# Beyond 2010: Strategies for understanding and responding to long-term trends in UK biodiversity

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## Conference report

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BEYOND 2010
Biodiversity monitoring & research
current practice and future needs

**Organised by**

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# 1. Executive Summary

1. The conference *Beyond 2010: Strategies for understanding and responding to long-term trends in UK biodiversity* aimed to highlight the central role long-term studies play in addressing key biodiversity-related issues, and to explore future directions for this area of research.
2. The UK has a rich history of long-term biodiversity monitoring and research in marine, freshwater and terrestrial environments, complemented by Natural History collections in museums, zoos, botanic gardens, herbaria, culture collections and biological resource centres. The estimated investment in biosphere monitoring is over £82 million.
3. Data are generated by a variety of programmes, some run by professionals, others by voluntary groups and amateurs covering a wide range of taxa and ecosystems and various temporal and spatial scales. Increasingly data are generated by participatory schemes, enabling non-experts to take part.
4. There are many policy and management requirements for evidence from long-term biodiversity monitoring and research, including compliance with European Directives. Long-term studies have helped inform and assess policy decisions in a number of areas. In other cases the potential application of existing long-term datasets has yet to be fully realised. In some areas, data on long term change in biodiversity parameters is lacking and represents significant evidence gaps.
5. Future biodiversity monitoring must link biological observations more clearly to pressures and to ecosystem functions and processes. Such information is perceived to be critical if the UK is going to be able to address the "Ecosystem Services" element of the Convention on Biological Diversity's COP10 strategic vision.
6. Currently there is no implemented UK strategy with respect to biodiversity monitoring. Most schemes operate in isolation. This lack of integration risks inefficient use of national resources, with respect to potential duplication of effort, and problems associated with data accessibility and data management.
7. Biodiversity monitoring and research faces the prospect of reduced funding. This is a particular concern for long-term monitoring programmes, which may be stopped or forced to modify their monitoring methods. Decisions concerning the funding of long-term programmes need to take into account the future consequences of terminating long-running time series of data.
8. The majority of delegates felt that a more integrated framework of UK biodiversity monitoring is required, though opinions varied on how such integration should be achieved.

## 2. Overview and key points

1. The conference *Beyond 2010: Strategies for understanding and responding to long-term trends in UK biodiversity* aimed to highlight the central role long-term studies play in addressing key biodiversity-related issues, and to explore future directions for this area of research.
2. Human health and well-being depends on biological diversity for the maintenance of many 'ecosystem services' that deliver food, fuel, clean water and medicines, and provide for our social, cultural and spiritual needs. Yet, due largely to human actions, biodiversity has been declining around the globe and in the UK.
3. Internationally-agreed targets for halting biodiversity loss by 2010 have not been met. New targets for 2020 have been agreed, placing more emphasis on ensuring ecosystems are resilient and able to continue to deliver "ecosystem services". How progress towards achieving these targets will be assessed remains a significant intellectual and practical challenge; it is clear that biodiversity monitoring and research will be central to this process but these activities will need to be developed in order to provide the necessary national capability.
4. Conference delegates repeatedly expressed concern that future biodiversity monitoring must reach beyond the routine measurement of abundance and distribution of species by linking biological observations more clearly to pressures and to ecosystem functions and processes. Such information is perceived to be critical if the UK is going to be able to address the "Ecosystem Services" element of the CBD COP10 strategic vision (see Annex B).
5. The UK has a rich history of long-term biodiversity studies (comprising monitoring and research) providing a wealth of data on status, trends, causes and effects of change in marine, freshwater and terrestrial environments. Some of these schemes are internationally unique and have generated multi-decadal time series.
6. Today, long-term monitoring of biodiversity is undertaken at a largely complementary range of spatial scales and frequencies, ranging from occasional spatially extensive surveys, e.g. Countryside Survey, through more frequent taxon-specific extensive monitoring, e.g. Continuous Plankton Recording and Butterfly Monitoring scheme, to the high frequency measurement of multiple drivers and biological response variables, e.g. Environmental Change Network.
7. Complementing these schemes, Natural History collections in museums, zoos, botanic gardens, herbaria, culture collections and biological resource centres represent a huge and largely untapped research resource with potential to provide many useful insights into environmental change and the impacts of change. Such collections are already providing information on, for example, phenological responses of organisms, changes in distribution and abundance over time, changes in morphology and information about past climates. Museum collections can be useful in providing a historical context for modern observations.

8. A catalogue of monitoring programmes covering all environmental domains has been collated by UK-EOF in an effort to build a clear picture of activities and the investment in monitoring, which for the biosphere is estimated at over £82 million (in 2008/09).The origin of the UK's long-term biodiversity schemes varies widely, from addressing scientific hypotheses (e.g. the Continuous Plankton Recorder) to direct responses to specific policy or statutory needs (e.g. the UK Acid Waters Monitoring Network). In many cases these long term records are now being shown to have value in addressing issues way beyond their originally intended application.

9. Today there are many policy and management requirements for evidence from long-term biodiversity monitoring and research, and monitoring is also necessary in order to ensure the UK complies with European Directives such as the Water Framework Directive and Marine Strategy Framework Directive. Long-term studies have helped inform and assess policy decisions in a number of areas. In other cases the potential application of existing long-term datasets has yet to be fully realised. In some areas, data on long term change in biodiversity parameters is lacking and represents significant evidence gaps.

10. Data are generated by a wide variety of programmes, some run by professionals, others by voluntary groups and amateurs covering a wide range of taxa and ecosystems and various temporal and spatial scales. Increasingly data are generated by participatory schemes such as BioBlitzes and Nature's Calendar, enabling non-experts to take part.

11. Currently there is no implemented UK strategy with respect to biodiversity monitoring, even within the professional sector. Most schemes operate in isolation and there have been few successful attempts to link them in an "interoperable" manner that will allow new questions to be addressed and existing problems to be explored more deeply. This lack of integration risks inefficient use of national resources, with respect to potential duplication of effort, and problems associated with data accessibility and data management.

12. Some UK organisations are contributing to international collaborative programmes to join up monitoring and research infrastructures and datasets. Examples include the Global Earth Observation System of Systems (GEOSS), new projects such as EXPEER, which will develop the European infrastructure for experimental ecosystem research and initiatives such as the Shared Environmental Information System (SEIS) and LifeWatch (which focuses on biodiversity). Within the UK, efforts have been underway for several years aimed at making more biodiversity-related data accessible; the most notable such initiative is the National Biodiversity Network.

13. Concomitant with the continuing uncertain economic climate there is an expectation within national and regional government and the environmental and conservation agencies for biodiversity monitoring to deliver to an increasingly wide range of policy and management needs. This will almost certainly require the provision of "more for less", making the need for scrutiny of current monitoring resources even more urgent.

14. Beyond 2010, biodiversity monitoring and research faces the prospect of reduced funding. This is a particular concern for long-term monitoring programmes, which may be stopped or

forced to modify their monitoring methods (e.g. by monitoring at fewer sites, at a reduced frequency or by monitoring fewer parameters). Decisions concerning the funding of long-term programmes need to take into account the future consequences of terminating long-running time series of data.

15. There is clear potential to increase the value of the data being collated to science and policy by better exploiting the various potential synergies between these systems.

16. There is also potential for greater contributions from the voluntary sector to nationally important biodiversity monitoring systems. Increased public participation may be driven by the Government's 'big society' and localism agendas. However, such contributions can not be taken for granted. It is important to appreciate that scientifically valuable voluntary contributions will be sustained into the longer term only if participants have a sense of data ownership and membership of the systems to which they contribute. Greater involvement in biodiversity monitoring by volunteers will need to be underpinned by a robust training system. Professional biologists must all frame the questions to be answered and design appropriate monitoring strategies.

17. Research has shown that there are many motivations for a person's involvement in voluntary biodiversity monitoring, such as fellowship, learning, concern for a local area and personal recognition of effort; it is important to understand the personal drivers of involvement and design volunteer schemes accordingly.

18. There is often serendipitous value in maintaining long-term monitoring over long time scales. Examples were presented at the conference – including the Continuous Plankton Recorder survey, the Rothamsted Insect Survey, the Cumbrian Lake surveys and numerous marine time-series which contribute to the MECN network – of research programmes which have been maintained for several decades. As a consequence, they now yield information which addresses questions and has practical applications far beyond those envisaged at the outset of monitoring. In some cases, research programmes have evolved – e.g. with the development of new methods, streamlined reporting and efficiency savings – to become important resources for policymakers; the Countryside Survey is an example.

19. Data from different monitoring programmes have been successfully combined to yield new information; the BICCO-Net project was one example presented at the conference, and there is scope for more such multiple analyses.

20. Remote sensing techniques are used widely in the study of marine and terrestrial ecosystems. Many earth observation (EO) products concern physical parameters, which can be applied to the study of biodiversity. Regular improvements are made to the spatial resolution of systems whilst lower-cost measurements at high temporal frequency are also possible; however, this also creates potential problems with respect to developing consistent long-term datasets. There is potential for greater direct measurements of biological parameters and processes such as leaf emergence and carbon fluxes, particularly if closer links can be made with ground-based monitoring programmes. A challenge to the greater use of EO is the lack of awareness of, and confidence in, derived EO products.

21. Generally an increasing amount of data is being generated by biodiversity and other environmental monitoring programmes. This is presenting challenges in terms of data management, storage and access, requiring investment in funds, skills, technologies and effort to resolve.

22. During discussion sessions, conference delegates provided many examples to show how long-term biodiversity monitoring has informed our response to biodiversity decline or helped to answer key environmental and social questions (see Section 5.1). They also listed many contemporary issues requiring an understanding of how biodiversity is changing (Section 5.2). The majority of delegates felt that a more integrated framework of UK biodiversity monitoring is required, though some expressed a concern that integration might take the form of top-heavy bureaucratic control; they favoured a looser collaboration and coordination of effort.

23. To develop this framework, delegates proposed a number of actions. Their ideas are listed in Section 5.3, and include:

    a. Clearer prioritisation of the questions that need to be addressed

    b. Clear quantification of the current UK biodiversity monitoring effort (extending the UK-EOF catalogue), coupled with information on why each programme exists and the key questions each can help to address

    c. A transparent process and clear criteria, to identify gaps, duplication and areas for collaboration in terms of monitoring programmes and stop, modify or start programmes accordingly

    d. A clearer national vision for the long-term funding of long-term environmental monitoring, with the aim of providing greater financial stability for key monitoring programmes and reducing inefficiencies associated with the continuous pursuit of new funding sources.

    e. Development of training programmes for the required skills to support both the professional and voluntary sector to ensure practical, taxonomic, statistical and other expertise are maintained and enhanced. The Field Studies Council could play a key role in skills training

    f. Development of a central portal for all biodiversity metadata.

    g. Increased interoperability and greater accessibility of biodiversity data

    h. A greater use of Earth Observation technology and closer linkages with biodiversity monitoring on the ground.

