Large Scale Biodiversity, Environmental Gradients and Ecosystem Sustainability

Report on workshop outputs from Marine and Terrestrial & Freshwater community perspectives
(15th and 16th December 2008)

Content

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Summary

This document outlines the objectives, background and outcomes of two workshops held at the Defra Innovation Centre, Reading on 15-16 December 2008. These workshops were held to help develop the ‘ecosystem sustainability’ priority action of the 2008 Biodiversity Theme Action Plan, to inform our understanding of biodiversity functions and processes across scales and systems. Introductory and background material are given in Section 1 and Annexes 1-4, with reports from the marine workshop in Section 2 and from the terrestrial and freshwater workshop in Section 3. Both workshops identified priority questions; assessed different approaches for addressing these questions; and commented on issues, concerns and opportunities that a large-scale study of ecosystem sustainability could offer.

The main outcomes of the two workshops were as follows.

i) All research communities (marine, terrestrial and freshwater) recognised that a large-scale, long term and collaborative biodiversity initiative would provide unique and exciting opportunities to advance scientific knowledge of ecosystem services and sustainability.

ii) No single priority research question was identified. However, both workshops emphasised the need to increase fundamental understanding of ecosystem sensitivity to change (tipping points, non-linearities and resilience) and ecosystem functioning across different scales, in order to improve management advice in a broader socio-economic context. These issues are closely linked.

iii) Focussing research effort on a single site was not favoured. Instead, both workshops preferred a nested, multi-site study that could cover a relatively wide geographic range and would include process-based experimental studies.

iv) Resource constraints, gaps in the national skills base and community cohesion were identified as issues requiring further consideration if viability and success of the programme is to be assured.

v) All research communities recognised the need for a clear, well-defined and appropriately funded work plan with defined aims and the establishment of a strong governance structure to ensure community cohesion and delivery of interdisciplinary science of societal value.

Section 1: Introduction

1 Workshop objectives

1.1 The objective of the two workshops was to start the process of identifying and outlining options for a possible future NERC research programme investment that would enable research on ecosystem sustainability and improve our understanding of biodiversity functions and processes across scales and systems. The specific aims of the workshop were to:

(i) identify the priority research questions that require a large-scale, long term approach for delivery,
(ii) consider the advantages and disadvantages of different approaches to achieving the desired science outcomes (e.g. a single site approach vs multiple experiments vs a virtual observatory), and
(iii) determine the resources required to deliver a programme of this kind that will contribute to global initiatives in ecosystem sustainability.

2 Background information

2.1 The primary challenge of the NERC Biodiversity theme is to "Improve understanding of biodiversity's role in ecosystems: processes, resilience, and environmental change." Addressing this challenge will require the generation of inter/multidisciplinary programmes and teams with expertise at all scales from molecular to landscape. However, research at large-scale and over longer time scales in particular is difficult to deliver through responsive mode type mechanisms and generally requires a more coordinated approach to investment.

2.2 Therefore, the 2008 Biodiversity Theme Action Plan identified a large-scale action as a priority for the theme. This action would be the first UK large-scale, multidisciplinary investigation of the stability of ecosystems that are linked across major environmental gradients and the associated functional role of biodiversity at the ecosystem level. This is an exciting opportunity to develop the essential paradigms that are currently lacking. Whilst the UK biodiversity research community is recognized as having world-class strengths, much of the community is not accustomed to working at cross-ecosystem scales in multidisciplinary teams to identify the interdependencies between ecosystems, traditionally pursuing independent, focused research at small scales. This action will also demand new approaches and ways of working for the biodiversity research community. Specifically, many of the questions will need to be tackled at spatial and temporal scales in which society has a stake as well as bridging the sub-disciplines within natural sciences and working at the interfaces between the natural, physical and social sciences. It is proposed to harness this intellectual capacity to achieve new synergies to facilitate major science advances by allowing the community to work through a large-scale, integrated approach.

2.3 The action should run for enough time to allow incorporation of significant environmental variation into models (e.g. interannual variability in climatic variables), and be of a spatial scale to allow comparisons to be made with large-scale studies elsewhere (in particular, the US LTER programme). It will also make a major contribution to providing policy makers with evidence needed to mitigate impacts of climate, to sustain biodiversity (meeting national obligations) and to maintain and enhance the provision of ecosystem services.

2.4 This scoping exercise will outline options for a world-leading research programme aimed at improving our understanding of biodiversity, environmental gradients and ecosystem sustainability at large scales by providing: i) a step improvement in understanding of the role of biodiversity in ecosystems; ii) marked improvement in understanding of effects of change on biodiversity and ecosystems with concomitant enhancement of ability to predict future response scenarios; and iii) a significant improvement in quality of advice to stakeholders.

3 Workshop process

3.1 There were four main sessions in each workshop:

(i) Introductory presentations and canvassing of 'opportunities', 'major issues' and 'concerns';
(ii) Presentation of a conceptual framework and the identification of priority research questions;
(iii) Group assessments of different research approaches, with plenary discussion;
(iv) Individual written comments on 'Things for NERC to consider'

4 Introductory presentations

4.1 Mark Ohman (Scripps Institution of Oceanography) provided an overview of research at biome sites within the NSF-funded Long-Term Ecological Research network (LTER, www.lternet.edu). Although mostly temperate and land-based, the 26 LTER sites together cover the climatic range from polar to tropical, with 10 sites having aquatic processes as major components. The 193,000 km^2 California Current Ecosystem (CCE) site became part of the LTER network in 2004, building on fishery-based surveys (CalCOFI; California Cooperative Oceanic Fisheries Investigations). Benthic studies are not directly included, but are covered by collaborative work.

4.2 All LTER sites measure five core variables, relating to primary production, population dynamics of representative species, nutrient cycling, decomposition and disturbance. They provide the framework for project-based experimental studies, and actively engage in outreach. More explicit linkages to socio-economic factors are being taken forward through the Integrative Science for Society and Environment initiative. The LTER network offers many unexploited opportunities for cross-site, cross-biome comparative science that could be further developed on an international basis.

4.3 Wouter Los (Zoological Museum, Univ of Amsterdam) and Gilles Lemaire (Institut National de la Recherche Agronomique, France) summarised the status of European coordinating activities and infrastructures linking environmental and biodiversity research, through LifeWatch (www.lifewatch.eu) and ANAEE (Analysis and Experimentation on Ecosystems; www.anaee.com). These EU activities are FP7-supported as preparatory studies to enhance the wider integration of national effort, the former with emphasis on large-scale, long term observations of natural systems, the latter on experimental facilities (e.g. the ecotron, used for manipulation of soil-vegetation systems, and marine mesocosms).

4.4 UK participation in LifeWatch is currently through CEH, MBA, NHM and the Cardiff eScience Centre. The involvement of terrestrial/freshwater researchers is probably higher than the marine community, although there is the potential for both to raise their profiles

4.5 Georgina Mace (NERC Centre for Population Biology, Imperial College) outlined a conceptual framework relating biodiversity research to spatial scale. Because of the difficulty in achieving manipulation replications and controls, 'landscape' studies and those at larger scale need to be closely linked to observational research and smaller-scale experiments, using modelling approaches to develop and test regional assembly rules.

Section 2: Marine Workshop held 15 December

5. Section summary

5.1 This section relates to the 15 December meeting. It was chaired by Lloyd Peck; jointly organised by NERC Swindon Office and Defra Innovation Centre facilitators; and attended by ~ 55 researchers and research users from over 35 organisations (Annex 1)

5.2 The main outcomes and conclusions of the 15 December workshop were as follows:

(i) The marine research community welcomed the development of a large-scale, long term biodiversity study relating to ecosystem services and sustainability. Such an initiative would provide major opportunities for policy-relevant scientific advances and interdisciplinary integration.

(ii) ‘High level’ priority research questions were identified as understanding the role of biodiversity in ecosystem function and in ecosystem responses to natural and anthropogenic change (sensitivity, resilience and thresholds), together with improved knowledge of scaling and connectivity processes. Such ecological studies need to be closely coupled to socio-economic research to help achieve sustainable management of marine resources.

(iii) Exclusive focus on a single site was not considered the most effective approach. Instead, a nested, multi-site study was favoured, building on existing time series and developed with partnership co-funding. The new programme would need to combine experimental, observational and modelling work, contributing to, and benefiting from, international collaborations.

(iv) There were concerns regarding resource constraints, programme design and implementation, the engagement of stakeholders, and gaps in the national skills base. These issues required further consideration to ensure programme viability and success. Direct engagement with the terrestrial and freshwater research communities was also considered desirable, assuming that funding was sufficient to cover all environments.

