Climate Change and Biodiversity Conservation: Knowledge needed to support development of integrated adaptation strategies

Report of an e-conference, September 2005

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Contents

Preface

Research on biodiversity is essential to help the European Union and EU Member States to implement the Convention on Biological Diversity as well as reach the target of halting the loss of biodiversity in Europe by 2010.

The need for co-ordination between researchers, the policy-makers that need research results and the organisations that fund research is reflected in the aims of the "European Platform for Biodiversity Research Strategy" (EPBRS), a forum of scientists and policy makers representing the EU countries, whose aims are to promote discussion of EU biodiversity research strategies and priorities, exchange of information on national biodiversity activities and the dissemination of current best practices and information regarding the scientific understanding of biodiversity conservation.

This is a report of the E-conference entitled "Climate Change and Biodiversity Conservation: Knowledge needed to support development of integrated adaptation strategies" preceding the EPBRS meeting to be held under the United Kingdom EU presidency in Aviemore, Scotland from the 2nd to the 5th October 2005.

Summary of contributions

The impacts of climate change on biodiversity and the degree to which autonomous and directed adaptation will lesson these impacts are likely to be complex and hard to predict. This will make the research information we gain particularly difficult to communicate to the people who will be required to act on this information, namely ecosystem managers, resource managers, the public and policy makers.

There seems to be some consensus over the fact that there exists a wealth of information relating to climate change and climate change impacts on biodiversity. Databases and shared information made public by integrated networks are helping towards making this information more accessible. In most cases, however, access to this information can be costly in terms of monetary and time constraints. A major priority is therefore to create digitised bibliographic information in searchable databases. This will help in preventing duplication of research, reduce the time spent in data gathering and support the provision of information on climate change to the public and policy makers.

Increased monitoring is seen as key to develop our understanding of climate change and its impact on ecological systems. Monitoring will help to separate short-term localised effects from more long-term trends. Exactly how this broad-scale long-term monitoring should be designed (including the issue of data standardisation), however, is an issue requiring further attention. A few of the more specific research areas identified as priority areas are identified below.

Gaps in knowledge and research priorities in understanding and predicting climate change impacts:

There is undoubtedly still a need for research on different climate variables on biodiversity. One example is the impact of changes in the rainfall to evapo-transpiration balance, which may have a greater impact on species than temperature alone. Research in this field could include gathering information on the response of individual species to water status and developing models of regional hydrological regimes, thereby identifying areas that are likely to go beyond the hydrological niche of given species.

Understanding climate change impacts on particular species and habitats continues to be a priority. Increased research on the migration routes of key species and on the habitats and areas most likely to be vulnerable to climate change are only a few of the research areas that need to be further developed.

The need to understand interactions in climate change scenarios is becoming very apparent when trying to understand and predict climate change impacts. These interactions include interactions between different pressures and drivers on biodiversity, interactions between temporal and spatial scales (essential both in physical planning and spatial ecology), and interactions between social and ecological processes. There are a number of initiatives already in place (see, for example, work within the MARS "observatories of the seas"), but many gaps in knowledge still exist. These include the need to better understand how climate change interacts with habitat loss and land use changes.

Although studies on single species can provide important information, process-based models using laboratory and/or field data may be able to account for the important interactions within ecological systems. Plant functional types and insect functional groups have already been used to predict potential responses to climate change. A traits-based approach to predict climate change impacts on biodiversity might be a possibility. Taking the example of the impacts of climate change on insect populations, responses to climate change might be predictable using a combination of life-history traits including mobility, intrinsic rates of increase, voltinism, feeding guild and tolerance to stresses. Another option is to focus less on individual species and distribution patterns and more on landscape functionality. However, despite the fact that process-based models may be the best approach, they may be impractical due to the complexity of ecological processes and the potential importance of stochastic processes. Bioclimatic envelope modelling may still be useful, for example in the screening of large sets of species or plant functional types to CO_2/temperature interaction. Research could include improving the bioclimate modelling of species distribution using both the improvement of traditional methods, and an ensemble forecasting approach i.e. to compare predictions from a range of independent models to help us reduce uncertainties and develop agreement on current and future trends. Another approach is to develop "hybrid" models combining bioclimate 'envelope' and mechanistic modelling with explicit mechanistic and correlative components.

It would appear that the development of a consensus regarding approaches to predict climate change impacts might only be achieved with the combination of a range of methodologies within well-funded networks of scientists.

A number of specific gaps in knowledge relating to modelling climate change effects on biodiversity exist relating to our understanding of physiological processes, our knowledge of sensitive systems, the need to model mechanistically the effects of evolution on species populations in a changing climate, our ability to model multi-species interactions across scales and the challenge of integrating drivers of change, other than climate, into models so that integrated, holistic views of the future of species, ecosystems and landscapes can be provided to inform planning and policy.

Gaps in knowledge and research priorities in the development of adaptation strategies for existing ecological sites and networks:

Identifying those ecological systems that may be most vulnerable to climate change (including semi-natural habitats and fragmented habitats) will be a key step towards developing adaptation strategies to allow us to build better conservation policies and practices to create ecosystems resilient to climate change. This identification will not only help define "dangerous interference" and help set mitigation targets for greenhouse gas concentrations in the atmosphere, but also guide the task of landscape planning for biodiversity conservation.

Another priority area for further research is the need to better understand the effects of extremes of climatic variability acting in conjunction with other drivers and pressures on ecosystem structure and function. The frequency and intensity of extreme weather events is likely to increase, and will be major drivers of land use change. Understanding the ecological responses to extremes of climatic variability and interactions with land use change will become essential for the formulation of adaptation strategies.

A number of key research themes to create resilient ecosystems and landscapes are: identifying time scales for the creation of different types of key habitats in new areas; establishing the edge effects of intensive land uses on semi-natural habitats; understanding the factors that promote habitat resilience; and developing land management practices that increase the permeability of different land uses to biodiversity.

A number of gaps in knowledge exist when it comes to planning for biodiversity conservation in a changing climate. How can we successfully integrate conservation targets into management plans? How can we develop a common strategy for European spatial development that can be implemented at the regional landscape level? And how to best incorporate ecological knowledge into the planning process? One possibility might be a combination of ecoregional and national conservation planning.

Regarding existing protected networks in Europe, there is a need to measure the potential of buffer zones in the conservation of protected areas, and to develop policies and practices that improve the quality and connectivity of the surrounding matrix. Considering the impact of policies like the Common Agricultural Policy (CAP), this may mean a shift towards a stronger emphasis on biodiversity and incentives for farmers to conserve biodiversity.

When discussing climate change impacts there is an increasing trend to approach the issue from an international perspective. However, there is a fine line between survival and environmental degradation in developing countries and relatively few activities seem to have been carried out in developing countries to mitigate the effects of climate change. There is a need to estimate the costs and benefits associated with the development and implementation of adaptation strategies, whether in the short or long-term, in both developing and developed countries. Another research need is to quantify the economic benefits of landscape scale action for biodiversity and the values of ecosystems and human lives lost.

Many argue that there is still a lack of policy responses to climate change impacts on biodiversity. There is clearly a need to identify all policies and practices already in place for the adaptation of climate change to biodiversity, and to assess their impact on biodiversity so that alternative approaches can be developed if needed.

There is a need for interdisciplinary research to address the development of policies that can deliver conservation goals on a broad geographical scale and for the development of an institutional framework capable for delivering appropriate incentives for stakeholders to conserve biodiversity.

Gaps in knowledge and research priorities in the development of adaptation strategies at regional and national scales - working with other sectors such as agriculture, forestry, water, and energy:

In the context of the agricultural sector, there needs to be a better understanding at the process level (especially in cropland soils), more research on data / inventory collation and meta-analysis, further development of future scenarios of agricultural land-use and management, the development of new technologies and methodologies for measuring soil carbon and greenhouse gas emissions simultaneously, process studies (both modelling and experimental) to couple the carbon and nitrogen cycles and a more complete biogeochemical / physical / socio-economic assessment of GHG mitigation options in agriculture. Additional priorities include the effects on secondary factors of agricultural production, of changes in frequency of extreme events on agricultural production, and the interaction with surrounding natural ecosystems.

In forestry systems, research includes the variability and extremes of future climate scenarios in order to plan future forest production systems, and on modelling the potential for reducing extinction rates/increasing population sizes of species in forests through altering the management systems adopted.

One fundamental research need for the development of adaptation strategies relating to sectoral responses is for more research on the ecological, economic and social effectiveness of different adaptation strategies in relation to conservation and other sectoral goals.

Gaps in knowledge and research priorities on identifying impacts and adaptation in marine and coastal ecosystems:

There is a requirement for long-term and broad scale monitoring to track change and to be able to separate short-term variability from long-term trends and impacts of localised human activities from climate change. The design of monitoring and decadal research networks needs to be further developed. There should also be a meaningful assessment of status and health of existing systems focussing on local and regional perspectives, as well as the identification of pressures adversely affecting marine and coastal biodiversity so that action to reduce the pressure can be prioritised.

This needs to be carried out together with process-orientated research on the underlying mechanisms enabling better predictive ability of rates and scales of likely future changes. Experimental studies (laboratory and field) should be carried out to test the reaction of organisms to likely effects of climate-induced change and therefore better understand what aspects of climate change are most important in threatening ecosystem structure and functioning. Specific experimental studies could include the assessment of the rate of atmospheric CO_2 conversion into biomass, impacts of temperature and saturated CO_2 levels on carbon fixation of individual species and the influence of temperature and salinity at organizational and functional levels of different species.

Predicting climate change impacts on biodiversity in marine and coastal ecosystems will necessitate the development of tools, and ways of constantly updating and integrating new methods and technologies as they develop.

Gaps in knowledge and research priorities in communication and knowledge transfer strategies to inform appropriate responses from public, commercial and policy sectors

Although scientists and policy-makers have very different "cultures", some successful mechanisms are already in place to bridge the gap between them, including the European Platform for Biodiversity Research Strategy (EPBRS), conferences on policy matters organised by Coastal Management for Sustainability and the Marine Life Information Network (MarLIN), and contributions from scientists to various committees. However communication of scientific results to policy-makers remain a key challenge for the development of adaptation strategies for the conservation of biodiversity in a changing climate. Scientific data needs to be made available to the scientific community, policy-making end-users and stakeholders in an accessible and digestible form in order for the information to be translated into rapid policy deliverables and ultimately into actions for the conservation of biodiversity.

Weaknesses exist at the science-policy interface as well as at the science-action interface, especially between data collection for scientific research and "what needs to be done". Mechanisms need to be put in place to ensure that (i) the research is to be given sufficient priority to be funded in the first place; and (ii) the results of the research are to be effective in influencing the actions of the many stakeholders who may be asked to change their ways as part of the broader strategy for biodiversity and adaptation to climate change.

Interdisciplinary research in climate change studies is a key priority. Scientists have to overcome the challenges of interdisciplinary research (and integrating different kinds of knowledge, including local knowledge) by developing methods to quantify uncertainty and assess risks and communicating results directly to governments and indirectly to other policy-influencing actors through interactive networks. Some suggest using a combination of paleoecological research to inform us about the past history of climate change impacts on biodiversity and modelling in order to predict what impacts may be in the future. Others have stressed the need to work more closely with scientists studying biogeography, ecohydrology, quantitative genetics, evolutionary ecology (in order to learn more about the genetic limits of climate tolerance) and ecogeography. The integration of social and economic sciences have to be encouraged and developed especially when addressing the links between society and nature, and to improve communication between science and society. Workshops integrating scientists from a variety of different countries provide a better basis for scientists and policy-makers from different countries to encourage adaptation and biodiversity conservation across different land use sectors and apply lessons learned across countries.

List of contributions

Understanding and predicting climate change impacts:

Adaptation strategies for existing ecological sites and networks:

Adaptation strategies at regional and national scales - working with other sectors:

Communication and knowledge transfer:

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Understanding and predicting climate change impacts on biodiversity

E-Conference introduction

Terry Parr, E-Conference Chair, CEH Lancaster, UK

The e-conference is structured around four parallel sessions on:
- Identifying the problem – how will climate change affect biodiversity of terrestrial, freshwater, coastal and marine ecosystems?
- Adaptation strategies for existing ecological sites and networks.
- Adaptation strategies at regional and national scales - working with other sectors such as agriculture, forestry, water, and energy.
- Communication and knowledge transfer strategies to inform appropriate responses from public, commercial and policy sectors.

Session 1: Problem? What problem? – Climate change impacts on biodiversity. Aim: To identify the key research and development required to reduce the uncertainty associated with our current assessments of climate change impacts on biodiversity.

If we are to adapt to climate change we must have a clear idea of its likely impacts. This session will be based on a recent report commissioned for the 2005 UK EPBRS meeting, on understanding and predicting climate change impacts in European terrestrial and marine ecosystems. Using just the limited data and published information currently available to us, it will show clearly that biodiversity has been much affected by climate change during the past century and that the prognosis for the next 50-100 years is not good.

But our forecasts about the future are dogged with uncertainty. What data, information and advances in knowledge do we need to reduce this uncertainty? Basic questions about the relationship between species diversity and ecosystem function remain unresolved and it is still a major challenge to determine how biodiversity dynamics, ecosystem processes and abiotic factors interact. And as we learn more about the stability and resilience of our ecosystems we may find thresholds of change that show that we are underestimating the sensitivity of biological systems to small changes in temperature and wider variations in weather associated with global warming.

Although the prognosis for climate impacts on biodiversity may seem bad we have not yet factored in the potential gains arising from adaptive management and policy responses. This will be the subject of the next two sessions.

Session 2: Making the best of what we've got: how can we adapt current protected site and ecological networks to deal with climate change? Aim: To identify the key research and development required to make sure that we make best use of the current sites and networks and can develop better conservation policies and practices to create ecosystems that are resilient to climate change.

In Europe, the implementation of the Habitats Directive and the establishment of the Natura 2000 network of sites is a major achievement for European conservation. But will many of these sites simply be blown away by climate change? Perhaps. But it is more likely that these sites will continue to be important areas for wildlife – we must just expect them to be different. But how different will they become and what point do we stop managing them for what they are now and manage them for what the will become in 50 to 100 years time? There are legal and policy minefields here that will be very difficult to navigate without some very incisive research.

The reality of climate change will also make us face up to the importance of the thousands of protected sites, not as individual sites, but as a single inter-linked network. What work on corridors and on the relationship between protected sites and the wider environment will need to be done in order to create a network of sites that enables species to disperse to new sites and gives the greatest resilience to climate change?

Session 3: Raising the ante – towards regional scale strategies for adapting to climate change. Aim: To identify the key research and development required to allow us to adapt land and water-related policies and practices to promote conservation of biodiversity under climate change

Of course protected sites are not immune from changes outside their boundaries and there are many other pressures on biodiversity apart from climate change. Furthermore, we are now observing a "homogenisation" of terrestrial landscapes and "the rise of slime" in the oceans, which point to worrying large-scale simplification of ecosystems and a large-scale loss of biodiversity that may be reducing the resilience of natural systems to climate change.

So what research is required to reverse this trend and enhance biodiversity both inside and outside protected areas? It's not rocket science to see that it's going to be difficult for biodiversity to adapt to climate change unless we take a more holistic view of biodiversity protection and develop adaptation strategies that involve working closely with other sectors (agriculture, forestry, water, energy etc). This larger-scale ecosystem approach will require complex inter-disciplinary research in which issues such as conflict resolution between multiple stakeholders, public attitudes, valuation of ecosystem services and policy science become just as important as ecological science in developing adaptation strategies. Fortunately, with the current policy commitment to sustainable development, such approaches are being developed, although often without a high premium being put on biodiversity. How can that be changed?

Session 4: How do we translate information and knowledge into action? Aim: What research and development is required to provide effective mechanisms for knowledge transfer between the research and policy communities?

Research by itself will change nothing unless the results can be used to inform and change the actions of the public, ecosystem managers and policy actors. In the past science has been guilty of assuming that this should happen automatically but now there is a greater appreciation of the need for associated research on knowledge management, technology transfer and communications.

There are many facets to this issue including:

- How to get beyond the usual "so what?" response to statements about biodiversity loss and win public and policy level engagement for the issue.
- Communicating uncertainty in ways that avoids "paralysis by analysis". In this complex world of multi-causality, multiple stakeholders, multiple-scales and complex and long-term responses in ecological systems, there will be no easy answers about how to adapt to climate change. But however complex the research challenge, we must find ways of communicating ideas to public and policy communities that enable them to understand the costs, benefits and risks of alternative responses. Creative use of data, information, models and visualisation techniques to arrive at best available solutions and timely solutions based on current knowledge will be needed to do this.
- Knowledge transfer to the developing world. Although the main emphasis of our discussions will be at the European level, we should remember that only a small proportion of Global Biodiversity is actually found in Europe. In the words of the G8 Gleneagles Communiqué. (2005) we should "as we work on our own adaptive strategies, .. work with developing countries on building capacity to help them improve their resilience and integrate adaptation goals into sustainable development strategies".

And finally ….in case you are wondering:

What is biodiversity? – For the purpose of this E. conference we will follow the definition of biodiversity used in the Convention of Biological Diversity, that is " the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

What about marine issues? We have made no separation between marine, coastal, freshwater and terrestrial issues as we believe the similarities between the research requirements and the opportunities to learn from each other probably outweigh any confusion or frustration that may arise because of the more obvious differences between the sectors.

Values

John Harvey, Trepens Ecology and Conservation and Eurosite

If all the issues raised by Terry Parr are followed up, then this will be an exciting conference. But to start with a comment about values.

Terry suggests that "the prognosis (for biodiversity?) for the next 50-100 years is not good". In its context this phrase can be interpreted as a casual remark on the likelihood of future climate change, but, to be provocative, at least two other meanings are possible. First that past change has not been "good", or second, that future change might not be "good". But on what basis is the judgement made as to what is "good" or "bad"? This question is not trivial, as in a later section Terry suggests that many sites, presumably their species and communities, will be "different" in the future. Similarly vegetation history since the last Ice Age suggests that change over time is the norm, whilst the number of animal species in the UK has probably increased in recent years as a result of new, probably climate induced, colonisations from the South.

Is different necessarily worse? Different may be worse from a preservationist viewpoint of conservation, or from a legalistic - Habitats Directive- position [see Pierre Ibisch's contribution], but need it be so in terms of species number or ecosystem functioning? The answer will of course depend on how species are able to respond to climate change in terms of mobility, ability to colonise, compatibility with new associates and the like.

The uncertainties involved in predicting the outcome of the multiplicity of direct and indirect climate impacts on species make it impossible, as Terry indicates, at this stage to say whether the new communities will be more or less stable, resilient, species rich, or whatever, and hence whether they are "better" or "worse".

My plea at the opening of this debate would be that we are very careful to refrain from value judgements as to what is good or bad, better or worse, and rather concentrate on the "knowledge" aspect of the conference title.

There are obvious links to be made between the fore-going paragraphs and the 4th session of the conference dealing with "public policy", especially in relation to the views of the "public" at large. What are the views on the possible change in the flora and fauna they experience of the 3.5 million members of the National Trust or the 1 million members of the Royal Society for the Protection of Birds? To what extent do they support these conservation organisations to preserve the status quo? How accepting will they be of change and to what extent should their views influence policy?

Identifying the problem

Ian Alexander, English Nature, Northminster House, Peterborough, UK

How will climate change affect biodiversity of terrestrial, freshwater, coastal and marine ecosystems?

I have only a layman's understanding of this issue and am just being lazy, hoping that someone here can answer a question that has been bugging me for months! The Gulf Stream (THC / Atlantic Conveyor) transfers huge amounts of energy from the Caribbean (or thereabouts) to Western Europe every year. Geologists seem fairly certain that this circulation has 'switched off' on a number of occasions in the past and that present data suggest that the circulation is weakening. If there is a switch (or substantial weakening) predictions are that Western Europe will become much colder (in winter). But as far as I can see no one has indicated what will happen to the rather large amounts of energy that will no longer be heating the UK? If it's not stored somewhere (unlikely?) then it has to do 'work' so where is it likely to turn up and what 'work' will it do? And if we don't know the answer to this shouldn't we try and find out?

An international perspective of climate change

John Hopkins, English Nature, Northminster House, Peterborough, UK

From a conservation perspective, I think that more sense can be made of the climate change if we take an international perspective. Some of our current conservation priorities are seemingly perverse when looked at in this way. Species that are common in other parts of Europe are sometimes given a high priority for conservation in the UK (I am not aware of evidence these populations are always genetically distinct from those in Continental Europe). We seldom focus on those aspects of international biodiversity that are centred on the British Isles (e.g. oceanic species some of which I assume are relicts of the Tertiary flora and fauna displaced in other parts of Europe as colder and drier conditions prevailed in the late Tertiary / Holocene- has anyone looked at this issue?).

The “value” I here promote is an importance attached to the conservation of the distinctive elements of European biodiversity in a global context, as opposed to narrow perspectives developed around ecologically arbitrary national and regional boundaries. I am by no means confident that the species highlighted in various international conservation frameworks (e.g. Habitats Directive, Berne Convention) reflect this thinking.

I would argue that, in the face of climate change effects upon species distributions, the more geographically narrow we are in framing our conservation targets the less successful we will be in the long term.

Urgent gaps in knowledge on the impacts of climate change on European plant species

Martin Sykes, Geobiosphere Science Centre, Department of Physical Geography & Ecosystems Analysis, Lund University, Sweden

SUMMARY: Current approaches to understanding the impacts of climate change on European species that rely exclusively on bioclimatic envelope modelling, are intellectually bankrupt. Real understanding is likely to be through process-based models where those processes relevant for the question are modelled as mechanistically as possible.

Understanding the impacts of climate change (and other drivers for change) on European plant species is among one of the most important questions of the 21st century. This is not only because all species have an intrinsic value in themselves, but also because of the possible short and/or long term effects of change (loss or gain of species) on habitats, on other species, on different trophic levels, and on ecosystems in general including the goods and services provided by them to society.

Assessing future impacts of climate change on European ecosystems has relied heavily on the development and application of dynamic and equilibrium computer models that simulate impacts spatially from local to global scales and through time. Equilibrium bioclimatic envelope type models simulate current and future species ranges. The envelope is constructed from the climate response variables that describe a species range under current climates using various statistical approaches to find the best fit, or from data on a species physiological response (if available) to a particular climate variable. Palaeoecological studies from the Holocene support the idea that species have in the past tracked climate and thus it is suggested that if selected climate variables can describe current ranges they can also describe future ranges. Such statistical models have been extensively used to describe the impacts of climate change on a wide range of taxa, including species of plants, birds, butterflies etc. Some studies have involved hundreds of species and have predicted major range changes and in some cases extinctions.

However the reliability of such predictions can and should be questioned and purely statistical approaches have been heavily criticised because a. climate change is likely to occur much faster than in the past when species were able to track climate; b. the answers are usually dependent on the choice of method; c. the assumptions made as in any modelling approach can be critical; d. and perhaps most importantly the lack elements considered important if we wish to really make any reliable predictions about impacts of climate change on biodiversity and ecosystems.

Such missing elements include representations of the changing atmospheric concentration of CO2 that not only contributes to climate change indirectly but also has direct effects on plants through photosynthesis. CO2 is already at its highest concentration for more than 20 Myrs and it is likely that plants will respond to changing CO2 individualistically leading to changed competitive relations and likely non-analogue communities from today. Changing concentrations of CO2 also interact with the water use efficiency of a plant via stomatal responses, especially in water limited ecosystems, and influence the competitive relationships between C3 and C4 plants.

Further elevated CO2 not only affect plants but via tissue quality influences the whole food web.

Other drivers for change including land use change, interactions with exotic species, and changing N deposition are also likely to impact on future ranges of species, both individually and collectively and in interactions with climate change, Other factors include the ability of plants to disperse and migrate across fragmented landscapes and importantly a species evolutionary response to heterogeneous environments throughout its range is likely to complicate any simple prediction we might wish to make based purely on simple climatic correlations for the full range.

Many if not all of these elements cannot be included in the current approaches involving bioclimatic envelopes and thus I suggest this approach is now well beyond its sell-by-date.

One way forward in predicting the impacts of global change, though not the only one, is to model as many of the processes that occur in ecosystems as required by the question. Currently this involves combining elements of the bioclimatic approach into the developing mechanistic dynamic vegetation models that describe vegetation dynamics such as competition, different ecosystems and their processes. These approaches are based on modelling of some of the important plant physiological processes such as photosynthesis, respiration etc. They include the responses to a range of drivers for change including climate, land use change, the direct effects of elevated CO2, the effect of N deposition. Such models aim to be as mechanistic as possible, though they do have simple bioclimatic parameterisation that limit PFTs (Plant Functional Types) or species ranges based on climate, and as with all models they rely on a series of assumptions. They can be applied from scales of the forest patch to the globe and through time for hundreds of years given the availability of gridded time series climate data. However they are currently restricted to describing vegetation and/or habitats through a limited number of woody (mainly trees) species or a small set of PFTs including a very limited description of the herbaceous layer. They have been mainly used describe the major functional characteristics of an ecosystem and its vegetation and by inference some generalised information about biodiversity.

However a number of processes are either not included or included very simply for example spatial dispersal and migration and the evolution of different responses to climate in different parts of a species ranges. There is also a chronic lack of physiological experimental data to allow good parameterisation. Biodiversity, in the sense of full range of taxa found in ecosystems, itself is not directly addressed as the approach uses either plant functional types or a limited species set, however diversity can be addressed more obliquely for example by describing habitats and the changes in habitats and thus the impacts on a range of taxa. Functional group approaches of this type could also used to model environmental effects on animals.