24. Opportunities for greater collaboration could arise from better geographical co-location of monitoring effort; tighter harmonisation of monitoring methods; increasing the skills/expertise of those in the voluntary sector to raise the amount and quality of information collected; sharing data and coordinating their analysis; increasing partnerships with industry (see Section 5.3).

25. Risks and barriers to greater integration may include: limited resources; disengagement and mistrust from volunteers, if their views and motivations are not properly taken into account; missed biota (if the framework is too prescriptive about what is measured); land use overload, increasing resistance from some private landowners (see Section 5.3).

26. Conference delegates made a range of other points concerning the reasons for better coordination of monitoring, what and how we should monitor, who should be involved, funding for monitoring, skills and training, informatics, communication and the establishment process.

# 3. Introduction

Human health and well-being depends on biological diversity for the maintenance of many 'ecosystem services' that deliver food, fuel, clean water and medicines, and provide for our social, cultural and spiritual needs. Yet, due largely to human activity, biodiversity has been declining around the globe, including within the terrestrial, freshwater and coastal habitats of the UK. Despite the aims of the Convention on Biological Diversity there is little evidence to suggest any decline in the rate of these losses. Biological monitoring allows not only the quantification of rates of change but, together with experimental and modelling approaches, also improves understanding of the drivers and processes of change, and allows the development of better strategies to protect biodiversity.

The UK boasts a rich history of biological and ecological surveying, monitoring and research, but very few monitoring programmes have been maintained for long enough to provide definitive data on long-term trends and their likely drivers or provide the necessary guidance for future management. Those that have survived face an uncertain future, particularly in the current economic climate, while developments in scientific understanding and instrumentation reveal new areas of concern and opportunity where monitoring should play an important role in the future.

*Beyond 2010: Strategies for understanding and responding to long-term trends in UK biodiversity* aimed to:

**Box 1: Why 2010?**

2010 was the United Nations International Year of Biodiversity because in April 2002, the Parties to the Convention on Biological Diversity (CBD) committed themselves **to achieve by 2010 a significant reduction of the current rate of biodiversity loss at global, regional and national levels as a contribution to poverty alleviation and to the benefit of all life on Earth.**

This target was subsequently endorsed by the World Summit on Sustainable Development and the United Nations General Assembly and was incorporated as a new target under the Millennium Development Goals. In October 2010, new biodiversity targets were agreed in Nagoya, Japan (see Annex B for these '2020 targets').

The 'Beyond 2010' conference was held as a contribution to the International Year of Biodiversity, and was one of many events that took place around the world during 2010.

*"International Year of Biodiversity … a celebration of life on earth and of the value of biodiversity for our lives. The world is invited to take action in 2010 to safeguard the variety of life on earth: biodiversity"*

– CBD IYB website

1. consider national requirements for biodiversity monitoring and research;
2. review how long-term studies are contributing to our understanding of key biodiversity-related issues;
3. illustrate through case-studies the challenges faced in improving the quality, reliability and efficiency of measurements; data processing, interoperability and analysis; and the communication of results;
4. explore opportunities to improve monitoring capability through recent developments in science, instrumentation, and public participation, and

5. consider the potential for synergies between programmes and future directions for this area of research.

Although the emphasis was on the UK, the conference was of international relevance, since many of the issues discussed are essentially global and often the solutions require international cooperation.

The 1½-day conference featured 27 speakers and attracted over 125 people representing over 65 organisations. During the afternoon of the second day, delegates participated in small-group discussion sessions exploring some of the conference themes in greater depth.

The purpose of this report is to summarise the conference and present some of the key messages arising from presentations and discussion sessions, with the expectation that it will enable better-informed decisions concerning the future of long-term biodiversity monitoring to be made.

# 4. Summary of presentations

Invited speakers contributed to seven conference sessions, which are summarised in this section. The sessions were as follows (see Annex A for the conference programme):

1. The national need for long-term biodiversity research and monitoring
2. Stakeholder applications of biodiversity monitoring
3. Systems for detecting and attributing environmental change
4. Assessing the impacts of pressures on biodiversity
5. The benefits of multi-decadal monitoring
6. The public's role in biodiversity monitoring
7. Opportunities and challenges for long-term biodiversity monitoring and research.

## 1. The national need for long-term biodiversity research and monitoring

Three speakers were invited to set the scene for the conference. Ian Bainbridge (Scottish Natural Heritage) and Peter Costigan (Defra) outlined contemporary issues in relation to biodiversity, the role of long-term monitoring, policy needs and the current funding situation. Andrew Watkinson (LWEC) then described the UK's Environmental Observation Framework, which is working towards a more joined-up structure for UK environmental monitoring activities (including biodiversity monitoring).

***Contemporary biodiversity issues and the role of monitoring***

Ian Bainbridge began by describing the UK's rich heritage of biological recording, which dates back at least to the observations of Gilbert White, author of *The Natural History and Antiquities of Selborne* (1789), and continued throughout the Victorian era. These early naturalists established a tradition of biological recording and collecting that continues today. Nature conservation at protected sites began in the 1920s, and with statutory nature conservation came an increased need for monitoring schemes.

Early long-term studies tended to be University- or Institute-based and designed to address scientific questions; later programmes such as the Environmental Change Network (ECN) and Countryside Survey (CS) are increasingly becoming more clearly linked to policy needs. Widespread public involvement in monitoring, pioneered particularly by the BTO, is a more recent phenomenon. This has undoubtedly been aided by developments in mass communication and the internet, which have also enabled the creation of the National Biodiversity Network, providing access to a huge number of datasets via the web.  Habitat monitoring has a shorter history than species observations, dating back to the first GB Countryside Survey in 1978, but is essential for targeting conservation efforts.

Although enjoying a wealth of information spanning many decades, the development of monitoring and specimen collection in the UK has evolved largely independently from the evolution of conservation policy needs, with the consequence that:

- The dominance of species recording over habitat monitoring has limited the provision of good site management information
- Species distribution mapping has developed with little attention paid to population estimates
- The growth in information on changes in terrestrial biodiversity has not been matched by that for marine ecosystems
- We have monitored the exciting and visible; and tended to ignore the obscure and invisible
- Most recording has been driven by scientific curiosity rather than to address political or legislative needs.

In considering future challenges for biodiversity monitoring, Bainbridge asserted that we still need to know where biodiversity is, and how much of it there is. We also need information on trends, and the drivers of trends. He asked whether we needed more phenological monitoring, given the increasing influence of climate change, and he suggested that a major challenge is how we should best monitor changes in ecosystem services provided by biodiversity.

In developing monitoring capability beyond 2010, a major barrier will be funding, and we will need to develop cost effective techniques for monitoring (e.g. with fewer people, with greater frequency or over a larger area). Ian Bainbridge felt that, given current funding restraints, we needed to:

- Be clear about the needs, scope and statistical adequacy of monitoring
- Consider risk (can we take a risk-based approach, based on speed of change and threat?)
- Address issues of frequency and intensity of monitoring and consider issues of scale
- Maximise compatibility and co-ordination
- Maximise 'citizen science'.

**Box 2: Challenges for biodiversity monitoring laid down by Ian Bainbridge, SNH**

- Mapping habitats and monitoring trends, e.g.
    - How do we develop compatibility between surveys and Habitats Directive?
    - Can we make connections between habitat monitoring and ecosystems?
- Monitoring the marine environment, e.g.
    - How do we monitor mobile species and habitat trends?
- Resolving monitoring frequency, e.g.
    - How infrequently can we monitor slow changes and how frequently must we monitor rapid changes?
    - Is there a role for the public in providing an early warning of habitat change?
- Managing the species balance, e.g.
    - Should we be monitoring more species?
    - How do we unmask hidden declines?
- Maximising the value of NBN, e.g.
    - How do we bring data in from a wider range of sources?
    - Can we use NBN data to measure change?
- Monitoring crypto species and soil biodiversity, e.g.
    - Can we develop and apply new techniques like DNA fingerprinting?
- Developing indicators and indices for ecosystem health and services, e.g.
    - Can we find biodiversity proxies of ecosystem health?
    - How should we monitor the changing value of ecosystem services?
    - How do we reconcile social and intrinsic values of biodiversity?

He concluded with a list of what he saw as some of the main challenges for biodiversity monitoring (see box 2).

***Policy needs and funding support***

The policy needs for monitoring and the current economic climate were outlined by Peter Costigan, who reminded delegates that 2010 had been a year of significant change, with a new UK government and the setting of new biodiversity targets in Nagoya. Significant publications during 2010 have included *Making Space for Nature*, a review of England's wildlife sites, the TEEB report

(The Economics of Ecosystems and Biodiversity), Countryside Survey reports and the Natural Environment white paper. The Defra business plan was launched on 8th November 2010 and sets out the coalition government's priorities in relation to the environment. Among these are:

- Support and develop British farming and encourage sustainable food production
- Help to enhance the environment and biodiversity to improve quality of life:
    - specifically, to enhance and protect the natural environment, including biodiversity and the marine environment, by reducing pollution, mitigating greenhouse gas emissions, and preventing habitat loss and degradation
- Support a strong and sustainable green economy, resilient to climate change.

**Box 3: The CBD strategic plan for biodiversity**

Pertinent to the conference is the statement in the strategic plan that to achieve the vision it is necessary to ensure that "… decision-making is based on sound science and the precautionary approach". Target 19 is that by 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied. It also states that "The following are key elements to ensure effective implementation of the Strategic Plan:

a) Global monitoring of biodiversity: work is needed to monitor the status and trends of biodiversity, maintain and share data, and develop and use indicators and agreed measures of biodiversity and ecosystem change;
b) Regular assessment of the state of biodiversity and ecosystem services, future scenarios and effectiveness of responses: this could be provided through an enhanced role for the Subsidiary Body on Scientific, Technical and Technological Advice as well as the proposed intergovernmental platform on biodiversity and ecosystem services;
c) Ongoing research on biodiversity and ecosystem function and services and their relationship to human well being;
d) The contributions of knowledge, innovations and practices of indigenous and local communities relevant to the conservation and sustainable use of biodiversity to all the above;
e) Capacity building and timely, adequate, predictable and sustainable financial and technical resources."