6 Initial brainstorming

6.1 Workshop participants were asked to individually identify opportunities, major issues, and concerns (separately, on colour-coded Post-it notes) that were relevant to the workshop aims. These inputs were not collectively discussed; however, they were grouped by Defra facilitators and displayed as background for subsequent sessions. The following contributions were made, with minor editing to avoid duplication:

6.2 Opportunities:

- *Integration and collaboration* (n = 25). To be achieved by scientific synthesis at national, European and international levels; linkage between biodiversity, environmental change and human activities; linkage between experiments, measurements and modelling; opportunity to cover range of habitats in a systematic and comparable way; use of innovative informatics; temporal integration, providing context for monitoring by connecting observational snapshots to dynamic processes.

- *Community development and cohesion* (15). Development of (much needed) ‘joined-up’ approach to address major issues and unified goals; organisational integration between distributed research communities (NERC Centres, HEIs and governmental researchers); maximising benefits of existing sustained observations, time series and other datasets; development of networks between scientists in other disciplines and environments, including terrestrial and freshwater.

- *Scientific benefits of large-scale approach* (10). Opportunity to address both fundamental and applied questions by studying marine ecosystems at the scales on which they operate; statistical advantages of pooled datasets and meta-analyses; potential advances in developing scaling laws and understanding natural variability; opportunity for 'end-to-end' ecosystem studies, from genes to biomes, across full taxonomic and size ranges, and including humans; opportunity for tractable hypothesis-testing, covering both top-down and bottom-up interactions within food-webs.

- *Societal relevance* (8). Sustainable marine management requires reliable baseline biodiversity data and process-based understanding; importance of ecosystem approach and 'good environmental status' for UK and Scottish Marine Bills and EU Marine Strategy Framework Directive; opportunity to improve fishery management advice by connecting single-species and ecosystem models; help develop conservation policy through design of Marine Protected Areas and assessment of their effectiveness.

- *Increased effectiveness of funding* (5). Added value of addressing wide range of issues and measuring many parameters together; programmatic approach and international linkages avoid inefficient duplication of effort; involvement of many organisations widens access to, and use of, existing data; opportunity to leverage additional resources from research users and other funders.

6.3 Major issues:

- *Links to socio-economics and policy* (13). Significant stakeholder involvement is needed for programme to successfully address sustainability issues; requirement for multi-disciplinary teams; ESRC needs to be engaged, preferably as co-funder; not clear how research results would be used by policy-makers.

- *Scope and programme balance* (11). Science questions need to be prioritised; importance of interactions between different forcing factors, including links with the Earth System Science-Biodiversity theme action on ocean acidification; need for major genetic/genomic component (eg. for 'barcode' identification and molecular-based stress indicators); integration of pelagic and benthic studies, and their connections to atmospheric and land-based processes; Arctic focus highly desirable as major biodiversity changes already underway.

- *Programme management* (10). How will overall direction, programme integration, and international complementarily be achieved? Conflicting needs for strong leadership and democratic engagement of research community; data management and informatics issues need to be addressed early on.

- *Funding issues* (4). Will funding be sufficient? What will the mechanisms be? How will technology development, contextualisation, analysis and synthesis be supported?

- *Links to terrestrial/freshwater* (3). Need for common, process-based approach to bring together marine biodiversity work with land-based studies; opportunities for cross-biome hypothesis testing.

6.4 Concerns:

- *Resource constraints* (19). Risk of insufficient funding to implement programme at necessary scale and over necessary time period to fully realise its benefits; high cost of observational infrastructure for deep ocean work (benthic and water column); long term commitment needed by all partners and stakeholders with interests; resources for data quality assurance and overall synthesis may be inadequate.

- *Programme design* (15). LTER model not directly appropriate for UK; lack of replication and risk of inappropriate site choice if all effort directed to single location; synthesis will be difficult if study is diffuse, lacks clear scientific direction and gives insufficient attention to contextualisation; need to have well-developed ideas on how results will assist sustainable management; current lack of collective focus.

- *Funding process and community engagement* (7). Risk of drawn-out programme start-up, with lack of transparency in scoping; fallibility of peer review (key components may be lost); concern that most support will go to relatively few research groups; programme-based approach not necessarily preferable to responsive mode; initial community consensus and subsequent integration may not be achieved.

- *Programme management* (5). Need for cost-effective and efficient coordination; not just a network – whole must be more than sum of parts; productive linkage between components won't be easy.

- *Data-related issues* (4). Data quality will be critical; will open data-sharing be achieved?

- *Skill shortage* (1). Are there sufficient taxonomists for programme viability?

6.5 Note that the numbers shown above should be considered as indicative. They have not been expressed as percentages since some workshop participants completed more than one note per category, whilst others contributed ideas that spanned the groupings given above. Table 1 rearranges the ordering of these groupings, to indicate that an opportunity can also be expressed as an issue or concern.

Table 1. Summary of initial brainstorming session. Sequence of major issues and concerns re-ordered to horizontally match topics also identified as opportunities, with font size indicating relative importance of the different issues (based on number of Post-it notes; Sections 3.2 - 3.4).

Opportunities	***Major issues***	***Concerns***
Integration & collaboration Community development Scientific benefits of large-scale approach Societal relevance Increased funding effectiveness	Programme management Scope & programme balance Links to terrestrial & freshwater **Links to socio-economics & policy** Funding issues	Programme management Programme design Data-related issues Skill shortage Funding process & community engagement **Resource constraints**

7. Priority research questions

7.1 Workshop participants were provided with a list of 50 pre-submitted research questions, solicited on the basis that they addressed the wider aims of the Biodiversity theme and required a large-scale, long term initiative for their delivery. These questions covered both marine and terrestrial/freshwater environments and had already been grouped been under three headings: understanding critical processes and functions; understanding trends and implications, and developing management solutions. Further synthesis, prioritisation and discussions were carried out in table-based groups of 6-8, with each table's conclusions summarised on an A3 page and orally presented by a rapporteur.

7.2 There was a very close match in the orally-delivered and written priority research topics from the seven tables, with consensus that the programme's scientific structure should be based on the following (linked) high level issues:

(i) <u>Ecosystem sensitivity and resilience: response to pressures.</u> What are the critical characteristics that determine how ecosystem functions (including provision of goods and services) respond to external forcing? Pressure-response behaviours of interest include stability, resilience/resistance, recovery from perturbation, and thresholds (tipping points, that may lead to regime shifts). Whilst these are the behaviours of greatest interest, it is initially necessary to improve our knowledge of the biodiversity-ecosystem function relationships. Such process-based information can then be used to produce realistic scenarios of ecosystem responses to climate change and management (human exploitation, conservation and restoration) over relatively long timescales, simulating interactions that are likely to involve non-linear changes, emergent properties, and functional redundancy.

(ii) Scaling and connectivity, from local to global. What are the key relationships that determine ecosystem scaling over a range of latitudes, water depths and time periods? How are individual species linked to ecosystem properties, through changes in their abundance, size, genotype, gene regulation and phenotype? What are the roles of migration and dispersal in determining responses to environmental change? These questions relating to the spatial and temporal structuring of ecosystems are fundamental to model development and the design of research studies, both experimental and observational. They are also of crucial importance in distinguishing local variability from large-scale patterns (involving downscaling as well as upscaling); for the translation of sound ecological theory into practical management advice; and in providing a basis for comparative analyses with freshwater and terrestrial systems.

(iii) Developing management solutions. What state do we want our marine ecosystems to be? How can we ensure that ecosystem goods and services will continue to be delivered? Ecosystem-based management of marine resources not only requires information on reference conditions for the components of concern, but also an understanding of their natural variability and responses to human pressures; i.e. the coupling of social and ecological systems. In addition to long-standing issues related to (un)sustainable fisheries, new policy-related challenges relate to the rapid expansion of marine renewable energy, the establishment of Marine Protected Areas, and the impacts of invasive species. These topic areas provide opportunities for hypothesis testing via large-scale management 'experiments' and the development of coupled ecosystem-bio-economic models to underpin decision-making.

7.3 Table 2 below identifies the ~ 12 specific questions that featured in the written reports of the seven break-out groups, developed from the original list of 50.

Table 2. Priority research questions, as subset of list provided and grouped under three high level headings. N, number of break-out groups identifying the same or closely similar questions.