Thus I suggest that current approaches to the impacts of climate change on European species, which rely exclusively on bioclimatic envelope modelling, have reached a dead-end. They always had limited value and any predictions they make are highly suspect.

The way forward is through process-based approaches, however substantial critical information is lacking with regard to, for example, plant physiological processes and to modelling mechanistically the effects of evolution on species populations in a changing environment. Substantial effort and interactions are required by plant physiologists, evolutionary scientists and ecosystem modellers to resolve many of the problems.

RE: Urgent gaps in knowledge on the impacts of climate change on European plant species

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Pierre Ibisch, Faculty of Forestry, University of Applied Sciences, Eberswalde, Germany

Martin Sykes' contribution, among others, correctly highlights the importance of synecological processes that will modify (worsen) the impact of climate change on species. He concludes that we need process modelling instead of bioclimatic envelope modelling.

Theoretically, this is absolutely right. Practically, I am not convinced that it really is possible and makes sense to model individual species' reactions to climate change. The systemic character of processes is so complex and the eventual importance of stochastic events is so large that it is completely improbable to model something that indeed might occur. How to model the occurrence and action of a pathogen to arrive in a certain area that - maybe or not - will affect a certain tree species that is especially vulnerable due to the effects of hydric stress after two extremely dry summers and air pollution and, thus, will cause the decline of a bird species that depends on the fruits of the mentioned tree, while this favours the spread of another invasive tree that shades out some sensible species in the herbaceous layer?

It's not about modelling, it's about developing a risk assessment, and this is something different in terms of scope and methodology. For a risk assessment, it absolutely makes sense to take into account the results of the bioclimatic envelope modelling; yet, they show how threatened species might be by the change of climatic parameters alone. When we know that a species probably might not be stable due to warming alone, it is less important to worry about the fate of its pollinators, dispersers, pathogens and competitors ...

Actually, I feel that the process modelling should be something scientifically challenging, and definitely it will provide some new insights of what kind of weird things could happen.

However, for the orientation of conservation strategies it is not really important. Finally, in many cases it does not matter too much to know which single species will be affected by climate change where and when (of course, it is rather desirable, especially in the case of dominant species that shape the structure of ecosystems or that are economically important...). The important issue for applied conservation science is to acknowledge that generally most communities are likely to disassemble or change drastically within some decades; therefore, conservation must stop to be preservationist and develop visions oriented in a static status, or even in the past.

Thus, resilience and functionality of ecosystems and populations shall be enhanced in the whole landscape and everywhere, and as much as possible.

When we reflect about the accidents that might affect individual species and communities as a consequence of rapid climate change in a (more or less) anthropogenically degraded patchwork of habitats and biotopes (compare, among others, contribution by Vos: Increasing European ecosystems' resilience), we should come to the conclusion that we cannot and ought not build our conservation strategies exclusively on the behaviour of these traditional conservation targets. Of course, there are individual species we are specifically interested in and that merit and require specific conservation efforts (e.g., involving ex situ measures), but for enhancing survival capacities of the large rest of the taxa, there is nothing else than the proposed adaptation strategies (especially: assure/restore 1. connectivity, 2. connectivity and 3. connectivity of habitats; well, actually, there some more than connectivity and equally important, such as conservation of local and regional hydroclimatic processes, and others). This is the real paradigm shift required. Let's stop to focus so much on individual species and their current distribution patterns, and let's work on landscape functionality.

In this context, responding to Ian Alexander, of course we shall not value if conservation activities in the past were right or wrong - simply we should assume that they were adequate to the available data and concepts - but we should be able to say, well, the situation has changed, and we need to adapt our concepts and strategies.

RE: Urgent gaps in knowledge on the impacts of climate change on European plant species

Ivan Nijs, Department of Biology, University of Antwerp, Belgium

Martin Sykes has argued that current approaches to the impacts of climate change on European species, which rely exclusively on bioclimatic envelope modelling, have reached a dead-end because they are not mechanistic and do not take into account interactions with other drivers such as elevated CO2, atmospheric N deposition, invasive species, etc. I could well imagine that such interactions will be critical to the fate of plant species in a future climate. However, as these factors have predominantly a negative impact (apart from perhaps elevated CO2), it is unlikely that they will 'save' species that are pushed outside their bioclimatic limits by a shift in climate. In other words, an approach based exclusively on bioclimatic envelopes still seems safe if it is used in one direction: if a region is no longer suitable for a given species for climatic reasons, the additional complexity of other negative factors is not going to reverse this. Conversely, when a species continues to fall within its envelope in a future warmer climate, one cannot simply assume its persistence is guaranteed: it may for example go extinct indirectly following the disappearance of a keystone species to which it is connected. So I would propose to use the outcome of bioclimatic envelope modelling in a restricted sense. The question remains whether elevated CO_2 compensates for unfavourable changes in the bioclimatic envelope (i.e. whether it enlarges the envelope). This is something that could be investigated experimentally in controlled environments, using two CO_2 levels and a range of temperatures as factors. This has already been done for selected species in studies on CO_2*temperature interaction, but to my knowledge not yet from the perspective of screening large sets of species or plant functional types.

RE: Urgent gaps in knowledge on the impacts of climate change on European plant species

Matyas Csaba, University of West Hungary

Impacts of climate change in terrestrial ecosystems are most dramatic in forests, at the lower end of the closed forest cover towards the Mediterranean and the East European continental steppes. The impact depends on the genetically set tolerance of the species, which means that climate change is to a large extent a genetic problem - with the constraint that very little is known about the genetic limits of climate tolerance, because of little economic and scientific interest in marginal conditions (up to now at least).

It is not very well known in ecology that in spite of all difficulties with studying forest trees, they are among the first plants where large-scale evolutionary ecological investigations started, well before Clausen Keck and Hiesey's famous work. A plethora of common garden tests have been established and evaluated; the reason being the economical / management interest in the productivity of populations adapted to different ecological conditions.

Although we know from Hamrick and consorts' studies that the adaptive behaviour of trees is diametrically different from what is known for annuals or grasses (Bradshaw, Antonovics's famous studies) it turned out that common garden tests of forest trees are very suitable objects for simulating effects of climate change scenarios.

Transfer analysis developed by the author provides realistic insight in plasticity and tolerance under drastically changing climate conditions. As forest trees are dominant and determinant elements of landscapes and ecosystems, these results should be considered with great care when preparing for future scenarios - especially at the threatened lower end of ranges. Interaction between quantitative genetics and (evolutionary) ecology should be promoted for that purpose by all means.

Bioclimate envelope- versus process-based modelling

Miguel Araújo, National Museum of Natural Sciences, Spain and Oxford University Centre for the Environment, UK

Martin Sykes: "Current approaches to understanding the impacts of climate change on European species that rely exclusively on bioclimatic envelope modelling are intellectually bankrupt. Real understanding is likely to be through process-based models where those processes relevant for the question are modelled as mechanistically as possible." This is a bold but equivocal statement:

1. "Understanding" is prior to modelling. If one builds mechanistic models without understanding, they should be no good. If one doesn't have detailed understanding but still wants a detailed response, then bioclimate models provide a framework of inquiry.

2. Both envelope and mechanistic models can be used as tools for research to explore 'what if' questions and to assess the sensitivity of modelling outcomes to initial premises. We should never forget that models are about how we think about things rather than how things are. This is true for both envelope and mechanistic models. Hence models do not provide predictions, but conditional statements which are necessarily sensitive to the initial premises entering the models. We need to investigate these sensitivities.

3. Both mechanistic and bioclimate modelling have their strengths and weaknesses and intelligent use models should be based on appropriate understanding of what each has to offer. Users of bioclimate envelope modelling are upfront about the weaknesses of their approaches (Guisan & Zimmermann 2000; Pearson & Dawson 2003; Hampe 2004; Pearson & Dawson 2004). I am not aware of such discussion on the species-climate mechanistic modelling literature (probably my ignorance), but I believe maturity in any scientific discipline comes more from recognition of weaknesses than blind acceptance of strengths (Whittaker et al. 2005).

4. The reason 'envelope' models are used so widely is because we don't have a mechanistic understanding of how biodiversity – at the species and population level - responds to climate change. Hence correlative, 'envelope', approaches offer a research framework that mechanistic modelling cannot offer at the moment. This is particularly true for animal species.

An alternative approach would be to model mechanistically responses of functional groups rather than species, but evidence has still to be provided that the uncertainties from grouping a variety of different evolutionary units into single response groups would reduce the uncertainties from modelling individual species with envelope approaches.

5. A useful research agenda would be:

a) Improvements on bioclimate modelling of species distributions. This will need to be addressed in two ways. First the traditional improvement of methods. This is an ongoing process with hundreds of groups around the world using comparing and proposing alternative methods to analyse species-climate (but also land use) relationships. The second is the promising ensemble forecasting approach. Climatologists are more advanced than ecologists in this endeavour. The whole idea is based on the principle that we cannot validate models that predict events that have yet not occurred (Araújo et al. 2005a). Hence rather than arguing for the strengths of our favoured models we should combine results of independent models and estimate their central tendency. A recent paper demonstrated that when a consensus from an ensemble of bioclimate envelope models was obtained uncertainties were substantially reduced when measured on an independent data set (Araújo et al. 2005b). This is the first test of the reliability of bioclimate envelope models under climate change and one that supports its usefulness. I suggest this study is read with a number studies addressing uncertainty in bioclimate envelope modelling (Araújo et al.; Pearson et al.; Elith 2000; Olden & Jackson 2002; Segurado & Araújo 2004; Thuiller 2004; Thuiller et al. 2004).

b) Bringing the best of bioclimate 'envelope' (e.g. precision and realism, sensu Guisan & Zimmermann 2000) and mechanistic modelling (i.e. generality and reality) together. This would involve developing 'hybrid' models with a explicit mechanistic and a correlative component. In fact some of the mechanistic parameters entering models are calculated with bioclimate envelope models rather than through detailed mechanistic understanding of species responses to climate.

Finally, I would like to stress that one of the problems of bioclimate envelope modelling is not the modelling per se but the way modellers convey their results (Ladle et al. 2004; Araújo et al. 2005a). This is a complex issue that I am not addressing here. However, I would like to mention that failure of a model to provide a given answer is often a failure of the user to understand the questions that can be asked with the tools offered by particular models.

Gaps in knowledge on the impacts of climate change on insect populations

Richard Harrington, Rothamsted Research, Harpenden, UK

SUMMARY: This contribution discusses the feasibility of a traits-based approach to predicting the impacts of environmental changes on insects.

Insects comprise about 80% of known animal species and occupy every terrestrial and freshwater habitat. They have profound effects on quality of life and social structure. Many are devastatingly detrimental (e.g. pests of agriculture, horticulture, forestry, wood and stored products; vectors of human and animal disease), many are benign and many are beneficial (e.g. natural enemies of pests; pollinators; decomposers; food for higher trophic levels such as birds; those of intrinsic beauty). All are influenced strongly by their environment. With such a variety of species and habitats, gaps in knowledge will always greatly exceed the knowledge base. Thus an important question is how to optimise and synergise the relatively little knowledge it is possible to assemble.

Much work has been and is being done to assess the impacts of environmental changes on insects, but this almost always involves one, or, a small number of closely related, species. Unless generalisations can be made, the value of findings will remain parochial, and expensive investigations will be required for every situation in which the impacts of environmental change require assessment.

Some hope that the search for such generalisations has potential can be gleaned by considering a possible explanation for an apparent paradox in the claims relating to environmental change impacts that come from entomologists working on pest insects and those working on insects of conservation interest. Researchers working on pest species often predict that insects will fare better under climate change scenarios, whilst those working on species of conservation interest often predict that they will fare worse. Many pests tend to be highly mobile with a high reproductive potential and the ability to utilise many different habitats. These traits may also aid adaptability to change. Threatened species tend to be less mobile and fecund and are often tied to a specific habitat structure. These traits may inhibit adaptability to change. Thus it might be possible to predict responses to environmental change on the basis of combinations of specific life-history traits such as mobility, intrinsic rate of increase, voltinism, feeding guild and tolerance of a range of stresses.

Plant functional groups have been widely used to assess potential responses to climate change (Bazzaz, 1990; Paruelo & Lauenroth, 1995; Condit et al., 1996; Diaz & Cabido, 1997; Cornelissen et al., 2001; Dormann & Woodin, 2002; Epstein et al., 2002). For insects, Landsberg and Stafford Smith (1992) used functional groups to predict the impacts of climate change on outbreaks of agricultural and forest pests. This approach has also been adopted in determining commonness and rarity in UK butterflies. Hodgson (1993) found that common species are large, have a strong migratory tendency, rapidly maturing larvae, hibernate as pupae or adults and exploit larval food-plants of productive habitats. Sensitivity to climate can be strongly influenced by an organism's trophic rank (Voigt et al., 2003).

Studies on single species must be subordinate to those on communities because species responses take place within communities and not in isolation. However, single species studies do have important roles in providing information that helps to define the range of traits (e.g. range of cold tolerance). Long-term monitoring and/or spatially extensive data from the field are inevitably derived from species existing within their communities and, therefore, subsume the community effects within those that are species specific. Whilst any correlations between individual species responses and environmental variables inherently take account of all the interactions in the system, they do not explain these interactions separately. Process-based models built using the results of laboratory and/or field experimentation can attempt to account explicitly for all of the important interactions in a system. However, because of the complexity of ecosystems, it is unlikely ever to be possible to include all appropriate variables and interactions in a predictive model. Also, the more parameters a model has, the more likely it is to provide a fit to independent data for spurious reasons. Only by combining a wide range of methodologies is a consensus likely to emerge. To achieve this, well-funded networks of scientists are essential.

Impacts of extremes of climate variability and biological responses: implications for adaptation strategies

Mike Harley, English Nature; **Richard Smithers**, Woodland Trust; and **Olly Watts**, Royal Society for the Protection of Birds

SUMMARY: Research into the impacts of climate change on biodiversity has focussed primarily on mean changes in climate variables and provides little indication of the significance of extreme events; while adaptation strategies should take account of the projected impacts of mean change, they also need to accommodate the implications of extremes of both climatic variability and biological responses upon species, habitats and ecosystems and their interactions with land use change.

Mean changes in climate variables, acting independently and in combination, are key drivers of environmental change and biodiversity. The research agenda for those concerned with understanding the impacts of climate change on biodiversity and its conservation has, to date, predominantly focussed on the assessment and analysis of observations and modelled projections of the responses of species, and by implication their habitats, to mean changes in temperature and precipitation. The climatic underpin to these studies has included records of recent and post-glacial climate change and GCM and RCM projections of climate change in the future (e.g. IPCC's Third Assessment Report, 2001; UK Climate Impacts Programme's Climate Change Scenarios for the United Kingdom, 2002).

Extremes of both climatic variability and biological responses (e.g. rare and chance long-distance dispersal; abrupt phenological change; rapid invasion) are increasingly thought to have a disproportionately strong effect on species and thus on ecosystem structure and function. Climate models suggest that the frequency and intensity of extreme weather events, including floods, droughts, storms and high temperatures, will increase. Furthermore, extremes of climate variability are likely to be major drivers of land use change and, therefore, policy development in agriculture, forestry, water management, planning, and coastal defence sectors; these changes and policy responses will have substantial indirect impacts on biodiversity.

Whilst we recognise and support the potential to further refine the methodologies and outputs from research into mean changes in climate variables on biodiversity (see Dr Pam Berry's submission to this e-conference), we also attach considerable importance to understanding the relationships between the extremes of climatic variability and ecological responses and interactions with land use change. We believe this is a fundamental research gap, which needs to be appropriately prioritised and resourced. Research outputs would have considerable relevance in the formulation of adaptation strategies for biodiversity, which should encompass measures for species' conservation, protected area management and the development of ecological networks to improve connectivity across wider landscapes.

Urgent gaps in knowledge on the impacts of climate change on UK landscapes, ecosystems and species

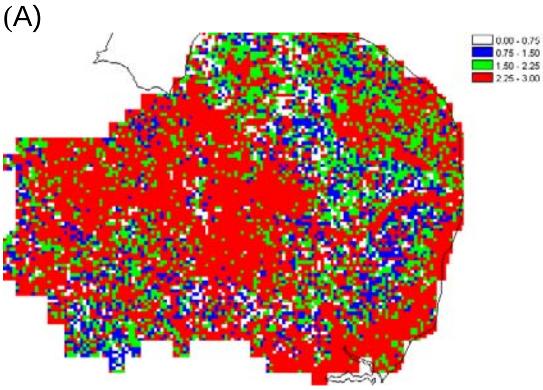
Pam Berry, Environmental Change Institute, University of Oxford, UK

SUMMARY: Gaps stem from lack of data, ability to model multi-species interactions across scales and to incorporate a range of drivers of change; this affects our knowledge of climate change impacts and the ability to initiate appropriate adaptation responses.

Landscapes, ecosystems and species represent an increasing hierarchy of knowledge about climate change impacts. Leaving aside the uncertainty represented by the climate scenarios themselves (Jenkins and Lowe, 2003), modelling has done much to advance our knowledge of the potential impacts of climate change on species (Berry et al., 2003; Thuiller, 2003 and Araujo et al., 2004). This has been based on mean changes in climate variables and provides no indication of the impacts of extreme events (see contribution by Harley et al., this e-conference).

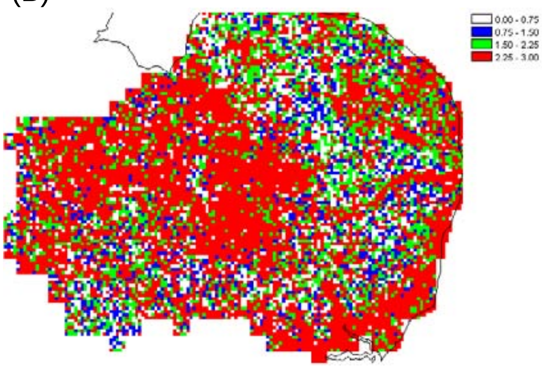
Figure 1: Maps showing the changing distribution of suitable environmental space for Silene gallica (Small-flowered catchfly), based on climate scenarios only (A) and on climate and land cover change scenarios (B)

(A)

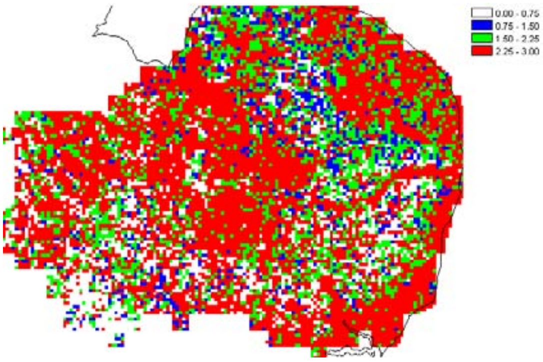


HadCM3A2 2020 scenario

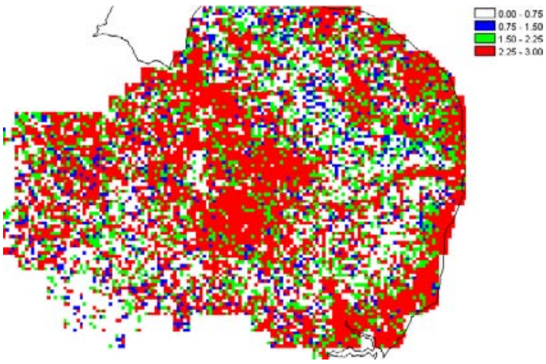
(B)



HadCM3 A2 2020 scenario



HadCM3 A2 2080 scenario

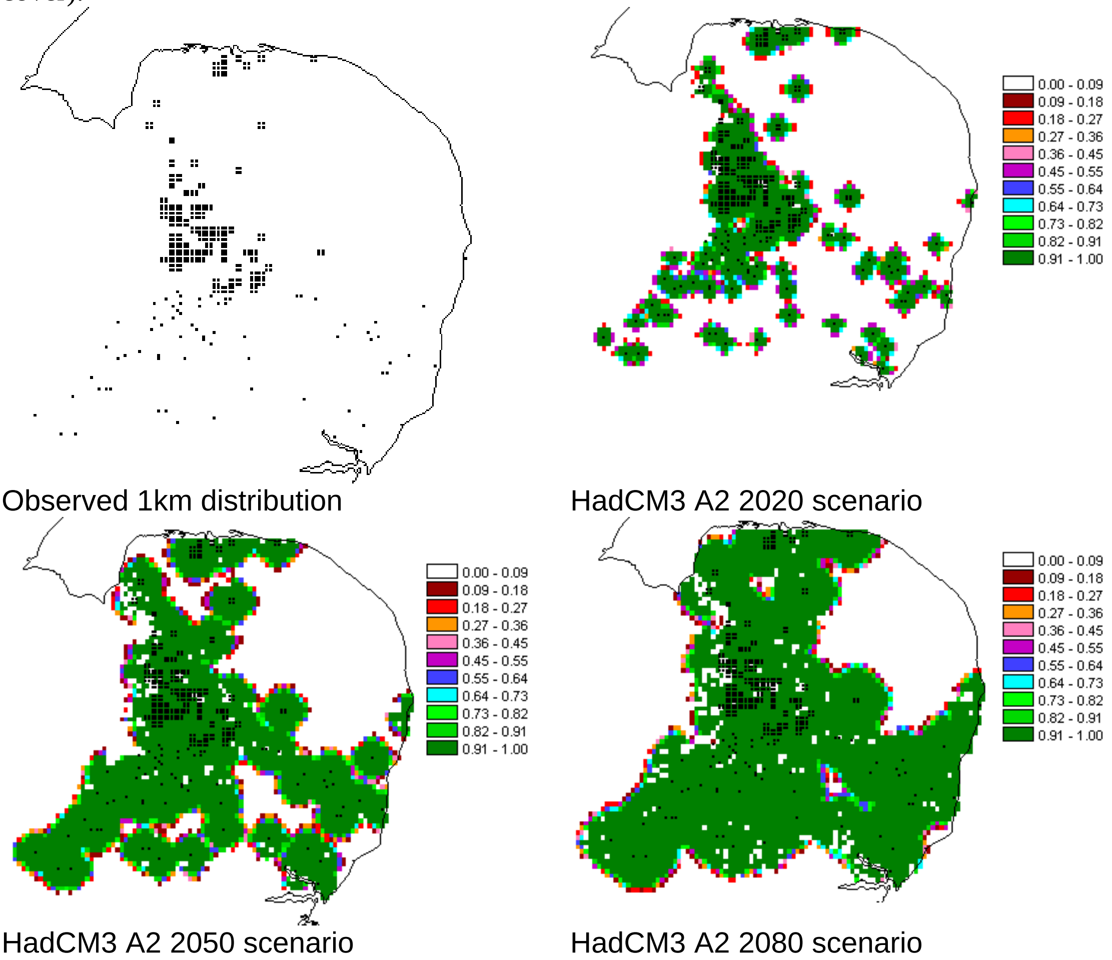


HadCM3 A2 2080 scenario

Climate envelope or niche models provide important information at the broad-scale on potential species' responses, but they do not include other drivers of change or factors such as habitat availability or biological processes that affect species' distribution at the finer scale (Pearson and Dawson, 2003). It is currently difficult to incorporate habitat availability, or even land cover as a surrogate, into niche models (Figure1; Pearson et al., 2004), especially as there are limited future scenarios; thus it must be assumed that these will remain static. This may be a reasonable assumption on short time scales (~10 years), but not when looking beyond this. Devising future habitat scenarios provides a conundrum: can habitats be modelled independently of their component species? If the answer is "No", then multi-species, multi-trophic models need to be devised unless species' responses can be "summed" to determine habitat response? If the answer is "Yes", then why bother with niche models?

The future suitable climate space simulated by niche models also represents an optimistic view for species, as not only do they omit the constraints mentioned above, but also they do not incorporate the ability of species to disperse and track these changes in climate space (Opdam and Wascher, 2004). Dispersal models exist, but are difficult to parameterise for most species due to a lack of data. The MONARCH project has tested coupling niche model outputs with future land cover changes and dispersal for selected species (Figure 2; Pearson and Dawson, 2005), but overall knowledge of the likelihood of species realising their future niches, especially in fragmented landscapes, is still limited.

Figure 2: Maps showing the dispersal probability surfaces for Meadow oat grass (*Helictotrichon pratense*), based on suitable available environmental space (climate and land cover).



Ecosystems, composed of interacting species, pose similar challenges to habitats for determining climate change impacts, as species respond individualistically (Huntley, 1991). This will lead to ecosystem composition changing, possibly non-linearly in response to extreme events, and to totally new ecosystems emerging. Identification of these new ecosystems and their future service provision represent further knowledge gaps.

Landscapes are composed of many elements, both biotic and abiotic, natural and anthropogenic, and climate is one of a suite of drivers of change (not necessarily the most important) operating both directly and indirectly. The biggest knowledge gap is at this level, given difficulties in upscaling results from the lower strata of the hierarchy and downscaling those from more global models. It could be argued that this is the most important level too, as it resonates most with humans and is the appropriate scale for spatial planning.

The strategic research challenge is to devise means of integrating drivers of change, other than climate, into models so that integrated, holistic views of the future of species, ecosystems and landscapes can be provided to inform planning and policy.

