monitoring

There is a need for efficient monitoring of the spatio-temporal trends in the establishment, spread and impact of NNS.

- Undertake surveillance of established NNS;
- Undertake a gap analysis of existing monitoring schemes for critical taxa for existing NNS, and identify methods for filling gaps;
- Evaluate systems for detection of new arrivals;
- Establish suitable schemes for monitoring pathways;
- Establish a centre or process for co-ordination and collation of survey/monitoring results.

Legislation and the regulatory context

Research is needed to evaluate the effectiveness of legislation and regulatory measures.

- Research the effectiveness of measures to regulate movement of species within countries;
- Investigate the value of formal standards set at the international level to deal with some pathways;
- Consider the potential effects that environmental liability regimes, depending on their formulation, could have on means of addressing invasive NNS issues;
- Investigate the benefits or disbenefits that regional approaches can provide to address issues on invasive NNS, e.g. sharing expertise and economies of scale;
- Assess the effects of the opening up of borders and removal of trade barriers on the controls that can act as a brake on the movement of NNS.

7. Climate change and adaptation

Background

The current and potential impacts of climate change and the need for action to allow wildlife to adapt to that change has been widely recognised. This theme cuts across all of these other areas of work and, given the widely acknowledged scale of the threat that climate change presents for Europe's biodiversity, is of critical importance.

Research themes and priorities

Assessing the effectiveness of landscape-scale initiatives for adaptation to climate change

We need to understand how the direct impact of future weather conditions, brought on by climate change, will affect specific habitats of conservation importance, in order to enable suitable management responses to be developed. In addition, a better understanding is needed of effective spatial planning measures to enable biodiversity to survive and thrive in changed climates and perhaps in changed locations.

- Predict the impact of future weather patterns on priority habitats;
- Review the effectiveness of implementation of landscape-scale adaptation initiatives.

Wetland, coastal zone and marine adaptation to climate change

There is a need to identify and develop the tools that make it possible to manage wetland and coastal ecosystems in the face of climate change. Mechanisms are needed to integrate climate change considerations with management of human activities, identification of conservation sites, and the processes for monitoring, assessing and reporting on the status of habitats, species and ecosystems. In order to develop an appropriate management strategy to counteract climate change in streams, rivers and lakes, further consideration needs to be given to the impacts of (summer) low flow and more frequent flood events, as well as changes in water temperature. An improved understanding of the key mechanisms involved in creating suitable managed retreat sites will improve our ability to predict the biodiversity value of these sites. An assessment is needed of the combined effects of ocean acidification and climate change, with the development of a composite index to track change. There is also a need to understand the impact of climate change on the marine environment, in isolation from anthropogenic impacts, and the consequences of climate change for key habitats and species of nature conservation and economic importance.

- Identify constraints and opportunities and provide recommendations for optimisation of adaptation to climate change in coastal zones;
- Identify the options for managing the marine environment in response to climate change;
- Investigate the implications of climate change on wetlands;
- Improve understanding of the biodiversity impacts of managed retreat practices;
- Assess the implications of ocean acidification and climate change in respect of the impact on key habitats, species and ecosystem function;
- Improve understanding of changes to sub-tidal marine ecosystems that are a consequence of climate change.

The impact of climate change on ecosystem goods and services

While it is accepted that climate change is happening, mechanisms must be found for communicating the impacts to those sectors whose actions and reactions will affect biodiversity, but that are attempting to move towards sustainability.

- Improve our understanding of the impact of climate change on ecosystem functions and ecosystem goods and services.

Monitoring the impacts of climate change and atmospheric pollution on biodiversity

There is a need to detect the impacts of climate change on biodiversity and allow them to be distinguished from the effects of air pollution and land management change. This work will provide long term surveillance and data analysis of atmospheric pollution, climate change and aspects of biodiversity on a series of sites across the UK, linked with existing Environmental Change Network (ECN)[4] sites and modelling programmes.

The Environmental Change Network assesses the biological effects of changes in climate and pollution. John Adamson, CEH.

- Undertake targeted monitoring of climate change and atmospheric pollution impacts on biodiversity.