Research questions (combining those that are closely similar)	N
Ecosystem sensitivity and resilience: response to pressures	
• How does biodiversity, complexity and ecosystem function affect resilience, stability and delivery of ecosystem services over different spatial and temporal scales?	5
• Can we determine how and when disturbance will severely affect ecosystem functions, resulting in non-linear behaviour (thresholds and tipping points)?	4
• What is the importance of genetic diversity for ecosystem resilience?	4
• What are the key natural and anthropogenic drivers affecting ecosystems?	3
• What is the extent of community adaptation to natural and anthropogenic change?	2
• Is functional capacity and stability more important than biodiversity?	2
Scaling and connectivity, from local to global	
• What processes (and at what level) link populations and ecosystems across local, regional and larger scales, including responses to natural and anthropogenic gradients?	5
• What are the commonalities (and differences) between marine and terrestrial ecosystems?	1
Developing management solutions	
• How can we use knowledge on biodiversity to improve ecosystem services?	3
• How should Marine Protected Areas be planned and assessed?	2
• What are the effects of management on biodiversity?	1
• What are the impacts of invasive species?	1

8. Evaluation of different research approaches

8.1 Workshop participants were divided into breakout groups to consider the practicalities of three different approaches that could be used by a large-scale biodiversity research programme: single site; multiple sites, few (4-6); and multiple sites, many (30-50). Two groups considered each option, setting out their ideas on wall posters and flip charts; in addition, a seventh group was given an 'unconstrained' scenario. The charts were displayed for additional comments to be appended by all workshop participants.

8.2 The outcomes of these discussions are summarised in Table 3, and presented to plenary by group rapporteurs. Both single site groups were unconvinced that such an approach was scientifically-optimal, a view endorsed by the wider meeting. Thus that approach attracting no supporters when put to plenary vote. Opinion was divided in the approximate ratio of 2:1 between the 'few' and 'many' multiple site options.

8.3 In group discussions (Table 3) and in plenary the point was made that the concept of 'site' was crucial to programme scoping yet had not been unambiguously defined. It could refer to a relatively large area within which detailed studies are carried out at many locations, each of which may also be regarded as sites. The US LTER 'biome sites' were of that dual nature, with the CCE being larger than the Irish Sea and Celtic Sea combined, and covering many different habitats and environmental conditions.

8.4 Furthermore: i) site stability and identity (boundary definition) varied greatly from pelagic to soft- and hard-bottom benthic habitats, and from deep water to coastal ecosystems; and ii) transect-based sampling (e.g. the Continuous Plankton Recorder survey) did not necessarily match a site-structured approach. Linear surveys were, however, well-suited to the study of large-scale environmental gradients, and could be related to the regional-to-global synoptic approaches of remote sensing and biogeochemical modelling.

8.5 Such considerations did not diminish the need for a large-scale, integrated UK programme of marine biodiversity research. Nevertheless, a key conclusion of the workshop was that the choice between single-site and multiple-site approaches was (for the marine environment) essentially a false dichotomy. Instead, nesting of research effort was required, with local, process-based studies and experiments occurring within a much larger observational framework. The programmatic linkage across the scales would then be hypothesis- and model-driven, transcending site specificity not only through standardised sampling, experimental protocols and data management, but also through European and international collaborations.

9. Final brainstorming

9.1 At the end of the meeting there were concluding table-based discussions of an open-ended nature. The main issues raised were: how the programme would fit wider social context and policy needs; the benefits of using existing sites (NERC-supported and others) as the 'programme backbone'; the need to invest in new technology; the importance of maintaining taxonomic expertise; the need for cross-disciplinarity; and the desirability of early delivery of high profile science outcomes (to ensure continued support over ~10 yr programme lifetime).

9.2 All workshop participants were also asked to individually identify the single most important "issue for NERC to consider" on Post-it notes. Whilst these comments and suggestions were relatively diverse (and some participants had left the meeting by then), the following groupings could be made:

- *Relevance to sustainability agenda* (12). Assessment of human impacts and role of biodiversity in delivering goods and services requires strong socio-economic component, with wide stakeholder/ research user engagement (via other Research Councils, Defra, devolved government etc); role of LWEC in promoting interdisciplinary approach and ensuring programme value is fully realised.

- *Linkage to National Capability* (7). Need to build on existing investments in time series, sustained observations/monitoring programmes, technology development, data management and modelling, including use of historical datasets.

Table 3. Summary of group-based discussions on programme approach

	Single site	Multiple sites: few (4-6)	Multiple sites: many (30-50)	Unconstrained*
Key features	*Not considered a useful approach.* "If we must" then site needs to be large, and carefully chosen to have wide applicability.	Could either be based on very different ecosystems or similar habitats widely separated (that may have different biotas).	High replication; regional to global approach covers very many natural and human drivers; spatial scales may also serve as (proxy) chrono-sequence for climate change	Ideally would cover full taxonomic range over full habitat/ ecosystem spectrum (estuary to deep sea, polar to tropical)
Priority research questions	Focus on process studies. Unsuitable for scaling/connectivity questions; limited value for management	Pressures/responses and management issues. Scaling not so well addressed.	All priority research issues potentially covered	All questions covered
Feasibility	Would be possible, but not scientifically desirable	Could build on existing observatories and time series, tailored to fit wider buy-in (by Defra, JNCC *et al*)	Doable, with nesting of effort - and building on existing observatories and time series (including Arctic and Antarctic)	Aspirational, but could be done if geopolitical will and international buy-in.
Main deliverables in 5-10 yr	Site-specific analyses of main drivers and processes – but problem in extrapolating	Baselines and some trend data; improved under-standing of natural and human-driven change; new models for forecasts	Comprehensive datasets for observing, understanding and managing changes in marine ecosystems; much more robust models	Major scientific advances and evidence base for sustainable use of marine bioresources
Resources; value for money	Cost depends on site size. Value only realised if fully networked with other (non UK) effort	Cost of £2-3m pa ? (excluding observational infrastructure, cruise costs and major experimental facilities, e.g. mesocosms)	Cost of £3-5m pa? (with exclusions as at left). Yet value for money, since would answer key questions, whilst providing many opportunities for leverage and outreach	Cost of £10m pa? Would need joined-up government support and strong link to climate change research
Scope for inter-national linkages	Matches (Pacific) US LTER biome approach, but limited scope for Atlantic comparisons at this scale	Multiple UK sites improves opportunities for European collaborations, e.g. via MarBEF network	Excellent opportunities for very wide range of links (via MarBEF, CoML, LTER, LifeWatch, Diversitas, IMBER etc)	UK could develop world leadership in this area
Main advantages	High resolution data for model parameterising; simpler management; interdisciplinarity easier to achieve	Could cover range of habitat types, with good supporting data	Comprehensive coverage and good replication improves confidence in outcomes; more likely to deliver novel insights and meet future needs	Flagship programme to answer science questions and meet UK and EU policy needs
Uniqueness	Very detailed studies, e.g. via manipulations and instrumented arrays; high local replication	Benefit of inter-site comparisons to identify and test patterns, trends and relationships at different scales	Mix of intensive and extensive, maximising benefits of nesting; flexibility; meeting both science and policy agendas	World leading – covering all spatial and temporal scales
Limitations	"Eggs all in one basket": difficulty in assessing wider applicability of results; site selection won't be easy; risk of making poor choice	Limited replication; not covering all ecosystems; problem of wider spatial and temporal extrapolation	May be constrained by available finances, e.g. reduced scope for experi-mental manipulations ; full suite of physical data unlikely at all sites; complex management	Could funding be found? Insufficient taxonomists; shortage of research ships; no controls for climate change or ocean acidification
How limitations would be overcome	Develop as part of wider European/ international network	Careful site selection, sampling design and choice of experiments; close links with modelling; funding support for collaborative work at non-UK sites	Co-funding and internationalising; careful design; close links with modelling, remote sensing and transect-based underway data collection	Joined-up government; investment in training; greater ship-sharing

*"unconstrained" interpreted by the group primarily in financial terms

- *Scaling issues* (5). Cross-scale, integrative approach required to address large-scale policy and societal issues through small-scale experiments and site specific studies; need for representative sites; importance of global context.

- *Funding concerns* (5). Importance of 10 year vision; how will resources be bid for and allocated?

- *Linkage to other NERC themes* (3). Programme needs to closely connect to other NERC themes (primarily Sustainable Use of Natural Resources, Climate System, and Earth System Science); also link to proposed Arctic initiative.

- *Programme scoping* (2). Need for more thorough assessment of key questions and long term goals, that will then have implications for programme structure.

- *Programme governance* (2). How will the programme be managed? How will links be made with terrestrial and freshwater work?

- *Training and capacity building* (2). National need to train more marine taxonomists.

9.3 A single day is a relatively short period for a diverse group of individuals to discuss and agree on a national research programme covering complex issues and a broad range of organisms, habitats and ecosystems. Nevertheless, it was considered that good progress was made in the marine scoping exercise, with the main conclusions and outcomes of the 15 December workshop summarised in the introductory Section Summary

Section 3: Terrestrial and Freshwater Workshop held 16 December 2008

1 Section **Summary**

1.1 This report presents the main issues, themes and questions raised at the second workshop (held 16th December 2008), which involved leading UK scientists and policy makers with interests in freshwater and terrestrial biodiversity.