Lessons from the Mediterranean

Ferdinando Boero, University of Lecce, Italy

The Mediterranean Sea is a small replica of the world Ocean and what is happening there is probably an anticipation of what will happen elsewhere. The Mediterranean Sea is undergoing an undeniable tropicalisation. The International Commission for the Scientific Exploration of the Mediterranean Sea published three atlases (available on its web page) of the exotic species that have entered the basin in the last decades. They are almost all of tropical affinity, hence the term "tropicalisation". Furthermore, the Mediterranean is also undergoing a meridionalisation. The species that thrive in the southernmost parts of the basin are now thriving also towards the north. This is valid for a high variety of animals, from fish to hydroids. Many of the seasonal species that are active in the summer, now are present throughout the year. Winter species are reaching greater depths, where the water is colder. The eco-biological answer of the Mediterranean to global warming is very evident. Of course, as suggested in the opening letter of this forum, one might answer: so what? Is there anything we can do about it? Well, there are people who deny that a change is underway, and there are governments that refuse to sign protocols regarding our impact on the world climate, often because they say that there is no proof that something is happening. Something is happening for sure.

Paradoxically, seen in this framework, this phenomenon is enriching Mediterranean biodiversity. New, tropical species are being added to the ones that were there before. If one asks how many species became extinct from the Mediterranean basin in historical times the answer is none. Some became locally extinct (like the monk seal), there are some cases of possible extinction (a mollusc from Malta, if I am well informed), but this is nothing compared to the terrible figures that we can hear in the press. Is that really true?

If the Mediterranean is becoming warmer, what is the part of the basin that will be more sensitive to this change? The colder one. The one where the cold waters of the basin are formed. That is: the Northern Adriatic. Up there, there is flora and fauna very similar to those of the Atlantic. There is a species of Fucus (Fucus virsoides) that is not found anywhere else in the Mediterranean. And there are other species that live only up there. I think that they are in danger.

If one asks me the name of a probable species that became extinct from the Mediterranean I say: Tricyclusa singularis. Never heard about it? Of course! We perceive extinction only if it affects popular species. We tend to register what we find, and not what we do not find. Especially for the inconspicuous groups. Tricyclusa is a little hydroid. It has been described by Schulze from the Gulf of Trieste (Northern Adriatic), its type locality, in 1865. Since then, it has never been found again in the Mediterranean. It is a rare species, of course. But very distinctive.

We should be able to make a list of putative extinct species. We need a species list for a place, and an accurate bibliographic search for all the records of the species. If one species is unrecorded let's say for one hundred years, we might say that it is possibly locally extinct. Reconstructing its "history" we might find the localities where it occurred and go there, see if we can find it. If we cannot, chances are good that it is gone or that, at least, it is in peril. You know who has this information? Taxonomists. This is another good reason to use them. And the literature. I was always surprised not to find bibliographic support among all the services for Biodiversity information that are offered around, based on heavy EU funding.

Bibliography is the key information in biodiversity. We need digital libraries. I am building one for the Hydrozoa (based on funding coming from the National Science Foundation) and strange things are coming out, like this Tricyclusa affair.

Providing a list of endangered or possibly extinct species, along with the list of the newcomers, will reinforce the perception of change in the public opinion and, maybe, also in the politicians. Then we will have to think about what to do. Change is part of the evolutionary game and we have to accept it, even if it brings things that we do not like. But we have to be able to distinguish natural change from anthropogenically originated change.

When the second type of change occurs, then we have to try to lessen our impact. The reason for doing so is very simple. We evolve at a very slow pace. Biologically. If the ecosystems around us change rapidly, we will not be able to cope with the change. We'll do it with technology. But it will not be so effective. If we use air conditioning to fight hot weather, we produce further heat in the atmosphere with our energy consumption, and make things better in the short term and worst in the long term. We need this environment. I could play some more and explain how a very inconspicuous species (like Tricyclusa) might be ecologically important, even for us. But such exercise requires a lot of space, and this message is too long already.

I wholeheartedly agree with Keith Hiscock, marine reserves are instituted to preserve beauty (like terrestrial national parks) and, eventually, for some spill over effect. This is understood by the public, but not by the scientists! They need cumbersome reasons for such things, beauty is not a scientific concept....

By the way, Tricyclusa is a beautiful hydroid, and it is highly valuable since it is the only species of a whole family, so if we lose it we do not lose just a species, we lose also a genus and a family. It is the only hydroid with three whorls of tentacles. Its only fault is that it is just 2 mm long.

RE: Lessons from the Mediterranean

Jan Dick, Centre for Ecology and Hydrology, Edinburgh, UK

Terry Parr asked us to 'identify the essential research and development required, to ensure that biodiversity and the services it provides can adapt to climate change'.

I would like to whole heartily support Ferdinando Boero assertion that 'We need digital libraries'. There is a wealth of information which is just too expensive in terms of time to use. The scientific community is moving fast to create databases and integrated networks with shared information posted on the web etc. but more needs to be done. While this may seem a pedestrian approach when there is so many interesting research questions I would urge the scientific committee when they present the results of the Electronic Conference at the EPBRS delegates meeting in Aviemore to emphasise the need to digitise bibliographic information in searchable databases as a very valuable tool 'to ensure that biodiversity and the services it provides can adapt to climate change'. This need I believe is relevant to all four of the themes covered in this E-Conference.

Web-based archives

Cornelia Nauen, European Commission, Directorate General for Research, Brussels, Belgium

We need easily accessible web-based archives, but not only for the literature, but for the content of the literature so that analyses can be carried out directly and new questions asked. That would instantaneously increase the value of uncountable individual pieces of research and data sets, which currently get analysed for very limited purposes by very few people. Making them available after a limited grace period for prior use for publications by the scientists in charge of the data collection, will open a vast range of additional analytical possibilities and provide qualitative leaps for many research teams and the public at large.

It's a big job, but it's been done (and continues to be developed and supported) for all 30,000 species of fish known so far (www.fishbase.org) and it can be done in other areas of marine science as well. Routine measurements of oceanographic parameters (t, S) from vessels operating in all oceans are stored in the COADS database, impact of the world's fisheries is painstakingly compiled and analysed with rapidly growing coverage at www.seaaroundus.org.

Database approaches to spatial distributions of the organisms and other characteristics of interest can produce data intensive maps that do not only speak to scientists, but also ordinary citizens. To get the big picture with reasonable local resolution for many questions of relevance here the oceans have been broken down into some 180,000 cells half degree square surface...

If more teams work in a shared framework of extracting, organising, analysing and sharing data/information and cater for interfaces with the public, many qualitative breakthroughs may be expected and gap analysis of critical missing elements becomes possible.

Gene banks

Ferdinando Boero, University of Lecce, Italy

There is an issue that is extremely important, besides digital libraries: Gene banks. People extract genes from some specimen and find genetic information on it. Beautiful. Then the information is posted in a gene bank under a specific name. Are we really sure of the identification? What is the taxonomic expertise of the person who did this job? Then other people use those genes as reference for the genomic information on that species, but maybe it is not that species, but something that resembles it. More or less the same happens in species lists in ecological papers. Inaccurate information is propagated quickly, blurring our perception of biodiversity. Maybe we find a beautiful thing in a species, something that only that species can do (like reversing its life cycle and rejuvenating), but if somebody wants to go and find it in the field, in order to work on it and uncover its secrets (to provide us the goods and services that we expect from biodiversity), maybe it will look for something else if the name is wrong.

RE: Lessons from the Mediterranean

Martin Sykes, Geobiosphere Science Centre, Department of Physical Geography & Ecosystems Analysis, Lund University, Sweden

As a modeller trying to assess impacts of climate (and other global change drivers) on ecosystems and biodiversity - one of our major problems is data (digital and otherwise)or the lack of it. I strongly support the gathering of a wide range of data, both experimental and observational - But I do not advocate collecting data just for the sake of collecting data, which has happened in the past. It’s time that modellers and those making predictions of the future discussed and influenced the gathering of data, so that it is relevant both to the questions asked but also relevant to the models.

Relevance is everything.

Assessing impacts

David Gowing, Open University, UK

Martin Sykes exhorts us to monitor relevant data, but to define relevance we must think about the mechanisms by which global change will impact biodiversity. The focus usually falls on direct temperature effects, but I suspect changes in the rainfall/evapotranspiration balance will have a greater impact on many taxa. The problem is that the spatial forecasting of this balance is even more uncertain than for temperature. However, it is still important to gather information on the response of species to water status. Predicting northward shifts in populations needs to take account of spatial variability in soils and river-catchment attributes, in addition to temporal changes in water balances and mean surface temperatures. As our estimates of the changing climate improve, then it should become feasible to model regional hydrological regimes and identify areas that will go beyond the hydrological niche of a given species, but more ecohydrological research and monitoring are required now to achieve that goal in the future.

RE: Assessing impacts

Martin Sykes, Geobiosphere Science Centre, Department of Physical Geography & Ecosystems Analysis, Lund University, Sweden

We clearly have to be aware of much more than just temperature change, for example changes in precipitation, evapotranspiration, seasonality are all important, and in some places really important.

It is without doubt too simplistic to talk of a trend related to latitude (and thus to temperature), the situation is very complex.... Regional climate model outputs are online and they “do” precipitate “better” but the actual situation now and in the future is complex - but that does not stop us identifying sources of missing data and doing something about it!

Marine vs. terrestrial

Ferdinando Boero, University of Lecce, Italy

When considering ecosystem functioning, we have to realize that there are enormous differences in terrestrial versus marine systems. Primary producers, on land, are long lived and form the main frame of landscapes: grasslands, forests, and bushes. They have cycles of activity and rest, but their bodies remain for long times and their turnover is slow. We can say that structure is rather constant (in our time frames) in terrestrial habitats, and things occur at a rather slow pace. In marine environments, on the contrary, the bulk of production is obtained by protists (phytoplankton). They do not form landscapes (they become evident only when they form coloured tides) and grow in pulses that sustain the rest of marine ecosystems. Animals are often landscape formers in the sea (from coral reefs to hydrothermal vent communities).

The rapidity of these processes, more or less reset at every seasonal cycle, has no counterpart in terrestrial habitats. It is obvious, from this point of view, that modelling terrestrial systems is much easier than modelling marine ones. The failures of models, in marine systems, become evident in very short times (think of the modelling of the impact of fisheries), whereas in terrestrial habitats such things are less evident and immediate. In terrestrial habitats, man has changed almost completely the functioning of ecosystems, privileging production versus diversity.

Agroecosystems are highly productive, but not diverse at all. Of course they provide goods and services to us, but this is leading to the suppression of biodiversity. At present, on land, we do not extract resources from any natural population (with the exception of wood from tropical forests), everything we use is cultivated. In marine systems, natural populations are still so healthy that we can extract resources from them in an industrial fashion (fisheries). In the sea we are still gatherers and hunters. The secret is the rapid turnover of the resources. But our rate of use of these resources is overcoming their rate of renovation, and we will soon move to deeper and deeper waters, to scrape the bottom of the barrel. Aquaculture is a big lie. It will not solve the problems of overexploitation. Aquaculture is like agriculture. It will require the destruction of natural habitats. Furthermore, with aquaculture, we rear carnivorous species! Can you imagine this, on land? We rear tuna now. It is like rearing lions to feed on them.

I think it is wise, in this forum, to put together terrestrial and marine problems, after all the world is one. But we have, nevertheless, to bear in mind that the two systems are very different in their functioning. We have also to bear in mind that 70% of the planet is covered by water, and that all phyla (besides the Onycophora) are in the sea, whereas just a few are present on land. The bulk of biodiversity (in terms of higher taxa) is in the sea. The sea is the rule; land is an exception. Of course we are terrestrial and we privilege our point of view, but the Earth is what it is because of the water. There are not ecology and marine ecology (implying that Ecology is synonym with terrestrial ecology, and marine ecology is an exception). There is ecology (the ecology of the majority of the ecospace and of the biosphere) and terrestrial ecology.

I concur with Martin Sykes, thus, and call for considering what is relevant when we construct our models. When people come and offer predictions, however, I become immediately suspicious. If our systems are non linear (and I think they are) very irrelevant causes (as far as we can tell) can have very relevant effects. We do not have the crystal ball model that predicts the future. We can depict scenarios and identify trends. In order to do so, we need a lot of understanding of natural history, so to single out what is relevant. Then, we can try to elaborate models. In our universities, at present, natural history is disappearing. To be substituted by modelling. It is a big mistake and will prevent us from identifying what is relevant (without mixing correlation with causation).

Mangrove ecosystem research priorities

Tanaji Jagtap, National Institute of Oceanography, Goa, India

Mangrove habitats are predominant eco sensitive features of shallow and sheltered marine environment in the tropics. They support various kinds of marine biota of ecological and socioeconomic importance. They are major contributors of Organic Carbon to estuarine and near shore waters sustaining the productivity. These habitats would be more vulnerable to the global warming and resultant increase in sea level, because of their proximity to the sea. Individual mangrove and associate floral species may alter their response to increased temperature, CO2 concentrations and changing salinity regime due to alterations in ambience. They may exhibit decline productivity beyond optimum tolerance, and thus affecting estuarine and near shore productivity. Mangroves are believed to keep pace with rising sea level by continuous sedimentation enriching the ambient environment with organic matter. Due to sea level rise the intertidal and supra littoral zones are likely to be extended farther inland (If there is scope for water to intrusion) causing destruction of existing mangroves and associated biota. If landward intrusion were limited the vertical rise would lead water logging killing mangroves. The changes in the salinity concentration due to alternations in rainfall pattern may cause genetic erosion as well as change in the species composition. There may be a total new assemblage of species in response to the changing salinity regime. Climate changes coupled with anthropogenic pressures and poor management practices may reduce productivity and loss of mangrove dependent biodiversity, adversely impacting ecological and socioeconomic benefits.

Climate change being slow, the impact of the same on the mangrove environment would be visible after long time. To develop mechanistic dynamic vegetation models as suggested by M. Sykes, we need to have enormous data from the natural habitat and under simulated conditions. We need to develop international programme for monitoring of such habitats from selected localities in understanding:

-Rate of atmospheric CO2 conversion into biomass and impacts of temperature and saturated CO2 levels on carbon fixation of individual mangrove species

-Change in forest structure such as density, biomass, and annual growth. Litter production, phonological pattern, gene regulation and manipulation mangrove and dependent biota, organic carbon and sediment, associated biota, hydrological characteristics, and time lapse land use land cover pattern

-Influence of temperature and salinity at organizational and functional levels of different species

-These habitats are closely linked with sub tidal seagrass and coral ecosystems adjacent to them. It is therefore necessary to formulate multidimensional holistic approach in understanding the impacts of climate variations and sea level rise on marine natural habitats.

Problem? What problem?

Dave Stanley, e3Consulting, UK

Let me start by clearly stating that I have no formal background in biology or any related subjects. I have a systems management background. It is with some trepidation that I comment on this debate on biodiversity.

1. Topic. 'Climate Change and Biodiversity Conservation: Knowledge needed to support development of integrated adaptation strategies'. If one is going for a change management process within any organisation, one would always commence by seeking to identify and gain agreement to the problem(s). Once achieved (rarely), the solution tends to be largely self-evident. I am not sure that I understand the problem as worded? Setting the term Climate Change to one side. If owning a car, "automobile factors supply chain management issues" does not have quite the same resonance as "engine failure". Are we considering "biodiversity conservation" or "maintenance of the biosphere" in some semblance that will permit the continuance of human existence? If we are talking about the loss of the "earths (my/your) life support system" – why not spell the problem out in language which most (including politicians) should understand?

2. At a simplistic level, I understand that the biosphere is the interface/buffer between the atmosphere/hydrosphere/lithosphere etc, which in its optimal state (say pre 1900?) provided a very acceptable, and only, habitat for "life – man". Since then there would appear to have been a number of significant changes including, to name a few:

* Change in the formulation of the atmosphere – increase CO2, methane, SOX, NOX, pollution, temperature etc reduction in ozone etc
* Change in oceans – increased acidification, temperature, "nutrients", pollution, decrease in salinity etc
* Change in the intensity and wavelengths of solar radiation at the earth's surface
* Changes in soils – increased acidification, temperature, contamination, decrease in organic matter, water, nutrients/trace elements etc
* Last, but not least, a 35% (?) reduction (loss) in the earths "biodiversity" (WWF).

This might suggest that there are a number of additional variables to those of Climate Change and Biodiversity?

3. Distracting factors in the environmental "debate" include well-funded proposals that typically amount to "how do we continue the way that we are – but just do it sustainably".

What is the logic behind, and meaning of, "Integrated adaptation strategies"?

4. I would query the following:

* Is the topic couched in terms that most would understand and recognise its critical importance?
* Is the scope too narrow by restricting to just Climate Change (an output/impact) – are we certain it is the main, or even the largest threat? What about the input of nitrates?
* Is there an implicit assumption that we have "business as usual" and are we merely going to try and adapt to a very dubious forecast.
* Should we not be seeking to rapidly identify the threats and reverse/mitigate the adverse impacts on the biosphere?

5. Could I suggest that the following might need to be considered as possible research issues:

* What are the biosphere stability drivers and associated significant threats to their functioning
* Which activities and inputs are causing the changes, or are major threats (direct or indirect) to the earths systems
* Which activities/actions might reinforce the stability drivers and reverse or mitigate the negative environmental impacts on the earths systems (deliver positive environmental impacts i.e. carbon sequestration in soils)

Research Priorities in Climate Change Biology

Lee Hannah, Centre for Applied Biodiversity Science, Conservation International

Mysteries about the response of nature to climate change span the past, present and future. I would like to highlight two issues from each of these timeframes that are particularly worthy research problems. Each are critical in their own way. Lessons from the past provide us with the only sure record of biodiversity response to climate change. Record of current change is critical to assessing the trajectory that man-made climate change may be taking, while modelling of future effects can help elucidate effects for which there is no past analogue.

Paleoecological research is needed to unravel the mechanism of rapid plant range migrations, migrations that are known to have been rapid and to have covered large areas in the temperate zones after ice ages. The mechanisms of these rapid responses are not well understood. A dominant view that long-distance dispersal was a primary driver of post-glacial vegetation shifts is now being replaced by the view that small pockets of vegetation hanging on in unusual microclimates may have been the foci of post-glacial vegetation changes. The latter school now dominates theories of Southern Hemisphere post-glacial dynamics and is gaining adherents in the Northern Hemisphere. If micropockets of vegetation did play a central role in past biotic change, this has important implications for the ability of vegetation to respond to rapid human-induced climate change. In the tropics, our picture of change is even more clouded. Did the tropics undergo major rapid climate changes like those documented for the North Atlantic? If so, how did vegetation respond? Few tropical paleoecological records have the ability to resolve rapid changes on the order of decades or centuries, or to the level of species, but such records are key to understanding how the high-biodiversity tropics may respond to rapid anthropogenic climate change.

Many present biological responses to climate change have been documented for terrestrial species, including range shifts, changes in phenology and physiology. Far fewer such changes have been reported for marine species. Understanding how the oceans are responding to climate change contribute two major research priorities for studies of contemporary climate change biology. Changes underway in fisheries is one particularly important topic in this field, with enormous economic implications. Direct effects of CO2 on ocean organisms is a second seminal field. Our appreciation for direct CO2 effects in the oceans is in its infancy but may eventually rival temperature change-related effects for importance to biodiversity.

Finally, the future. We know that limiting climate change is the most certain strategy for avoiding impacts on biodiversity. The UN framework convention on climate change (UNFCCC) has avoiding dangerous interference in the climate system as its major goal, and ecosystems adapting naturally is one benchmark of that goal. Thus, a key for the future is understanding what ecological systems may be most vulnerable to climate change. These sensitive systems will help define ‘dangerous interference’ and help set low-end caps on greenhouse gas concentrations in the atmosphere. Meanwhile, we’ll have to cope with climate change from gases already in the atmosphere, which requires climate change-integrated conservation strategies. Understanding how climate change interacts with habitat loss will be one of the critical research priorities for designing effective dynamic conservation. Together, research on past, present and future climate change biology will play a telling roll in our ability to bring the planet’s species and ecosystems through the coming period of rapid human-induced climate change.

Understanding and adapting to change in marine and coastal ecosystems

Keith Hiscock, Marine Biological Association, Plymouth

The following text is a summary of some of the views that I have developed over the past few years by keeping an eye on the literature, in discussion with other scientists and in various workshops. The aim of this introduction to the topic is to provoke you into providing your view of what we understand and need to understand and how we can adapt to change – to the benefit of biodiversity. The changes referred to and the sources of information that suggest them are described and illustrated in http://www.marlin.ac.uk/PDF/MLTN_Climate_change.pdf. I have included a minimal number of references as starting points for any further research that you undertake.

We know that: The abundance and distribution of species will change as a result of warming air and sea temperatures – and that plankton and fish will respond most rapidly (Hiscock et al. 2004; Beaugrand et al. 2002; Perry et al. 2005). Sea level will rise (Viles, 2001) resulting in economic pressure to build more hard coastal defences (but opportunities to allow some defences to breach).

We think that: Some non-native species may become more of a nuisance as seawater temperatures rise, increasing the fecundity and competitiveness of warmer water species (see http://www.waddensea-secretariat.org/QSR/chapters/QSR-08.3-intertidal-musselbeds.pdf). There may be a mismatch between availability of preferred planktonic prey and the production of larvae requiring those prey (Hiscock et al. 2004). Storminess may be increasing as a result of global climate change (McCarthy et al. 2001). Stratification of the seas will strengthen, reducing upwelling of nutrients and therefore reduction in productivity (Roemmich & McGowan 1995) and, in enclosed water bodies, causing de-oxygenation of deeper layers (Hiscock et al. 2004). The north-east Atlantic thermo-haline circulation (the Gulf Stream) will slow-down (Houghton et al. 2001).

We speculate that: Rising levels of CO2 dissolved in the ocean will be sufficient to increase acidity to a level where marine life (especially marine life with calcium carbonate skeletons or structures) will suffer (The Royal Society. 2005). The north-east Atlantic thermo-haline circulation (the Gulf Stream) will ‘switch-off’ – however, even if that happened, it is thought that the seas of western Europe will still warm significantly. Methane would be released from methane hydrates currently ‘sealed-in’ by cold conditions.

In some instances, for example the likely increase in abundance of colourful Mediterranean-Atlantic species in temperate waters of the north-east Atlantic, the changes might be welcomed. In others, for example increased stratification and consequent de-oxygenation causing mortality, the changes will be unwelcome. Most marine communities are highly resilient and will adjust to change without major catastrophes. ‘Integrated adaptation strategies’ might mean removing or reducing the pressures on the environment that we can influence so that unstoppable climate change effects are not so severe. The adaptation strategies might also mean accepting that change is inevitable and making best use of the change for marine and coastal biodiversity.

As for ‘knowledge needed’, the available parts of the jigsaw are each quite clear but how they fit-together is academically challenging – especially when a large number of the pieces are missing!

Taking-off other pressures; The impact of fishing – on fish stocks and on the environment generally – is well-documented (Kaiser& de Groot 2000). Some stocks are close to commercial extinction and, with a bit more of a ‘push’ will go over the edge (as did the cod stocks on the Grand Banks). Some species have declined markedly as a result of damaging fishing practices and, if they are near to their southern limits of distribution, may not come back because of too warm temperatures (possibly the horse mussel reefs in Strangford Lough). Clearly, not all fishing is ‘bad’ but if fish stocks are to be maintained in the face of adverse climatic conditions, those stocks need to be identified and more effective conservation measures taken.

Non-native species include many (if not the majority) that have been brought into Europe and further spread around Europe as a result of mariculture. Our biosecurity is virtually non-existent and is breached by irresponsible introductions and movements of stocks. Some of those species (the Pacific oyster Crassostrea gigas has already taken-over native mussel beds in some areas) will reproduce and survive more effectively in warmer climes. So, take measures now to stop new and potentially damaging introductions.

Increased nutrification of inshore waters (the result of sewage discharge and agricultural run-off) together with warming seas could result in eutrophication effects including increased bacterial infections of organisms or toxic algal blooms (perhaps the death of many large sessile invertebrates along the coasts of Provence (France) and Ligury (Italy) in 1999 was the result of such a mixture of warming and nutrients) (Laubier 2001). So, reduce nutrification and take that pressure off.

Make the best of it; Human activities are influencing the marine environment and changing ecology not always for the best. Concrete defences reduce the extent of intertidal areas especially with rising sea levels on one side and concrete on the other ('coastal squeeze'). These coastal defences together with offshore structures such as wind farms and wave-break reefs can act as stepping-stones for the spread of species. Rising sea level and possibly increased storminess are likely to result in calls for more hard coastal defences. There are two stark choices: do it, or let the sea break through. Both options can be used to enhance biodiversity. Design of coastal defences could take account of providing a variety of habitats for species – including commercial or recreational species of crustaceans and fish (see: http://www.delos.unibo.it). If the sea is allowed to breach existing defences and create new habitats, design of sluices and culverts could create lagoons with a biota that is valued as unusual.

Let it happen naturally! Well, 'naturally' is probably not the right word when referring to change brought about by global increase in carbon dioxide emissions. But, if species are going to migrate from one part of Europe to a different part, let them do it themselves. Just because the ormer Haliotus tuberculata, previously 'trapped' as far north as the Channel Isles by the significant barrier of the English Channel can survive now in the Isles of Scilly or north Cornwall is no reason to introduce it there!