Indicator species

Multi-species indicators for monitoring responses of key taxa to climate change need to be developed. We need to establish a monitoring network to continue long-term quantitative time series and broad-scale quantitative and semi-quantitative surveys of intertidal indicator species.

- Develop headline indicators of climate change impacts on biodiversity;
- Understand the responses of marine biodiversity to climate change using inter-tidal indicators.

Review of conservation targets

Conservation targets in Special Protection Areas (SPAs), Special Areas of Conservation (SACs)[5] and Biodiversity Action Plans (BAPs) need to be reviewed in relation to climate change, before developing tools for setting and helping to meet climate change-proofed conservation targets. In order to do this, an assessment is needed as to whether recent temperature increases have affected the abundance of species that are designated features of protected sites.

- Review the suitability of conservation targets in UK SPAs, SACs and BAPs in light of climate change.

[4] The UK Environmental Change Network (ECN) is the UK's long-term, integrated environmental monitoring and research programme. ECN gathers information about the pressures on and responses to environmental change in physical, chemical and biological systems.

[5] SPAs and SACs are designated under European Directive: SPAs under the Habitats Directive, SACs under the Birds Directive.

Soils, sediments and resilience

The majority of terrestrial ecosystems depend upon processes in the soil. Despite the importance of this area of research, we know relatively little about resilience in soil ecosystems. A parallel project is needed to improve understanding of the function of freshwater and marine ecosystems, addressing the role of sediments, their biodiversity, and the functions of the communities within them.

- Improve understanding of the impacts of climate changes on soil biodiversity;
- Initiate research on the functional role of biota in sediments.

Climate change and phenology, distribution, population dynamics, and breeding success

Research is needed to understand the mechanisms by which large-scale changes in abundance are influenced and determined by climate change impacts on a species' biology. For example, suitable projects could be used to predict changes in bird populations caused by broad-scale habitat change arising as a result of climate change. In addition, there is a need for basic knowledge of species distribution, population dynamics and breeding success; and these results need to be related to climate change and then used to predict and map future changes.

- Model impacts and test the accuracy of predicted faunal responses to climate change;
- Initiate studies on species' autecology and distribution in response to climate change;

Planning and implementation of adaptation strategies

Practical approaches to habitat management need to be developed in order to make habitats more resilient to the impacts of climate change. We need to determine methods for on-the-ground implementation of adaptation and test their effectiveness. Research with a specific urban focus is required to establish the potential value of biodiversity at protected and non-protected (e.g. green roof) sites for economic, social and environmental purposes. A series of case studies are needed to illustrate the impact of climate change on various species and ecosystems. The results would feed into adaptation strategies used for the selected species or ecosystems which could act as a model for other species and ecosystems. There is a need to bring together stakeholders to assess how practical theoretical suggestions for adaptation really are. There is much ecological theory about the value of permeable landscapes and corridors allowing species to move as a result of climate change and, while their value has been assessed via models, there has been little experimental work on this topic.

- Establish approaches to site/habitat management which allow adaptation to climate change;
- Improve planning for urban biodiversity under climate change;
- Improve the evidence base for understanding of climate change impacts on landscape permeability and wildlife corridors;
- Evaluate which approaches to adaptation work for biodiversity.

Genetic conservation

Further molecular research remains to be undertaken, to establish which genotypes are better able to adapt to climate change, e.g. in forestry, southerly species are better able to adapt than northerly ones. One aim is to test experimentally whether populations in currently colder parts of a species' range will be able to cope with climate change towards that found in the warmer parts of its range.

- Undertake research on whether local genetic adaptation within species limits adaptation to climate change.

Atmospheric chemistry and pollution

Cross-sectoral research is necessary to provide consistent projections of climate and atmospheric pollutant concentrations, as part of a strategy to facilitate future policy-relevant work.

- Improve understanding of CO_2 feedbacks in natural and anthropogenic systems, and implications for adaptation and mitigation strategies;
- Undertake integrated projections of climate change, atmospheric pollution and terrestrial ecosystem response.