The CBD COP10 (Convention on Biological Diversity – Conference of Parties) meeting in Nagoya, Japan, resulted in a new strategic vision for biodiversity:

"Take effective and urgent action to halt the loss of biodiversity in order to ensure that **by 2020 ecosystems are resilient and continue to provide essential services**, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication."

The strategic vision for biodiversity is backed up by 20 specific targets (see Annex B). It is clear that there is still a need to halt biodiversity loss, but there is now an emphasis on healthy ecosystems and safeguarding ecosystem services. More details about the strategic plan are provided in box 3.

The *Making Space for Nature* report (chaired by Prof. Sir John Lawton) considers protected areas for nature conservation in England and calls for the creation of an ecological network, stating: "The essence of what needs to be done to enhance the resilience and coherence of England's ecological network can be summarised in four words: *more*, *bigger*, *better* and *joined*". Peter Costigan also highlighted a conclusion of the report, that "Too few people have easy access to wildlife".

Both policymaking and science are increasingly considering ecosystem services, as is demonstrated by the recent initiatives such as the TEEB[1] report (which attempts to place an economic value on nature), the National Ecosystem Assessment and the Countryside Survey Integrated Assessment (which, for example, has yielded a tentative map of ecosystem service provision value).

Peter Costigan explained that the recent Government spending review would inevitably have an impact on biodiversity monitoring and research. All Government departments would have to make savings, and it would be necessary for the biodiversity monitoring community to:

- Be clear on the purpose
- Prioritise and rationalise
- Remove any overlaps
- Work in partnership
- Achieve greater integration of monitoring & data
- Explore greater voluntary involvement
- Make greater use of Earth Observation.

Other recent political drivers of significance are the 'Big Society' (in which more people volunteer their time to deliver community services) and the localism agenda (in which more information is made available for use at a local level).

The UK Earth Observation Framework's estimate of the cost of monitoring the biosphere is £39.5 million, plus some £42.7 million in-kind effort, a total of £82.2 million (figures for 2008/09). Of the funded portion, about £25 million is funded by the Defra network (i.e. Defra and its agencies such as EA, NE, etc.).

Finally, Peter Costigan considered "data transparency". He said there was a need to make more data accessible e.g. from Countryside Survey and NBN, to make data interoperable and combinable (i.e. datasets from different sources formatted and made available in ways that enable them to be easily linked together and analysed to address specific issues) and to use 'smart' approaches (such as crowdsourcing, involving citizens[2]). A website, data.gov.uk, has being developed under the Government's transparency agenda.

***UK Environmental Observation Framework***

Andrew Watkinson, Director of the *Living with Environmental Change* programme (LWEC), presented an overview of the UK Environmental Observation Framework (UK-EOF). The Framework was launched in 2008 as initiative of the Environmental Research Funders Forum (ERFF), and was in response to the status of environmental monitoring at the time, which was felt to be fragmented, uncoordinated and lacking any strategic direction. Effort was being duplicated, opportunities were being missed, funding for key data series was at risk and data sharing was inadequate. UK-EOF is a five year programme to identify and address the issues surrounding environmental observations

1 The Economics of Ecosystems and Biodiversity

2 For an introduction to such approaches and to the issue of greater access to publicly-funded data, see http://data.gov.uk/blog/video-of-nigel-shadbolt-at-activate-2010

made for and by the UK. The framework seeks to provide a cost effective mechanism to work in partnership across government, the devolved administrations, agencies and the voluntary sector to make best use of expertise and resources in support of national and international goals. UK-EOF has the overall aim of shaping the UK's capability to 'facilitate the ongoing environmental evidence required to understand the changing natural environment, thus guiding current and future environmental management, policy, science and innovation priorities for economic benefit and quality of life'. The goals of UK-EOF are:

- To develop a holistic picture of the evidence needs of the UK and the role of observations
- To share Knowledge & Information
- To understand use of observation data & tools for knowledge transfer
- To enable funding mechanisms for long-term observations
- To build strong community to share data & expertise

Now coordinated by the LWEC programme, UK-EOF is owned by LWEC members, guided by the UK-EOF Management Group, progressed by the Secretariat and partners and advised by data experts. (Funding is currently £450k per year, soon to fall to £270/yr).

The Environmental Observation Framework has five parallel workstreams. Progress to date includes:

**Catalogue** – this database of environmental monitoring programmes (www.ukeof.org.uk) went live in 2009 and data are now being updated. Across all environmental domains, over 1000 activities are listed.

**Costs** – Guidance has been produced for comparing the costs of very different programmes.

**Statement of Need** – this asks what is needed by whom and for what purpose.

**Decision Support Framework** – tries to ensure there is greater transparency between funders over what is commissioned and for what purpose. In the current climate, this could also be used to determine what is least necessary with respect to UK national capability and therefore least damaging to stop or modify.

At least 50% of UK-EOF Catalogue entries relate to the biosphere and about 50% of these involve observations made by volunteers. This is a huge bottom-up effort, but it is fragmented and would benefit the national need by being better coordinated.

There are many relevant initiatives both at the UK, EU and global level. Through the UK-EOF Data Advisory Group, initiatives such as data.gov.uk, SEIS, INSPIRE, and GEO are beginning to be linked. UK-EOF is working to ensure all data collectors and funders are aware of the initiatives and kept informed of changes. GEO (Group on Earth Observations) presents the global environmental observation community with a unique opportunity to collaborate and foster partnerships. The UK has itself adopted a collaborative approach at a national level through activities such as UK EOF and Living with Environmental Change.

*Towards a Statement of Need* (published in February 2010) gathered information from a series of workshops, one for each of six environmental domains. Within the document, observation requirements are examined from three angles: (1) headline environmental issues; (2) organisational viewpoints, and (3) from the perspective of the environmental domain (such as land, water, biota, air). The headline issues for the biosphere domain include the environmental change aspects associated with: population growth and pollution; economic growth and sustainable use of resources; future states of the earth including the carbon cycle, fisheries, agriculture, food security and water supply; human health and well-being; extreme events and disasters; biodiversity and ecosystem services; climate variability; technological advancement. Perspectives from different components of the observation community (Policy, Science, Voluntary and Industry), were considered.

UK-EOF has developed guidelines for reporting the full economic costs per year for all elements of the observing process. It is estimated that at least £300m per year is invested by 18 public sector funders. With over 200 organisations involved including industry, Local Authorities and the voluntary sector, the overall investment could be nearer £1billion per year (across all environmental domains).

Priorities for UK-EOF in 2010/11 are to:

- Help organisations use UKEOF tools to resolve:
  - What the UK should invest in
  - How to ensure the UK is collecting the most necessary data
  - How information can be best shared in a timely manner
- Align observations and funding activities
- Improve the use of environmental socio-economic information
- Develop new observation frameworks, e.g. Virtual Observatory, OPAL, UKMECO
- Encourage cultural changes in the collection and sharing of data so that good practice – including provision of meta data and clear protocols for data collection– becomes the norm.

## 2. Stakeholder applications of biodiversity monitoring

The three presentations in this session provided examples of how long-term biodiversity monitoring is used for a range of user needs. The three perspectives were: statutory conservation (Keith Porter, Natural England), compliance with the Water Framework Directive (Geoff Phillips, Environment Agency) and the global long-term ecosystem research community (Terry Parr, CEH).

A range of monitoring activities designed for different purposes were covered in this session. Site condition monitoring focuses on the notified features of a site (e.g. its invertebrate assemblage, nationally rare or scarce species or specific habitats of interest). Monitoring may include assessment of the extent of a habitat, its structure, species composition or species population status. In order to comply with the Water Framework Directive (WFD) catchments are grouped into river basin districts (RBDs). River basin management cycles are six years long and continuous monitoring takes place on the basis of an understanding the character of the district, pressures, risks and impacts. Following the defining of environmental objectives, an action plan is developed and implemented. The nature of biodiversity monitoring for research purposes varies greatly and ranges in spatial scale from extensive remote sensing of land cover to intensive site-based monitoring and research.

Increasingly, monitoring may include socio-economic dimensions and may involve inter-disciplinary collaborations between natural and social scientists.

Site condition monitoring at Sites of Special Scientific Importance (SSSIs) and River Basin Management monitoring under the Water Framework Directive are both designed to determine the condition of systems and set management goals, with the ultimate target to improve the condition of ecosystems. These contrast with question-driven repeated observations for research purposes (although the knowledge gained may be applied to achieve beneficial outcomes). Despite these differences they share common traits and applications, such a providing baseline measures of states or trends over time.

Keith Porter stated that 'integration is king' and indicated that greater integration must take place for the sake of improving national capability. Terry Parr explained there were many drivers for integration, e.g. from the International Council of Science, which identifies the challenge of developing, enhancing and integrating the observation systems needed to manage global and regional environmental change. There are currently various activities that are seeking to develop cross-programme or trans-national monitoring and research infrastructures. Examples include the global GEO Global Earth Observation System of Systems initiative and, in Europe, projects like EXPEER, which aims to create a distributed infrastructure for experimental ecosystem research. Key components of both are ground-based networks of intensively-studied Long-Term Ecological Research (LTER) sites, linked internationally through ILTER. One developing concern is the lack of comparative developments in the southern hemisphere. Terry Parr argued that the UK should take a lead role in integration of biodiversity research and monitoring internationally.

The outputs from biodiversity monitoring programmes are applied in a variety of ways and presented to a range of audiences: monitored data and accompanying knowledge generally has the potential to serve a greater number of purposes and users than it may be designed for. Porter stated that good data are very important and it is vital to use these data in ways that have impact, whilst Phillips concluded that monitoring under the Water Framework Directive, was yielding data with much wider application.

A common goal of many governments, scientists and stakeholders is to improve comparability of long-term ecological data from sites around the world, and facilitate exchange and preservation of these data. Ongoing initiatives such as LifeWatch could help. LifeWatch is a European project which aims to establish a pan-European e-Infrastructure for biodiversity and ecosystem research, providing easy access to a wide range of datasets, modeling and analysis tools and a collaborative environment in which to use them.

All the speakers emphasised the importance of developing stronger collaborative partnerships, for example to improve the effectiveness of site condition assessments. It was also argued that the UK currently lags behind other countries in Europe and North America in the development of Long-Term Socio-Ecological Research platforms (LTSER) which aim to provide a focus for inter-disciplinary work involving both natural and social scientists.

Terry Parr outlined the following broad challenges, for the future development of societally-valuable biodiversity monitoring programmes:

- Capacity building with respect to:
    - the developing world
    - the use of new technology – ecosystem observatories
- Informatics: integration of data, with respect to:
    - scales
    - between countries & geographical regions
- Socio-ecological engagement:
    - Cross-sectoral solutions require a whole socio-ecological systems approach
- Knowledge transfer:
    - Demonstrating relevance and impact.