'Just ask'; All too often, so called 'Environmental Assessments' are minimal exercises reluctantly undertaken by developers or regulators. Perhaps they are frightened that 'environmentalists' will always be negative about developments. Certainly, many developments are undesirable for 'naturalness' but, often, the imaginative scientist will see ways of at least reducing the impact of developments or new regulations and sometimes suggesting ways in which biodiversity may benefit from the development.

What else do we need to do to improve knowledge? The world is awash with information – library search facilities and the Internet should be able to identify relevant sources of information even for the laziest environmental consultant. However, using that information to improve knowledge and to give good advice requires relevant experience and good judgement (= wisdom). It is also going to be the way that we bring together and interpret that knowledge that may help us to target adaptive strategies that will minimise potentially adverse effects and perhaps maximise gains for biodiversity. We should:

- Work hard to identify those pressures already adversely affecting our marine and coastal biodiversity so that action to reduce the pressure can be prioritised – even action that is 'uncomfortable'.
- Undertake experimental studies (laboratory and field) to test the reaction of organisms to likely effects of climate-induced change and therefore better understand what aspects of climate change are most important in threatening ecosystem structure and functioning.
- Continue long-term and broad scale monitoring to track change and to be able to separate short-term variability from long-term trends and impacts of localised human activities from climate change.
- Present information in an accessible and digestible form, especially for decision-makers.

RE: Understanding and adapting to change in marine and coastal ecosystems

Ferdinando Boero, University of Lecce, Italy

I concur with Hiscock and Hawkins about research priorities. To detect change (both in climate and in biodiversity) we have to identify trends (and their causes and, eventually, the remedies).

Meteorological stations and satellites collect information about the weather (then translated into climate over the long trend). Who collects information on biodiversity, so to identify trends?

Information from long term series in fisheries are flawed by several reasons (in some countries declared yields are lower than real ones due to taxation, in others are higher due to production targets).

We should take long term information from long term series of field observations. In the marine environment, these are often carried out at marine stations. But marine stations are in a state of crisis. Port Erin is closed, Endoume is being partly dismissed. We need a network of marine stations (observatories) with a network of biodiversity observations. This is partly done by MARS, but it is not supported enough. The way data are collected, furthermore, needs cautious assessment. Long term monitoring of plankton is often carried out at single stations. With a single station, there is no way to discern temporal variability from spatial variability, so that the identified "trends" are not so reliable.

Long term monitoring of biodiversity is not so rewarding from a scientific production point of view and it does not lead to rapid publication in impacted journals. The people in academia refrain from doing it, and nobody else is appointed to do it.

We need a network of monitoring points and a common sampling protocol, so to store validated information in a centralized system so to identify trends at both a temporal and a geographic scale. Part of this work will be routine, but the design and the analysis of the data require high specialisation.

Most biodiversity is impacted at a habitat scale. We need at least a list of marine habitat types of Europe that is agreed upon by the whole scientific community, and we need to map these habitats as it has been done on land. With a whole picture, then we will be able to detect trends of habitat degradation, fragmentation, and so on.

Then we'll have to pass to species, so to have, for each one of them, the complete list of records and the dates, so to identify species that are expanding, species that are disappearing, new species in a given geographic area.... This second exercise can be done by taxonomists. The information on species will have to arrive to the genetic level, so to cover the whole range of the definition of biodiversity.

The monitoring of biodiversity requires a complete change in the policy of research, with the re-launch of marine stations and long term series, this time in a coordinated fashion and with precise targets in mind. What happened by chance in the past, has to be planned carefully for the future, with an European strategy.

Proper sampling to get proper data for analysis

Alan Feest, University of Bristol, UK

Ferdinando Boero has put his finger on the problem which recurs in all of these biodiversity conferences. How to arrive at a standardised sampling to derive usable data that could used to show changes in biodiversity over time. We seem to have only two datasets for terrestrial taxonomic groups that are presented in a form that allows meta-analaysis. These are for birds: the common bird census methods (but they are poor indicators) and for butterflies (which are good indicators); the Pollard and Yates method. It would seem it would be even harder to prepare a methodology that will work for marine waters but surprisingly it has been done. Using methods that generate data similar to the terrestrial survey data methods Danavaro, R., Dell'Anno, A. and Pusceddu, A (2004) showed it was possible to link changes in Marine Sediment Nematodes in the Mediterranean to changes in sea temperature. This is a very promising start but seems to rely on the use of rare taxonomic skills to be effective. Are there other comparable groups that could be used?

RE: Proper sampling to get proper data for analysis

Keith Hiscock, Marine Biological Association, Plymouth

Alan Feest points out "proper sampling to get proper data for analysis!" and draws particular attention to marine. But statistically rigorous and taxonomically challenging quantitative sampling for inventory purposes is rarely attractive to grant funding agencies. And some change can be as plain as the nose on your face. The 'promising groups' for research that I will advocate are the conspicuous, can't-possibly-be-mistaken-for-anything-else species - especially climate change and non-native species.

And the promising sector to do the work are the public - well, the properly directed public. Engaging the public seems to be attractive to funders (even while I was writing this e-mail I was interrupted by a 'phone call advising me of a new source of significant funds likely to be available soon for public outreach in relation to marine). However, marine biology is never going to get the amount of interest that folks have in birds (or butterflies, or orchids) but the potential to use the public to track distributional changes in species is being achieved in a directed way through the Seasearch (http://www.seasearch.org.uk) programme for divers and through recording schemes run by the MarLIN programme (see http://www.marlin.ac.uk/learningzone/recording/rec_logon.asp). There are also rare fish reporting schemes. Identification guides to support these surveys have been produced and schemes set-up to work with schools in particular. These volunteer based programmes can be used to better understand rates of change in the distribution of those conspicuous, can't-possibly-be-mistaken-for-anything-else species - especially climate change and non-native species.

Research priorities in understanding and predicting climate change impacts in marine ecosystems

Stephen Hawkins, Moore, P., Frost, M.T. & Jenkins, S.R., The Marine Biological Association, Plymouth, UK

To manage biodiversity and ensure an ecosystem approach to marine stewardship it is necessary to separate the influence of global environmental change, such as anthropogenically forced climatic warming, from regional (e.g. fishing, eutrophication and modification of coastal processes) and local impacts (e.g. point sources and hot spots of pollution, acute pollution incidents, specific sea defence schemes, habitat loss due to coastal development such as ports and harbours, oil and chemical spills and recreational activities). This can only be done via broadscale and long-term research networked over appropriate spatial scales and with assured parallel funding throughout participating organisations. In the case of climate change, congruent changes need to be detected over several degrees of latitude and over many decades.

Whilst single nations with extensive territorial seas and coastlines (e.g. Italy, Spain, Portugal, France, U.K., Ireland, Germany, Norway, Sweden, Finland) can make significant contributions, the problem needs to be addressed transnationally. For operational reasons the European Union and its associated states are an appropriate unit to make a vital contribution to international programmes. This work is also essential for stewardship of the natural heritage and biodiversity of European seas and coasts. Europe is ideal for such research as it encompasses both polar and warm temperate regions. Biogeographically there are also major boundary zones in the Iberian Peninsula and further north straddling the British Isles, Ireland and France.

The research agenda is simple: long-term and broadscale observations must be sustained. This must be done with appropriate quality control, intercalibration and above all integration and synthesis. It also needs to run parallel with process orientated research on the underlying mechanisms enabling better predictive ability of rates and scales of likely future changes. Moreover the data collected needs to be made available to the scientific community, policy making end-users and stakeholders - including an increasingly informed and concerned electorate. However, policy end-users must be aware that any baseline will be a fluctuating one that can obscure trends unless the time series are of sufficient duration and have broadscale coverage.

Biodiversity and natural heritage are mostly managed by area-based designations such as Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). Offshore Marine Protected Areas (MPAs) are now very much on the agenda for implementation. Such area-based management occurs in a fluid 3-dimensional environment - the sea. The greater connectivity of marine ecosystems means that boundaries will shift and therefore broader scale contextual monitoring is essential to explain local changes in designated areas. If species are observed to decline or disappear, is this due to local impacts or due to global change?

So what should we discuss?

1. How do we design monitoring and decadal research networks?
2. How do we constantly update and integrate new methods and technologies as they develop?
3. Data access – How do we protect data gatherers from data predators?
4. How do we ensure rapid policy deliverables?
5. How do we ensure sustained cross-national funding?

A plea for a dynamic conservation of biodiversity

Gérard Second, Jean-Louis Pham and Serge Hamon; Institut de Recherche pour le Développement (IRD). UMR Diversity and genome of cultivated plants (DGPC), Montpellier, France.

SUMMARY: Evolution of plants and the domestication process of crops show the importance of wide hybridization in plant species adaptation. Globalization of exchanges provides model cases for research in this area. Actions are needed to promote research towards an approach of a safe dynamic conservation of biodiversity to cope with current environmental changes.

Fear of encouraging the spread of invasive plants and engaging restrictions associated with international agreements on the property and movements of biodiversity should not result in the abandonment of valuable conservation strategies for a dynamic conservation of biodiversity involving intercontinental artificial populations.

Our arguments come from specific examples: Evolutionary scenarios deduced from molecular studies show that distantly related species brought into contact through human interference, at times resulted in the creation of new biodiversity with remarkable adaptation. In the genus Oryza (rice), for instance, allotetraploïd wild species endemic to tropical America integrated recently genomes that originated in Asia, Africa and Australia. The most vigorous plants in the genus resulted from this integration and are now established as exotic immigrants in natural ecosystems.

The history of crop domestication reveals that complex hybridization between plants of various geographic origins is often associated with, and presumably explains, the success of some of the most important cultivated plants. Cassava offers in addition an example of a scheme of dynamic conservation in traditional fields: in the Neotropics, Indian traditions of cultivation have resulted in considerable accumulation of genetic diversity within a single field of cassava through long distance exchanges of cuttings; Dynamic conservation of this diversity is traditionally through the recruitment of sexual seeds, in a crop that is otherwise vegetatively reproduced.

Conscious or unconscious exchanges of organisms have accompanied the movement of humans between continents. The so-called Columbian exchange offers an opportunity to study model cases of successful introductions in a well delimitated time span. Indians living in a largely anthropogenic "primary" forest, and fugitive slaves (after epidemics dramatically reduced the demography of native peoples in the Americas) certainly were instrumental in disseminating largely some of the exotic organisms. Hybridization was undoubtedly a stimulus in the successful adaptation of new genotypes sometimes recognized as different species by their authors.

Some historically documented cases of introduction of plants also resulted in complex hybridizations that challenge the most advanced controlled breeding work. Diploid and tetraploid Coffea species can be exceptionally grown together in the same fields in New Caledonia, thanks to local microclimate. This resulted in the proven spontaneous transfer of resistance to the devastating rust disease, from diploïd to tetraploïd coffee plants growing in the same old fallows.

We recognize now the risks but also the benefits of these intercontinental exchanges that have prevailed for millennia. We are largely unable to eliminate the cryptic but world scale exchanges that go on and sometimes result in damageable invasive species. It is paradoxical that, meanwhile, research to develop safe strategies for dynamic conservation of biodiversity does not receive the needed attention, in particular in a context of climatic change requesting new adaptations of living organisms.

How to bridge the gap between spatial scales in ecology and planning?

Paul Opdam, Wageningen University, The Netherlands

SUMMARY: In the discussion on the research agenda so far, there is little attention expressed for the interaction of processes at different levels of spatial scale, both in physical planning and in spatial ecology.

Spatial scale plays a key role in the response of biodiversity to climate change, and it does so in quite different ways. See table 1below.

Geographical unit	Political responsibility	Conservation measure	Ecological functional unit	Climate change factor
Europe	EU policy	PEEN	Geographical range	Temperature rise
Country/region	National/regional government	National ecological networks	Range/metapopula tions	Temperature rise
Landscape region	Multi-actor landscape planning	Ecological networks at landscape level	Metapopulation	Increased weather perturbations
Site	Local manager	Natura 2000 sites	Local population	Increased weather perturbations

The interesting message of this table is that while much energy is channelled to the site level, be it without taking into account the potential effects of increased weather extremes (Harley, this conference), relatively little is done at the other scales, and the relationship between measures and potential climate change impacts is practically non-existent. A major challenge in planning science is how to insert the need for problem solving detected at a European or countrywide scale into regional development plans, where many actors who are not aware of large-scale ecological problems decide on future ecological conditions. This gap in planning scale level is a one of the major problems to overcome. This is certainly a huge challenge for a combined effort of landscape planning science and landscape ecology.

In ecological science, we have a gap to bridge as well. Biogeography is only recently entering more mechanistic domains, and largely neglected how the underlying pattern of ecosystems caused patterns of density and local extinction/ recolonization processes within the range. Very little is known about the interaction of processes at the species distribution ranges with metapopulation and source-sink processes (Opdam and Wascher 2004, but see Holt et al. 2005). This is a major knowledge gap if we want to detect:

1. Where in a species geographical range, the pattern of ecosystems is not climate proof, because the spatial cohesion of the ecosystem pattern is not strong enough to cope with increased frequencies of extreme weather events;
2. Where, in case of a species responding to temperature rise, in the expanding front of the range the distances between key sites are hard to bridge;
3. Where the Pan European Ecological Network is climate change proof, and where it isn’t;
4. How landscape region development plans can be given proper messages to solve such problems.

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Adaptation strategies for existing ecological sites and networks

Week One Summary and Update

Terry Parr, E-Conference Chair, CEH Lancaster, UK

During week one we had a wide-ranging discussion on climate change impacts on biodiversity. If you haven't had time to keep up with the conference, some of the more detailed comments are summarised below and it's my feeling that these are beginning to crystallise around research priorities in 5 key areas:

1. Development of knowledge management systems to enable effective use of existing data and information resources;
2. Development of process based approaches that enable us to deal with the interacting pressures and non-linearities in ecological systems;
3. Development and use of functional types to simplify process-based approaches and to enable us to focus on ecosystem processes rather than individual species;
4. Improved linkage between modelling, observational and experimental approaches focussed on relevant policy and management issues; and
5. Large-scale, multi-dimensional and holistic approaches.

There is till time for contributions to Session 1, but in week two we should start to concentrate on adaptation strategies. There will be two concurrent sessions:

Session 2 Aim: To identify the key research and development required to make sure that we make best use of current sites and networks, and can develop better conservation policies and practices to create ecosystems that are resilient to climate change.

Session 3 Aim: To identify the key research and development required allowing us to adapt land and water-related policies and practices to promote conservation of biodiversity under climate change

The need for adaptation strategies for existing ecological sites and networks (Session 2) looks like being a hot issue and several important statements have already been made. Claire Vos's contribution articulates the issue very clearly and is worth reading by way of introduction to this session. Others have also emphasised the need to move away from site-based thinking and stressed large-scale international, multidimensional and holistic approaches to understanding and responding to climate change impacts in both terrestrial and marine habitats. But what advances in ecological knowledge and what research are required if we are to manage biodiversity on this scale? And what research is required to provide appropriate advice to ecosystem managers in protected areas to enable them to play their part in this process of large-scale adaptation to climate change? We now need to be much more specific in pinning down the research priorities needed to address these, and other, issues.

Session 3 has not yet attracted much interest even though many of the contributions for the first two sessions point clearly to the need for a holistic approach to biodiversity conservation and hint that we may need to develop radical new ways of managing multi-functional landscapes (or the open-seas equivalent) that may challenge some of the sacred cows of current policies. It's easy to suggest that the research requirements related to the management of these areas for biodiversity are likely to involve complex inter-disciplinary research. But is this good enough or can we be more specific?

Summary of Session 1: Whilst discussing the tropicalisation of the Mediterranean, Ferdinando Boero called for more emphasis on taxonomy (both in the field and in the creation of gene banks) and bibliographies. This was further emphasised by Jan Dick who called for the digitisation of bibliographic information in searchable libraries. According to Ferdinando Boero this information could provide lists of endangered or extinct species that could be used to reinforce the perception of climate change in the public and political spheres. Martin Sykes warned against data gathering for the sake of data gathering and suggested that modellers and those making climate change predictions should discuss and influence the gathering of data relevant to questions asked and models used. Following on from Martin Sykes' comment on the relevance of data, David Gowing called for more ecohydrological research and modelling on the mechanisms by which climate change impacts biodiversity, e.g. changes and spatial forecasting of the rainfall/evapotranspiration balance.

On the topic of modelling, Martin Sykes argued that approaches focussing only on bioclimatic envelope modelling were at a dead end and called for more process-based models. In this regard he highlighted that important knowledge gaps existed, namely relating to plant physiological processes and modelling mechanistically the effects of evolution on species populations in a changing climate. Although Pierre Ibisch acknowledged that process-based models were theoretically the best approach, he expressed doubt regarding their practicability due to the complexity of processes and the potential importance of stochastic approaches. He concluded by urging participants to focus less of individual species and distribution patterns and more on landscape functionality. Ivan Nijs suggested using bioclimatic envelope modelling but in a restricted sense, for example in the screening of large sets of species or plant functional types to CO2/temperature interaction.

Regarding the impacts of climate change on insect populations, Richard Harrington discussed the feasibility of a traits-based approach to predict impacts. However he acknowledged that this required a well-funded network of scientists to combine methodologies and reach consensus.

Possible research issues suggested by Dave Stanley focussed more on biosphere stability drivers and the activities driving climate change.

Lee Hannah discussed the need to use a combination of paleoecological research to inform us about the past history of climate change impacts on biodiversity and modelling in order to predict what impacts may be in the future. He identified a number of urgent gaps in knowledge including a better understanding of sensitive systems, increased knowledge of the interaction between climate change and habitat loss, and further exploring the possible impacts of climate change in marine environments.

We received a number of contributions focussing more on the marine environment, including a contribution by Keith Hiscock who suggested more research on the identification of pressures already affecting the marine environment, experimental studies to test organism reactions to likely climate change effects, and increased monitoring to follow changes and help separate the short-term localised effects from more long-term trends. Still on the issue of monitoring, Stephen Hawkins asked how this broad-scale long-term monitoring should be designed. He also raised the issues of upgrading and integrating new methods and methodologies, ensuring sustained cross-national funding and the production of rapid policy deliverables. Tanaji Jagtap stressed the threats of climate change on mangrove ecosystems and called for research on the conversion of CO2 into biomass, changes in forest structure, temperature and salinity impacts on species and the necessity to have a multidimensional holistic approach to understanding climate change impacts on natural marine habitats.

Natura 2000 and climate change adaptation

Pierre Ibisch, University of Applied Sciences, Eberswalde, Germany

I am especially pleased that the minefields related to Natura 2000 have been made clear from the very beginning.

The objectives of the Natura 2000 areas are exclusively related to the maintenance of the presence and the current status of the selected targets. Many of the sites focus on single occurrences of certain species without protecting viable populations. E.g., in Germany the rather large state of Bavaria has achieved the establishment of 674 SACs, more than in any other state. However, 69.6% of the sites are smaller than 1,000 ha, and 21.4% even smaller than 50 ha; only 1.8% are larger than 10,000 ha (according to data by BfN 2005b). The placement of the sites within this extremely fragmented protected area system has not been planned in function of connectivity or other aspects related to functionality. In the light of projected climate changes and short-term loss of stability for many species (e.g., Bakkenes et al. 2003) it is highly improbable that Natura 2000 alone can accomplish its objectives.

The minefields are not exclusively of a legal and political nature. As far as I understand, many conservationists in Germany and Europe are not amused at all that after a decade of hard battles and struggling for Natura 2000 (which definitely has absorbed a major portion of conservation resources and attention spent by governmental and NGO actors) we come and tell them that the approach is wrong (or let's say too narrow). Some conservationists even feel that it might be dangerous when politicians get informed that this expensive and bothersome Natura 2000 is far from being based on recent conservation science.

Until now, among most conservationists (in Germany) adaptation to climate change is not a relevant topic. Conservation is much too segregative focusing on areas where interesting and beautiful flowers and bugs are. Although the ecosystem approach is an official CBD issue it does not touch the hearts of the traditional conservationists. As we are documenting for a paper, most protected area managers have not heard of the ecosystem approach or do not know what it means. Thus, there are scientific minefields as well...

Of course, the key question is Terry's "But how different will they become and at what point do we stop managing them for what they are now and manage them for what they will become in 50 to 100 years time? " Definitely, there should be some rapid assessments done using habitat suitability models and climate change data in order to show how the warming alone will affect the Natura 2000 targets (without taking into account systemic/synecological effects of climate change that cannot be modelled but that definitely will worsen the impact). This is a first step that should be used for a careful communication to conservationists and politicians. The challenge is that we need to abandon the site-based species and representation centered conservation approaches as soon as possible. We should not spend large amounts of money for the Natura 2000 target monitoring and management alone but instead use much of it for improving the habitat quality of the matrix between protected areas and establishing a best possible network of corridors. The set of Natura 2000 areas is a patchwork, not a network. And this must be changed. In central Europe the fragmentation by roads and settlements and agricultural areas is an enormous conservation problem - even in a static world. With the expected dynamics triggered by climate change the consequences might be fatal.

RE: Natura 2000 and climate change adaptation

Ian Alexander, English Nature, Northminster House, Peterborough, UK

Well having identified that: "The minefields are not exclusively of a legal and political nature. As far as I understand, many conservationists in Germany and Europe are not amused at all that after a decade of hard battles and struggling for Natura 2000 (which definitely has absorbed a major portion of conservation resources and attention spent by governmental and NGO actors) we come and tell them that the approach is wrong (or let's say too narrow). Some conservationists even feel that it might be dangerous when politicians get informed that this expensive and bothersome Natura 2000 is far from being based on recent conservation science." is a potential problem have you asked the question is it necessary to do it that way?

As of today I don't think I agree that the way 'conservation' has operated in recent decades has been 'wrong' (or even too narrow).

Remember that for decades we have been (at least in much of the UK) fighting a rearguard action against a mighty agriculture industry that in five decades has greatly impoverished the biodiversity in our countryside. This was for years (and correctly in my view) seen as the 'real and present danger' to biodiversity; the principle focus of action for the conservation movement - and protected sites was a reasonable part of the response.

With CAP reform (and other changes) the threat from this direction is decreasing and relative to the emerging threat from climate change it is, arguably, decreasing rapidly. But that does not mean, to me, that the past response was wrong. It might mean that it is less suitable or even unsuitable for the future; that we need to adapt our approach quickly - all of that I might buy. But I see no need to alienate a whole generation of conservation workers by telling them that what they have been doing is 'wrong'?

RE: Natura 2000 and climate change adaptation

Michiel WallisDeVries, De Vlinderstichting - Dutch Butterfly Conservation, Wageningen, The Netherlands

Natura 2000 provides a valuable basis for the conservation of biodiversity and it should be seen as a considerable step in Europe's nature conservation. There is probably no disagreement about this. Having said that, it is undoubtedly true that Natura 2000 is still far from satisfying the requirements of a connected network that can meet future changes in the landscape, including climate change. To achieve this network further improvement of the quality and connectivity in the surrounding matrix is a crucial next step. Reforms of the common agricultural policy (CAP) (and its subsidy system) should take up this challenge!

At the recent meeting of the European Grassland Federation in Tartu, Estonia there was a widespread agreement that CAP reform was far from meeting the requirements for the 2010 target to halt the loss of biodiversity in the EU. Even after the intended CAP reform, intensification of agriculture will be stimulated together with the abandonment of low-productive, species-rich areas. However, several agri-environment schemes (see Grassland Science in Europe (2005), Vol. 10) have shown that the 'production of biodiversity' and the improvement of landscape connectivity can be successfully met when ecological criteria receive an adequate priority, for example in Switzerland. Also, large-scale low-input ranching systems may be an ecologically and socio-economically viable option in the future (Kumm, 2004; J. Nature Cons. 12, 213-218). So, upgrading the priority for biodiversity in CAP reform by providing farmers with incentives to promote biodiversity, can lead to a strengthened Natura 2000 network and thereby may contribute to a solution for the climate change problem.

What should park managers do to adapt to climate change?

David Welch, Parks Canada, Canada

Change is happening and will continue to happen at a rate akin to the great climate changes and extinctions of the geological past. Protected areas must be managed accordingly. Managers cannot stop these global threats, but they can adapt policies and strategies to facilitate natural resilience for biodiversity, geodiversity and self-sustaining populations of native plants and animals. Some principles, goals and actions were suggested by Welch (2005). The principles follow.

Principles: House-in-order and public communications. High profile public agencies have a unique opportunity to explain global change issues to a wide citizenry through interpretation and outreach. House-in-order and demonstration projects add credibility. Examples include the elimination of cosmetic pesticide use, reduction of greenhouse gas emissions and waste reduction and recycling.

Risk management to foster resilience. Some species and ecosystems may be able to adapt to climate change by migration or in situ change. However, there are many other stresses impinging on natural areas and their greater ecosystems. A risk management approach will reduce or eliminate these confounding stresses through collaborative efforts.

Focus on mandate, complement with partnerships. Tourism, regional development and foreign policy should not be put ahead of restoring and protecting natural and cultural heritage. Priority should be accorded to actions within the direct responsibility of the agency and its staff. So, for example, ecological integrity must supersede carbon sequestration in protected ecosystems. However, to the extent that resources allow and that its prime mandate is respected, a park should cooperate in activities like education, emission reduction, climate science and landscape stewardship.