Conclusions

UK BRAG has adopted an interdisciplinary approach to highlighting knowledge gaps and identifying the research needed to address these. The various themes have been assessed from a social science, economic and natural science perspective. This assessment has identified the following generic issues for UK biodiversity research:

- Apply best practice techniques to uncover the values of biodiversity for different stakeholders;
- Understand perceptions about the types of ecosystem society wants;
- Evaluate the effectiveness of current incentives to conserve biodiversity;
- Test the cost-effectiveness and efficiency of existing conservation efforts;
- Increase the capacity of existing decision methods to deal with complex environmental impacts.

The remaining research priorities can be categorised under the four broad headings set out below. These combine topics from the seven cross-cutting themes addressed by the UK BRAG (socio-economic issues; the role of biodiversity in ecosystem function; monitoring and surveillance of biodiversity and evaluation of actions; habitat and ecosystem management; conservation of genetic diversity; the impact of NNS; climate change and adaptation).

1. Definition, Distribution and Status of Biodiversity

This incorporates surveillance and monitoring and, whilst not necessarily research, their importance has been recognised across many research themes.

2. Ecosystem Management

The need for management to occur at a range of scales (site, habitat, ecosystem, landscape, region etc.) has been recognised. As well as developing and testing new approaches, it is important to evaluate the effectiveness of current management strategies for site maintenance. Furthermore, in the face of environmental change (see below), there is a need to understand the effectiveness of implementation of landscape-scale initiatives.

3. Ecosystem Goods and Services

The importance of biodiversity to the functioning of ecosystems, in particular the provision of goods and services, has been recognised in many themes. A number of fundamental research questions remain to be addressed.

4. Environmental Change

This is an important cross-cutting issue, with priority actions required within a number of themes. It is not restricted to climate change, with processes such as atmospheric pollution and eutrophication being important drivers.

The individual research topics falling within each heading are shown in Table 1, below. It should be emphasised that these broad headings are not "silos", i.e. some of the research topics are truly cross-cutting.

Table 1. Linkages between the four broad research priorities and the cross-cutting themes.

	Broad research priorities			
	Definition, Distribution and Status of Biodiversity	**Ecosystem Management**	**Ecosystem Goods and Services**	**Environmental Change**
socio-economic issues		Strengthen the socio-economic dimensions of an ecosystem approach	Identify the ecosystem processes, or functions, which underpin the provision of ecosystem goods and services, and the strength of the relationship between biodiversity and these processes; Improve valuation of the contribution of biodiversity to changes in ecosystem processes and functioning	Improve techniques for evaluating the ecological effects of biodiversity change; Understand how changes in economic activities and structures of governance affect the vulnerability of ecosystems to biological invasions, the costs of invasions and their control
ecosystem function	Define and classify ecosystem functions, including resilience; and develop techniques by which they can be measured		Improve understanding of the links between biodiversity and ecosystem function (with reference to resilience and stability); Identify the environmental limits of acceptable change; Assess changes in ecosystem function in response to environmental change; Evaluate the use of ecosystem function as a surrogate measure for biodiversity and ecosystem health (what is a healthy ecosystem?)	

	Definition, Distribution and Status of Biodiversity	Ecosystem Management	Ecosystem Goods and Services	Environmental Change
monitoring & surveillance	Improve interdisciplinary use of data in order to make links between changes in the status of biodiversity and the drivers of change; Ensure protection for long-term data, since these are vital for identifying the causes of change; Make best use of existing monitoring initiatives and ensure that results are 'fit for purpose'; Produce guidance and standards to help make data more comparable and accessible to secondary users			
habitat & ecosystem management	Develop and apply a unified system for auditing the distribution of priority habitats within the UK, compatible with existing European schemes	Develop predictive models and Decision Support Systems to improve ecosystem management		
conservation of genetic diversity		Appraise the specific landscape or management conditions over which populations of different species with different life history traits are likely to become genetically isolated, and also to establish their abilities to disperse to new sites; Undertake genetic and field-based studies to evaluate the fitness consequences of genetic isolation versus population networks in the context of different population sizes, different environmental gradients and different species attributes; Undertake further development of conservation programmes aimed at linking the above types of genetic information with targeted management action		Assess the likely response of different species and populations to large scale environmental change, from a genetic perspective