1.2 The main outcomes and conclusions of the 16th December workshop were as follows:

(i) The Terrestrial and Freshwater community saw this as an opportunity to develop a cross-disciplinary, collaborative research programme that would address common question(s) encompassing different scales and ecosystems.
(ii) The workshop participants emphasised the need for strong governance of the programme of work to ensure community cohesion and effective delivery of agreed research aims.
(iii) A single, 'high level 'over-arching research question was not identified but five broad and inter-related areas of research that would benefit from a large-scale approach were identified. These were: tipping points, non-linearities and resilience; ecosystem functioning, redundancy and adaptation to drivers; management; scaling issues; and ecosystem services.
(iv) Focus on a single site approach was not favoured. Instead, a multi-site approach incorporating a nested experimental design was the preferred option. This approach would: ensure cross ecosystem relevance and comparisons;, that gradients and scaling issues were addressed, and would enhance statistical power to detect attribute and model environmental responses.

2 Initial brainstorming

2.1 Following the introductory presentations, the participants were asked, as individuals, to identify a single *opportunity* that a large-scale initiative might provide, a *concern* regarding the action and a *major issue* that they felt the action should address / consider. Comments for each were collected on the day and subsequently grouped to identify common themes for each category. These are summarised below.

2.2 Opportunities (n=60)

- *Cross system integration / comparison* (n=15). To be achieved by: linking biodiversity and ecosystem function and landscape structure through interdisciplinary research; from genes and individuals through groups, populations, communities and ecosystems; cross-site and cross-scale comparisons through standardised measurements; bioinformatics enhancements and availability of much larger data sets (including linking existing monitoring and research sites).

- *Interdisciplinary collaboration* (n=13). Advantages include: applying a co-ordinated 'systems' approach to understand ecosystem function; bringing together observations, models and experiments to understand large-scale processes; developing common approaches across the terrestrial, freshwater and marine communities; enabling a more effective interface with socio-economic sciences for policy.

- *Community building* (n=12). Opportunity to: provide / create a lively and open research community involving different disciplinary views; generate cross ecosystem generalisations (ecological 'laws'); lead to synergism and more rapid progress towards a common 'holistic' vision and shared research needs; landscape scale research involving stakeholders to quantify, value and conserve biodiversity.

- *Tackle big questions / Address global issues* (n=11). Opportunity to improve understanding of large-scale drivers of ecosystem change that require long-term experimentation; provide an understanding of the baseline variation inherent in ecosystems both in space and time, and in so doing enable the UK to engage with the international science agenda to make progress to mitigate the effects of environmental change.

- *Link to policy* (n=6). Opportunity to raise the profile of biodiversity to policy makers, through linking it to large-scale land-use and other societal issues and through development of scenario testing to aid policy decisions.

- *Funding* (n=3). The initiative was seen as a means of securing / stabilising funding for large scale monitoring and experiments, with the opportunity to work with and leverage resources from other partners.

2.3 Concerns

- *Programme focus and governance* (n=30). Risk of insufficient focus and lack of consensus in formulating the programme of work; lack of agreement on definitions of biodiversity and ecosystem services. Could be difficult to make the programme inclusive if it could only cover limited components of biodiversity or ecosystem function due to scale constraints / omissions; vested interests and silos could compromise common goals; and the governance structure might be insufficient to ensure co-ordination and synthesis, resulting in poor targeting of large sums of money.

- *Inefficient data gathering / management* (n=10). What is the right balance between observation, modelling and data-basing? What are the right attributes to measure to ensure utility, including data compatibility and comparability?

- *Research focus* (n=8). What is the right balance between flexibility of research objectives and focus of the research hypothesis being addressed, and how will that be achieved? What is meant by large scale and long-term in this context?

- *Funding continuity / security* (n=6). Will sufficient funds be available? Will insufficient funding compromise the opportunities for success? One participant suggested that the action should be developed as a stand-alone programme that then encourages external collaboration, rather than developing a collaborative programme from the outset.

- *Creative opportunities* (n=3). Would a community level programme stifle individualism and would scientific quality suffer as a result?

- *Valuing Biodiversity* (n=3). Policy relevance, e.g. valuing biodiversity, should not be lost or overlooked as the programme develops.

2.4 Major Issues

- *How do we collaborate and integrate?* (n=15). Is a large-scale platform approach efficient and manageable? Can existing long-term and large-scale monitoring and research activities be integrated and built on? Will there be sufficient support for bioinformatics?

- *Dependencies* (n=15). How do we understand the dependencies? The comments grouped here were mixed but raised concerns that specific linkages might be overlooked. These include links between: resilience and genetic diversity; genomic expression and environmental change; behaviour and life-history traits; biodiversity and biogeochemical cycles; biodiversity and extreme events; biodiversity / ecosystem function and landscape heterogeneity and connectivity; biodiversity / ecosystem restoration and ecosystem services; and the processes operating at the interfaces of ecosystems.

- *Multi-disciplinarity* (n=6). How do we incorporate socio-economics to meet policy needs? Need for early integration through consideration of socio-economic drivers, theory and human behaviour to meet policy / end-user requirements.

- *Scales* (n=5). How do we ensure the scales are right? Scaling dependencies are difficult to address and could be overlooked. Can the initiative be sustained for a sufficient length of time to generate ‘added’ value?

- *Climate Change* (n=2). How do we focus on climate change? How ecosystems can be manipulated to cope with climate change?

- *Funding security* (n=2). How can sufficient long-term funding be ensured*?*

2.5 Summary

The opportunities, concerns and major issues can be grouped under five headings. Interestingly,the five headings under the each of the three categories share common themes (Table 1).

Table 3: Summary of the broad themes identified among the opportunities, concerns or major issues comments. Related themes that emerged from each set of comments are shown on the same line with font size indicating the relative importance of each theme (based on numbers of Post-it notes).

Opportunities	***Concerns***	***Burning Issues***
Community building	**Programme focus & Governance**	**How to collaborate & integrate?**
Interdisciplinary collaboration	Creative opportunities	**How to understand the dependencies?**
Cross system integration / comparison	Inefficient data-gathering / management	How to ensure the scales are right?
Link to policy	Valuing Biodiversity	How to incorporate socio-economics to meet policy needs?
Tackle big questions / Address global issues	Research focus	How to focus initiative to address impacts from climate change?
Funding	Funding continuity /security	How to ensure future funding?

2.6 The main issues arising from this exercise suggest that a large-scale, ecosystem sustainability action would:

- provide an opportunity to build a collaborative, interdisciplinary community to address a common ecological question across different ecosystems and scales; and
- require strong governance of the science programme and data to ensure linkages are recognised and interpreted to address the question / hypothesis.

3 Priority questions to be addressed by a large-scale platform

3.1 In advance of the workshops all attendees, from both the marine and terrestrial / freshwater communities, were invited to submit three priority questions that might be addressed by an ES Action. The 50 questions submitted were provided to each group divided under three headings:

(i) understanding critical processes and functions;
(ii) understanding trends and implications;
(iii) developing management solutions.

3.2 Participants, working in eight groups, of no more than eight, were asked to refer to the list of questions and identify up to five priority questions that could be addressed working across the scales outlined in the presentation. The groups were also asked to summarise the reasoning behind each question.

3.3 Priority Question: Feedback

- In their feedback, the rapporteurs identified 37 questions, but only rarely made reference to the list of questions provided. The priority questions identified were diverse, and, whilst they can be ‘binned’ into five broad areas, they do not readily translate into an over-arching framework or researchable question for the action. Many of the questions are pertinent to more than one research area. The questions, grouped under each primary research area and their cross links to the other research areas are shown in Annex 1. The five research areas are summarised below:

- *Non-linearity / tipping points / resilience* (n=11). What is the role of cryptic diversity in resilience? How does the degree of local adaptation affect resilience to environmental change? How do we manage resilience at the landscape scale? How do we identify and model critical thresholds and tipping points, as well as the critical dynamics that lead to non-linear responses?

- *Ecosystem functioning / redundancy / adaptation to drivers* (n=10). What is the role of biodiversity in ecosystem functioning and how are both affected by multiple drivers? How do you quantify and manage species and systems ability to adapt? What is the role of redundancy in these processes?

- *Management* (n=8). How do we improve methods to predict the responses of biodiversity and ecosystem services to environmental change and what constitutes appropriate management practices?

- *Scaling issues* (n=4). How do we improve our ability to work across biological, spatial and /or temporal scales? These questions have direct relevance to most other research areas.

- *Ecosystem services* (4). What is needed to improve understand ecosystem services and the processes that underpin them so that better strategies for management for ecosystem services at landscape scales can be employed?