Permeable landscapes. Parks should be part of networks of ecological areas within which biodiversity can survive, move and be appreciated. Park agencies should promote the importance of regional ecosystems characterized by connectivity and permeable for wildlife movement.

Actions; These principles can be applied through five types of action, together forming the acronym ALARM. Awareness: staff and stakeholder orientation; visitor interpretation and outreach to the general public. Leading by example: reduce greenhouse gas emissions; promote personal action plans for staff; adapt natural region representation strategy; address climate change adaptation in management plans; report on natural and management adaptations to climate change. Active ecosystem management: eliminate or mitigate in situ non-climate threats; apply adaptive management; use science results; adjust park boundaries as needed for climate change adaptation. Research: understand the impact of past and future climate change; identify values at risk of being significantly impacted by climate change; support downscaled climate modelling. Monitoring: promote parks as long term integrated monitoring sites; data gathering and reporting.

Goals; Specific actions should be phased to achieve three targets. The actions don’t need to be sequential. Short term: appropriate climate change information is available to all aspects of park management. Mid-term: climate change is factored into all aspects of ecosystem and asset management, and duly reflected in park management plans. Long-term: natural areas are nested within regional landscapes that are permeable for the movement of native species and which are free of significant threats to ecological integrity.

Connectedness in the marine environment

Keith Hiscock, Marine Biological Association, Plymouth, UK

Terry Parr notes "the importance of the thousands of protected sites, not as individual sites, but as a single inter-linked network. ..... to create a network of sites that enables species to disperse to new sites and gives the greatest resilience to climate change?"

I have never believed that an interconnected 'network' of marine protected areas is a possibility - and argued that point with folks who worked hard to get "network" into the wording from the World Summit on Sustainable Development to "develop a representative network of marine protected areas (MPAs) by 2012".

The marine environment is highly connected - species that have planktonic larvae or that are free-swimming/drifting spread readily especially via water currents. It is most likely that man-made structures (artificial reefs, wrecks, coastal defences) provide stepping-stones that are aiding spread of species as a result of seawater and air temperature warming.

Exceptions to connectedness occur - especially where larvae are short-lived or where asexual reproduction is the norm or where larvae are trapped by geography.

Recent work undertaken at Queens University Belfast (Mark Jessop, Louise Allcock, Mark Johnson, Catriona McInerney) University College Dublin (Olwyen Mulholland, Tasman Crowe) and University College Cork (Rob McAllen) and presented at the European Marine Biology Symposium last week suggests, through genetic mapping, that in some reserves such as Lough Hyne, species are genetically isolated from the adjacent coast. In others, such as Strangford Lough, connections can be found but do not generally extend more than about 35 km (my interpretation). My interpretation of their findings is that reserves are important as 'high value refuges' which might supply larvae and juveniles to exploited areas immediately adjacent to them but not because they are connected and they will not re-colonise each other in case of disaster. Recolonisation would come from the adjacent (un-designated) sea area.

There are also naive calculations being undertaken to identify critical distances between SACs established under the Habitats Directive. Only if the biotopes in those SACs are the same should critical distances for those biotopes and their component species be suggested.

All-in-all, my view is - do not go looking for connectedness between protected areas in the sea; such connections are only part of a generality. Marine protected areas should work to maintain the richness and 'specialness' of the particular area and, especially if strictly protected, should have the bonus of supplying larvae and individuals to adjacent exploited/damaged areas. Protected areas work to mitigate the effects of climate change by taking-off other pressures which, with climate change, might otherwise have adverse effects.

RE: Connectedness in the marine environment

Dan Laffoley, English Nature, Northminster House, Peterborough, UK

It's been becoming clear for sometime that marine species may be more functionally isolated within their broad population then many might think. The examples Keith cites are from the UK, but we still need to be very cautionary about how we interpret such results. 'Connectivity' processes are likely to be also dependent on longer-term physical processes and events, which cause occasional replenishment of species and populations, perhaps only every 25 - 50 years or so. Some of these longer-term cycles are well document but others are not. So before we jump to conclusions about outcomes of specific studies we need to factor in this temporal perspective.

If we are serious about building marine protected area networks then we need to increase the depth and breadth of applied research to support network development, particularly on connectivity. Results should be viewed alongside the need for wider conservation measures throughout the seas, because some may seize on ‘connectivity’ facts in isolation to undermine the case for any more marine protected areas, when the direct opposite is more the truth.

Within this debate it is important to clarify that:

1. Sites are critically important for the continued survival of species in the sea. Greater understanding of connectivity crucially strengthens the need for effective replication and full representation of marine biodiversity in marine protected areas. We are generally many years away from building true ‘networks’ that address ‘connectivity’.

2. Sites are just part of the picture. Over the past few years we have pushed hard at all levels to ensure that MPA ‘networks’ are accompanied by more effective measures across the wider marine environment.

3. Improving our understanding of connectivity will help us understand much more about the size and nature of individual protected areas and network design. Connectivity may work in protected area networks (if carefully designed) for some species but probably not others * we need to be clearer on this point, and whether there are any general guidance principles that can be developed.

4. Greater understanding of connectivity strengthens the need for highly protected marine reserves as a key element of a tiered approach to marine conservation. The general assumption that we can exploit all the seas ‘because there are plenty of those species and they will readily recover’ does not hold up. Environmentally and ethically society should protect a representative set of examples to pass onto future generations. Unless highly protected marine reserves form a core element of the approach, we will use already degraded sites to come to conclusions about connectivity. What we see may not be the true behaviour of all species, and probably isn’t as documented by case studies and subscribed to by some scientists.

Perhaps armed with studies from areas we leave alone from exploitative pressures, we may gain greater insight into ‘connectivity’, the role that area-based measure can and should play in the future, and how they should be best organised within a wider framework to optimise their success.

Increasing European ecosystems' resilience

Claire Vos, Alterra, Wageningen, The Netherlands

One of the biggest problems for species that (try to) respond on climate change by range shift is that nature areas in the European landscape have become fragmented and land use pressure in the matrix in between natural areas is high.

In landscape ecology the answer to maintain biodiversity in fragmented landscapes has been the development of ecological networks. If single areas are too small for long term survival, species can survive as a metapopulation in a network of habitats, as long as these areas are connected by dispersing individuals. In some parts of the world the creation of ecosystem networks have become part of conservation policy: for instance the ecological main structure in the Netherlands.

However conservation problems will increase when species are confronted with the additional stress of climate change. It is very likely that size and spatial cohesion of current ecological networks will not be enough, to maintain biodiversity levels (Opdam and Wascher 2004).

Some considerations to make the European ecosystems more resilient for climate change.

1. Connecting networks over a species range. We will need to identify weak spots in species networks, in present range and potential range after climate change, and improve connectivity so that species will be able to follow changing climate conditions. This asks for international cooperation in spatial planning (Natura 2000). However the actual implementation will be on a regional level and asks for close involvement of regional stakeholders (e.g. BRANCH project).

2. Robust corridors between protected areas. Improving connectivity in ecosystem networks will imply more than creating dispersal corridors. Many species have small dispersal capacity and need reproduction habitat at close ranges. Robust corridors are a combination of dispersal corridors combined with new nature areas. These robust corridors are based on integrated area requirements and dispersal capacity of a wide range of species (Vos et al. in press).

3. Enlarge areas. Increase of extreme weather events will enhance population fluctuations. Large areas, which hold large populations will lower the risks of extinction.

4. Increase (internal) heterogeneity of ecosystems. Internal heterogeneity could be a strategy of lowering the risk of extreme weather, by avoiding regionally correlated environmental fluctuations.

All these adaptation measures will require more space for natural areas. The spatial requirements need to be quantified which asks for, basic ecological research, modelling and risk analysis. However the implementation of these adaptation measures asks for very different actions, e.g. communication about the importance of resilient ecosystems, involvement of stakeholders, multifunctional spatial planning (see BSIK research programme Climate for Space, www.klimaatvoorruimte.nl).

RE: Increasing European ecosystems' resilience

Jan Jansen, University of Nijmegen, The Netherlands

The contribution of Claire Vos was focused on artificially fragmented areas and I fully agree with her comments. In addition, research should also focus on natural fragmented areas, e.g. islands, inselbergs, isolated mountains. Take for instance the highest mountain of Portugal, the Serra da Estrela. This has been an isolated mountain for millions of years. It is the largest NATURA 2000 area in Portugal (ca. 1000 km2). A number of species there depend on snow, like the annex II species and strictly endemic Festuca henriquesii. I assume that areas with prolonged snow cover must have functioned as a source from which this strictly endemic grass once originated. With climate change this species and its habitat may become totally extinct. It has no natural way to move out. The research priority here is how can we improve the connectivity in these kinds of environments. As the areas in the NW quadrant have a very long history, historic studies may reveal natural solutions from the past, during climate changes.

Artificial snowing is probably not an option because of eutrophication, although this has not been studied in situ (Jansen 2005a). Perhaps there is only one way and that is transporting the species to another, suited area. However, such mountain areas in the NW quadrant of the Iberian Peninsula host endemic species and micro-endemics of more common meta-populations. Research in this field is needed.

The aforementioned example was one of plants, but what will happen with animals, e.g. lizards? These are not dependent on snow of course, but if temperatures keep on rising, perhaps they also will become extinct. One of them is an annex II endemic taxon of the Serra da Estrela: Lacerta monticola subsp. monticola. Three related subspecies occur in the Iberian Peninsula, forming similar isolated mountain populations. What will happen if these populations meet through introduction? These kinds of questions should be researched.

In the Netherlands much attention has been given to reference areas to the west (Ireland) and to the east (Poland). In order to have a better knowledge of the behaviour of species that are expected to come to the north, it would be interesting to give also attention to more southerly-situated areas (Jansen, 2005b). North-South cooperation between Natura 2000 areas would be of importance. In that respect it is a pity that Interreg-projects are situated within a limited area.

Adaptation to climate change and ecological networks: research priorities

Peter Bos and **Sander van Opstal**, Ministry of Agriculture, Nature and Food Quality, the Netherlands

Adaptation to climate change is an important area for the Convention on Biological Diversity for 3 reasons :

- Adaptation activities to climate change will be required in most countries and in most sectors. Their impact at the national level is likely to be maximized as part of an overall approach that includes national biodiversity strategies and action plans. Therefore adaptation activities involve a broader approach to sustainable development by explicitly including land degradation and desertification, climate change, and the conservation and sustainable use of biodiversity;
- Although adaptation activities may be necessary to reduce the impacts of climate change on human well being, they may have either beneficial or detrimental impacts on biodiversity. These potential impacts need further in-depth examination so that sound guidance can be provided to Parties, Governments, international organizations and other bodies;
- Biodiversity by itself is a necessary component of a climate change adaptation strategy. The degree of ecosystem resilience—which in turn is dictated by biodiversity structure and function—is an essential element of social-ecological systems if they are to maintain their adaptive capacity.

Therefore, adaptation and biodiversity are highly interlinked as more resilient ecosystems may be better able to cope with climate change while providing essential services to society. The ecological network approach is one of the more important tools to respond to the need for pro-active and flexible instruments to counteract the effects of climate change. It is not sufficient to protect nature within individual protected areas when the threats, such as human activities and climate change, take place on a much wider scale. A more spatial approach, distinguishing between core areas with high biodiversity values, necessary corridors and buffer zones is needed. Within Europe therefore work takes place to develop national ecological networks as well as the Pan-European Ecological Network. Within the EU there is growing recognition that in the light of future pressures and changes, especially from predicted climate change, it may be necessary to ensure the resilience of the NATURA 2000 network by developing its connectivity. The ecological network approach can provide a good framework for interactive, participatory measures. That function requires communication of the positive opportunities of ecological networks for long-term solutions that take into account the ecological as well as the social-economical interests of a region. There are still many questions about the exact effects of climate change in different regions, and the ways in which an ecological network approach can be an effective part of an adaptation strategy.

Issues that need further research and exploration include:

- A monitoring system of target species and ecosystems is necessary, allowing for the identification of long-term changes and trends (as for example SynBioSys Europe).
- Related to this work, a good analysis of ecological aspects, incorporating drivers, pressures and responses of target-species and ecosystems (especially to the diverse aspects of climatic change) is necessary. Identify and assess hazards and risk to biodiversity in protected areas. Identify minimum viable population size. Insight into the dynamics of species, interactions between species, interactions between biotic and non-biotic factors.
- Develop, test and improve models that predict changes in biodiversity in response to climate change. In particular identify potential areas in Europe where biodiversity would change most. Identify the degree to which biodiversity is really influenced by climate change instead of other factors.
- Enhance understanding of ecological resilience. Identification of the major factors that contribute to ecosystem resilience under the current and expected impacts of climate change, and of particular adaptation options.
- Assessment of the potential consequences for biodiversity of selected adaptation options, including ecological networks.

- Another priority is the study of the permeability of landscapes for species that are dependent of migration and/or dispersal, and the further development of scientific theories as the metapopulation theory (Hansky and Opdam), and its application in a large group of ecosystem-types.
- Enhance understanding of past, current and future dispersal and migration of species under climate change in fragmented landscapes.
- To support this application, the further development of scientific models, based on the metapopulation-theory as LARCH, GREENVEINS, BIOPRESS and others, delivering important impulses for spatial planning and the planning of ecological networks on several levels (landscape, national, international).
- Develop science-based plans for the adaptation and development of networks of protected areas, taking into account of potential changes in climate.
- Identify, improve the understanding of, and develop methods to conserve ecosystems that potentially buffer against climate change, such as old growth forests and wetlands.
- Strengthen the scientific foundation for the specification of protection regimes: understand how to manage, maintain and if necessary restore the favorable condition of protected areas.
- Understand how to design and manage buffer zones around protected areas so that they help to maintain ecological integrity within the protected areas.
- As the network approach relies on other sectors as agriculture, forestry and water conservation, research is needed into the possibilities (and impossibilities) for the integration of these functions in core-areas and buffer zones. Research into new forms of cooperation in order to reconcile different soil and landscape use requirements in core areas and buffer zones, and develop participative use systems.
- Understand how EU policies such as the CAP, CFP etc influence biodiversity all over Europe.
- How can the stewards of biodiversity (farmers, foresters, fishermen, hunters, land owners) be rewarded for providing ecosystem services?
- Develop diagnostical-instruments that allow identifying the consequences of spatial changes on the conservation state of species and ecosystems.
- Finally research related to implementation strategies and communication with stakeholders and the general public is urgently needed.

These research priorities are cited/ adapted from EPBRS Lesvos meeting, several National Bioplatform- action plans, Dutch research priorities for Ecological networks and climatic change.

Gaps in knowledge in adapting to climate change in coastal areas

Robert Nicholls, School of Civil Engineering and the Environment, and the Tyndall Centre for Climate Change Research, University of Southampton

Coastal zones around the UK and Europe have faced many changes during the 20th Century due to a range of natural and direct and indirect human pressures. These pressures will continue and evolve through the 21st century due to socio-economic and other changes, although the precise nature of these future trends is highly uncertain. Hence, sea-level rise and climate change are an additional pressure and assessing impacts and planning responses needs to take note of this fact.

The potential impacts of sea-level and climate change on human systems are significant. However, if we plan ahead, in Europe we can probably manage these risks. Coastal habitats and ecosystems are also threatened by sea-level rise and climate change. For intertidal systems, the Baltic, Mediterranean and Black Sea coasts are most vulnerable to sea-level rise due to their low tidal range and in the worst case, intertidal ecosystems could be largely eliminated in these areas by the 2080s. In the UK, intertidal habitats on the east and south coasts appear most threatened. However, actual impacts of climate change are highly uncertain and will depend on the magnitude of climate and other change and the success of human adaptation to that change.

The natural ecosystem response to rising sea levels is onshore migration, but this is stopped by fixed sea defences, producing coastal squeeze. Thus, there is a fundamental conflict between protecting socio-economic activity and sustaining the ecological functioning of the coastal zone in Europe under rising sea levels. This conflict needs to be explicitly acknowledged and resolved by coastal management policy. It suggests a need for more soft protection, and especially managed realignment where the land use does not make hard defences essential. Hence climate change raises important questions about land use planning in coastal (and other) areas (e.g., www.branchproject.org).

Lastly, global sea levels are likely to continue to rise for many centuries irrespective of future greenhouse gas emissions. Therefore, sea-level rise will remain an important issue for management of coastal ecosystems beyond the 21st century. Strengthening our capacity for long-term coastal management is fundamental to our response to climate change and sea-level rise.

Three important issues require more research:

1. How to meaningfully assess the status and ‘health’ of existing systems focussing on both local and regional perspectives.
2. Prediction of coastal ecosystem response to future conditions remains a crude science and new tools and methods need to be developed to explore policy choices and uncertainties through the 21st Century.
3. How to promote proactive adaptation policies such as managed realignment, as sustaining coastal ecosystem in a ‘healthy’ status is more likely under these conditions.

Issues of adaptation to climate change and the developing world

Nino Nadiradze, Environmental Consultant

Thanks for a very interesting and informative discussion on adaptation to climate change and ecological networks: research priorities. I currently work as a Technical Advisor for the CIDA funded project Adaptation to Climate Change in Tajikistan (Former Soviet Union Country). It is a sixteen months pilot project with a goal to enable selected rural communities to effectively respond to climate change through strengthening their adaptive and innovative capacities to develop sustainable livelihood approaches in response to identified vulnerabilities due to climate change avoiding resource-use and traditional practices that negatively affect protected areas and biodiversity.

The project objectives are the following:

- Develop and pilot a cost effective participatory adaptation and development framework which will enable rural communities and households to effectively respond to the direct impact of climate change in their communities,
- Increase awareness of links between climate change and vulnerabilities and facilitate necessary and direct linkages between communities and Tajikistan institutions and specialized agencies for implementation of adaptation plans,
- Transfer appropriate technology, ecological, technical, socio-economic knowledge and practices for reduced vulnerability to adverse effects of climate change.

We understand that adaptation to climate change goes hand in hand with land degradation/desertification and the conservation and sustainable use of biodiversity but there are no easy ways for countries like Tajikistan to meet these challenges. Countries like Tajikistan walk along a fine line between survival and environmental degradation. What to do? What are the options to avoid hunger and cold? Can people sacrifice today’s food and heat and commit themselves to the long-term environmental sustainability? It is a hard chose that the poor have to make today in order to survive tomorrow. I could be mistaken but I believe that up to now there is little done (activities at a local level not policies) to help the developing world to cope with the global threats of climate change, loss of biodiversity and land degradation. Eventually, these countries will be effected the most because of their inability to fund, enforce and implement adaptation strategies to cope with climate change, loss of biodiversity, and land degradation. Does anybody know of any climate change adaptation activity(ies) (could be a research) implemented in a developing country that successfully worked on a local level and at the same time contributed to the global environmental objectives?

The benefits and costs of adapting to climate change

Mac Callaway, UNEP-RISØ Centre, Roskilde Denmark

SUMMARY: The author discusses three stages of adaptation to climate change, the economic costs and benefits of adaptation and concludes with a few discussion points.

Adaptation to climate change takes place across a spectrum of time scales that are closely related to our ability to detect these changes at local scales. I see three distinct "stages" of adaptation that I will illustrate with a water resources example. The discussion that follows is based on Callaway (2004a and 2004b).

The first stage involves what economists call short-run adjustments to existing climate variability. When climate change is taking place, people adapt to it whether or not they know climate change is actually occurring. If they can't detect climate change, they adapt to it as if it were unusual climate variability using the existing institutions, infrastructure, technology and behavioural practices they have at hand. For example, if climate change is actually producing more frequent and or severe droughts (but we can't detect this), people will adapt to it with the drought coping options they already have, such as changing the operating strategy of a reservoir for a particular drought and instituting water restrictions.

The second stage involves medium-run adjustments to unusual climate variability. If the unusual climate variability persists but people still can't detect it as climate change, they may decide to alter their behavioural practices and perhaps their technology because it makes them "better off" to do so. But they probably won't change their institutions and infrastructure, because this is costly and, without being able to detect the changes in the climate, the benefits are very risky. For example, over a span of a decade or so, there may be both more, and more severe, droughts than expected, but one still can't statistically reject the null hypothesis that the climate isn't changing. In that case, reservoir operators may change their standard annual and seasonal operating plans and cities and farms might try to improve the efficiency of water use. These types of medium-run adjustments, while they might not be economically "optimal" based on the observed climate record, but they are a good way to hedge your bets in a risky environment, meaning that even if climate is not changing, the benefits of taking these actions still exceed the costs. However, if climate is not changing, and you build a new storage reservoir based on climate change expectations that turn out not be true, then the story might be very different because you will have spent a lot of money for no good reason.

The third stage involves long-run adjustments to climate change. When people are finally able to detect climate changes that affect their lives, the benefits of changing institutions and making infrastructure investments that are better adapted to climate change become less risky. The null hypothesis that climate isn't changing can be confidently rejected. This reduces, but by no means eliminates, the risk of being wrong and water capacity planners can more safely develop and implement plans to build additional storage capacity and cities and farms can undertake new options to reduce water use that are "optimal" for the climate change.

If people do not adjust to climate change, however it is perceived, they will experience economic losses. If, in the short-run, the seasonal reservoir policy and water restrictions are not implemented in the first stage, people will be worse off than if these measures had been taken, and the same is true for the medium- and long-run adjustments. Crops fail, additional money has to be spent on wastewater treatment, lawns dry up and have to be replaced, aquatic ecosystems dry up and people die. The economic value of these losses is referred to as "climate change damages." The economic benefits of adjusting (or adapting) to climate change in each of these three stages are the economic losses that one avoids by taking measures to adjust to climate change, no matter how it is perceived. The costs of these adjustments are measured by the value of the additional resources used to make these adjustments. The difference between the benefits and costs of these adjustments are called "the net benefits of climate change". The climate change damages that can't be avoided are known as the "imposed climate change damages."

I want to raise three discussion issues:

- How can we estimate these various benefit and cost measures?
- Is it useful to do so in a developing country context?
- What do we do about the value of ecosystem and human lives lost?

RE: The benefits and costs of adapting to climate change

Rob Tinch, Environmental Futures

Mac Callaway's interesting post ends up with 3 questions, which I'll take in reverse order:

3) What do we do about the value of ecosystems and human lives lost? Death is only the end of the world at a very individual level. We have a problem dealing with this, I think because in the West our lives are now so much less precariously held than in the past. We need to accept that loss of life and of species is inevitable: we could spend all of our resources on avoiding it, and it would still happen (and the world probably wouldn't be a better or happier place). Which is not to say that we could not do better than at present by aiming for somewhere between business as usual and the extreme case outlined, but that just begs the question of where we draw the line: and that's what valuation can perhaps help with. So the short answer is, I think, that we make the best fits we can of estimating these values on exactly the same terms as other values (see below) and use the results as an aid to deciding how to act.

2) Is it helpful to measure costs and benefits in a developing country context?
For all countries, it depends on what we're going to do with the measurements. It would be a pretty pointless exercise if it's just for accounting purposes. As an aid to decision making and policy formation, yes, it could be useful.

There are particular problems associated with summing up values across countries (and indeed within countries, and across times) if the values have been estimated using economic methods (based on willingness to pay, whether through markets, or revealed/stated preference techniques) because willingness to pay is predicated on ability to pay. This means that the value estimates tend to reflect underlying income distribution, resulting in fights between "economic-" and "political correctness", as in the widely-reported case of the different values of statistical life for the US and India (etc.) In fact, all these differences do is hold up a mirror to contemporary income distribution. If we don't like the comparisons arising from applying the same valuation techniques here and overseas, then we should blame the root cause (poverty / income distribution); it's a strange reaction to ignore that and instead criticise a methodology which is particularly good at bringing into stark focus the inequities that are a feature of market values across the global economy (and which we take advantage of on a daily basis).

1) How can we estimate these various benefit and cost measures? This is a huge topic! All I will say here is that economic valuation techniques are only part of the story. They seem to me to be a useful aid to decision making (prioritising expenditures and so on). But if we can do without currency measures of value, and instead focus on the need to make decisions, there are many more techniques which aim to elicit public preferences over different outcomes without going through the financial medium (which may in some cases distort the expression of preferences). As for what it is we are trying to assess or value, whether economically or otherwise: human preferences. Which can include our views about how to defend the interests of nature, but these can only ever be our views. Nature may or may not have her own views and values, but that is beyond science – call it philosophy, spirituality, or whatever – and there is no way we could ever know these values or take them into account except through the mediation of human views. There is a huge amount more which could be said, of course; I've touched above on the problems of how to aggregate different humans' preferences, and how to deal with future preferences, for example. We

could have a lengthy debate about it, and the attendant research needs, but I suspect the bar in Aviemore would be a better venue than this e-conference, because it would drift a bit too far from "adaptation for conservation sites" theme.

RE: The benefits and costs of adapting to climate change

Renat Perelet, Institute for Systems Analysis, Russian Academy of Sciences, Moscow, Russia

The discussion underway has stimulated me to make the following proposal. There is general consensus that climate change is leading to substantial biodiversity change on our planet. Ways should be sought and found on how to save biodiversity and maintain a sustainable use of it in the circumstances. This is in fact a goal of the Convention on biodiversity (CBD). The Framework Convention on Climate Change has a market based way of curbing human contribution to CC through the implementation of the Kyoto protocol.. It is suggested that a similar (and complementary to the Kyoto) Protocol on conservation and sustainable use of biodiversity be made as a protocol to the CBD. It would be of a multiple mutual advantage for the developing countries that are rich in living natural capital on the planet and poor in produced (industrial goods and technologies) and human capital. A new biodiversity protocol would bring living natural capital into the world market system which is not the case now and which is a major cause of its loss and depletion, lately aggravated by climate change. In addition, such a protocol would help the poor nature-rich (sorry for this paradoxical word combination) that are the world's ecological donors develop, have a better incentive for and access to technologies in the developed countries in exchange for their ecosystem goods and services adapted to climate change.