## 3. Systems for detecting and attributing environmental change

This session covered a range of approaches and resources that provide the potential for linking changes in biodiversity to drivers at temporal scales ranging from seasonal to centennial. Don Monteith (CEH) introduced the concept of "integrated environmental monitoring" in terrestrial landscapes, i.e. co-located measurement of environmental drivers and ecological responses, through the example of the UK Environmental Change Network (ECN). Matt Frost (MBA) then explained the origins and development of the Marine Environmental Change Network (Marine ECN). Finally, Steve Brooks (NHM) outlined the potentially serendipitous value of museum collections of biota for developing a clearer understanding of long-term change in biodiversity at multi-decadal to centennial levels.

The UK's Environmental Change Network (ECN) and Marine Environmental Change Network (MECN) function independently, but while differing in origin and design, they share a range of similar traits and objectives. Both are partnerships of organisations receiving some support from Defra (and in the case of ECN, from NERC) for central coordination. Both focus on the high frequency collection of a wide range of physical, chemical and biological data from a few highly specific locations representative of a range of UK habitats. Don Monteith suggested that the greatest strength of the ECN in future would come from its application in wider collaborative frameworks incorporating measurements drawn from a range of spatial scales to assess the dynamics and causes of environmental change.

The ECN was established as a single programme and while most of its 12 terrestrial sites, ranging from montane and upland grassland through to lowland woodland and lowland agricultural sites, have a long history of environmental monitoring, all signed up to a standard set of monitoring protocols at the onset of the network. High frequency measurements are made of climate, deposition and soil chemistry and a range of plant and animal groups. The MECN, in contrast, is a slightly looser affiliation of largely non-statutory monitoring programmes, that while sharing common aims in terms of integration, operate for different purposes. However, MECN is working towards harmonising some monitoring methodologies, and developing novel analytical approaches.

One highly valued feature of ECN is that, in addition to the regular provision of data, sites provide platforms for local scientific investigations where the impact of factors such as grazing, moor burning etc. can be determined through controlled experiments.

A key aim of both MECN and ECN is to provide information to policy makers and other end-users to enable them to produce more accurate assessments of ecosystem state and gain a clearer understanding of factors influencing environmental change.

Both networks are involved in scientific assessment and knowledge transfer. Both science programmes are concerned with how to best apply multiple datasets to assess changes over long-term time-scales (see for example “MECN Long-term Datasets Analysis”; report to Defra, 2009; and Morecroft et al., 2009). Long-term changes in biodiversity in relation to drivers such as climate change and fishing in the marine environment, or upland land-use have also been examined using some of the individual time-series. Several examples were provided to illustrate how long-term marine records were providing valuable insights into long-term change in the marine environment. These included the remarkable Eddystone Reef record that has charted substantial changes in benthic communities of the western English Channel at a centennial scale (i.e. 1895-2007).

The MECN knowledge transfer programme is aimed at providing evidence to support policy by increasing our understanding of factors influencing change in marine ecosystems and enabling policy makers to produce more accurate assessments of ecosystem state through mechanisms such as the Marine Climate Change Impacts Partnership and the United Kingdom Marine Monitoring and Assessment Framework (UKMMAS). Matt Frost emphasised that the big science questions in the future will be heavily influenced by the policy community particularly as we look at key issues such as the Marine Strategy Framework Directive. ECN have a well developed communications policy that is aimed not only at the policy community (through for example regular interactions with officials in Defra) but also, largely through its website, at other scientists, schools and the general public.

There is currently no geographic co-location of ECN and MECN sites but there is increasing scientific interaction between programmes with respect to sharing of knowledge and experiences with quality control procedures, databasing and data analysis. Increasingly ECN data are being linked to data from compatible monitoring programmes operating at wider spatial scales.  A comparison of temporal variation in vegetation indicators for UK broad habitats between ECN and the Countryside Survey (CS) provided an illustration of how the higher frequency ECN data can be used to provided a stronger temporal context for this more occasional, but spatially more intensive, monitoring programme.

In contrast to both the ECN and MECN, the use of natural history collections is a largely untapped resource. Steve Brooks explained that natural history collections in the UK contain millions of biological specimens, drawn from a wide range of locations (and the source location of many specimens can be pinpointed with confidence). Curated “modern” and fossil specimens not only provide broad taxonomic coverage from which inferences can be made of past geographical distributions, but also potentially provide biological material with which modern bio-chemical techniques, including DNA and isotope analyses can be applied.

Museum collections are contributing either independently, or in collaboration with modern surveys, with respect to:

- phenological responses (e.g. in  butterflies, flowering plants and bird eggs)
- changes in the geographical distribution of both taxa and genetic markers, with the advantage of high quality voucher material for reliable identification
- verification of the arrival of invasive species
- changes in abundances and species composition over time (where regular and frequent sampling collections are available), both in processed material and unsorted bulk samples
- changes in morphology
- sclerochronology (growth rings), changes in growth rates (e.g. fish otoliths, corals, long-lived bivalves)
- Isotopes and trace elements as proxies for past climates and environments, and dietary changes
- Fossil collections used to understand responses to past climate change
- Ancient and modern DNA changes in genetic diversity.

Although there are some limitations to using collections, and taxonomy may reflect old nomenclature, specimens can be verified, something that is rarely possible with respect to modern atlas records. Spatial and temporal biases exist, but it could reasonably be argued that sampling biases are equally, if not more, prevalent with respect to observational data that results from targeted monitoring to meet specific policy concerns or is based on the distribution of people, for example around urban centres and tourism hotspots.

Current limitations to the wider use of museum collections in biodiversity studies include the lack of centralised detailed metadata on museum holdings, the disparate location of potentially complementary collections in different museums, the fact that collections may not be digitised to specimen level (especially with respect to insect collections) and restrictions on levels of destructive sampling. However, the enormous range of safely archived material, including specimens of extinct species and those from destroyed or degraded habitats and regions that are currently inaccessible, should be more widely recognised as a scientific tool.  Currently there have only been 27 studies of this type worldwide and to date not one of 75 leading international museums had reviewed their collections as a resource for investigating long-term change. There is clear potential for UK museum collections to provide robust long term historical information to support a range of contemporary monitoring programmes.

While the types of data that can be gleaned from museum collections may at first appear fundamentally different from those collated by contemporary networks, there is potential in some cases for museum records to provide a much longer historical context for modern observations, in a similar, if less direct, manner to the way palaeoecological data are providing a historical context for modern algal assemblages at on the Acid Waters Monitoring Network (see Section 4).

## 4. Assessing the impacts of pressures on biodiversity

In this session, the aim was to show how monitoring is used to determine the impacts of some major pressures on biodiversity. The three examples presented were acidification of freshwaters due to air pollution (Rick Battarbee of UCL), weather & climate change (David Roy from CEH) and land use (Lisa Norton from CEH). At the end of this session, Lawrence Way (JNCC) presented some thoughts on the current status of UK biodiversity monitoring. He also proposed some possible improvements and changes that may be necessary in the face of current challenges.

Rick Battarbee described how The UK Government established the Acid Waters Monitoring Network (AWMN) in 1987 to monitor the state of acidified waters, following its acceptance that air pollutants were responsible for the widespread acidification of lakes and streams through the effects of "acid rain". The AWMN has monitored water chemistry and a range of biotic variables (e.g. aquatic macrophytes and salmonid fish) in 22 acidified lakes and streams, and, through meticulous observation over the past 20 years, documented declining sulphate concentrations, rising pH and declining concentrations of biologically reactive aluminium (a highly toxic product of soil acidification). AWMN data demonstrate how communities of aquatic organisms such as diatoms and invertebrates have responded to the improvement in water quality. One unique approach of the AWMN that allows recent changes in biodiversity to be placed in a more historical context in lakes is by comparisons of algal assemblages preserved in lake sediment cores, with those collected annually in sediment traps. These comparisons provide irrefutable evidence that, despite recent significant changes, the ecology of these systems remains very different from "pristine" or pre-acid rain conditions.

Importantly, the data from the AWMN have repeatedly shown that environmental and ecological responses have rarely occurred in the manner predicted and the developing datasets are continuing to deliver surprises that are increasing scientific understanding of these upland water systems. While sulphate concentrations in these waters have declined in line with reductions in deposition, levels of nitrate (a contributor to both acidification and nutrient enrichment) remain elevated, despite a reduction in nitrogen emissions. The AWMN was the first system internationally to first identify and later develop a scientific understanding of large increases in dissolved organic carbon in waters across large parts of northern boreal systems, and the high detail of its biological records is increasingly contributing to our understanding of freshwater ecosystem dynamics, and the sensitivity of these systems not only to acidification but also to climate change and changing land use (e.g. forestry or upland grazing) practices. Rick Battarbeee argued that the AWMN has proven its worth as a long-term ecological and biogeochemical research network. A strategy to augment the AWMN to create an Upland Waters Monitoring Network, informing on a range of air, land-use and water quality policy, management and scientific interests, has now been fully endorsed by Defra.

In contrast to the air pollution policy focus of AWMN, the Countryside Survey (CS), the subject of Lisa Norton's talk, was initially developed by landscape ecologists as a research programme, but is now of increasing value to policy customers. As a result CS has evolved to meet policy requirements and seen a shift in the funding which reflects the interests of those policy customers.

First conducted in 1978, CS has been repeated in 1984, 1990, 1998 and 2007. Surveys are made of a stratified random sample of 1 km squares (based on 32 land classes). The number of squares has increased over the series of surveys, with 591 sampled in 2007. The parameters measured have also changed over time, though considerable effort has been made to maintain consistency of data collection across surveys for much of the core data collected. Vegetation plot data has shown that species richness in fields, woods, heaths and moors decreased by 8% between 1978 and 2007. Supporting AWMN findings, soil acidity declined over this period.

Improvements have been made in many areas of CS, such as the use of rugged digital devices to capture data electronically in the field, improved analysis and web based data accessibility, better data interoperability and improved analyses and reporting methods. As a follow-up to the 2007 survey, the CS Integrated Assessment project is attempting to use the data to provide information on ecosystem service provision and interactions between services.

David Roy explained that impacts of recent climate warming have been observed in a wide range of aquatic and terrestrial organisms (e.g. IPCC 2007). Evidence of changes in the timing of seasonal events (phenology) and changes to species' ranges dominate recent reviews, yet a comparable assessment of changes in population abundance has been lacking.