	Definition, Distribution and Status of Biodiversity	Ecosystem Management	Ecosystem Goods and Services	Environmental Change
impact of non-native species	Undertake a GB audit of status and trends of terrestrial and aquatic NNS, including monitoring of trends in establishment, spread and impact of critical non-native taxa; Assess the environmental, economic and social risks and impacts of NNS; Identify, quantify and characterise present pathways and vectors for the introduction and spread of NNS into and within GB	Appraise the true economic costs and benefits of NNS, including incentives for control; Initiate research to address social perceptions, awareness and resolution of NNS conflicts; Evaluate the most effective approaches to management of NNS, and the ecosystem consequences of their removal		Improve our understanding of how established NNS may respond to future environmental change
climate change and adaptation	Undertake targeted monitoring of climate change and atmospheric pollution impacts on biodiversity, including in marine ecosystems; Develop headline indicators of climate change impacts on biodiversity	Establish how ecosystem management, at different scales, can contribute to climate change adaptation strategies for biodiversity	Identify the impact of climatic changes on soil biodiversity	Investigate the implications of climate change on wetlands; Managed retreat: improve understanding of the ecological, social and economic costs and benefits; CO_2: improve understanding of feedbacks in natural and anthropogenic systems and their implications for adaptation and mitigation strategies

Further information

For each of the research themes outlined, the UK BRAG has produced a detailed research strategy paper. The following papers have been produced:

Fay, F.M. and Ferris, R. (eds) (2007) Genetic conservation research needs. Edited by the UK BRAG Secretariat on behalf of the Genetic Conservation sub-group. March 2007. The UK BRAG, Peterborough, UK.

Ferris, R. (ed) (2006) Research priorities: climate change and adaptation. Edited by the UK BRAG Secretariat on behalf of the Climate Change and Adaptation Research Priorities sub-group. December 2006. The UK BRAG, Peterborough, UK.

Ferris, R. and Bainbridge, I. (eds) (2005) Strategy for NNS research. Edited by the UK BRAG Secretariat on behalf of the Non-Native Species sub-group. September 2005. The UK BRAG, Peterborough, UK.

Ferris, R., Pullin, A.S. and Charman, K. (eds) (2005) Research strategy for Management of Habitats and Ecosystems. Edited by the UK BRAG Secretariat on behalf of the Habitat and Ecosystem Management sub-group. October 2005. The UK BRAG, Peterborough, UK.

Perrings, C. and Ferris, R. (eds) (2004) Socio-economic biodiversity research perspectives relevant to the delivery of the UK Biodiversity Action Plan (UKBAP). Edited by the UK BRAG Secretariat on behalf of the Socio-Economic Issues sub-group. August 2004. The UK BRAG, Peterborough, UK.

Robson, J. (ed) (2006) Research needs analysis for the role of biodiversity in ecosystem function. Edited by the UK BRAG Secretariat on behalf of the BRAG Biodiversity and Ecosystems sub-group. October 2006. The UK BRAG, Peterborough, UK.

Rose, P.M. and Ferris, R. (eds) (2005) Research strategy for monitoring and surveillance of biodiversity and evaluation of actions. Edited by the UK BRAG Secretariat on behalf of the Monitoring and Evaluation sub-group. September 2005. The UK BRAG, Peterborough, UK.

These are freely available, and can be downloaded from the UK BRAG website at http://www.ukbrag.org

Future Actions

Between 2003-2006, the focus of the UK BRAG has been on highlighting knowledge gaps and identifying the research needed to fill these. To some extent, the range of themes under consideration has been determined by the earlier work of the BRWG (see Introduction). However, working in a responsive mode, recognising new directions and priorities for the biodiversity research community, both nationally and internationally, the UK BRAG has taken a key role in identifying research across a number of developing areas.