Naturally, the preparation of such a protocol faces a number of problems (saying nothing about the necessity of the political will of countries), primarily dealing with presenting ecosystem goods and services in market terms through putting monetary values on them, clear property rights, to mention but a few but it may be a worthwhile effort that would last several years, bring together many interdisciplinary scientists and politicians, and that should be started as early as possible. Comments to the above proposal would be much appreciated.

Knowledge gaps for the implementation of adaptation options for biodiversity conservation in a changing climate

Jo Hossell, ADAS, Wolverhampton, UK

SUMMARY: Information on the location of most sensitive areas and networks is key to identifying where to focus adaptation management but it is also important to ensure that the value of biodiversity to other sectors is recognised in order to ensure that its adaptation to climate change is encouraged within all aspects of the landscape.

Integrated solutions require knowledge not just of biodiversity responses but how other sectors of society may respond to climate change, and how such responses will interact. Project such at regional (Holman and Loveland, 2002) UK level, county level (Harrison et al., 2001; Berry et al., 2003), and EU level (ACCELERATES) have attempted to address interactions between biodiversity and other land use sectors but links between the biodiversity models and the other sectors has been limited (moreover freshwater and marine environments have not been well studied). The consideration of the value of ecosystem services may facilitate the inclusion of biodiversity into a more integrated modelling system, both providing better indications of how biodiversity relates to other sectors and by providing a common currency by which to relate them.

Although work has been undertaken to model species level (Parmesan, 1999; Thomas et al. 2004), and to a lesser extent habitat level (Emanuel et al., 1985), responses, and monitoring of trends is revealing current response trends (Rotzer and Chmielewski, 2000; Sparks et al. 1999), the net effect of such impacts is still uncertain, as there is a lack of analysis of the interactions between such altered species distributions. Moreover, most studies have generally not looked beyond changes in average climate; the impacts of extreme events are not well studied nor how these interact with changes in average conditions to affect the balance and health of species and habitats.

Much of the work on climate change impacts on biodiversity has focussed on individual species, and since the structure of conservation policy and action is largely site based there is a need to identify key areas of both climate and species sensitivity. The case study area approach (Holman and Loveland, 2002; Berry et al. 2003) has partly addressed this issue but there is still a need at the country and EU level to examine how shifts in individual species' ranges may combine to produce regions of greatest change, where sympathetic management may be most valuable in assisting biodiversity adaptation. Such climatically sensitive areas could be the focus of practical management experimentation to encourage change. Case study information and best practice from such areas would also be useful to facilitate local adaptations elsewhere.

Modelling of future species distribution provide only a snapshot in time show nothing about how that change may be achieved. So there is also a need to explore the routes that such shifts take. Monte Carlo type analysis of species dispersal in response to climate change can provide an estimate of the probability of species' distributions reaching a suitable future climate space (e.g. in MONARCH 2 (Berry et al. 2003)). It should also be possible to examine the most likely routes for such movements. This should allow bottlenecks for species movements to be identified, which may then permit conservation management to be focussed in these areas.

Combined with climatically sensitive areas, such key distribution routes should guide the task of landscape planning for conservation under climate change. BRANCH is attempting to develop some conservation tools in NW Europe but it may also be illuminating to apply some of the tools for landscape level biodiversity conservation planning that have been used elsewhere (e.g. TAMARIN in South America) to the UK and European landscapes. Such models combine conservation principles with economic theory to explore options for environmental and social goals. This work may also be facilitated by a concerted action type workshops to determine how countries may work together to encourage adaptation and protect biodiversity across different land use sectors and how conservation targets should be revised to take account of climate change.

Adapting to multiple pressures

Allan Watt, Centre for Ecology and Hydrology, Banchory, UK

I strongly agree with Pam Berry's conclusion (Session 1) that: "The strategic research challenge is to devise means of integrating drivers of change, other than climate, into models so that integrated, holistic views of the future of species, ecosystems and landscapes can be provided to inform planning and policy."

This relates directly to an approach to adaptation that if probably rarely considered but which is included in a recent CDB document (UNEP/CBD/AHTEG-BDACC/1/2). To quote directly from that paper:

"Many human activities, especially through land use and land cover change form multiple pressures on biodiversity; climate change is an added pressure on many ecosystems and species. Reduction of these other pressures maybe a realistic adaptation option for biodiversity in many systems."

While discussion on adaptation in this e-conference is right to consider sites and networks, we must consider other adaptation options and the research needed to evaluate their effectiveness and, if appropriate, put them into practice.

RE: Adapting to multiple pressures

Josef Settele, UFZ Centre for Environmental Research Leipzig-Halle, Germany

Referring to Allan Watt, who himself referred to Pam Berry's conclusion (Session 1) that: "The strategic research challenge is to devise means of integrating drivers of change, other than climate, into models so that integrated, holistic views of the future of species, ecosystems and landscapes can be provided to inform planning and policy.", let me just add that this is right at the heart of the objectives of the Integrated Project ALARM (www.alarmproject.net) which has now been running for about one and a half years and will end in January 2009.

A major challenge is to establish working relationships between hitherto mostly unrelated scientific communities. As soon as a common wavelength has been found, the fun/work starts - and that's where we are at this very moment. One aspect of this productive interaction you could already witness in the discussion between Martin Sykes and Miguel Araujo, who are both members of the ALARM team and work within the same module...

I'm optimistic to see more of these productive interactions within ALARM as well as with the outside community. Anyone who is interested in being associated to the ALARM project, for exchange of information and probably joint activities, please get in touch with me - it might well help to adequately tackle the problem of multiple pressures.

From the perspective of an ecological sociologist

Mercedes Pardo, University Carlos III, Madrid, Spain

As an ecological sociologist I would like to comment on the questions that have been posted for debate.

1. What we already know about impacts of climate change on biodiversity and the policy options available;

In addition to other specific things, we already know that there is an important connection of both climate change and loss of biodiversity to societal activities and organization. This is not a minor knowledge as it was not the case in the past. From the ecological complex perspective the four basic spheres to take into account when analyzing a society (Population, Environment (biophysical), Technology, and social Organization (including the economy) are interconnected in an exponential way. The analysis of both a particular society and a particular biophysical environment would emphasize one or another sphere (for instance Technology and affluence in the case of developed countries, and demography in the case of undeveloped ones, just to show the extremes). Even such a basic model might be questioned in some ways, it illustrates the basic general agenda to research on in order to improve our scientific knowledge of the societal-nature interconnections. Not to say that is much needed and it is far from being something simple.

2. What are the most important things that we need to find out in order to develop adaptation strategies;

On this second question I would like to remind that the very word 'adaptation' means intervention (even to preserve biodiversity) and thus it takes us to society. Environmental problems are basically social problems, as society produces many of them and is being affected by them. Such a general statement is far from being something obvious for some people including some researchers and some politicians to mention only a few. If we agree on that, adaptation means to change society to adapt to global change. Not to say that the word 'adapt' does not mean to accept but to change the patterns that have leaded to the current environmental degradation. Thus, the relevant research agenda on the societal-nature connections should be organized around the specific spheres of society (social organization, economy, etc.), at the several levels of analysis: social relevant actors either institutions, groups, individual… So far, little research funds has been put into such connections. Interdisciplinary research is a must, which opens new and fascinating challenges.

3. How we can ensure the flow of knowledge from research into policy development.

Such a flow is increasing. Currently researchers are relevant social agents and our opinions are increasingly taken into consideration by society (media, public opinion, politicians…). More needs to be done, of course, but basically from our part. Researchers need to understand better the importance of informing to society about our studies and develop ways of doing so. At the same time, researchers should understand that our opinion is not necessarily the most important one. There are other problems in society besides environmental ones. Clearly we know the risks we are facing regarding global change, but it has to go together with dealing with other society problems.

Research priorities in the adaptation of ecological networks to climate change

Fred Buchholz, Marine Station, Helgoland, Germany

The UN- Earth Summit, at Rio de Janeiro in 1992, decided on the Agenda 21 which centred on major environmental issues and defined the biodiversity crisis. The Rio convention helped in focusing already existing initiatives to establish an observational system of biodiversity and ecological change in the marine, particularly coastal environments of Europe. Marine research stations were considered as Observatories of the Seas and the network of European Marine Research Stations -MARS- was inaugurated in Paris in 1996 incorporating 56 stations from Svalbard to the Canaries and from the Azores to Cyprus. Since then it became well established that the seas are warming globally at a drastic pace. Clear effects are seen both in the plankton and benthos, particularly in invasions of warm adapted organisms - via propagules - to Northern waters. In fact, whole species communities have been experiencing a northward shift. The composition of functional communities in the food webs in pelagic and benthic systems is affected causing impacts on the productivity of the seas. From a geophysical standpoint discussion is still under way in how far a natural warming trend is superimposed by the green house effect. Nevertheless, both mitigation of deleterious influences of the warming trend and the prognosis of rates and effects of change in marine ecosystems have been defined as major research issues on a global scale. The MARS network helped to establish an EEC sponsored concerted action of marine stations BIOMARE and currently a Network of Excellence, MarBEF, Marine Biodiversity and Ecosystem Functions. The latter co-ordinates European research along three topics centred at biodiversity: Patterns, based strongly on long-term oceanographic observation series; Functions, with a footing on excellent experimental facilities at research stations e.g. for scenario testing; and Socio-Economics as the link between ecological research and management. Basically, such a threefold approach may be taken as a template to adapt and integrate biodiversity research on a broader scale. To compare effects of climate change latitudinally, the observation series are most valuable, but a better integration of data sets is still necessary, including further data mining and management. In parallel, experiments with single species in the laboratory and/or communities in the field will allow conclusions towards the organisms' adaptive capacity in response to thermal and trophic changes. Physiological methodology in particular will help to define limits of adaptation and thus the future persistence of species in a particular area. Molecular genetic tools have become standard by now – however, the interfacing with traditional taxonomy has still to be advanced to be able to detect and understand hidden diversity or simply to better define the species concept. Such tools have become invaluable in microbial ecology as well – the study of functions of viruses and bacteria in regulating food web dynamics is still a wide-open field. A fast developing field is ecological modelling from simple conceptual models over individual based models to ecosystem modelling. There is great need for proper parameterization, based on experiments and hypothesis testing by way of field observations, to gauge the prognostic capacity – which has to be the basis of ecosystem management.

Ecological networks are developing from asking the questions what and where? to how and why? aiming to understand changes in food web dynamics and to enhance predictive capacity in order to support ecological management.

Information needed for modelling and prediction

Kioumars Ghamkhar, Centre for Legumes in Mediterranean Agriculture, University of Western Australia, Crawley, Australia

First of all, I am a plant phylogenetics and biogegraphy expert. Do not know much about the climate change (not as much as other people in this forum do).

I agree with Fred Buchholz on the ways that screening the biodiversity must be done. There are tens (if not thousands) of factors that can affect the adaptiveness in a species and its populations. I do not really know how bad the climate change can be because as an evolutionist I guess change is necessary, anyway. The important issue is “to what extend change is not harmful for the nature as a system”. To understand that, the basic need is to find out how exactly the tree of life has been formed and connect that information directly to the information obtained from biogegraphy and the history of ecogeographic changes. Without this sort of information we will not have any logic for modelling and prediction studies.

Biodiversity conservation should become part of a multifunctional decision making process in spatial development

Paul Opdam, Wageningen University, The Netherlands

SUMMARY: Most of the discussion thus far implicitly assumes that ecosystem functioning and species distribution will change, but protected sites and the surrounding world won't. By contrast, climate change will become a major driver in spatial development, most likely causing extensive land use changes across Europe.

There are many reasons to believe that the adaptation of a Natura 2000 portfolio of protected sites into a functionally coherent ecological network will not be an isolated activity by conservationists. Instead it will have to be part of a large-scale change in land use. Temperature change will have enormous effects on food and energy crops, recreation patterns, human and animal health, water supplies, water quality, energy use, fires, floods affecting the distribution of human housing areas worldwide, changes in human distribution and humans attitude to nature. All these effects will affect the spatial development of landscapes across Europe. This development offers threats as well as opportunities for nature. Any conservation policy that is defensive will be ineffective to cope with such a dynamic world. Hence, biodiversity conservation should become part of a multifunctional decision making process. This challenge can be translated into several research goals:

1) How do we insert conservation targets into spatial development plans? What kind of information on the role and functioning of ecosystem networks do decision makers in spatial development need to make ecologically sound decisions and make sure that resilient ecosystems providing essential services is really a part of sustainable development? How can we help them to seek a balance between economy, social aspects and ecological aspects?

2) Most of the decision making about spatial development will be on the regional landscape level. How can we develop a common vision for the spatial development of Europe that can be used as a coordinating view for problem solving in regions and localities across Europe? How can a local planning group, for example trying to implement CAP and Natura 2000, be aware of and committed to proper measures which contribute to an ecologically better landscape at a higher spatial scale?

3) Ecological knowledge should be made tailor-made for planning and negotiation processes. Inserting ecology into planning is not a matter of ecologists telling local planners what to do. Ecological information should be inserted at every step of a multifunctional planning process, for example in setting feasible targets, making functional combinations with other land use, and making a proper spatial design. Complex ecological models are unsuitable here. Flexibility is a key element: e.g. how to make design rules for ecological networks with enough flexibility to make the ecosystem pattern compatible with other land use functions.

Spatial planning and the conservation of biodiversity in a changing climate

Pierre Ibisch, University of Applied Sciences, Eberswalde, Germany

SUMMARY: Climate-change-integrated conservation strategies require a top-down planning approach from the larger region to the locality. This means a substantial change in conservation planning schemes of many countries and regions. A combination of ecoregional and national conservation planning is recommended. Experiences with proactive ecoregional conservation planning in Bolivia are mentioned.

Paul Opdam has risen very important issues. Biodiversity adaptation research, actually, is not only/less about complex ecological models that try to predict individual responses of single conservation targets – which in many cases simply will not be possible. It is much more relevant that a preventive and more functional conservation is implemented on the ground facilitating dynamic changes rather than keeping an open-air museum of highly representative but fragmented and not viable conservation targets.

In this context, Opdam's research needs related to spatial planning are absolutely right. Actually, it is a problem that spatial planners normally are not advised by conservationists interested and trained in macroecology. And vice versa, too many conservationists have not been interested in getting involved in spatial planning on larger scales. Of course, in many countries we have very advanced and sophisticated schemes for spatial planning, but mostly conservationists interfere on a local level. Actually, there is no strategic land-use planning on a national or regional scale that integrates a biodiversity vision and corresponding conservation goals.

In Europe, generally, land for conservation is allocated according to the availability of such land and to conservation values that are identified on a local scale, such as the presence of certain rare or endangered species or communities – without taking into account the bigger picture. E.g., in Germany the many thousands of mostly small Natura 2000 sites, in a bottom-up process, have been identified by the federal states without any large-scale vision of landscape ecosystems and macroecological functionality. There was no national planning trying to identify the highest national spatial priorities for conservation, without any acknowledgement of the dynamic characteristics of biodiversity, large-scale connectivity or corridors. The recently published draft of the national biodiversity strategy has not any spatial vision at all, apart from claiming that the Natura 2000 protected area network will provide the required connectivity. And of course, on the European scale there has not been any spatial planning approach apart from the static biogeographical regionalization.

It is absolutely right. This is a field where in the future we need to make a difference. And we consider some experiences made in countries where pioneering conservation approaches are not expected. E.g., in Bolivia there has been formulated an ecoregional conservation plan for the Chiquitano Dry Forest that recognizes that conservation of biodiversity cannot be achieved in isolated protected areas but needs to develop a conservation vision for the whole landscape. Land-use scenarios have been taken into account as well as the need of maintaining a large-scale connectivity (in this case, e.g., towards the Amazon) facilitating the shift of species ranges that might be caused by climate change. The vision for the complete region comprising several municipalities has been consulted and agreed with the local actors and the relevant political authorities. A foundation is funding conservation initiatives in the different areas of the region, working with cattle farmers and indigenous people as well as with protected area managers. Currently, in Bolivia, a national gap analysis is undertaken that identifies the spatial conservation priorities without exclusively looking at and statically focusing on the current distribution patterns of biodiversity. The result will be an important input for a national spatial conservation planning that goes far beyond the identification of sites for new protected areas required for the representation of distinctive biodiversity.

The spatial approach of planning conservation on an ecoregional scale is promoted by important international NGOs, such as WWF and The Nature Conservancy. We suggest a combination of ecoregional and national conservation planning exercises in order to develop conservation visions that integrate the adaptation to climate change as a cross-cutting issue. Because of the large spatial requirements of climate-change-integrated conservation strategies a top-down planning approach from the larger region to the locality is absolutely necessary. This means a substantial change in conservation planning schemes of many countries and regions.

Landscape-scale principles

Richard Smithers, The Woodland Trust, UK

SUMMARY: A need to create ecologically functional landscapes in response to climate change requires research to: develop inventories of all semi-natural habitats; determine edge effects from intensive land use; address landscape permeability; and quantify economic benefits.

The Woodland Trust, the UK's leading woodland conservation charity, believes that our highly fragmented landscapes and projected rates of climate change require the creation of ecologically functional landscapes if the widest biodiversity is to adapt and evolve. It advocates that this should mean:

- Seeking to conserve all semi-natural habitats not just a representative sample of sites
- Considering the synergies between all semi-natural habitats and accommodating vegetation dynamics rather than putting habitats in boxes.
- It will be counterproductive to try and maintain the current structure and composition of habitats in the face of climate change
- Restoring all semi-natural habitats planted with non-native conifers where any significant relict features survive
- Targeting habitat creation to where biodiversity has greatest chance of being put on a sustainable footing, i.e., areas where there are greatest concentrations of ancient or semi-natural habitats
- Seeking to increase the resilience of semi-natural habitats by targeting habitat creation to buffering them from negative edge effects with intensive land use and extending their area
- Seeking to increase the ability of the widest biodiversity to move across landscapes by reducing the intensity of the intervening land use (i.e., agriculture, forestry and built development) between semi-natural habitats rather than simply physically linking them. Physical corridors are unlikely to increase the rate at which most species of conservation concern can disperse, as they are relatively immobile, but a general reduction in the intensity of land use should increase the frequency of successful chance long distance dispersal events
- Not treating conservation as a segregated activity but seeking to integrate landscape-scale action for biodiversity with the wider benefits that it delivers, for example, in relation to soil conservation, air and water quality, flood alleviation, high quality food, health, employment, recreation etc
- Taking action across a country or region as a whole not polarising land use. Whilst habitat creation should be targeted to concentrations of ancient or semi-natural habitat, it is important to note that the other principles seek to avoid greater intensification of agriculture, forestry and built development across intervening landscapes.

  In this regard, research is required:
- To develop inventories of all semi-natural habitats, inclusive of those planted with non-native conifers where any significant relict features survive
- To determine the distance to which negative edge effects from intensive land use penetrate semi-natural habitats
- To evidence actions that will increase the frequency of rare and chance long distance dispersal events
- To quantify the economic benefits of the ecosystem goods and services that landscape-scale action for biodiversity could deliver.

RE: Landscape-scale principles

Oliver Watts, Royal Society for the Protection of Birds, The Lodge, Sandy, UK

Richard Smithers raises many interesting points on the developing and perhaps future ethos of nature conservation. There is growing interest towards integrating conservation at the landscape scale; although whether landscapes can be truly ecologically functioning, given the pressure on land use across Europe, is a moot point. At this early stage of climate change and its impacts on biodiversity the RSPB also believes that it is important to continue to strive to maintain current biodiversity, habitats and communities, until it is clear from observational evidence that this is no longer tenable; but perhaps this is not so far from the Woodland Trust's shorter term aims, given the desire to increase the resilience of semi-natural habitats.

Three further research objectives that may be helpful in this area are:

- To identify the geographical areas that are likely to be most important for biodiversity in the second half of the 21st century, perhaps taking a broad habitat approach
- Identifying the likely time scales for the creation of different key habitats in new areas, to various stages of maturity towards becoming self-sustaining communities
- To research and further develop land management practices that increase the permeability of different land uses to biodiversity to the suite of species particularly likely, and desired, to be present in those land uses over the next 25 to 60 years; and to develop policy mechanisms to achieve the wide adoption of these practices.

Setting realistic objectives

Paul Sinnadurai, Brecon Beacons National Park, UK

Rather than an essay (nearly out of time), here is a list of points, some of which are interrelated, with respect to adapting to climate change and allowing adaptations to occur:

- We shouldn't necessarily emulate our current techniques for nature conservation in order to deal with the great unknown of biological and ecological responses to climate change.
- Climate change demands that we set longer term goals for biodiversity conservation, with milestones set for successive generations to achieve.
- Perhaps the most cost-effective approach to adaptation is to observe and seek to understand. We shouldn't be driven by the need to publish results as much as by the need to identify what is critical in the current resource and what will become critical in future.
- Is it more beneficial to concentrate on air, soil and water rather than species and habitats?
- As well as research we need to be confident enough to rely on judgement and on-the-ground evidence to make decisions now.
- Evaluate the relative merits of applied research versus expert opinion in adapting to climate change. Which is more cost-effective?
- Clever agricultural policy, forestry policy, marine policy, water and soil policy that lead to more land released for wildlife may do more to help to conserve biodiversity in the wider countryside than any amount of research and conservation effort.
- Designated sites are genetic reservoirs, where we need to stockpile as much biodiversity as we can, relying on policy to make the right adjustments elsewhere.
- Designated sites are not necessarily ecosystems; rarely if ever are they designated on the basis of ecosystems or biogeography. The same might not be true for different categories of protected landscape.
- Protected landscapes might prove vital in helping us to understand and observe the effects of climate change, not least of all Category V landscapes such as the national parks and AONBs in Britain, where humans are as important as the environment.
- Understanding biogeography and meta-population dynamics must be pushed to the top of the conservation policy agenda.
- In Britain, land ownership is very important and may serve as a significant obstacle to landscape-scale conservation. Policy research, including the role of underwriters, needs to discover ways of dismantling this obstacle.

Phenology

Richard Smithers and **Nick Collinson**, The Woodland Trust, UK

Phenological responses may have wide ranging implications for interactions between species: annual release of gridded baseline climate data, and adoption of UKPN protocols by others at sites where a wide range of variables and other biological responses are also recorded, could enable projection of the future impact of phenological change.

Phenology is the study of the timing of recurring natural events, particularly in relation to climate. The UK Phenology Network (UKPN) is run jointly by the Woodland Trust and the Centre for Ecology and Hydrology. It was started as a pilot scheme in 1998. The website was the first of its kind worldwide (www.phenology.org.uk) and is being developed for use by other networks around the world including members of the European Phenology Network. We now have over 21,000 online and paper-based recorders distributed right across the UK. The database includes a large number of historic datasets extending back to 1736.

The first three months of 2001 were, on average, only 0.03 degrees C warmers than the 30-year average (1961-1990 Central England Temperature). This near-average temperature allows us to presume that phenological timing in spring 2001 was also close to a '30-year norm' with which we can compare other results. Spring 2002, by contrast, was very warm, with temperatures in the three months February- April being on average 2.6 degrees C above the 30-year average. As expected in a warmer spring, all events were considerably earlier in 2002 but there were considerable differences between taxa (e.g. bird activity was on average 6 days earlier than 2002, while plant and insect activity were on average 13 and 18 days earlier respectively) and within taxa, with early spring events seemingly responding to rising temperatures the fastest. Such responses have the potential to cause problems for the life cycles of individual species (e.g. frogspawning was recorded before Christmas in 'spring 2005'), loss of synchrony between interdependent species, and changes in competitive advantage leading to shifts in community composition).

Phenological studies have focused historically on the important relationship with temperature. However, phenological events are likely to be influenced by a number of climatic factors; for example, analysis of UKPN data for autumn leaf tint has revealed relationships with rainfall and sunshine hours. An exploratory analysis of the UKPN database has been undertaken recently to try and relate phenological data gridded by 5km square with climatic databases produced on the same grid by the UK Met Office and UK Climate Impacts Programme (UKCIP). The intent was to explore the relationships between the phenology of species and a range of climate variables, singly and in combination, using mass observation and long-term datasets, then seek to project future phenological events using the UKCIP02 scenarios and consider potential consequences for community composition. The analyses were constrained by the gridded baseline climatology, which is only currently available to 2000. This is unfortunate as there has been significant growth in UKPN records in recent years. Many other research projects make use of baseline climate data and given the rate of climate change, there may be burgeoning demand for this dataset to be updated annually rather than every ten years.

A greater understanding of the potential future impact of phenological change could be developed if UKPN protocols would be adopted at sites where a wide range of variables and other biological responses are also recorded. This would enable any analysis of data in relation to such sites to be extrapolated across the UKPN dataset as a whole thereby greatly increasing its power.

UK PRESIDENCY OF THE EU 2005

Adaptation strategies at regional and national scales - working with other sectors

Linking impacts research to adaptation options

Iain Brown, Environmental Change Institute, University of Oxford, UK

Linking impacts research with adaptation options remains one of the most significant knowledge gaps. The IPCC recognised this in their last assessment, with ecosystem functioning highlighted as one of 3 critical issues (the others were food supply and sustainable development).