David Roy's presentation focussed on BICCO-Net (Biodiversity Impacts of Climate Change Observation Network), a collaborative project providing the latest information on the impacts of Climate Change on UK biodiversity. BICCO-Net is a Joint Research Initiative sponsored by Defra, CCW, NIEA, NE and SNH and managed by JNCC. It aims to establish, test and start to implement a process for the collation, systematic analysis and dissemination of evidence for observed impacts of climate change on UK and England terrestrial and freshwater native and non-native species and habitats. Such evidence can be used to provide recommendations to Defra to guide the further development and review of biodiversity monitoring and reporting strategies, and the results will also be communicated more widely. BICCO-Net is the first attempt to examine the population level consequences of recent climate change across a range of taxa including plants, invertebrates and vertebrates. It is based on data from established national monitoring programmes in the UK, such as the Environmental Change Network (ECN), the Rothamsted Insect Survey, the Butterfly Monitoring Scheme and monitoring run by The Bat Conservation Trust and British Trust for Ornithology. The project has already revealed some previously unseen effects. Taxonomic groups differ in their responses, .e.g. birds tend to decline following cold winters and increase following warm and wet years, whilst there are negative effects of mild winters on invertebrate populations and mammals. In general, invertebrate populations respond to warm conditions during key stages of their life cycles – typically during spring and summer. Analysis of skylark data suggests that changing land use (cereal yield) has been the major factor leading to the decline of skylarks. Such confounding effects of land use may mask or interact with climatic effects.

BICCO-Net provides perhaps an unprecedented example of the power of UK biodiversity-related long term monitoring initiatives when brought together for a common purpose. Data from over

13,000 sampling sites was included in the analyses, which covered 721 species from 8 groups; in total, the monitoring dataset comprises more than 84,000 population estimates.

**The value of monitoring may go up as well as down; 2020 vision**

Lawrence Way, Joint Nature Conservation Committee

Day 1 of the conference was brought to a close by Lawrence Way who reminded delegates that whilst funding for monitoring is likely to be reduced, the need for evidence will surely increase. The requirements of funders need to be better understood as they will increasingly expect monitoring programmes to deliver information of practical value to addressing problems of key national concern Funders are also increasingly likely to question which is preferable: investment in long-term monitoring or short-term studies designed to answer specific questions. It is important for the biodiversity monitoring community to demonstrate its value and to become a critical component of assessments, reporting and research. It will also be necessary to consider ways to reduce costs through more efficient monitoring.

Fundamental science-based questions the monitoring community need to consider include:

- How is biodiversity changing?
- What are the principle factors causing this change, and what is driving them?
- Can we predict the likely effect on biodiversity given projections and policy options?
- How do ecosystem functions work and how does biodiversity change affect them?

While the most pressing questions coming from the policy arena that need to be addressed include:

- Are biodiversity strategies achieving the desired outcomes?
- How successful have been interventions such as the Rural Development Programme?
- Can we deliver biodiversity information adequately to our European and international commitments?

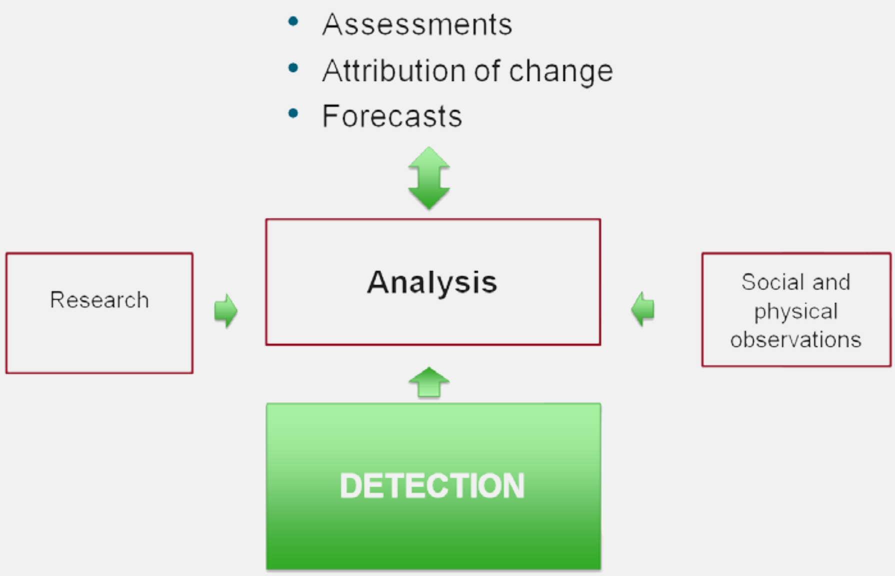
The increasing focus on ecosystem services should place a greater emphasis on local decision making. Lawrence Way argued that more research would be necessary to calibrate provisioning and regulating services to habitats, develop traits for species and link these to functions, establish how biodiversity relates to resilience in functions and develop metrics of value and benefit. Related monitoring will therefore need to:

- Improve habitat maps and detect condition changes that will affect services
- Detect change in high profile species and habitat quality to relate to cultural values
- Detect resilience across functions by increasing change detection to a wider range of taxa.

With respect to the need to deliver “more for less”, Lawrence Way argued that long-term monitoring could change and adapt. New, improved methods can be introduced to replace older, less efficient ones. Satellite and airborne monitoring could provide greater coverage with time series from the 1970s. The Global Monitoring for Environment and Security, GMES, has 30 years of funding and will provide an abundance of consistent data. Processing techniques for earth observation (EO) data need to use ecological rules. New technologies could and should deliver high resolution habitat mapping and condition assessments, as well as sampled stock and change information, although EO solutions would need to be competitively priced compared with field mapping and air photo interpretation. There was also scope to expand opportunities for volunteers, through adherence to well-designed protocols, in the delivery of high quality data. For example, volunteer involvement in plant or vegetation monitoring could be used to boost surveys to an annual frequency, providing a better context for measuring interventions. Similarly, improvements could be made in the way data are analysed. New statistical techniques could, for example, be applied to the more than 50 million records in the National Biodiversity Network, e.g. to interpret change through groups of species, rather than individually. More could be done to analyse multiple datasets together, as had been demonstrated by BICCO-Net, and there was scope to work more closely with other sectors, e.g. using other datasets and translating results.

Lawrence Way concluded with a vision for biodiversity monitoring in 2020 (see box 4) in which monitoring (detection), research and social & physical observations were combined in analyses to attribute change, and provide assessments and forecasts. Detection of change would use spatially and temporally intensive monitoring that was simple and cheap, including a 'virtual' Countryside Survey (e.g. of birds, butterflies, bats, plants and other biological recording) alongside remote sensing of habitat change. Research would encompass process studies and experiments and address traits, functions and valuation. Abiotic data would include Met Office Grid data, farm surveys, visitor data, human population statistics and pollution load models.

**Box 4: A model for future monitoring envisaged by Lawrence Way, JNCC**




See text above for more information

## 5. The benefits of multi-decadal monitoring

This session focussed on particularly long time series monitoring programmes, with examples from Peter Burkill from the Sir Alister Hardy Foundation for Ocean Sciences (Continuous Plankton Recorder Survey, CPR), Stephen Maberly from the Centre for Ecology & Hydrology (long-term surveys of Cumbrian lakes) and Richard Harrington of Rothamsted Research (Rothamsted Insect Survey, RIS). In all cases the datasets have addressed a far wider range of questions and made a range of ecologically important observations way beyond those envisaged at the outset of monitoring. All three presentations therefore highlighted the serendipitous value of maintaining environmental long-term monitoring over long time scales.

Peter Burkill explained how the Continuous Plankton Recorder (CPR) Survey was initiated by Alister Hardy in 1931 in order to use plankton distributions to improve fish catches in the North Atlantic and the seas around the UK. The survey involves the towing of a purpose-designed plankton recorder behind regular freight and passenger vessels ('ships of convenience'). Plankton are collected on silks that rotate on a drum at a speed proportional to the speed of the vessel. Sampling time and location can therefore be back calculated from the position of the sample on the silks. Samples are preserved and some 500 species are identified by optical and molecular techniques back at the lab. The CPR Surveys have provided invaluable insights into numerous aspects of plankton dynamics and ecology, particularly with respect to effects of climate change, eutrophication, harmful algal blooms and most recently the impact of ocean acidification on marine ecosystems. CPR data are available for free to scientists the world over.

Stephen Maberly introduced the Cumbrian lakes database, which comprises some of the longest and most comprehensive lake datasets in the world. Not originally conceived as a long-term monitoring programme, some measurement series started in the 1930s (consistent measurement of a range of variables started in 1945), initially as a research project by John Lund. They were then continued by other Freshwater Biological Association staff and, latterly, by CEH. Physical, chemical and biological parameters are measured, and methods have been consistent, or cross-calibrated if a change has been necessary. Modern techniques such as automatic monitoring and hydroacoustics complement the long-running surveys.

The data are used in a range of ways, e.g. to develop understanding of nutrient cycling and enrichment, to study the effects of weather, climate change and invasive species and to assist species conservation. Stephen Maberly stressed that the data had most value when used in combination with laboratory and field studies. For example, the data have been used to show that chrysophytes, an indicator of good ecological status used in Water Framework Directive assessments, are not necessarily a good proxy for phosphate concentrations, and are affected more by carbon dioxide concentrations. The data collected at Bassenthwaite Lake and Derwentwater have also contributed to a study of the rare vendace fish, a declining UK BAP species. It is a northern species at the southern limit of its range and is affected by warm water. Data are used in models, such as the PROTECH phytoplankton model, which can be used to predict algal blooms. Stephen Maberly also emphasised that the data are most valuable - i.e. best interpreted - when measurements are made at a range of physical, chemical and biological (range of trophic groups) scales, providing the opportunity to identify both responses to and drivers of change.

Richard Harrington provided the terrestrial example for the session with the Rothamsted Insect Survey. Insect suction traps and light traps around Great Britain have been collecting daily data since the mid 1960s. The work was initiated by Roy Taylor following the publication of Rachel Carson's *Silent Spring*. The light trap network has provided evidence of widespread declines in moths, which may be due to any of several factors including landscape simplification, climate change and air pollution.

There are about 600 known species of aphids in the UK, some of which are important pests. The suction trap network has multiple applications to the study of aphids, including in unforeseen ways, such as investigating aphid resistance to insecticides. Although intended to study aphids, other species are trapped. They include mosquitoes and midges, and these data are used in projects concerning disease transmission. Samples from the traps are stored for future use, but a challenge is securing the funding for additional species to be analysed.