4 Evaluation of different research approaches

4.1 The participants were randomly assigned to one of seven groups and asked to discuss and comment on 10 aspects of an experimental approach. Two groups each independently discussed: a single site approach; a 4-6 multi-site approach, or a 30-50 multi-site approach. The seventh group was given *carte blanche* to develop an 'unconstrained' approach.

4.2 The 10 aspects considered for each approach were: its key features; which priority research areas it could address; its feasibility; the likely deliverables in 5-10 years time; the resources necessary for success; scope for international linkages; its main advantages; any unique attributes; any limitations and suggestions of how these might be overcome. One person from each group then gave a summary of the group discussions. These are summarised below and in Table 4.

4.3 **General themes in the feedback**: Workshop participants stressed that the overarching research question or framework for the action would strongly influence the final experimental design. Most groups also indicated that they would adopt a nested experimental design as this would add statistical power and help address issues of scaling and comparability across the landscape.

Table 4. Summary of group-based discussions on programme approach

	Single site	Multiple sites: few (4-6)	Multiple sites: many (30-50)	Unconstrained
Key features	Needs to incorporate defined gradients – transects & contrasts. Nested design using sub-plots. Allows scaling for relevance for organism – ecosystem.	Potential to work across gradients in a limited number of habitats. Larger sites allow nested design. Within and between site comparisons.	Potential to: work across multiple environments, gradients, & nested scales; incorporate replication and hence have UK relevance.	Would incorporate multiple nested scales & be interdisciplinary. Basal, standardised measures at each site with scope for flexible add-ons at different sites. Observation and interpretation to lead manipulations. Would cover natural gradients.

	Single site	Multiple sites: few (4-6)	Multiple sites: many (30-50)	Unconstrained
Priority research questions	Identifying tipping points & understanding functionality and redundancy at different biological scales, especially along gradients. Possibility of looking at adaptation responses.	Identify thresholds of ecosystem response. Ecosystem function. Scaling issues. Management issues.	Non-linearity Scaling Ecosystem function Management (some services)	This approach could address each of the priority areas; tipping points, ecosystem function, management issues, scaling challenges and ecosystem services.
Feasibility	Both groups felt that this approach was feasible. The necessary expertise in a range of disciplines including ecology, hydrology, geomorphology, soil scientists. Modelling & social sciences.	Both groups indicated that this option was feasible. It could build on existing data sets, sites & initiatives and would need to incorporate a high level of modelling and meta-data analysis.	Feasibility will be determined by the scale of the Action and the research priority. Could build on existing networks.	The approach was seen to be feasible, but only if it were run for longer – a minimum of 15 years. It would build on existing capabilities.
Main deliverables in 5-10 yr	These would be dependent on the site chosen but could include scale (gradient / catchment) dependence of impacts. These would influence management strategies.	Proactive community, inc stakeholders (5 yr) Modelling infrastructure. Identification of thresholds. Characteristics associated with rapid adaptation. Data capture and products.	Management advice (<5 yr) Broad scale understanding (5 yr) Process understanding (10 yr)	Collaborative UK community. Cross-ecosystem baseline measures, linkages and modelling framework. Information to aid landscape design and to model management scenarios.
Resources; value for money	One group estimated 6 PDRA and £9M for recurrent, equipment, co-ordination and data management. One group did not give any estimate of resource needs and simply stated '*probably not value for money*'.	Both groups estimated a cost of £10 M over 5 yr. Value for money: would produce less science (papers) but would address multiple questions across unprecedented scales.	Both groups' estimates were for £20-40 million pa over 10 years. (N.B. one specified a minimum of £30 M)	It was proposed that this would need to open ended, with the main funding being for data and infrastructure (co-ordination / management). Large-scale manipulations proposed to be costed outside of NERC.
Scope for inter-national linkages	The groups proposed linkages with LifeWatch and ANAEE. The results would have relevance for the WFD.	Good – would complement EU & US initiatives, especially if standardised measures collected and data protocols.	Good – would link with ANAEE, experimentation could complement requirements for EU frameworks.	Good – would link with international modelling / data and observation networks (inc LifeWatch & ANAEE). Links to climate, agricultural production, hydrology, etc models.
Main advantages	Logistically easy to acquire deep, but narrow, knowledge of one site, through manipulations. Initial data focus would ensure that the question evolves from the community and drives the research – but avoids undue influence by 'vested interests'.	Experimental design – replication, nested sites exploiting existing gradients. Leverage of additional resources from stakeholders.	Experimental design feasible Leverage of other funding & sites Cross ecosystem comparisons Gradients and design will yield strong conclusions Inclusive of many researchers & stakeholders	Combines existing observations with opportunity for curiosity -led, innovative experimental design. Flexibility.
Uniqueness	One group proposed that a unique habitat that	Between & within site comparisons, integration	Representative-ness Scale easily	National scale understanding and

	Single site	Multiple sites: few (4-6)	Multiple sites: many (30-50)	Unconstrained
	could be the focus of such a study in the UK is heather-dominated uplands. The other groups indicated that there was nothing unique about this approach.	of multivariate data. Value for money. Landscape scale relevance.	incorporated. Statistical power Coherent signals - fundamental truths or errors	relevance of analyses.
Limitations	Site choice is central to success. The time frame might be too short. The results would be dependent on pseudo replicates and would not have general relevance.	Site identification. Management of manipulations. Insufficient time for clear signals. Sample size / replication limitations.	Costs of or control over manipulations, if bringing in other stakeholders. Probably only shallow study possible.	Insufficient money for the number of sites Effort could be spread too thin.
How limitations would be overcome	Both groups recommended comparing the site with other sites. The exploitation of gradients within the site might increase the relevance of the results to some degree.	Involve good statistical team from outset. Appoint a good project leader. Collaborate /integrate with other initiatives (inc international). Incorporate natural gradients and measures of natural variation.	Control of sites. Nested experimental design will give greater depth, as would fewer sites.	International collaboration. Leverage of external funds to undertake policy relevant manipulations.

- **The single site approach:** The single site approach resulted in relatively few written comments from both groups. It was not supported by either group. This is largely because it was seen to be limited, both in terms of replication and the range of ecosystems that could be incorporated, and hence it would not have UK wide representative-ness.

- **The 4-6 multi-site approach:** The 4-6 multi-site approach stimulated a large number of comments from both groups that discussed it. One group was very enthusiastic about the ability to link this with ongoing agri-environment schemes and that this would have direct policy relevance and provide opportunities to leverage additional support. The other group was less enthusiastic due to concerns over control of any manipulations / treatments. Both groups recognised the strengths of the approach and listed several options to overcome all of the perceived limitations.
-
- **The 30-50 multi-site approach:** The 30-50 multi-site approach stimulated an intermediate number of written comments. It was noted that this approach provides an opportunity to incorporate replication and so build in UK wide relevance but would be expensive if implemented in full. As with the 4-6 multi-site approach concerns were raised over control of sites and manipulations / treatments.

- **The unconstrained approach:** The approach developed had at its heart the assertion that the UK is a biodiversity data rich country with much of this being provided by a range of disparate (research community - voluntary organisations) bodies. The aim would be to make this existing system work better through a strong investment in data, data management and data integration. This in turn would support a powerful modelling framework to encourage and enable research across multiple nested scales. Manipulation of sites would be '*costed outside of NERC(?)*'.

4.4 **Discussion**: A straw poll of participants showed that no one favoured the single site approach; there was a minimal level of support for the 30-50 multi-site approach (n=3); there was some support for the 4-6 multi-site approach (n=13) and the remaining (n=ca 30) participants favoured the approach promoted by the 'unconstrained group'.

5 Final Brainstorming

5.1 **Feedback at the end of the day:** The participants in eight groups of no more than eight participants discussed the day and gave verbal feedback. There were several widely supported messages:

- The initiative should be driven by the science rather than the delivery mechanism.
- Despite the progress that had been made on the day, more work would be needed to identify the highest priority over-arching question(s) or research framework.
- Once the question has been identified an expert panel should consider the best experimental design to address that/those question(s).

5.2 One participant commented that the workshop participants represented different sectors of the UK biodiversity research community, who are not used to working together because they typically ask questions in different ways and use different experimental approaches.

5.3 **'… things NERC should consider'**: All participants were asked to identify 'things NERC should consider'. These have been collated under four areas, the first three of which centre on identifying an appropriate research area for the action:

- *Identifying 'the' question* (n=12). These comments reiterated the feedback from the third session (see 5.1), i.e. that the overarching research question needed additional scoping, and that the question would determine the approach adopted.

- *Policy relevance* (n=5). The focus of any action should have societal / policy relevance.

- *Constructive suggestions / comments* (n=18). Suggestions for consideration in developing a large-scale action included: the need to work across spatial and temporal scales; the need for this to deliver real advances in understanding in five years; the effects of environmental changes, e.g. climate and habitat connectivity on biodiversity, should be the focus of the action; relevant research on-going in non-NERC Institutes should be considered, and the goals would need to be considered carefully to match the budget available and timescale proposed.