In both cases, this work will continue into the future. There remains a need to maintain an overview of research activity in existing themes, necessitating periodic sub-group updates. In addition, the UK BRAG needs to keep abreast of developing research agendas in the newer, transdisciplinary research themes, e.g. biodiversity and ecosystem function.

Having identified an extensive suite of research needs, the UK BRAG needs to move on to highlight and promote priority biodiversity issues in the research and funding communities. This is recognised in the UK BRAG's new Terms of Reference (Appendix 3), which propose the use of 'a variety of mechanisms to take forward its agenda, which might involve organisation of workshops, seminars and conferences, including an annual report and research symposium; providing an opportunity for engagement with a broader constituency, and dealing with specific and cross-cutting issues.'

Underpinning this is a need to 'ensure that research priorities are promoted more effectively, so that they are more likely to be incorporated within the strategies and programmes of research funders, or taken forward in other ways.'

The UK BRAG will be working in partnership with a number of bodies in order to meet these objectives. Activities include an annual science conference as part of the Annual Meeting of the British Ecological Society; engagement with the Environmental Research Funders' Forum (ERFF); and contributing to the BioSTRAT project, which aims to provide support to the European Platform for Biodiversity Research Strategy (EPBRS) and national biodiversity platforms.

For further information visit http://www.ukbrag.org, or e-mail ukbrag@jncc.gov.uk

References

Bulte, E., Hector, A. and Larigauderie, A. (2005). ecoSERVICES: Assessing the impacts of biodiversity changes on ecosystem functioning and services. DIVERSITAS Report No.3, 40pp.

Defra (2001). *Science in Action for Biodiversity.* A report of the Biodiversity Research Working Group, 1998-2001. Defra, November 2001.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Biodiversity Synthesis.* World Resources Institute, Washington, DC.

Appendices

Appendix 1: Relationships with other organisations

The European Platform for Biodiversity Research Strategy (EPBRS) www.epbrs.org

The EPBRS is a forum for scientists and policymakers to ensure that research contributes to halting the loss of biodiversity by 2010. Its participants, from across Europe, meet to identify and promote strategically important biodiversity research that will contribute to policies and management to reduce biodiversity loss, and help to conserve, protect, restore and make the use of the components of biodiversity sustainable.

The EPBRS encourages and helps to establish national platforms for biodiversity research, with a shared purpose to identify knowledge gaps whose reduction would help support national policy, and to bring these national concerns to the attention of the EPBRS. The UK BRAG uses the EPBRS agreements to identify issues that are of particular national importance.

The Environmental Research Funders' Forum (ERFF) www.erff.org.uk

The ERFF is a focus group which brings together the UK's major public sector sponsors of environmental science, aiming to maximise coherence and effectiveness of that funding. The ERFF concentrates on activities that clearly add value, could not be done by a single member acting alone, and have the potential to advance environmental research in the UK and internationally.

The ERFF aims to provide a "joined-up" approach to UK environmental research strategy, allowing funders to present a more coherent picture of their specific contribution; to determine areas where joint or complementary activities would yield benefit and add value; to identify and consider taking action on any gaps in environmental research; and to shape national and international future science direction through identification of UK priorities for environmental research funding.

The Global Biodiversity Sub-Committee of the UK Global Environmental Change Committee (GECC-GBSC) www.ukgecc.org

The UK Global Environmental Change Committee (GECC) is an inter-agency cross-governmental committee which was established in 2000. It forms a forum for the co-ordination of the UK's involvement in climate change science and technology, nationally and internationally and reports annually to the Government's Chief Scientific Adviser. Detailed GECC work is undertaken by specialist sub-committees. The remit of the Sub-Committee on Global Biodiversity (GBSC) is to inform UK science strategy relating to biodiversity conservation and sustainable use at the global level, including the implications for human society.