Some of the challenges common to all the examples in this session are:

- Funding – essential for data collection, fundamental and applied research
- Database management – the use of automatic sensors, e.g. in the lake surveys, presents particular problems because of the large volume of data generated
- Retaining expertise – e.g. species identification
- The introduction of new technologies – e.g. automatic recording and data transfer, automatic species identification, e.g. through DNA sequencing.

## 6. The public's role in biodiversity monitoring

There were six oral presentations in this session which began with an assessment of the motivations and aspirations of volunteers (Sandra Bell, Durham University) and was followed by examples of public participation in projects to monitor butterflies and moths (Richard Fox, Butterfly Conservation), birds (Andy Musgrove, British Trust for Ornithology), marine species (Keith Hiscock, Marine Biological Association), phenological events (Tim Sparks, UK Phenological Network) and projects to attract new audiences to biomonitoring (John Tweddle, Natural History Museum).

One of the key themes to come out of this session was the need engage and maintain the interest of participants through feedback. Common to the feelings of many data-providers is a sense of data-ownership, and that their data are being provided as a 'gift' that entails some level of reciprocation. Providers need to feel valued and be assured that their data are being put to good use. Failure to ensure this may result in an early sense of disappointment and possible disengagement.

However, expectations will vary and volunteers may not require the same types of encouragement as the professionals who often design the monitoring schemes. Participants may be looking for fellowship through shared approaches and a common interest with other volunteers engaged on the project, providing them with an alternative world which breaks down the social barriers they are used to in their everyday life. Other motivations include opportunities for purposeful learning and receipt of recognition for the records they provide. Volunteers may be motivated by working on their local patch but also by seeing their data used to build up a national picture.

Engaging volunteers is labour intensive, and requires significant investment of time and energy.

Science is a big draw and projects can be targeted at particular interest groups. Even those who have no previous scientific experience may be keen to participate, while communities may receive motivation from within their ranks through involvement of dynamic individuals. Sandra Bell warned, however, that as the number of citizen science projects continues to increase there is an imminent danger of survey overload. There is not an infinite resource of volunteers and the increasing age demographic could be a problem. Currently a significant proportional of the most active recorders are newly retired, and it is vital to increase the recruitment of younger generations.

Public engagement surveys involve tens of thousands of volunteers who generate millions of records annually. The most successful projects are those that are well-publicised, those where aims and approaches are communicated in simple language, and those where participants have a clear affinity with the project outcomes.

## 7. Opportunities and challenges for long-term biodiversity monitoring and research

This session aimed to consider the potential for greater application in biodiversity monitoring of some recent advances in earth observation (Andy Shaw, National Centre for Earth Observation), soil microbiological recording (Jim Prosser, University of Aberdeen), environmental informatics (Stuart Ball, JNCC/NBN) and communication of results with policymakers (David Noble, BTO).

All the speakers considered both opportunities and challenges in relation to new technologies and developments in science, informatics and communication. A common issue was the rapid increase in volume of data; new Earth Observation and gene sequencing approaches both yield large amounts of data, whilst information-handling services such as the National Biodiversity Network (NBN) also have to cope with ever-increasing amounts of data (e.g. NBN and GBIF are looking towards ‘parallel’ computing systems, which use the power of a cluster of computers). Advances are therefore closely coupled with developments in computing, and this raises a further point: i.e. the extent to which the development of new approaches in biodiversity monitoring and data handling would benefit from linking more closely with other, better-funded areas (for example, new genetic techniques typically emerge from the field of medicine). This could of course be seen equally as advantageous or disadvantageous.

In terms of earth observation, remote sensing techniques are already widely used in studying marine and terrestrial ecosystems. Many Earth Observation (EO) products concern physical parameters but these measurements, and derived measurements, have applications relevant to the study and monitoring of biodiversity. Recent technological advances mean that greater temporal frequency of measurements is now possible. Rapid changes such as tree leaf emergence could be monitored over a wide area using remote sensing. Improvements are also being made in the spatial resolution of measurements. Smaller, cheaper satellites provide wide area images for rapid regional coverage; the trade-off is lower spatial resolution than more expensive systems. Satellite-based radar systems now allow us to 'see' through clouds and study, for example, terrestrial carbon sources and sinks. There is also a wide variety of airborne sensing techniques such as LIDAR, hyperspectral imaging and digital photography.

An issue to be addressed is whether or not GEO-BON is the way forward, and indeed where, when and how the UK EO and biodiversity community develops a linked strategy. One challenge was how to promote wider awareness, acceptance and confidence with respect to EO derived products, whilst David Noble also considered confidence in results as an issue. These concerns are particularly relevant in the case of outputs from new, cutting edge methods. Another issue covered was complexity. While we are continually increasing our ability to study the immense complexity of natural systems, we are facing new challenges, for example in linking datasets, modelling complex systems (incorporating data from many sources) and communicating results.

David Noble emphasised the need to continue long-term time series wherever possible, given the unanticipated uses of data in the future. Andy Shaw saw the maintenance of methodological consistency as key challenge in relation to remote sensing. When considering the evolution of methods; how do we balance the need for continuity with the introduction better or more cost effective approaches?

Jim Prosser described how bacteria are responsible for a wide range of essential processes such as the maintenance of soil fertility and quality, nutrient cycling and the degradation of pollutants. He explained some of the shortcomings of traditional methods of assessment of microbes in the environment and how more modern techniques involving the extraction of genetic material from soil samples largely have overcome these to reveal a huge diversity of soil bacterial species.

The key challenge now was to understand the ecological functions that these microbiological 'species' perform, but comparison with closest known relatives does not always help. Advances in a range of 'omics' techniques may help and could be applied elsewhere to the monitoring and study of microorganism diversity, Potentially beneficial techniques include proteomics (the study of protein diversity) and metabolomics (metabolic diversity).

Stuart Ball's presentation on developments in informatics focussed on the National Biodiversity Network (NBN) and the Global Biodiversity Information Facility (GBIF). The NBN now provides access to around 57 million records in a range of distributed databases and the volume of data handled is growing rapidly. The growth in the amount of data has resulted in a change in approach, which in turn has led to new problems. For example, the owners of datasets do not always provide their updates in a timely fashion, demonstrating that many problems in informatics are due to people, not computers.

In order to enable greater use and reporting of data held in NBN, a range of web services have been developed and an increasing number of websites are using these tools to provide access to data (e.g. the distribution maps on the Moths Count website, www.mothscount.org).

Investment in skills and technologies is necessary, but it may also be necessary to accept that simple, more manual solutions may in some cases provide the best solution.

David Noble described how data gathered about bird populations are used to inform policymakers. Monitoring can provide information on trends and changes in spatial distribution, and data are used in conservation, in major planning decisions and to develop and evaluate policies, management plans and decisions. For example, to inform the UK government's response to outbreaks of avian influenza, a modelling tool was developed that plotted likely migration routes and determined the expected timing of movements for key species. This used data from many parts of Europe (trans-national collaboration is of value).

David Noble identified some lessons learned and future challenges, including:

- The need to provide clearer guidance on confidence in results (e.g. trends)
- Recognition that while outputs that provide a simple message are most effective, simple messages may not convey the complexity and diversity of natural systems
- Monitoring is often most effective at generating useful results when targeted on a particular issue, but such programmes can be costly to maintain.

# 5. Summary of workshop discussions

A set of group workshop discussions took place at the end of the conference (Session 8) in which participants were invited to consider three areas pertinent to the monitoring of biodiversity in the UK: (1) past/present examples of monitoring that demonstrate how long-term biodiversity monitoring has informed our response to biodiversity decline or helped us to answer key environmental and social questions, (2) societal needs – the environmental and social issues that require an understanding of how biodiversity is changing and the fundamental requirements in terms of information/knowledge that biodiversity monitoring may provide, and (3) whether there is a need for a more joined-up framework for biodiversity monitoring and if so, what level of integration would be beneficial and how this might be achieved.

## 1. The past

Delegates were asked to …

1. List **two examples** that demonstrate how long-term biodiversity monitoring has informed our response to biodiversity decline or helped us to answer key environmental and social questions.

The following were among the examples proposed:

- **Acid Waters Monitoring Network** has monitored the response of upland aquatic ecosystems to legislation governing air pollution emission, demonstrating significant, if often muted, national improvement
- **Various evaluations of agri-environment schemes (AES)** have enabled AESs to be tailored to halt declines
- **Bird reports and farmland bird monitoring** (e.g. as carried out by the BTO) have led to the development of aggregated data indices, influencing environmental stewardship schemes, funding and action. Changes in bird populations have reflected agricultural change at a large/national scale
- **Game and Wildlife Conservation Trust study of partridges and invertebrates** has informed understanding of the decline in birds and invertebrates in relation to agricultural management intensification
- **Peregrine eggshell measurements** which led to the banning of DDT
- **Butterfly Monitoring Scheme** has influenced Biodiversity Action Plans and reporting against agri-environment schemes. Along with farmland bird monitoring, BMS has led to the development of EU Headline Indicators
- **Rothamsted Insect Survey** has revealed the state of Britain's larger moths and shown aphid responses to environmental changes

- **Studies of dragonfly range changes** have revealed rapid distributional changes of most UK species in response to recent climate warming
- **Continuous Plankton Recorder survey** has provided global scale environmental insights into environmental change, particularly with respect to climate change affects on marine ecosystems, and the link between plankton and fisheries
- **Countryside Survey** has informed our understanding of changing landscapes and biodiversity, and led to the legislation to protect hedgerows in the early 1990s
- **Eddystone long-term marine time series** -has informed fisheries policy and biodiversity trends
- **Environmental Change Network** has revealed an apparently widespread decline in carabid beetle activity in upland habitats and stimulated a range of studies to understand drivers.
- **Various studies** revealing declines in fish catches that influence decisions about fish quotas and have promoted work on the genetic modification of oilseed rape to provide an alternative source of fish oils
- **The use of collected specimens** in museums and herbaria, such as DNA extracted from aphid samples and the phenology of the spider orchid used to reveal responses to climate change
- **Monitoring relevant to pollution** such as freshwater monitoring leading to cleaning up rivers in the UK and the monitoring lichens since the 1950s, demonstrating their potential as indicators of air quality
- **Studies of invasive species and range expansion** in other species, leading to the recent Lawton review of habitat connectivity
- **Various local level studies**, e.g. on stag beetles, which influenced policy on green spaces
- **Informal monitoring of certain plant species** to determine the possible response to climate change
- **Long-term studies of animal behaviour and sociality**, e.g. red deer on Rum and meerkats in the Kalahari Desert, which have increased our understanding of group dynamics and behavioural ecology
- **Studies of charismatic species** (e.g. birds of prey) which have had a significant influence on policies and management plans concerning their conservation.