- *Other comments* (n=3). A small number of participants suggested that the proposed funds should be redirect to responsive mode.

5.4 The main conclusions and outcomes of the 16 December workshop are summarised in the introductory Section Summary

Section 4: Annexes – provided as separate pdf files

1 ANNEX 1: Workshop attendees

2 ANNEX 2: Delegate pack – marine workshop (15th Dec)

Includes introductory letter, briefing note and evidence collected from providers of current ecosystem scale approaches that was provided to workshop attendees prior to the workshops to provide a starting point for discussions

3 ANNEX 3: Delegate pack – terrestrial and freshwater workshop (16th Dec)

Includes introductory letter, briefing note and evidence collected from providers of current ecosystem scale approaches that was provided to workshop attendees prior to the workshops to provide a starting point for discussions

4 ANNEX 4: Pre-collected questions

Prior to the workshops, participants were asked to provide questions relating to a large-scale study of ecosystem sustainability. These were collated into three areas (i) Understanding critical processes and functions, (ii) Understanding trends and implications and (iii) Developing management solutions. These questions were used at the workshops as a starting point for discussion.

ANNEX 1 Workshop attendees

Marine Workshop, 15th December 2008

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*Workshop Chair **Speaker ***Rapporteur

Terrestrial and Freshwater Workshop, 16th December 2008

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*Workshop Chair **Speaker ***Rapporteur

Ecosystem Sustainability Scoping Study Workshop – Marine
Defra Innovation Centre, Reading
Monday 15th December

09 December 2008

Dear Delegate,

We are pleased to confirm that you have registered for the workshop on marine ecosystem sustainability scoping study workshop on the 15th December.

Registration will take place between 9.30 and 10am, and refreshments will be available on arrival. Please note that talks will start promptly at 10am, so please register early. The workshop will aim to finish by 4pm.

We attach the following information to ensure that we make best use of the time.

1. **Workshop Briefing Note** – Summarising the objectives of the workshop and the rationale for undertaking this action

2. **Evidence** – Collected from inviduals or organisations working on relevant programmes and initiatives

3. **Map and travelling instructions** for the Defra Innovation Centre.

We would greatly appreciate it if you could read the briefing notes and evidence documents before arriving at the workshop, so that we can optimise the valuable time that we have together.

If you have time between now and the 11th December, could you send me what you consider **to be the top three priority research questions that require a large-scale, long-term platform for delivery (maximum 50 words each).** These will be collated and used as a starting point for the workshop sessions.

We hope that you will have time to read this information and to think about the questions from the perspective of your organisation and from your own experience in studying ecosystems. You should also consider the needs of others in the community and seek opportunities to understand each other's viewpoints.

If you would like to claim for travel and subsistence to and from the workshop, please contact me and I will send you the NERC guidelines on T&S and a claim form.

To contact the innovation centre on the day of the workshop, please call: 0118 955 7800.

We look forward to meeting you at the workshop

Nichola Badcock

Ecosystem Sustainability Scoping Study Workshop – Marine
Defra Innovation Centre, Reading
Monday 15th December

Briefing Note

We are delighted that you have applied up to attend the workshop on the 15th December. We have about 50 confirmed delegates from a wide range of organisations and backgrounds. It promises to be an interesting workshop. We are also aware that each of you will have a different starting point and knowledge of the ecosystem suitability scoping study.

Workshop Objectives

This scoping exercise will identify and outline options for future planned activities in developing an unprecedented cross-scale biodiversity experiment of global significance to inform our understanding of biodiversity functions and processes across scales and systems. The programme options should be world-leading and integrated within the context of other national and international activities in this area. The purpose of the scoping activities is to:

(i) determine what the priority research questions are that require a large-scale, long term platform for delivery,

(ii) consider the advantages and disadvantages of different approaches to achieving the desired science outcomes (e.g. a single site approach vs multiple experiments vs a virtual observatory), and

(iii) determine the resources required to deliver a programme of this kind that will contribute to global initiatives in ecosystem sustainability.

Background Information

This scoping exercise directly relates to delivery of the NERC Strategy, in particular the Biodiversity theme. A greater understanding of the factors dictating ecosystem sustainability addresses the main Biodiversity theme challenge, "biodiversity in ecosystems, processes resilience and change". It is also relevant to specific challenges within the Biodiversity theme, challenges 2 ("detailed study of a single system to demonstrate a systems biology approach"), 4 ("biodiversity for life support), and 5 (tools for valuing the environment. There are also links with the Virtual Observatory action that would facilitate comparisons with distributed small-scale ecosystem projects, which has emerged from the Sustainable Use of Natural Resources theme.

This action would be the first large-scale, multidisciplinary investigation of the stability of ecosystems that are linked across major environmental gradients and the associated functional role of biodiversity at both the landscape and ecosystem level. This is an exciting opportunity to develop the essential paradigms that are currently lacking. Whilst the UK biodiversity research community is recognized as possibly the best in the world, much of the community has not been accustomed to working at cross-ecosystem landscape scales in multidisciplinary teams to identify the interdependencies between ecosystems, traditionally pursuing independent, focused research at small scales. This action will also demand new approaches and ways of working for the biodiversity research community. Specifically, many of the questions will need to be tackled at spatial and temporal scales in which society has a stake as well as bridging the sub-disciplines within natural sciences and working at the interfaces between the natural, physical and social sciences. It is proposed to harness this intellectual capacity to achieve new synergies to facilitate major science advances by allowing the community to work with a large-scale, integrated experimental platform at the landscape scale. The benefits of multi-disciplinary, large team efforts in field campaigns are well established in the marine and atmospheric sciences and the proposed experimental platform will deliver similar benefits for NERC's biodiversity programme. The action should run for enough time to allow incorporation of significant environmental variation into models (e.g. cold, warm and low and high precipitation years). This work will also put us in line with the highly successful US LTER programmes. It will also make a major contribution to providing policy makers with evidence needed to develop strategies to mitigate impacts of climate and other environmental change on biodiversity and ecosystem services.

This scoping exercise will outline options for a world-leading research programme aimed at improving our understanding of biodiversity, environmental gradients and ecosystem sustainability at large scales by providing (i) a step improvement in understanding of the role of biodiversity in ecosystems (ii) marked improvement in understanding of effects of change on biodiversity and ecosystems with concomitant enhancement of ability to predict future response scenarios, and (iii) a significant improvement in quality of advice to stakeholders.

Ecosystem Sustainability Scoping Study Workshop – Marine

Defra Innovation Centre, Reading

Monday 15th December

Evidence

Marine

- PML GLOBEC (Global Change and Marine Ecosystems) - Manuel Barange
- MarBEF (Marine Biodiversity and Ecosystem Functioning) – Carlo Heip
- MBA MECN (Marine Environmental Change Network) – Matthew Frost
- Oceans 2025 – Phil Williamson
- PGP Mesocosm Experiment – Ian Joint

Terrestrial and Freshwater

- CEH (Centre for Ecology and Hydrology) – Mark Bailey
- CPB (Centre for Population Biology) – Georgina Mace
- ECN (Environmental Change Network) – Don Monteith
- Ecological Continuity Trust – John Silverton
- LifeWatch – Terry Parr
- UKPopNet – Dave Raffealli

Virtual

- EcoGRID – Emiel van Loon

GLOBEC (Global Change and Marine Ecosystems)

A core project of the International Geosphere-Biosphere Programme, co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission of UNESCO (IOC)

GLOBEC, a study of Global Ocean Ecosystem Dynamics, was initiated by SCOR and UNESCO-IOC in response to recommendation of a joint workshop which identified the need to understand how global change, in its broadest sense, will affect the abundance, diversity and productivity of marine populations comprising a major component of oceanic ecosystems. The programme has four specific objectives:

1. To better understand how multiscale physical environmental processes force large-scale changes in marine ecosystems
2. To determine the relationships between structure and dynamics in a variety of oceanic systems which typify significant components of the global ocean ecosystem, with emphasis on trophodynamic pathways, their variability and the role of nutrition quality in the food web
3. To determine the impacts of global change on stock dynamics using coupled physical, biological and chemical models linked to appropriate observation systems and to develop the capability to predict future impacts
4. To determine how changing marine ecosystems will affect the global earth system by identifying and quantifying feedback mechanisms

GLOBEC was globally implemented in 1999[1], with a mandate to run until December 2009. It is therefore in its integration and synthesis phase. GLOBEC is coordinated through an International Project Office, based at the Plymouth Marine Laboratory. The IPO is co-funded between NERC and PML, and receives funding for its activities from USA-NSF, SCOR, IGBP, IOC, and had hoc support from a number of funding agencies.