Most impacts research to-date has tended to be based on a continuation of current policies. There are some notable exceptions that have looked at different futures through tools such as socio-economic scenarios, but these have usually been found difficult to interpret by many stakeholders. We also have the identification of potential adaptation options in the generic sense, but what is missing are explicitly defined options that can be explored through the impact models. As well as scientists being prepared to push the envelope with models, this requires more input and vision from stakeholders on what the range of future options are, in terms of land-use change, spatial planning, priority habitats etc. Such multiple options need to be spatially explicit, with an emphasis on exploring the full range of potential options, without in any way suggesting at this stage that such a policy would be implemented. Some of this work has happened already on the coast, albeit at a local scale, through the identification of potential (and in a very few cases, actual) sites for coastal realignment and formation of new intertidal areas. However, what is actually required is a much larger scale definition and evaluation of options across Europe.

Such an exploration of options leads into identification of conflicts between competing land uses, recognising that biodiversity has to co-exist with other strategic objectives (maintenance of food supply etc.). The role of different actors in these future worlds could also be explored through the use of tools such as ‘agents’, hence providing a full expose of the pros and cons of a particular adaptation option. The point is that we know little about how the adaptation process will occur from a human perspective (decision making, competing priorities, etc) as from an ecological perspective.

Species conservation and climate change: What policy responses do we need?

Frank Wätzold, UFZ Centre for Environmental Research Leipzig-Halle, Germany

So far, there is very little social science or economic research on how to deal with the effects of climate change on biodiversity, and in particular, on what policy responses are needed.

In economic terms, climate change will probably alter the costs and benefits of species conservation in a certain location. The climate and the habitat may become less suitable for the species, i.e. the benefits of species conservation in this location become less obvious. Is it really a benefit to carry out management measures to conserve a species in a location where it naturally may go extinct? In contrast, as management measures probably have to be intensified the costs of these measures may rise to an extent where they may be considered too high. But who makes this decision? And on what basis will this decision be made? How can an institutional framework that is responsible for such a decision look like?

If we are unable to conserve a species in a particular location this may still be possible in another location. In fact, new locations may become suitable that have previously been unsuitable for a species. How may policy react to that? First, policy needs to develop conservation goals on a broad geographical scale, e.g. the European level. This allows some flexibility regarding the location where we want to conserve the species. Second, an institutional framework has to be created that gives appropriate incentives to stakeholders to conserve the species in new locations. How should such a framework look like? How can we create incentives that make it worthwhile for stakeholders to identify and maintain new habitats?

A lot of research is needed to enable social sciences and economics in co-operation with natural sciences to answer these and other questions related to species conservation and climate change. The reason is that the challenge that arises from climate change to biodiversity conservation is new and requires answers different from those given to traditional challenges faced by biodiversity conservation (e.g. ecological effectiveness, cost-effectiveness, social acceptance).

Research priorities for the adaptation of agricultural policies and practices to climate change

Pete Smith, School of Biological Sciences, University of Aberdeen, UK

SUMMARY: The steps necessary to reduce greenhouse gas emissions from agriculture are well known, but will not occur unless suitable policies and incentives are put in place to encourage their use by land managers.

Agriculture is a significant source of the three main biogenic greenhouse gases (GHGs), carbon dioxide, nitrous oxide and methane. Within the EU-15, croplands are a significant source of both carbon dioxide (78 Mt C y-1) and nitrous oxide (~60 Mt C-equivalents y-1). Since agricultural management is responsible for much of this flux, there is potential within the EU-15 to reduce this flux or to sequester soil carbon. Many factors drive GHG emissions from agriculture, a significant number of which are socio-political.

Meta-analyses of data in Europe could help to provide better emission factors than current defaults for use in Europe. In the future, dynamic emission factors (that respond to, for example, climate, soils, crop, fertiliser etc.) might replace the static default emission factors currently used. Well-evaluated process-based models, linked to a series of benchmark sites, may play a role in GHG accounting in the future. Verification of GHG emission estimates will be difficult.

Greenhouse gas emissions in 1990 and 2000 for EU-15 are estimated to be as follows: nitrous oxide-1990: 60 Mt C-equivalents y-1, nitrous oxide-2000: 57 Mt C-equivalents y-1, methane-1990: 54 Mt C-equivalents y-1, methane-2000: 50 Mt C-equivalents y-1, carbon dioxide-1990s: 78 Mt C y-1.

A recent study for four country level case studies and the EU as a whole shows that because cropland area is decreasing, and there are no current incentives in place to encourage soil carbon sequestration, carbon sequestration has been small or negative in the EU-15 and all case study countries (with a small level of sequestration in Belgium). The only trend in agriculture that may be enhancing carbon stocks on croplands at present is organic farming, and that is highly uncertain. Previous studies had focused on the potential for carbon sequestration and showed quite significant potential when examining the sequestration likely to occur by 2010, but the recent study suggests that this potential will not be realised. Without incentives for carbon sequestration in the future, cropland carbon sequestration under Article 3.4 of the Kyoto Protocol will not be an option in EU-15.

For reducing emissions of nitrous oxide (and methane) there are a number of options that offer significant GHG mitigation, most of which rely upon better fertiliser (mineral and organic) use and water management. The livestock and manure management sectors offer greater mitigation potential for methane. There may be trade-offs between different greenhouse gases, especially between carbon dioxide and nitrous oxide, so it is important to assess potential mitigation options for their impact upon all greenhouse gases.

Future priorities include the need for a better understanding at the process level (especially in cropland soils), data / inventory collation and meta-analysis, further development of future scenarios of agricultural land-use and management, the development of new technologies and methodologies for measuring soil carbon and greenhouse gas emissions simultaneously, process studies (both modelling and experimental) to couple the carbon and nitrogen cycles and a more complete biogeochemical / physical / socio-economic assessment of GHG mitigation options in agriculture.

RE: Research priorities for the adaptation of agricultural policies and practices to climate change

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Mac Callaway, UNEP-RISØ Centre, Roskilde, Denmark

You might want to talk with Ewe Schneider at Hamburg about the market impacts of these mitigation measures. In a US study he did, he found that agricultural markets took back some of the potential GHG reductions so that the simulated reductions in GHGs after accounting for market interactions was less than the "engineering" potential. He is doing a similar study for the EU. Other studies in the US show the same type of effects for carbon storage in forests and on cropland. There are numerous leakages due to market adjustments. Beating the market is hard. Incentives, unless they are extremely well-designed, make things even worse. In the EU you have the CAP to deal with. This distorts product and asset prices so much that it is not easy to predict what will actually happen. To add more distortions to encourage farmers to store carbon or reduce emissions will greatly increase welfare losses and may not affect business as usual as much as one would think. Get rid of CAP and you will get more carbon (crop land reverting to forest land) - that's for sure, unless EU agricultural suddenly becomes a lot more competitive as a result of dropping the subsidies, set-asides, etc.

Research priorities for the adaptation of agricultural production systems to climate change

Jørgen Olesen, Danish Institute of Agricultural Sciences, Tjele, Denmark

SUMMARY: Research on adaptation of agriculture to climate change needs to be better integrated in current research on developing sustainable farming systems through improved technologies, infrastructure and policies.

The research on impacts of climate change and increasing atmospheric CO2 concentration has so far primarily focused on the direct effects on crop production (Marracchi et al., 2005). The primary effects of climate change on agricultural production in many parts of the world relate to the use of water resources (Rosenzweig et al., 2004). Much less emphasis has so far been put on the indirect effects through impacts on soils, weeds, pests and diseases (Scherm, 2004; Perarnaud et al., 2005).

Large differences in climate change impacts on agriculture are expected between northern and southern parts of Europe (Olesen and Bindi, 2002). In northern areas positive effects on agricultural production may predominate through introduction of new crop species and varieties, higher crop production and expansion of suitable areas for crop production. Disadvantages may be an increase in the need for plant protection and the risk of nutrient leaching. In southern areas the disadvantages will predominate with increases in water shortage and extreme weather conditions causing lower yield and increased yield variability.

It is useful to distinguish between adaptation at farm level and adaptation that requires changes at regional to national levels in infrastructure, planning and support schemes. Most farm level adaptation measures are autonomous in the sense that they no other sectors are needed in their development and implementation. Such adaptation measures include changes in planting dates, varieties, use of external inputs and tillage practices, and they have been abundantly studied (Easterling et al., 2003). The adaptation at higher scales include changes in land use, farming systems, plant breeding etc, some of which are expected to greatly change the European landscape (Rounsevell et al., 2005).

Attention so far has focused heavily on the capacity for farm level adaptation, and studies of climate change impacts have often assumed this adaptation to be perfect, which is not likely to be the case in view both of uncertainties in climate predictions and in the large variation in farmer's adoption of new information and technologies (Easterling et al., 2003). Also, farm level adaptations are not likely to be efficient without changes at higher scales and within the agroindustry (Burton and Lim, 2005). Effective adaptation strategies thus need to effectively account for the entire food production chain, including farmers, suppliers, the processing industry, and also policy and research.

The research will have to deal with the effects on secondary factors of agricultural production, on the quality of crop and animal production, of changes in frequency of extreme events on agricultural production, and the interaction with the surrounding natural ecosystems. There is also a need to study combined effects of adaptation and mitigation options, and include assessments of the consequences on current efforts in agricultural policy to develop a sustainable agriculture that also preserves environmental and social values in the rural society. The research will need in particular to incorporate climate change as an element in the development of new technologies and policies related to agricultural production, environmental protection, food security and food safety.

Research priorities in the adaptation of forest production systems to climate change

Keith Kirby, English Nature, Northminster House, Peterborough, UK

SUMMARY: Climate change may have a much greater effect on biodiversity in many woods through its effects on forest production systems, than through direct effects on the species themselves.

Climate change is affecting the growth and distribution of many forest species, changing their survival in different sites, their phenology and rates of growth. However climate change will also affect biodiversity in many woods through its effects on forest production systems.

A forest system summarises the way that areas of trees are treated to meet management objectives within a particular set of environmental, social and economic constraints. In the middle ages high transport costs, use of hand tools and an economy based largely around use of small diameter poles led to the flourishing of the coppice system; in the UK in the twentieth century mechanisation and an emphasis on producing cheap wood-fibre lead to large-scale, even aged conifer plantations harvested by clear-fells.

Climate change will affect the growth and survival of particular tree crops, but more importantly it will change the economics of other land-uses, of transport costs, or the competitiveness of different countries forestry industries. Changes in the forest systems will affect the biodiversity of the forest areas, their appearance in the landscape, or their impact on water and soil resources.

Possible effects include:

- Changes in growth/survival of key forest species e.g. beech may become less suited for south-east England, walnut more so, changing the patterns of tree species grown.
- Changes in markets or transport costs alter the balance between different production systems: increased use of wood-fuel for local energy production (to reduce emissions) could favour restoration of coppice regimes.
- Increased concern about extreme events may encourage more mixed age/mixed species systems.
- Changes in agricultural land-use, for example restrictions on intensive irrigation, may favour natural development of scrub and forests, either for extensive grazing or other forms of low-intensity silvicututre.
- Changes in the fire-risk may alter the acceptability of large areas of even-aged conifers or other flammable crops.
- Development of carbon sequestration markets might provide an additional (albeit small) incentive for woodland expansion.

Models of potential change of climate space for survival and growth of forest trees are reasonably well advanced with respect to mean temperatures and rainfall changes. However, the longevity of tree crops makes them particularly sensitive to rare (once a decade, once a century) events. More research on the variability and extremes of future climate scenarios is needed if we are to plan future forest production systems.

Forest systems can be used to mediate local climate conditions both within the woodland (contrast variations within a coppice cut or clear-fell, under shade, or in the dappled shade of continuous cover systems), and in the surrounding landscape (shade trees, windbreaks, etc). How far can landscape planning with forests help to mitigate local climate effects?

Much biodiversity research has gone into landscape ecology models and designs to increase landscape permeability and connectivity between woodland blocks, in order to increase colonisation of new sites. Yet efforts to increase connectivity may not be effective for woodland species for 50 years, by which time some populations could have gone extinct in their current locations. More effort should be put into modelling the potential for reducing extinction rates/increasing population size of species in woods through altering the management systems adopted. Such work to reduce extinction could be effective immediately.

Perverse adaptation strategies

Allan Watt, Centre for Ecology and Hydrology, Banchory, UK.

SUMMARY: Adaptation strategies to climate change in agriculture, energy and other sectors are a more serious risk to biodiversity in the short-term than climate change itself. Research effort must switch from its current emphasis on predicting the future impacts of climate change on biodiversity towards research on the many adaptation policies and practices already being implemented.

As Jørgen Olesen has well demonstrated, the agriculture industry is already implementing strategies to adapt to climate change. Pete Smith describes how agriculture is likely to contribute to further climate change unless there is a change in policies and incentives. Taken together, the outlook for biodiversity is poor: new cropping patterns potentially accelerating climate change pose new risks to biodiversity in agricultural landscapes. In another sector, Keith Kirby provides examples of how the forest industry is likely to adapt to climate change and in so doing have an impact on biodiversity.

One research priority must therefore be to identify actual and potential adaptation policies and practices in agriculture, forestry, energy and other sectors, assess their impact on biodiversity and develop alternative approaches to adaptation that do not have a negative impact on biodiversity.

A further, related research priority follows on from Frank Wätzold's call for more research on critical evaluation of different conservation options: to investigate the ecological, economic and social effectiveness of different adaptation strategies in relation to conservation and other sectoral goals.

Communication and knowledge transfer

Week Two Summary and Update

Terry Parr, E-Conference Chair, CEH Lancaster, UK

We've had a wide-ranging discussion on climate change impacts on biodiversity and there is a common view that we need better modelling to reduce the uncertainty attached to predictions of future impacts. Then out of an instructive exchange on the respective merits of empirical versus process based approaches to impacts modelling came the idea that we should follow the IPCC "ensemble" approach and compare predictions from a range of independent models to help us reduce uncertainties and develop agreement on key trends (Araujo). Worth a go, I think.

During week two we extended the debate to look at research requirements for adaptation strategies. At a general level the key research recommendation here is "to develop science-based plans for the adaptation and development of networks of protected areas taking into account of potential changes in climate" (e.g. Bos)" but particularly research aimed at "improving the quality and connectivity in the matrix surrounding protected sites" (e.g. WallisDeVries) and including the identification of the most vulnerable areas and "bottlenecks" restricting species' movements (Hossell).

We've provided a more complete summary of the contributions to Sessions 2 and 3 (see below). But one recurring theme is on the need to understand interactions: interactions between different pressures and drivers on biodiversity; interactions between scales (e.g. sites and their surrounds); and, above all, interactions between social and ecological processes. There have been some useful suggestions as to how this might be done ranging from observation networks (e.g. the MARS "observatories of the seas" Buchholz), better use of existing data and knowledge and general pleas for inter-disciplinary approaches (Watzold).

One conclusion is obvious from the contributions to the first three sessions: climate change impacts and the natural and anthropogenic processes through which ecosystems will adapt to them are going to be complex. This will make the research information we gain particularly difficult to communicate to the people who may be required to act on this information; namely ecosystem managers, resource managers, and public and policy actors. This brings us on nicely to the final Session of this E-Conference.

Session 4: Communication and Knowledge Transfer. Aim: What research and development is required to provide effective mechanisms for knowledge transfer between the research and policy communities?

We've already had several key contributions on this subject (Saez, Pardo) and Peter Moll drives the message home by reminding us that communication process is not just a last-minute add-on but a new and legitimate form of scientific activity (what he calls a solution-oriented and policy-directed "Third Task Science") that will require systematic support, funding structures and economic incentives to young scientists if it is to prosper.

Neither is communication a one-way process and the key role of participatory approaches for biodiversity conservation has already been identified by several contributors including Nino Nadiradze talking about his experience in Tajikistan as an example of adaptation to climate change in the developing world.

Summary Of Contributions During the Second Week (See also summary of 1st week for earlier contributions)

Session 1: Aim: To identify the key research and development required to reduce the uncertainty associated with our current assessments of climate change impacts on biodiversity?

Miguel Araujo suggested a research agenda including improvements on the bioclimate modelling of species distribution (using both traditional improvement of methods, and an ensemble forecasting approach), and the development of "hybrid" models with explicit mechanistic and correlative components.

Both Ferdinando Boero and Alan Feest discussed the important issue of standardised sampling in order to detect changes in biodiversity over time. Responding to Alan Feest's request for promising species groups for research, Keith Hiscock suggested using non-native species, and discussed the potential of engaging the public in tracking distributional changes in marine species.

Taking the example of hybridization in plant species adaptation in the context of climate change, Gerard Second called on more research to develop safe strategies for the dynamic conservation of biodiversity.

Session 2: Aim: To identify the key research and development required to make sure that we make best use of the current sites and networks and can develop better conservation policies and practices to create ecosystems that are resilient to climate change.

Jo Hossel called for increased research on key species distribution routes and the identification of climatically sensitive areas in order to guide the task of landscape planning for biodiversity conservation. Jo also called workshops to understand better how countries encourage adaptation and biodiversity conservation across different land use sectors.

Peter Bos and Sander van Opstal discussed the applicability of ecological networks in their contribution and highlighted a wide range of research priorities including a monitoring system capable of detecting long-term changes and trends, followed by a comprehensive analysis of the monitoring data. In terms of adaptation options they called for research on the consequences for biodiversity of different adaptation options. They also highlighted the importance of better understanding habitat resilience, climate change impacts in fragmented landscapes, and the potential of buffer zones in the conservation of protected areas.

Natura 2000 received relatively little attention. Although he agreed on the potential of the network, Michiel Wallis DeVries noted that the quality and connectivity of the surrounding matrix needed to be much improved, and suggested a reform of the CAP with a stronger emphasis on biodiversity and incentives for farmers to conserve biodiversity.

Within the marine environment, Dan Laffoley suggested more applied research to support network development, particularly on connectivity. Regarding adaptation to climate change in coastal areas, Robert Nicholl suggested three main research areas: the meaningful assessment of status and health of existing systems focussing on local and regional perspectives; the development of tools to predict coastal ecosystems' response to climate change; the development of methods to promote pro-active adaptation policies.

A few contributions focussed on the developing world. A contribution by Nino Nadiradze highlighted the fine line between survival and environmental degradation in developing countries and the fact that few activities had been carried out in developing countries to mitigate the effects of climate change. This was followed by an analysis by MacCallaway on the costs and benefits of adapting to climate change, particularly in the context of developing countries.

Finally Allan Watt drew our attention to a recent CBD document (UNEP/CBD/AHTEG-BDACC/1/2) and urged participants to consider research needs for the evaluation of a wider range of adaptation strategies.

Session 3: Aim: To identify the key research and development required allow us to adapt land and water-related policies and practices to promote conservation of biodiversity under climate change

Frank Waetzold stressed the lack of policy responses to climate change impacts on biodiversity. He especially discussed the need interdisciplinary research to address the development of policies that can deliver conservation goals on a broad geographical scale and for the development of an institutional framework capable of delivering appropriate incentives for stakeholders to conserve biodiversity.

Pete Smith agreed with the need for policies and practices to be developed to encourage land managers to conserve biodiversity and pointed out the following gaps in knowledge in the context of the agricultural sector: the need for a better understanding at the process level (especially in cropland soils), data / inventory collation and meta-analysis, further development of future scenarios of agricultural land-use and management, the development of new technologies and methodologies for measuring soil carbon and greenhouse gas emissions simultaneously, process studies (both modelling and experimental) to couple the carbon and nitrogen cycles and a more complete biogeochemical / physical / socio-economic assessment of GHG mitigation options in agriculture. Jorgen Olesen also discussed research priorities for the adaptation of agricultural production systems to climate change focussing on research regarding the effects on secondary factors of agricultural production, of changes in frequency of extreme events on agricultural production, and the interaction with the surrounding natural ecosystems.

Keith Kirby discussed adaptation to climate change in forestry systems and suggested research on the variability and extremes of future climate scenarios in order to plan future forest production systems, and on modelling the potential for reducing extinction rates/increasing population sizes of species in forests through altering the management systems adopted.

Researchers & policy actors: who drives whom?

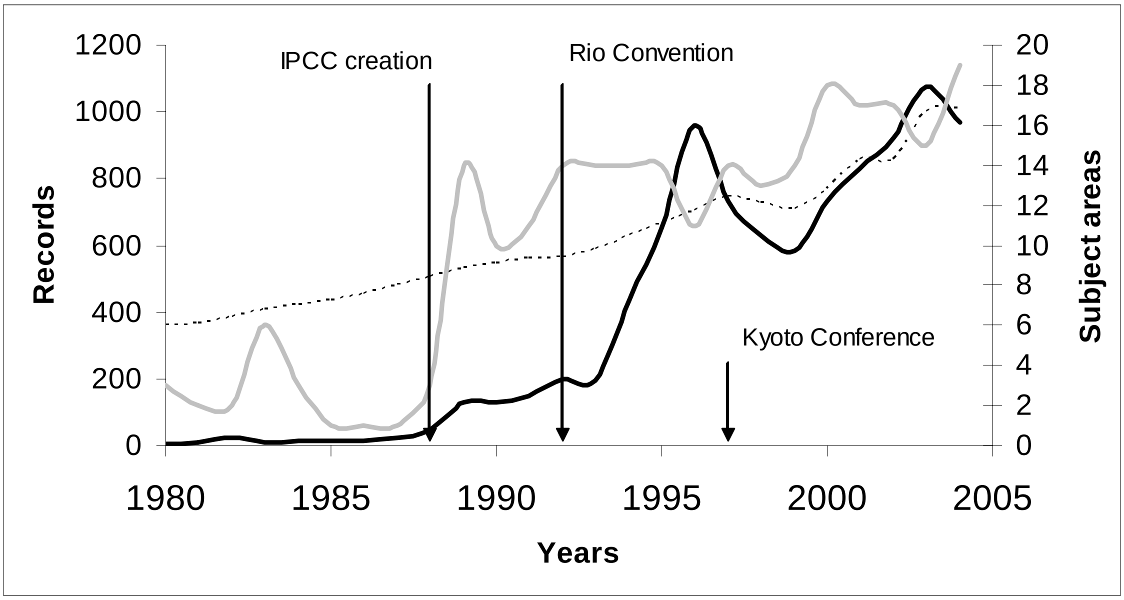
Juan Delgado, Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario (IMIDRA), Alcalá de Henares Spain.

This session deals with the development of effective mechanisms for knowledge transfer between researchers and policy actors in order to translate information into action. In order to slow down (or even prevent) climate change we must adapt our world to these changes, with the involvement of the whole society. But we also need the support of society in order to generate new information and knowledge to reach that aim.

As Ferdinando Boero has pointed out ("Lessons from the Mediterranean"), bibliography is a key element of knowledge. Its analyses should reflect the interest of both the research and the policy communities. A thought-provoking article will produce a cohort of related ones, but it is also true that research is driven by the availability of funds. A significant contribution on a topic should stimulate the supply of new funds that in turn will produce more knowledge. But the coin has also a dark reverse; without economic support no knowledge is generated in order to stimulate new fund supplies.

As I am documenting for a paper, scientific production on Global Warming (GW) and International Policy Events on climate change seem to be linked. The number of articles about GW has increased more than expected in both the 1994-1996 period and the year 2000 (Fig.1). It should be highlighted that higher increases of GW citations follow the signing of the United Framework Convention on climate change held in Rio (June 1992) and, to a lesser extent, the Conference of the Parties held in Kyoto (November 1997).

Figure 1. Temporal evolution of journal results offered by Scirus on ′global warming′ (black line) and number of subject areas which contribute (grey line) compared with total number of records (in thousands; dashed line). Three international policy events on climate change were also noted.



The analyses of the relative contributions of the different research fields should also provide us with a measure of the impact of the topic. The fact is that GW did not attract attention in many areas until 1989 when more than half of the subject areas dealt with the topic. This year could be established as the beginning of concern regarding GW, just after the creation of the International Panel on Climate Change (1988). An interesting pattern arises when comparing with GW records, because every increase in the number of contributions coincided with a decrease in the number of subject areas (Fig.1). It seems that when interest in this topic is increasing it gets attention of many subject areas but just for a short time; most contributions belonging to a few specialized areas.

In my opinion, these results suggest that scientific production about a topic is mainly a result of Policy events, more exactly a consequence of funds assigned to specific research on that topic. It seems that society gives funds to solve its worries and that scientific community respond enthusiastically. If we are the first ones detecting a problem, what must we do to make it visible to the whole society and particularly to politicians? I think that we have at least two disparate possibilities:

1) To offer the most impressive results of our research in an as spectacular as possible way.

2) To work daily to transmit what we are and what we do to the society.

While the first option is likely to be reserved to a handful of chosen, most of us could contribute to report to the society about our work. University courses, conferences, divulgative articles in science and technology magazines are good alternatives for making science more visible. Then, they could accept more easily the fact that we use “their money” to obtain more questions than answers.

Science and the polity/third task science

Peter Moll, independent science consultant and University of Bremen, Germany

Juan Delgado has raised a few questions in last Friday's contribution (Researchers & policy actors: who drives whom?) that I would like to follow up on. He asked:
- Why and when does a science topic attract attention from the polity or larger society? and
- What is the nature of the inter-linkage and / or dependency between science and the polity?