## 2. Societal needs: ends and means

Delegates were asked to …

1. List what you feel are the ‘big’ environmental and social issues that require an understanding of how biodiversity is changing.
2. Identify the **three** most pressing of these issues and the fundamental requirements in terms of information/knowledge that biodiversity monitoring may provide.

The following environmental issues were identified. Suggested information requirements are also shown:

- Acidification of terrestrial and freshwater ecosystems by transboundary air pollutants
- Acidification of the oceans resulting from rising levels of atmospheric $CO_2$.
- Changes in air quality in rural and urban environments
- Climate change
    - baselines and indicators
    - trends in phenology, range changes, abundance and distribution
    - tipping points and thresholds
- Conservation
    - the optimum size for conservation areas
- Ecosystem integrity and resilience
    - baselines and indicators
    - process studies
    - ecosystem resilience (modelling approaches)
- Eutrophication of surface waters through diffuse, point source, and atmospheric pollution
- Interactive effects of pressures, e.g. climate change, air pollution and land-use on ecosystem structure, function and services.
- Maintenance of ecosystem services (including, provisioning, supporting, regulating and cultural services)
    - Dependence of ecosystem services on biodiversity, ecological functions and functional diversity
- Renewable energy generation
- Environmental attitudes
    - the economic and other values of biodiversity, nature and green spaces
- Food and water security (see also ecosystem service entries above)
- Potential impact of genetically modified organisms on the natural environment
- Habitat loss, fragmentation, degradation
    - baselines
    - tipping points and thresholds
- Human health
    - Monitoring can provide early warnings of, e.g. disease vector arrivals
- Arrival, abundance and impact of invasive species
- Land use change implications
- Ocean management
- Planning and development, urbanisation, urban green spaces
    - Monitoring can provide evidence to challenge planning applications
    - An urban version of the Countryside Survey may be of value (until recently a survey was conducted in London)
- Quality of life
- Soil quality
- Sustainable development

    - baselines and indicators
- Unanticipated value of gene pools
- Water quality, eutrophication

The three most widely perceived threats to biodiversity in the UK were future climate change, pollution (particularly from diffuse inputs from the air and land) and habitat fragmentation. No clear consensus was achieved with respect to the information need but the most often repeated concern related to the need to ensure that biodiversity monitoring reached beyond the routine measurement of abundance of species by linking biological observations more clearly to pressures and to ecosystem functions and processes. Such information is perceived to be critical if the UK is going to be able to address the "Ecosystem Services" element of the CBD COP10 strategic vision.

The following points were raised:

- There are multiple, interacting pressures on the environment, with differing magnitudes from place-to-place. Determining national-scale priorities is therefore highly challenging. An integrated approach to biodiversity monitoring (involving the assessment of pressures and responses) is essential for the development of a clearer understanding of these complex interactions.
- There should be a greater expectation on monitoring programmes to make data more freely available. Some data transfer should be obligatory, e.g. biological data from development surveys should be deposited with the NBN or local record centres.
- Equally, there is a need to respect the vital contribution of the scientists who ensure the maintenance of many of our highest quality datasets, and ensure that sufficient scientific incentives remain for their continued commitment.
- We should change our thinking about major funding streams. While regular review is necessary, long-term monitoring programmes should not need to compete with new environmental assessment initiatives in order to survive. An effective, nationally coordinated, funding system is necessary to fund the long term monitoring required to support research, policy or agency needs, and foster, develop and maintain voluntary recording efforts
- Knowledge from monitoring and research can feed into public education and awareness-raising
- Monitoring needs to be complemented by – and can support – experimental research.

## 3. Developing biodiversity monitoring capability

Delegates were asked …

1. The need for a more integrated UK monitoring framework is generally accepted. Does your group agree?

2. If YES …
    a. what are the key features of an integrated framework (e.g. how should it be coordinated; what should be the relative mix of professional and public involvement, etc.)?
    b. what steps need to be taken to deliver it?
3. If NO …
    a. can you identify other areas of development?
    b. what steps are needed to deliver these?

***General Summary***

**Is there a need for more integrated UK monitoring framework?**
Five out of seven groups agreed there was a need for a more integrated framework. One group (Group 5) was split, with those representing marine monitoring disagreeing, whilst the terrestrial monitoring community favoured greater integration.

One group warned that integration implied greater bureaucratic “top-down” control that could put off many in the volunteer sector if they felt disenfranchised from the direct engagement in projects they currently enjoy. But the general consensus was that integration should be thought of more as loose collaboration and coordination rather than a centrally imposed framework. Integration should be of a level that would encourage “value-added” cooperation without hindering the existing raison d’etre of monitoring programmes.

There were many opportunities and risks identified by the groups: these relate primarily to how the framework would work rather than to the principle of more joined up efforts itself.

**What are the features of a framework and what is needed to deliver it?**
The following points were made:

1. We require a very clear assessment of current UK biodiversity monitoring effort (e.g. using the UK-EOF catalogue or further development of it)
2. We need to have a clear understanding of why each programmes exists and what key questions the data can help to answer
3. We need to determine how monitoring  activities are or could be linked - in terms of governance and organisation, remits, data collection, commonalities of datasets as well as how the data generated can be inter-calibrated
4. We need to prioritise clearly the questions we wish to address
5. A central portal for all biodiversity meta data will be essential.  Centralised delivery of raw data would be ideal (e.g. through NBN) but not necessarily practicable

6. We need to consider the best use of resources and effort (from professionals, amateur experts and the wider public) – identify the gaps, duplications and areas for collaboration - i.e. stop, modify or start programmes
7. Depending on the outcomes above it will be necessary to develop programmes for the basic skills training required of both the volunteer and professional sectors e.g. using the Field Studies Council and others, to ensure practical, taxonomic and statistical expertise is maintained and ideally enhanced
8. It will be vital that a data sharing culture is developed and then maintained to ensure incentives are provided for those in professional and voluntary sectors. We will need to ensure there are adequate and easy to use data storage and sharing methods.

Opportunities for collaboration may stem from:

- **Where the activity is undertaken** - can more data be collected at the same site?
- **How the data are collected** – could protocols, technologies be shared?
- **Who collects the data** – are there shared skills and training that could be cost-effectively delivered? Could more be collected by the same volunteers? Note this was felt to be a sensitive area. There is no direct control over volunteers and they have multiple motivations. The greatest opportunity was for volunteers to look at habitats occupied by commonly monitored organism groups (e.g. birds, plants, invertebrates) and their condition, rather than asking for additional species to be surveyed. There are also opportunities to ask land owners and/or farmers to monitor aspects of their own land
- **Scientific research, data analysis and interpretation** - if datasets are shared and inter-calibrated, the science community can use these data for more powerful analyses of environmental changes and impacts. This will in turn generate information and knowledge to improve support for the management of natural areas and the formulation of policies which help to protect them
- **Connections and support from industry** - A coordinated framework would attract more interest from industry as there would be a clearer understanding of where new efforts would be needed. Research into the economic benefits of recording may convince commercial interests of the benefits to them.

There are a number of risks and barriers:

- **Resources** – for example, the use of volunteer networks does not come free of charge. At present funding comes from many disparate sources and is directed to particular causes. It would be very difficult to redirect this
- **Disengagement and mistrust** from the large volunteer network if they are not consulted, do not understand the reasons for the changes, do not have visibility of how the data are used, are asked to do too much or do not have the skills and training

- **Missed biota** – if the framework is too prescriptive about what is measured then data on some taxa and habitats which become important in the future could be missed
- **Monitoring being either too specific or too vague** – a balance needs to be found between the two
- **Land-use overload** – there is already resistance (by private owners) to the same pieces of land being used multiple times for science studies.

***Other points made***

The following specific points were made in addition to those reported above:

Why we should better coordinate monitoring

- A hypothesis-driven approach is needed, drawing upon appropriate monitoring, experiments and research to answer questions and generate solutions
- The Government is committed to halting biodiversity loss, so it needs a way to measure this
- Scientists and specialists generally know what datasets are available but policymakers are less well-informed, so integration would benefit them more
- There needs to be good links to process studies and research and modelling such that the monitored information is used and understood.

What and how we should monitor

- We need to maintain a diversity of monitoring approaches but better linked together (i.e. a flexible approach, harnessing people power)
- There needs to be broad taxonomic coverage
- Related abiotic data collection should be included
- DNA monitoring should be included and could become a public engagement exercise
- Voucher specimens should be retained
- There should be a strong spatial (GIS) component
- Effort could be put into monitoring along standard transects, and sharing the results
- Some arenas will continue to need a professional/high technology approach e.g. genetic diversity of soil bacteria or offshore marine investigations.  A strategic approach needs to be maintained under these circumstances.

Who should be involved?

- Public involvement is good where it will realistically work and there is the will, but professional specialists are also needed
- Possible coordinators of a framework are JNCC or RCUK. A range of partners would be involved (they need to have clearly-defined roles) and a small team could administer the framework
- There needs to be strong local ownership where local interests are retained.

Funding

- Funding of the core elements is essential (it can't all happen for free!)
- Public investment could be valuable in places but this should be undertaken in a pragmatic way
- More funding is needed, especially long-term funding
- There is a need for centralised funding for reporting and communicating the results
- Research funding could be provided to enable the many specialist groups to work more closely with the academic sector (related points: Research Councils now require those seeking funding to demonstrate the societal impact of their work; the Angela Marmont centre is attempting to reconnect with Natural History Societies).

Skills and training

- There could be more coordinated training and a central (virtual) pool of expertise to underpin a national framework
- Develop a register of expertise
- Training is an area for key collaboration as its costs a lot in time and money
- Analysis and interpretation skills are important
- A multi-disciplinary approach should be developed.

Informatics

- There are areas around data which could be greatly improved. If there was a standard way of collecting the data, or at least a way of recording the quality assurance process and providing an audit trail, then the user would be able to use data more easily. Data accessibility could also be greatly enhanced (protocols for data sharing and ownership could be published)
- The inter-calibration of the various datasets collected by numerous programmes is essential to be able to compare trends.
- We need to have access to draw in, and make more use of, all publicly-funded data e.g. MoD and hydrographic data. Also some private data sources (e.g. collected by consultants) could be utilised
- The NBN must play an integral role in managing and sharing data.