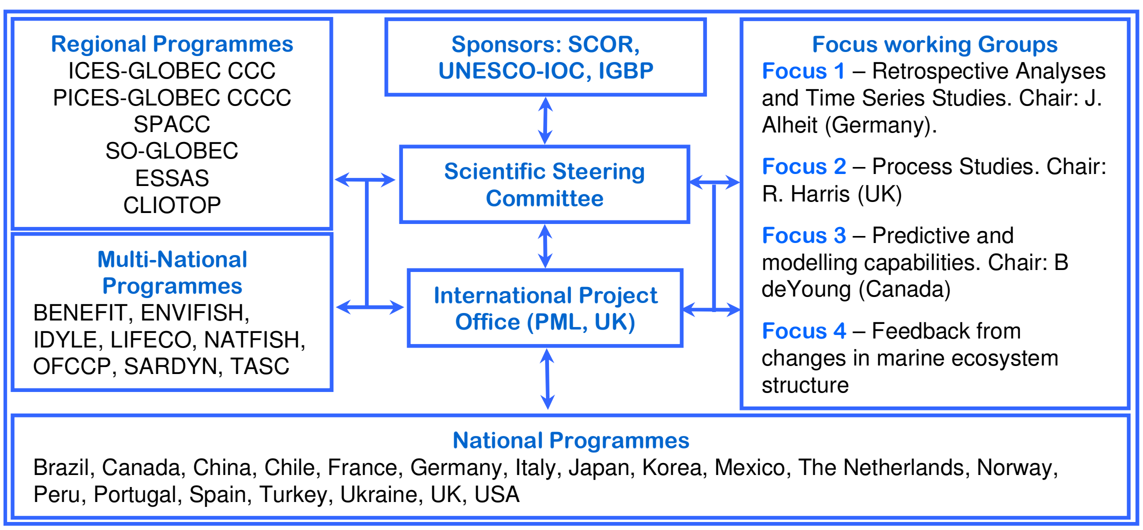

Figure 1. Programmatic structure of GLOBEC. See text for explanations.

GLOBEC has been implemented on the basis of national and multi-national field programmes (Figure 1). In addition, a number of regional programmes have been set up, to cover most marine ecosystem types and to recognise the basin-scale nature of many global change impacts. These are:

- ICES-GLOBEC Cod and Climate Change (CCC)
- PICES-GLOBEC Climate Change and Carrying Capacity in the North Pacific (CCCC)

[1] GLOBEC 1999. Global Ocean Ecosystem Dynamics. Implementation Plan. IGBP Report 47 and GLOBEC Report 13. 207p.

- Small Pelagic fish And Climate Change (SPACC)
- Southern Ocean GLOBEC (SO)
- Ecosystem Studies of Sub-Arctic Seas (ESSAS)
- CLimate Impacts On marine Top Predators (CLIOTOP)

Some national programmes (e.g. USA) and most regional programmes have there own support office that works closer with the IPO. Most of them also have there own steering committees or executive committees. In the case of regional programmes, these committees respond to the GLOBEC SSC and receive funding through it. Approximately 30 countries contribute to the research conducted at national, multinational and regional level. The North and South Atlantic and Pacific Oceans, the Southern Ocean and the equatorial Indian Ocean are the main implementing regions.

In addition, GLOBEC runs four working groups, designed to extract information from the field programmes and conduct activities conducive to integration and synthesis. The membership of working groups tends to reflect the national and regional programmes. Their mandates are:

- Focus 1 – Retrospective Analyses and Time Series Studies.
- Focus 2 – Process Studies
- Focus 3 – Predictive and modelling capabilities.
- Focus 4 – Feedback from changes in marine ecosystem structure

The work of GLOBEC has been summarised, among others, in 26 special issues in peer-reviewed journals, over 3,000 logged publications (2,600 peer-reviewed), 4 synthesis books (3 in press) and 10 international symposia (for the period 2000-2009). The final GLOBEC Open Science Meeting will take place in Victoria, Canada, 22-26 June 2009. In the last year of the programme GLOBEC will also put together a brochure of scientific highlights (research highlights are already selected and published annually) and a summary for policymakers, to complete its knowledge transfer requirements.

As requested by the theme leader, we will briefly address the following two questions:

Strengths and weaknesses of GLOBEC's approach

Without umbrella programmes global scientific synthesis (not global assessments) would be almost impossible to achieve. They certainly would not have the credibility and influence that umbrella programmes provide, partially because these are developed by large sections of the community and with non-partisan international support. By being strongly connected to international science and policy bodies, GLOBEC does influence research planning and the delivery of knowledge to decision makers. This approach also adds considerable value to the research investments conducted at national level and helps building capacity across large regions (one of our major goals). GLOBEC has been particularly successful in implementing work at regional level, working closely with policy and science bodies at that geographical scale to identify and resolve important questions. The lack of a single "unit" (like Carbon has been for other programmes) has made our synthesis more complex, and yet much more diverse and unexpected. The work has gradually focused more on impacts of global change to human societies and has become increasingly more multidisciplinary. In this sense it has develop frameworks of interaction between the natural, social and economic sciences, of broader use. On the negative side it is difficult to keep enough rotation at the management and scientific leadership level to ensure the effort truly represents a global consensus. Also, the success of working groups depends very much on the drive and vision of a few individuals. One of the reasons for our success has been the setting of a sunset clause, to ensure focus on our delivery and synthesis, as opposed to continued efforts with no planned end and moving objectives. Sunset clauses allow the community to revisit the science after some time and design fit-for-purpose programmes.

Indication of the costs (both of the programme and its management)

Most of the funding of GLOBEC is devoted to field work and is raised through standard mechanisms by national scientists. In addition, the GLOBEC IPO generates "glue money", to support workshops, publications, conferences and travel support. It is difficult to estimate the actual investment in GLOBEC's science. The US GLOBEC programme, for example, has invested USD140 M during its life. Globally this figure probably exceeds USD250 M, but different funding mechanisms preclude an accurate estimate. The international coordination of international project offices, including manpower, workshops, committees, publications, etc., has been estimated by the International Group of Funding Agencies (IGFA) to be typically of the order of US$500-750k per year, probably less than 2% of the research funding. In addition, substantial funding is generated by IPOs, so that their central funding can be consider an investment rather than a direct cost.

For more information, contact the Director of the IPO, Dr Manuel Barange, Plymouth Marine Laboratory, m.barange@pml.ac.uk, 01752 633160; www.globec.org

MarBEF: Marine Biodiversity and Ecosystem functioning

FP6 Network of Excellence: 95 Institutes (56 full members) across 24 nations and over 600 scientists involved

Introduction

Knowledge on marine biodiversity in Europe is fragmented within and between disciplines. The approach to understanding the effects of increased anthropogenic pressure on marine biodiversity has hitherto been ad hoc and local. In particular, to understand how marine ecosystems will adapt to climate change, we need addressing especially the long-term and large-scale changes in marine biodiversity. This requires an entirely new research framework.

The network of excellence MARBEF (Marine Biodiversity and Ecosystem Functioning) aims at integrating research efforts by forming a dedicated group of marine scientists and institutes and creating a virtual European institute with a long-term research programme and dedicated links with industry and the public at large. This involves besides coordination of research the training, exchange and outreach activities in several relevant fields of science, including marine ecology and biogeochemistry, fisheries biology, taxonomy and socio-economic sciences. Better integration of research is also required to support the legal obligations of the EU and its member states and associated states for the Convention for Biological Diversity, the OSPAR and Barcelona conventions as well as several EU directives (Bird Directive, Habitat Directive, Water Framework Directive) and the future EU Maritime Policy.

The network improves links between the academic and governmental institutions and the large and growing number of industries depending on the sustainable use and exploitation of marine biodiversity. This includes tourism, fisheries and aquaculture but also new industries that explore and commercialise marine genetic and chemical products.

MarBEF's primary objectives are:

1. To develop a better understanding of marine biodiversity and ecosystem functioning.

2, To understand and minimize the negative impacts of human activities.

3. To ensure sustainable management of natural resources and marine ecosystems as well as the protection of genetic resources.

MARBEF's primary goal is to create a virtual European centre of excellence in marine biodiversity and ecosystem functioning that will deliver the top quality science needed to underpin these three objectives.

The integrated science component

The integrated science component of the NoE has three general themes:

1.To understand how marine biodiversity varies across spatial and temporal scales, and between levels of biological organisation, in order to develop methods to detect significant change.

Research activities within this theme aim to understand, and assess marine biodiversity (species and genetic levels) on a global scale in an ecosystem context, taking into account the combined effects of the main drivers (anthropogenic and natural) in determining patterns in marine biodiversity.