Appendix 2: Membership of the UK BRAG, 2003-2006

Chair:	Peter Costigan (Defra) (Miles Parker, 2003-2005)
Secretariat:	Richard Ferris, Joint Nature Conservation Committee
Steve Albon	The Macaulay Institute
Melanie Austen	Plymouth Marine Laboratory
Mark Bailey	Centre for Ecology and Hydrology – Oxford
Sallie Bailey	Forestry Commission
Ian Bainbridge	Scottish Executive
John Baxter	Scottish Natural Heritage
Tim Blackstock	Countryside Council for Wales
Richard Brand-Hardy	Department for Environment Food and Rural Affairs
Kevin Charman	English Nature
Mike Fay	Royal Botanic Gardens Kew
Mary Gibby	Royal Botanic Garden Edinburgh
Michel Kaiser	University of Bangor
Pamela Kempton	The Natural Environment Research Council
Paul Leonard	Department for Environment Food and Rural Affairs
David Macdonald	WildCRU, University of Oxford
Davy McCracken	Scottish Agricultural College
Scot Mathieson	Scottish Environment Protection Agency
Havard Prosser	The Welsh Assembly Government
Andrew Pullin	Wildlife & Countryside Link – The British Ecological Society
Paul Rose	Joint Nature Conservation Committee
Jane Sears	Wildlife & Countryside Link – RSPB
Pete Robertson	Central Science Laboratory
Martin Sharman	European Commission
Andrew Stott	Department for Environment Food and Rural Affairs
Kerry Turner	University of East Anglia
Michael Usher	University of Stirling
Johannes Vogel	Natural History Museum
Allan Watt	Centre for Ecology and Hydrology – Banchory
Kevin Watts	Forest Research
Sarah Webster	Department for Environment Food and Rural Affairs
Mark Wright	Environment and Heritage Service – Northern Ireland

Appendix 3: Revised Terms of Reference for the UK BRAG

Overall aims

- To identify, promote and facilitate biodiversity research to support UK and individual country biodiversity action plan commitments[6], with reference to the Convention on Biological Diversity (CBD), the EU Biodiversity Strategy and associated initiatives;
- To coordinate effective and efficient UK engagement with European biodiversity research issues and hence fulfil the role of a national biodiversity research platform;
- To contribute to effective biodiversity research networking in the UK, integrating natural sciences, economics and social sciences, and increasing interdisciplinary capacity;
- To support knowledge transfer activities in relation to biodiversity research, ensuring that these are an integral part of all aspects of the UK BRAG work.

The UK BRAG will not act as a funding body for biodiversity research in the UK.

Operating methods

In order to undertake these activities in an effective manner, the UK BRAG will:

- Be restructured, such that a smaller subset of the main group will address administrative co-ordination issues. This subset would consist of representatives of each of the principal funding agencies and of the BAP Country Groups. This would help to ensure a more formalised engagement with the Country Groups and a clearer alignment with the UK BAP. It would also free the main UK BRAG meetings for discussion of more strategic and prioritisation issues.
- Specialist sub-groups would be established, whenever needed, to address issues which require a particular level of experience. These would provide an overview of the state of the science, identifying significant knowledge gaps and the research needed to address these. Such sub-groups would have a responsibility for producing technical reports for consideration by the main Group.
- Use a variety of mechanisms to take forward its agenda, which might involve organisation of workshops, seminars and conferences, including an annual report and research symposium; providing an opportunity for engagement with a broader constituency, and dealing with specific and cross-cutting issues.
- All members of the UK BRAG are encouraged to be pro-active in promoting the work of the UK BRAG, particularly its research recommendations.
- Ensure that research priorities are promoted more effectively, so that they are more likely to be incorporated within the strategies and programmes of research funders, or taken forward in other ways.
- Exchange information with the Global Biodiversity Sub-Committee of the Global Environmental Change Committee (GECC-GBSC) and undertake joint activities where appropriate.

[6] UK BRAG will not address research needs associated with individual HAPs and SAPs, instead focusing on cross-cutting, generic issues.

Performance measures

The success of the UK BRAG should not be tied to formalised performance measures. The Group's influence is more subtle. Therefore, it is proposed that success should be determined through periodic consultative reviews which should consider:

- improved networking within and between researcher, policymaker and practitioner communities;
- increased capacity for biodiversity research in the UK, particularly interdisciplinary approaches; and
- more effective knowledge transfer, including science-to-policy, facilitated by the Group's activities.