Communication

- Communication of data and feedback to the producers is very important to maintain moral and motivation
- Greater coordination between public-facing organisations is needed (e.g. when attempting to recruit participants)
- Academics/experts could be encouraged to pass on knowledge and enthuse people (i.e. act as ambassadors), for which funding could be provided for travel and public engagements.

Establishment process

- The needs and views of the volunteer networks should be considered before any framework is introduced
- A network may already exist – centred on the NBN – the challenge being for individual schemes to link to it
- There is a perception that marine monitoring is currently more integrated that its terrestrial counterpart
- We need to recognise that some people prefer to focus on particular species groups, habitats, etc. and maybe unwilling or unable to record more (though some elements of some schemes could be adapted)
- Integration must create a simpler system for practitioners, not a more complex one
- A top-down strategy could be counter-productive and coordination should be left to grow organically
- There should be a clarity of purpose at each point
- Integration should be done at local and regional levels
- Recruitment of young people is a concern
- Linking monitoring of marine and terrestrial systems may not be necessary, though they are interlinked in coastal waters. It was argued by some that marine species are different – different species operating at different scales and having distinctive processes
- In the marine world, the Marine Strategy Framework Directive will be a strong driver for data gathering in the near future
- Volunteers may be more resistant to a top-down, prescriptive approach to monitoring
- Contributors need to be able to see their data being used (but note that some may object to certain uses)
- Volunteers may be motivated by being able to learn new skills and visit new places
- Guidelines could be prepared, e.g. on the design of participatory schemes.

Other points made

- The framework should be non-prescriptive and allow volunteers to do as much or as little that they would like
- Any framework needs to be flexible and adaptable to change
- A framework could identify and propagate best practice.

# Annex A: Conference programme

## Tuesday 16

**1. The national need for long-term biodiversity research and monitoring**
**Chair: David Roy, Centre for Ecology & Hydrology**

| | | | | |
|---|---|---|---|---|
| 13:00 | - | 13:05 | Don Monteith, CEH | Welcome; conference objectives |
| 13:05 | | 13:10 | Mike Dixon, Director of the Natural History Museum | Welcome to the NHM |
| 13:10 | - | 13:30 | Des Thompson and Ian Bainbridge, Scottish Natural Heritage | **Keynote** - Contemporary biodiversity issues, the role of long-term monitoring and future challenges |
| 13:30 | - | 13:55 | Peter Costigan, Defra | **Keynote** - Biodiversity monitoring: policy needs and funding support |
| 13:55 | - | 14:10 | Andrew Watkinson, LWEC and Beth Greenaway, Environmental Observation Framework | The Environmental Observation Framework |
| 14:10 | - | 14:30 | | **Plenary discussion:** The national need for biodiversity monitoring |

**2. Stakeholder applications of biodiversity monitoring**
**Chair: Clive Bealey, NE**

| | | | | |
|---|---|---|---|---|
| 14:30 | - | 14:35 | Clive Bealey, NE | Introduction |
| 14:35 | - | 14:50 | Keith Porter, Natural England | Long-term biodiversity monitoring: a conservation user's perspective |
| 14:50 | | 15:05 | Geoff Phillips, Environment Agency | Compliance monitoring: An introduction to the Water Framework Directive, and the importance of long-term monitoring |
| 15:05 | | 15:20 | Terry Parr, Centre for Ecology & Hydrology | Meeting the international needs for biodiversity and ecosystem data: progress and challenges from a research perspective |
| 15:20 | - | 15:45 | | ***Refreshments*** |

**3. Systems for detecting and attributing environmental change**
**Chair: Mark Bailey, CEH**

| | | | | |
|---|---|---|---|---|
| 15:45 | - | 15:50 | Mark Bailey, CEH | Introduction |
| 15:50 | - | 16:05 | Don Monteith, Centre for Ecology & Hydrology | The Environmental Change Network: Integrated monitoring of pressures on biodiversity |
| 16:05 | - | 16:20 | Matt Frost, Marine Biological Association | Long-term monitoring in the marine environment: the Marine Environmental Change Network (MECN) |
| 16:20 | - | 16:35 | Steve Brooks, Natural History Museum | The value of natural history museum collections |

**4. Assessing the impacts of pressures on biodiversity**
**Chair: Don Monteith, CEH**

| | | | | |
|---|---|---|---|---|
| 16:35 | - | 16:40 | Don Monteith, CEH | Introduction |
| 16:40 | - | 16:55 | Rick Battarbee (with Ewan Shilland), UCL | Tracking the biodiversity response of upland waters to environmental change: the value of the UK Acid Waters Monitoring Network |
| 16:55 | - | 17:10 | David Roy, Centre for Ecology & Hydrology | Population fluctuations and weather: a multi-taxa assessment |
| 17:10 | - | 17:25 | Lisa Norton, Centre for Ecology & Hydrology | Repeat, spatially-intensive survey: vegetation trends from GB Countryside Surveys |
| 17:25 | - | 17:45 | Lawrence Way, Joint Nature Conservation Committee | **Keynote** - The value of monitoring may go up as well as down; 2020 vision |

# Wednesday 17

**5. The benefits of multi-decadal monitoring**
**Chair: Victoria Cadman, Ecological Continuity Trust**

| | | | | |
|---|---|---|---|---|
| 09:30 | - | 09:35 | Victoria Cadman, ECT | Introduction |
| 09:35 | - | 09:50 | Peter Burkill, Sir Alister Hardy Foundation for Ocean Science | Ocean Acidification, Calcareous Plankton and the Continuous Plankton Recorder Survey |
| 09:50 | | 10:05 | Richard Harrington (With Jason Chapman), Rothamsted Research | From Aphids to Zygaenids: The Rothamsted Insect Survey |
| 10:05 | | 10:20 | Stephen Maberly, Centre for Ecology & Hydrology | Long-term monitoring on Cumbrian lakes: integrated studies to attribute the causes of change |

**6. The public's role in biodiversity monitoring**
**Chair: Linda Davies, Imperial College**

| | | | | |
|---|---|---|---|---|
| 10:20 | - | 10:35 | Linda Davies, IC | Introduction |
| 10:35 | - | 10:50 | Sandra Bell, Durham University | Volunteering for Biodiversity Monitoring: Setting the scene from a social science perspective |
| 10:50 | - | 11:05 | John Tweddle, Natural History Museum | From bluebells to BioBlitzes: involving diverse public audiences in wildlife recording and monitoring projects |
| 11:05 | - | 11:30 | | ***Refreshments*** |
| 11:30 | - | 11:45 | Richard Fox, Butterfly Conservation | From *buddleia* to biodiversity conservation: Public involvement in butterfly and moth recording |
| 11:45 | - | 12:00 | Tim Sparks, Woodland Trust, Poznań University of Life Sciences & Technische Universität München | Phenological monitoring |
| 12:00 | | 12:15 | Andy Musgrove, British | Harnessing people power: birds, volunteers and |

| | | | | |
|---|---|---|---|---|
| | | | Trust for Ornithology | the BTO |
| 12:15 | - | 12:30 | Keith Hiscock, Marine Biological Association | Volunteer monitoring of marine species |
| | | | | |
| 12:30 | - | 13:30 | | ***Lunch*** |

**7. Opportunities and challenges for long-term biodiversity monitoring and research**
**Chair: Steve Brooks, Natural History Museum**

| | | | | |
|---|---|---|---|---|
| 13:30 | - | 13:35 | Steve Brooks, NHM | Introduction |
| 13:35 | - | 13:50 | Andy Shaw, National Centre for Earth Observation | Earth observation approaches to biodiversity monitoring |
| 13:50 | - | 14:05 | Jim Prosser, University of Aberdeen | Developments in soil microbiological recording |
| 14:05 | - | 14:20 | Stuart Ball, JNCC/National Biodiversity Network | Developments and challenges for environmental informatics |
| 14:20 | - | 14:35 | David Noble, British Trust for Ornithology | Using information on bird populations and movements to influence policy |

**8. Discussion workshops**

| | | | | |
|---|---|---|---|---|
| 14:35 | - | 14:45 | | *Introduction to discussion workshops* |
| 14:45 | - | 16:15 | | *Discussion workshops*<br><br>*Please refer to the separate guide for details of the workshop topics and to find the location of your discussion group*<br><br>***Refreshments available in break-out rooms*** |
| 16:15 | - | 16:50 | Rapporteurs | *Feedback from workshops* |
| 16:50 | - | 17:10 | | **Plenary discussion:** Where next for long-term biodiversity monitoring?<br>**Chair: Terry Parr, CEH** |
| 17:10 | - | 17:20 | | Closing thoughts |

## Annex B: 2020 biodiversity targets (CBD)

The following text is extracted – without change – from the advanced, unedited version of the CBD Strategic Plan for Biodiversity, 2011-2020 (http://www.cbd.int/cop/cop-10/doc/advance-final-unedited-texts/advance-unedited-version-strategic-plan-footnote-en.doc). Some of the text may be altered in the final version.

**IV. STRATEGIC GOALS AND THE 2020 HEADLINE TARGETS**

1. The Strategic Plan includes 20 headline targets for 2020, organized under five strategic goals. The goals and targets comprise both: (i) aspirations for achievement at the global level; and (ii) a flexible framework for the establishment of national or regional targets. Parties are invited to set their own targets within this flexible framework, taking into account national needs and priorities, while also bearing in mind national contributions to the achievement of the global targets. Not all countries necessarily need to develop a national target for each and every global target. For some countries, the global threshold set through certain targets may already have been achieved. Others targets may not be relevant in the country context.

***Strategic goal A. Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society***

***Target 1*****:** By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.

***Target 2*****:** By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.

***Target 3*****:** By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio-economic conditions.

***Target 4*****:** By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.

***Strategic goal B. Reduce the direct pressures on biodiversity and promote sustainable use***

***Target 5*****:** By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

***Target 6*****:** By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.

***Target 7*****:** By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.

***Target 8*****:** By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.

***Target 9*****:** By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

***Target 10***: By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.

***Strategic goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity***

***Target 11***: By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascapes.

***Target 12***: By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

***Target 13***: By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.

***Strategic goal D: Enhance the benefits to all from biodiversity and ecosystem services.***

***Target 14***: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

***Target 15***: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

***Target 16***: By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation.

***Strategic goal E. Enhance implementation through participatory planning, knowledge management and capacity building***

***Target 17***: By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.

***Target 18***: By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels

***Target 19***: By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred,[3] and applied.

***Target 20***: By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan 2011-2020 from all sources and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization should increase substantially from the current levels. This target will be subject to changes contingent to resources needs assessments to be developed and reported by Parties.

[3] A reference to Article 16 of the Convention will be added to the technical rationale.