The second question to my mind is more easily dealt with. It seems to be an inter-linkage that is much more complex. There are probably nearly as many dependencies for politicians and people within the administration from experts these days than the other way around. I therefore am of the impression that there is not just a one-way dependency.

The first question seems more difficult. There must be myriads of experiences that may be evaluated to answer it. Let me single out just one: With more than 10 million copies sold worldwide the most successful individual scientific study - in the sense of publicity and distribution - to this day is more than thirty years old. It still is the "Limits to Growth" (1972), written by Donella Meadows and commissioned by the Club of Rome. This is old stuff but still a wonderful resource when dealing with problems of scientific impact assessment. Over a period of three years I once worked on the question why this study has been so successful. Among the key factors where the following:

- The study came just at the right time at a height of public attention and openness towards problems from a changing and degrading environment (Stockholm 1972...)

- The book focussed on environmental topics but was commissioned by a group of not only scientists, among them CEOs of well known multinational companies (and that's what the media picked up on) which from the very beginning made it tricky to neglect the study by putting it into the eco-corner

- It was wonderfully written (meaning that it is easily understood by laypeople) by Donella Meadows and there where easily digestible tables to look at

-It was based on most advanced technology - at time that was computer modelling (!) and the first world models (what would be an equivalent today?)

- It had a clear (although by press reviews as well as peer critique much distorted and to large extents misunderstood!) message. But this mixture of understanding and misunderstanding was a lot more powerful than the much more complex message of the book...

These few points already make it obvious that no single normal group of scientists could strive to manage such an event of publicity. However, there are things that can be done. Global change research in the last say ten years has been particularly strong in these respects when involving experts and stakeholders not just from within but also from outside science. Such transdisciplinary approaches do open for possibilities not just to enlarge the understanding of the problem but also for reaching beyond its peers and academia at large. This development together with a different form of science communication that comes with it to me is one of the keys towards attracting more attention from the polity and society at large.

In this connection let me mention an effort the Swedish Government started some three years ago. Recognising the lack of possibilities and incentives for scientists to fully engage into what tentatively can be described as new forms for scientific activity, i. e. working towards publicly accepted solutions, publicity of results, stakeholder involvement, management of highly complex applied science projects etc. the Swedish Government initiated a discussion on third task science. First task science in this definition would be science and research, as we mostly know it - its main output being knowledge and science publications. Second task was defined as teaching in universities and other science institutes. Third task science was then the solution oriented and policy directed science that among many other tasks works towards fulfilling international declarations and conventions such as the CBD, UNFCCC, Ramsar Convention, Aarhus Convention and others. But also large parts within e.g. technology assessment would fall under this definition. It seems indeed much to ask from scientists to fulfil all three functions without even first recognising and at least tentatively defining all of these functions and tasks that come with them. And it seems high time to think more carefully about systematically supporting such efforts within science, not leaving out careful thought (and action) on new funding structures and economic incentives for (young) scientists who are able and willing to go for a career in third task areas. This, if I may suggest, could be an interesting topic for the EPBRS to take up at Aviemore.

RE: Science and the polity/third task science

Cornelia Nauen, European Commission, Directorate General for Research, Brussels, Belgium

Reaching out with scientifically validated knowledge to citizens can be done. www.fishbase.org, the public web archive with recently more than 20 million hits/month, has shown it can.

Mapping information in non-manipulative ways that are transparent about error margins is potentially an even more powerful way to present results in ways that give citizens access and inform their choices.

Possible mechanisms for knowledge transfer between the research and policy communities that could bridge certain gaps

Horst Korn, Federal Agency for Nature Conservation, Isle of Vilm, Germany

Before making proposals, let me first try to outline the major differences between the research and policy communities. The analysis may be biased by my personal perception and could be an issue for discussion:

Many researchers are forced by severe competition into a very narrow field of expertise. They feel uncomfortable providing advice on matters outside their topic or on issues with a high degree of uncertainties because they fear that they may loose credibility as a scientist. The reward system in the scientific community is based on publications of original research and the acquisition of research money. Neither of those can normally be offered by the policy community.

Policy advisors or politicians often need to prepare or make decisions on a comparatively short-term basis and based on incomplete knowledge. They have to make decisions on a wide range of issues in parallel. Therefore they cannot spend too much time on a single issue. They are no experts in the field but still want to make scientifically sound decisions. The reward system to them is the satisfaction that a goal is reached (e.g. a law or regulation is adopted by parliament, a decision in an international treaty is taken that will lead policy into a wanted direction, a programme to finance certain activities is passed). A politician may get public recognition; his advisor may eventually be promoted. In the process of political decision-making the scientific advice looses its author(s)! The bill or the programme has no reference to it, who had the original idea or who gave advise on it!

In brief: both communities have different styles to work, different reward systems and different languages.

Some mechanism that tries to bridge the "gaps" between scientists and the policy community are in place. One of those is the European Platform for Biodiversity Research (EPBRS). It can certainly be improved but it is in place and functioning. Others are the scientific and technical advisory body of the Biodiversity Convention (SBSTTA) and similar scientific advisory committees of other international treaties or in support of EU-legislation. The scientific members of such committees are familiar with the general issues, like biodiversity conservation and sustainable development, but they are no experts when it comes to the details of the issues dealt with in a single meeting which could range from taxonomy, conservation of deep sea genetic resources, effects of climate change on biodiversity, inland water biodiversity, financing of protected areas, and more. Just to give some examples!

The problem is, how to reach out to the "wider scientific community" to get advice on all these issues. One attempt is to make assessments. They could be on the global, regional or national level or deal with specific issues. Generally these assessments specify the problems and point out possible solutions. Different audiences receive different targeted outputs of the same study. Meanwhile the main report may have several thousands of pages (IPCC-Reports, MEA etc.), a summary report may contain only about 150 pages, an executive summary for decision-makers 30 pages and a press communication only 2 to 3 pages. Any factual statement or conclusion drawn in a condensed version can, if necessary, be verified by going back to its original source in the fully referenced main report. In these assessments any author or reviewer at least get full credit for their contribution.

Government agencies often invite experts to give them advice. This could be individually or by organizing a workshop or seminar. On the other hand, scientific societies can improve communication by inviting politicians or policy advisors to their meetings. There they could ask for the information they need from the experts to make decisions and to solve problems.

Another possibility to provide expert input into political decision-making processes could be to use the collective expertise of a scientific conference, be it taxonomy, vegetation science, ornithology, marine research etc to come up with advise on certain relevant issues. A document that should be short (one or two pages only) and contain the most important points that they as experts want to address to decision makers. The text has to clearly state the problems in a simple language and to provide sensible guidance for possible solutions. To catch the attention of decision-makers it is also very important to link the suggestions to actual and real world problems that need to be solved. That document could be sent to the press and other news media, but also to relevant ministries, government agencies, politicians, etc. When the message is short, clear and relevant to help resolve real world problems, decision-makers will take it up!

Such a document could be elaborated and agreed on in each scientific conference. I do not think that it would need an incredible amount of work but could make a lot of difference for political decision-making.

RE: Possible mechanisms for knowledge transfer between the research and policy communities that could bridge certain gaps

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Keith Hiscock, Marine Biological Association, Plymouth, UK

I come from a background of working in an environmental consultancy followed by a nature conservation agency and now a research laboratory.

Scientists who advise policy makers are often employed by nature conservation/environment protection agencies, fisheries laboratories and the like. They provide a 'middle layer' between scientists with a constant imperative of publishing in high impact factor journals and the civil servants who advise ministers and who would never dream of doing scientific research.

We considered the information needed by managers in marine fields and a couple of years ago brought those thoughts together into a paper (Hiscock et al. 2003).

Two examples now come to mind that have worked in informing policy-makers with scientific information (on the marine front):

1. The annual 'Coastal Futures' conference in London and other conferences on policy matters organised by Coastal Management for Sustainability (see http://www.coastms.co.uk. These have become very popular events for summarising the science informing current issues and attract many of those 'middle layers'.

2. The Marine Life Information Network (MarLIN: http://www.marlin.ac.uk Web pages which summarise key information on biology and sensitivity of species and biotopes, all linked to Habitats Directive, Biodiversity Action Plans etc. as well as providing ready access to survey data, topic notes (briefing notes) on current issues etc. Not exactly a 'one-stop-shop' but providing understandable information for those middle layers and, to some extent, the policy folks directly.

Yes, BioPlatform is also important.

Yes, projects such as Cost-Impact http://www.pml.ac.uk/pml/costimpact.htm, Marine Biodiversity and Ecosystem Functioning (http://www.marbef.org) and European Lifestyles and Marine Ecosystems (http://www.elme-eu.org) are designed or have a part of them designed to inform managers.

So, I am not sure that we are short of information sources for decision makers (or more likely the middle layers advising them) but they need to be able to navigate to them and be willing/able to use them.

RE: Possible mechanisms for knowledge transfer between the research and policy communities that could bridge certain gaps

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Francisco Pugnaire, Consejo Superior de Investigaciones Cientificas, Almeria, Spain

Horst Korn referred to differences between the research and policy communities, pointing to different working styles, different reward systems, and different languages.

While agreeing with most of his analysis, I would like to point that a big effort is being also made by the scientific community to overcome the lack of communication with policy makers. Examples range from massive contributions to IPCC or MEA to a more management-focused research, with a surge of journals addressing now applied questions related to the environment. It is noticeable also a genuine interest in many professional societies to find ways to help managers in what ever is needed.

But if both society and policy makers want to spend resources in a research of excellence, necessarily scientists have to narrow their field of expertise. Some scientists are to blame by focusing too much on their academic career, but I guess few of them would refuse to give advice if asked. Since research funds are administered by policy makers, who decide where to put the money, it would be easy to find ways to involve them in the decision making process. Horst's suggestion to draw practical conclusions from every meeting may help in this way.

Finally, a reason by which researchers do not get more involved may be that policy makers do not take often into account their advise, resulting in frustration and disenchantment.

Bringing things together

Peter Moll, independent science consultant and University of Bremen, Germany

Horst Korn made some to my mind very useful comments on the different "cultures" between scientists and politicians. I fully agree with his descriptions. Let me just add a few points that to my understanding are still missing for successful knowledge transfer and which would be good research objectives for the years to come.

The idea of writing up results and recommendations of e. g. a science conference on a single sheet of paper is good. This proposal however also points to an underlying problem. To be capable to write things up in very concise and clear manner needs a capacity of "bringing things together" and even more difficult - the ability to see through vast amounts of information and knowledge and pull out of all this that knowledge that is needed for implementation work and in the end decision-making. What I mean to say is: There is usually a huge gap between the data and information gathered for research reasons and project work that is discussed among scientists and the answer to the question "what needs to be done?". And unfortunately, for large areas of science there are even good reasons for that. Many disciplines within science are not predominantly purpose driven and policy oriented and to my mind shouldn't be.

Other areas of science are in fact strongly policy-oriented and aim-driven (for example the aim of working towards fulfilment of international conventions such as CBD or UNFCCC). This is clearly the character of global change research including climate change, biodiversity and desertification studies. Here we do need this transfer and are very aware of this gap. But to bridge it we need more researchers who are trained in more than one discipline and ideally people who have some understanding of how nature sciences AND social sciences tick. Such education for "global change research generalists" who we ideally would need for writing the one page summaries is still not easily available. And we face a very similar problem in day to day project work. In a great many implementation oriented global change projects today there is at least one job vacant: The post of a coordinator who is able to overlook all the individual contributions from the research team involving biologists, economists, social scientists etc. His / her job of course would also be to extract the policy relevant messages and maybe even contribute with own writing and multi-stakeholder management towards an implementation oriented follow-up of the research phase. To be able to do all this there needs to be recognition of these "extra duties" for policy oriented and aim driven science from the funding agents and proper funding to come out of some sort of "idealism trap" that seems to be in place today.

There is recognition of this basic transfer problem from a minority within the science community. Just a few examples: At the University of Birmingham the Centre for Evidence Based Conservation recently has been set up (www.cebc.bham.ac.uk) which tries to develop methods that could help to fill this gap. Other initiatives are underway at places like e g. the International Institute for Sustainable Development (www.iisd.org - see for example their tool "proposal development & project implementation cycle"), within the science evaluation community (e. g. the approach towards "realistic evaluation" by Ray Pawson and Nick Tilley), and interestingly really a lot is happening within the development studies field. See e. g. the "impact modelling" tool by the German GTZ for implementation oriented follow-up in development studies projects or the "outcome mapping" tool developed by the International Development Research Centre (www.idrc.org) in Ottawa. All these approaches are of greatest interest for dealing with the mentioned problems and would deserve to be much more broadly disseminated.

The mentioned gap however still needs a lot more new and original research and still more recognition from the science community itself.

Research priorities in the development of effective mechanisms for knowledge transfer between the research and policy communities

Rehema White, Centre for Ecology and Hydrology Banchory, UK and **Christoph Goerg**, UFZ, Leipzig, Germany

SUMMARY: To produce and communicate policy relevant research relating to climate change, scientists need to address the challenges of interdisciplinary research and combining different forms of knowledge, develop methods to quantify uncertainty and assess risks and communicate results directly to governments and indirectly to other policy influencing actors through interactive networks.

Exchange of knowledge across the science-policy interface is complex and currently limited. Firstly, policy formulation and implementation is influenced by much more than scientific information. Even environmental policy is made within a societal context such that environmental benefits are weighed against societal welfare and economic growth (SoBio 2005, Watson 2005). Policy decision making is affected by the overall discursive framework, economic costs, political and power gains and may be value laden. Policy makers are influenced by the views of the public and by lobbying parties including businesses and NGOs.

Knowledge transfer across the science-policy interface is particularly difficult for issues such as climate change and, even more complex, the cross-cutting issues around conservation and sustainable use of biodiversity (van den Hove and Sharman 2004). Scientific information in this case is subject to high levels of uncertainty and complexity; it is not possible to produce the results of a massive controlled experiment to 'prove' results; there is dissension amongst scientists that has been exploited for political reasons, with the views of dissidents given equal weighting by many politicians and some media. In addition, scientists demand both short and long term and local and global actions, which are often difficult for political structures to support.

In order to influence policy through knowledge transfer, scientists need to conduct relevant research and communicate research results effectively. Research not only needs to be relevant to policy issues but can be more useful when provided in a more comprehensive context; when interdisciplinary research integrates ecological, economic and social aspects (SoBio 2005), when transdisciplinary research tries to grasp the political and socioeconomic contexts of the problems involved or when local knowledge and scientific knowledge are combined. Currently social science is under-represented in biodiversity related research (SoBio 2005). In the case of research on climate change, this would also imply assessment of the interactions between climate change and other pressures on biological and socio-economic variables (Watson 2005). Collaboration is also required between different groups of natural scientists. For example, taxonomy provides baseline detail on species distribution and abundance, ecology examines species and habitat responses and modelling enables predictions for the future; appropriate and diverse information thus needs to be combined to suggest adaptive strategies to policy makers.

Effective communication of research results to policy makers and the wider public is then required to impact on policy. It is important to produce peer reviewed papers to provide quality tested underpinning science but, although such papers may be included in governmental reviews, generally more pro-active communication is necessary. Since, as described above, the decision making process is not linear, scientists may need to communicate research results to other actors in the policy making cycle, including the public, NGOs, lobbying groups or interested parties (NERC 2005). So doing can strengthen the case of lobbying groups and influence the discursive framework within which policy is made. Direct communication to policy makers can be made through scientific advisers, specific committees (such as the IPCC), request for consultations, personal contacts within government departments, professional society contributions and other means (NERC 2005). Generally, policy makers prefer to view a number of options for practical action, along with the pros and cons of each option, sources of information and quantification of levels of uncertainty, rather than being presented with only one hard pushed recommendation (NERC 2005, Watson 2005). A further mechanism to increase uptake of scientific information is to link, for example, mitigation against biodiversity loss, to goals already endorsed by governments (Watson 2005 - eg the Millenium Development Goals, Convention on Biological Diversity, Kyoto Protocol). Since policy formulation and implementation take place at different scales, it may be necessary to follow different strategies for different target levels. In practice a model for informing policy rarely occurs and a model for more participatory mutual learning between actors in the decision making process is more likely (van den Hove and Sharman 2004). Knowledge transfer between scientists and policy makers should thus be two way.

Whilst many of the barriers to effective science-policy knowledge transfer are thus known, there remains a need for research to identify other barriers and to optimise solutions for science relevance and communication. Research priorities include overcoming challenges to inter- and transdisciplinary research and the integration of local and scientific knowledge; reliable quantification of levels of uncertainty and methods for risk assessment; developing a culture of evidence based decision making; combining research results from across the natural sciences as well as other disciplines to provide integrated scenarios; and identifying methods of improving communication channels between scientists and policy makers.

General remark on science - policy communication of global change

Peter Moll, independent science consultant and University of Bremen, Germany

I do not think we are dealing with the issue of "change for nature as a system". Even if we knew how nature as a system really works we unfortunately at present would probably not be in a position to meaningfully work about such a vastly complex system which we to this day find difficult to describe or even to recognize. But it would be the very thing to do if we were able to. Because it is most likely that "nature" in fact does function as a system and can only be fully understood as such. But how on earth is that to be communicated to the broad public and to politicians?

There might be steps forward. One does not (as I personally would) has to go as far as James Lovelock (et al in his Gaia Hypothesis) who conducted two decades' long research into proving that nature most probably acts not only as an entire system but just like a living organism that in peculiar ways is making sure that conditions of stability that enable life on this planet are in place over millions of years. He found a "nature" who also is able to entirely modify and adapt to totally changing parameters for life on earth.

One of the most convincing facts which can also be communicated to me is that nature / the global earth's environment (in this case its atmosphere) has in the past endured much stronger change than those taking place right now. Such change included about two aeons ago a full reversal from a carbon dioxide, methane and ammonia based atmosphere to a predominantly oxygen based atmosphere. This change was so immense that all we talk about today in climate change, although of possibly devastating effects for us humans and many other species of the time, in comparison still look like very minor events. But this "story" tells us a lot and shows to what lengths "nature" is able to go.

The issue for global change research and the lines on which to communicate what we do therefore is not to understand how to "save nature" but to lay the basis for good decisions on safeguarding the human environment and the existing living beings and organisms that make for the biodiversity that we enjoy and are depending on in so many ways. Or to say it even more bluntly: The issue never has been to save nature as such but to save the known biodiversity and to understand the conditions for possible human survival.

This is a different perspective altogether. One has to be careful not to overdo it as perceptions of doom are seldom good policy advice. But the message as such is important. And it has not sunken in with the broad public nor with most politicians. Such a perspective to my mind could be a more adequate platform for sound long-term policymaking as it links very clearly to most "policy relevant" topics. And even the most stubborn social Darwinists, of which there seem to be still some in charge these days, may be addressed this way.

Week Three Conclusion and final summary

Terry Parr, E-Conference Chair, CEH Lancaster, UK

Most contributors in the E-conference have endorsed the general idea that adaptation to climate change will require large-scale “holistic”, “regional scale planning” and “integrated landscape-scale (and ocean-wide)” actions for biodiversity. This will involve complex multi-stakeholder adaptive responses and top-down planning. The corollary of this is that the research agenda will be correspondingly complex and forward-looking and quick solutions may be difficult to find.

Very few contributions have considered the more immediate research requirements of policy in relation to current policies and policy instruments and current targets or legal requirements. Hence we paid little attention to the Habitats Directive, Birds Directive and the 2010 target to “halt biodiversity loss”. We may even have been a bit cavalier (even un-scientific) in our neglect of the current pre-dominantly site based approach and we hardly considered the research required to provide advice to all those site, ecosystem and resource manager who have responsibility for managing these sites in the here and now. Of course, until we understand the bigger picture it will be very difficult to provide advice on what to do at more local scales. But as Oliver Watts (16/9) says in relation to the management of the RSPB’s sites in the UK - “it is important to continue to strive to maintain current biodiversity, habitats and communities, until it is clear from observational evidence that this is no longer tenable”. In the absence of appropriate research and better advice who can argue with that, even though much of the discussion in this E-conference suggests we should.

Knowledge transfer and making the “best use of best available information and knowledge” must be one of the key priorities for research. The essential issue here is one highlighted in the final session on knowledge transfer. With only a few exceptions there is a general weakness at the science-policy interface; what Peter Moll (16/9) describes as the gap between data collected for scientific research and “what needs to be done”. It was not so easy to identify research requirements in this area (although there were some suggestions) but it was clear that a radical re-think is required if (i) the research is to be given sufficient priority to be funded in the first place; and (ii) the results of the research are to be effective in influencing the actions of the many stakeholders who may be asked to change their ways as part of the broader strategy for biodiversity and adaptation to climate change.

Summary of contributions during the third week (See also summaries or week 1 and week 2 for earlier contributions)

Session 1: Aim: To identify the key research and development required to reduce the uncertainty associated with our current assessments of climate change impacts on biodiversity?

Paul Opdam highlighted the importance of research on interactions of processes at different spatial scales, both in physical planning and spatial ecology and highlighted the role biogeography could play in climate change studies.

Csaba Matyas commented on the fact that little was known about the genetic limits of climate tolerance and suggested research using a mix of quantitative genetics and evolutionary ecology to bridge this knowledge gap.

Renat Perelet suggested developing a protocol (similar to and complementary to the Kyoto protocol) on conservation and sustainable use of biodiversity, bringing the living natural capital into the world market system.

Session 2: Aim: To identify the key research and development required to make sure that we make best use of the current sites and networks and can develop better conservation policies and practices to create ecosystems that are resilient to climate change.

Josef Settele described the ALARM project, which aims to develop and test methods and protocols for the assessment of large-scale environmental risks in order to minimise negative direct and indirect human impacts. He identified one of the major challenges as the creation of a working relationship between unrelated scientific communities.

Paul Opdam identified a number of research questions in his contribution including how to successfully integrate conservation targets into management plans, how to develop a common strategy for European spatial development that can be implemented at the regional landscape level, and how to best incorporate ecological knowledge into the planning process. Pierre Ibisch agreed with Paul Opdam's contribution and suggested a combination of ecoregional and national conservation planning.

Rob Tinch continued the discussion on the costs and benefits of adapting to climate change by answering Mac Callaway's initial questions on the valuation of ecosystems and human lives, the use of measuring costs and benefits in a developing country context and how to estimate cost and benefit measures.

In answer to the issue of determining the threshold at which change is harmful to nature as a system, Kioumars Ghamkhar suggested finding out how the tree of life had been formed and linking the information to biogeographical data and ecogeographic changes.

Richard Smithers stressed the need for inventories of semi-natural habitats, establishing the edge effects of intensive land uses on semi-natural habitats, addressing landscape permeability and quantifying the economic benefits of landscape scale action for biodiversity. Olly Watts added a few research needs including the identification of geographical areas likely to be most important for biodiversity in the second half of the 21st century; identifying time scales for the creation of different key habitat in new areas; develop land management practices that increase the permeability of different land uses to biodiversity and finally to develop policy mechanisms to achieve the adoption of these practices.

Session 3: Aim: To identify the key research and development required to allow us to adapt land and water-related policies and practices to promote conservation of biodiversity under climate change

Following on from Pete Smith's comment on how agriculture was likely to contribute more to climate change without a change in policies and practices, Mac Callaway suggested the only way in the EU was to reform the CAP dramatically.

Allan Watt however called for more research on the identification of adaptation policies and practices that are being implemented in all sectors, and the assessment of their impact on biodiversity so that alternative approaches can be developed if needed. He also called for more research on the ecological, economic and social effectiveness of different adaptation strategies in relation to conservation and other sectoral goals

Session 4: Aim: To identify what research and development is required to provide effective mechanisms for knowledge transfer between the research and policy communities

Horst Korn described the major differences between the science and policy communities and mechanisms already in place to bridge the gap between the two communities (for example the EPBRS). He also commented on a number of ways to reach out to the "wider scientific community" including making assessments, links between government agencies and experts and using the collective expertise of a scientific conference to provide advice on particular issues. Both Keith Hiscock and Francisco Pugnaire highlighted a number of successful initiatives of knowledge transfer between scientists and policy-makers. Both however highlighted that policy-makers needed to be willing or able to use the information provided, and that ignoring the advice could lead to frustration and disenchantment of scientists.

Mercedes Prado suggested more interdisciplinary research on the links between society and nature, and for better communication between science and society. This was reflected in the contribution by Juan Delgado Saez, who suggested making science more visible to society through university courses, conferences, articles etc.

Peter Moll reminded us that communication process is not just a last-minute add-on but a new and legitimate form of scientific activity (what he calls a solution-oriented and policy-directed "Third Task Science") that will require systematic support, funding structures and economic incentives to young scientists if it is to prosper. In another contribution he highlighted the huge gap between data gathering and the next step, i.e. "what needs to be done". This requires more training for "global change generalists" who would have a good understanding of natural and social sciences, and would be able to convey complex scientific information into concise one-page summaries for policy-makers.

Neither is communication a one-way process, and the key role of participatory approaches for biodiversity conservation has already been identified by several contributors including Nino Nadiradze talking about his experience in Tajikistan as an example of adaptation to climate change in the developing world.

Rehema White and Christoph Goerg highlighted the need for scientists to overcome the challenges of interdisciplinary research (and integrating different kinds of knowledge, including local knowledge) by developing methods to quantify uncertainty and assess risks and communicating results directly to governments and indirectly to other policy-influencing actors through interactive networks.

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