2. To generate theory, models and tests of the relationship between marine biodiversity (assessed at different levels of organization: genetic, traditional species, and functional groups) and ecosystem function through the integration of theoretical and modelling exercises, comparative analyses and carefully-designed experimental tests.

This theme addresses the relationship between ecosystem functioning and biodiversity, and aims to predict the consequences of changes in biodiversity to marine ecosystems in terms of their stability and functioning, and on their ability to provide goods and services

3.To understand the economic and social value of marine biodiversity by developing the research base required to support the sustainable management of marine biodiversity, the monitoring of the health of marine ecosystems, the management of aquaculture, the conservation of marine biodiversity, the history of marine resource exploitation, and the leisure use of marine ecosystems.

This third theme addresses the socio-economic implications of marine biodiversity. The aim is to approach the social and economic implications through a range of initiatives, working at the interface between marine ecology and socio-economics, promoting research exploring the societal drivers leading to biodiversity loss, and ways in which these may be reduced.

Organisation

The NoE is organised in 10 workpackages of which three address primarily the integrated research objectives of MarBEF. The work within the three research themes are organised in a two-way approach:

1. A top down organised Core Strategic Programme (CSP) ensuring that the main goals of the network are being reached, supplemented with
2. Bottom up organised (dedicated) Responsive Mode Projects (19 RMPs) that fill in the gaps of the CSP.

Methodologies (site related approaches)

Theme 1, and some of the RMPs within it, are working with a set of large integrated databases containing primary biodiversity data of a network of sites, contributed by the individual participants. IPR is an important issue.

The work of theme 2 is primarily organised around the activities of the individual RMPs. Depending on the research focus of these RMPs, the projects are focussed on a network of sites, or processes linked to spatial patterns.

The science within theme 3 is either conceptual, linked to specific case studies (sites), and/or linked to spatial patterns, or general processes (functions).

Strength and weaknesses of the approach

+ The combination of the top down and bottom up approach works very well.
+ The commitment within the RMPs is very high
+ The investment of the participants in MarBEF is very high
- The managerial burden (paperwork) for the participants (full members) is too high
- The lack of a future for large NoE’s within FP 7 and beyond complicates the development of a long lasting infrastructure for the network and the consortium commitment
- It remains difficult to get end users (policy makers, politicians) involved
- The investment of the participants in MarBEF is very high: therefore a high value for money is delivered which is not in balance with the market principle of the members involved in strategic (applied) science.

Estimation of costs

The total budget of MarBEF is 8.7 Milion €. Total management costs are maximal 7% of this budget. Because of mainly the management requirements for the EC, the management costs most probably will exceed this limit.

Marine Biological Association of the UK

The MBA has been involved in systematic observations of the marine environment for over 100 years. The MBA has an international reputation for global environmental change research based on the extensive time-series that the laboratory has collected since the start of the twentieth century, coupled with laboratory and field experimental research into the mechanisms behind species responses to both acidification and warming of the world's oceans. The MBA receives substantial funding from a variety of Research Council and other sources for both blue skies and strategic research, including the NERC Oceans 2025 marine science strategic programme. The laboratory is ideally situated in an oceanographic breakpoint region where cold boreal and warm lusitanian waters meet, and conducts monthly benthic sampling at multiple sites in this area to monitor ecosystem fluctuations in response to environmental change. The MBA has an extensive seawater aquarium with both treated and untreated seawater supplies sourced from directly below the laboratory in Plymouth Sound. Facilities include controlled environments where temperature, seawater chemistry and irradiance can be artificially manipulated for open or closed experimental seawater systems. This resource plays an integral role in research programmes investigating environmental change and impacts on marine biodiversity, providing an essential facility for long-term holding and conditioning of species in thermally and pH-controlled environments. The MBA also has a state-of-the-art cellular and molecular suite which is being used to pursue novel research into the impact on biological mechanisms of global climate change.

The Marine Biological Association has several research programmes dedicated to environmental change and biodiversity, and hosts the national Marine Environmental Change Network. It is a core member and data contributor to the Western Channel Observatory and the MECN also functions as the Knowledge Transfer and Exchange mechanism for this web-based resource. Both the MBA and the MECN are active members of the MarBEF European Network of Excellence. These programmes and organizations are interlinked within the MBA to provide an holistic approach to the detection, quantification and prediction of the effects of global environmental change on the marine environment.

Marine Environmental Change Network

In 2002 the Marine Environmental Change Network was established by DEFRA and the Marine Biological Association of the UK in response to the cross-sector recognition of the need for the continuation, restoration and enhancement of marine observations around the UK (Inter Agency Committee for Marine Science and Technology, 2001). MECN has brought together seventeen major groups from the research and university sectors responsible for maintaining long-term recording of the marine environment around the British Isles, and is expanding to incorporate government agencies with long-term monitoring programmes.

MECN's strengths lie in the cross-cutting nature of the datasets and monitoring from the partners. The time-series and long-term research programmes maintained and re-started by these MECN partners are unique due to the length of time over which measurements have been collected (many are multi-decadal) and the number of environmental and biological parameters which are measured. These cover intertidal, subtidal and nearshore benthic and pelagic systems. Multiple recording sites have been established for each parameter, enabling MECN to provide information at local, regional and national scales. MECN is a member of the FP7 Network of Excellence MarBEF, and is involved with the MarBEF LargeNet European database project. Several UK datasets have been submitted to LargeNet via MECN, and MECN in turn has access to this European database covering pelagic, soft and hard benthic systems, allowing MECN to provide information at the European scale. MECN is in the process of linking with the terrestrial Environmental Change Network to promote a large-scale, cohesive 'catchment-to-coast' approach encompassing both systems, and to integrate common data collection and archival standards across the natural ecosystems within the UK. Via links to Lifewatch, this will also be extended to the European scale. Weaknesses are focused around the multi-source funding structure of the varu

MECN also functions as a conduit between scientists and policymakers and stakeholders, with the remit, '*to ensure that information from the network is provided to policy makers and other end-users to enable them to produce more accurate assessments of ecosystem state and gain a clearer understanding of factors influencing change in marine ecosystems*'. Information on long-term trends in the marine environment has been given to the relevant government bodies to provide the context in which climate impacts (and other factors) can be assessed. MECN has also initiated scientific collaborations between the MECN network partners and meta-analyses of multiple datasets from the network to answer emergent questions regarding the state and changes to the UK coastal marine ecosystem.

Fig.1. MECN partner institutes.

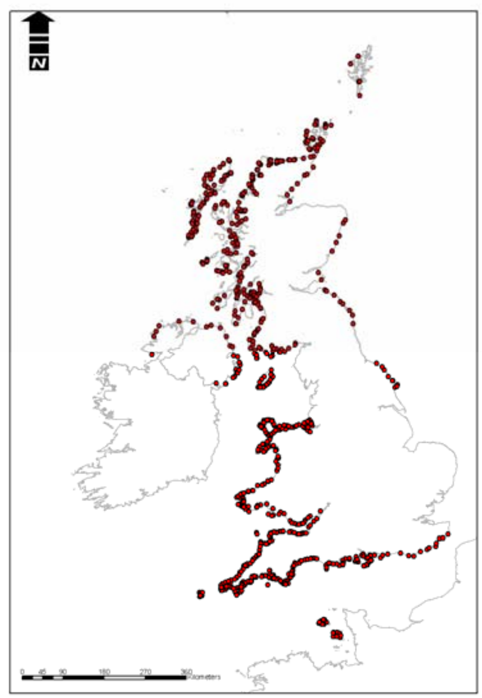

Fig.2. Rocky intertidal survey sites in the UK

Marine Biodiversity and Climate Change

The MBA maintains several long-term time-series, which include some of the most temporally extensive datasets globally. A suite of parameters are regularly measured including temperature, salinity, phytoplankton, fish, rocky intertidal and soft sediment benthos. Several research projects at the MBA use these time-series as a basis for process-driven research into the impacts of climate change including behavioural, physiological, cellular and molecular responses. The rocky intertidal time-series captures data from over 400 locations around the UK coastline (Fig.2), and has been extended to coverage of the Atlantic coastline of Europe and Scandinavia. A collaborative project with the National Institute for Water and Atmospheric Sciences, NIWA has established the first biodiversity baseline in New Zealand for the monitoring of future climate-driven changes to marine biodiversity. The multi-site, temporally extensive nature of the datasets allow ecological responses to climate change to be tracked in different components of coastal and shelf ecosystems. Weaknesses again centre on the short-term nature of funding. Approximate costings for the maintenance of the time-series and the associated research are £350,000 p.a.

Large-scale biodiversity, environmental gradients and ecosystem sustainability

Oceans 2025 perspective for NERC Biodiversity Workshop: 15 Dec 2008

1. The (marine) challenge

1.1 The variety of animals, plants and microbes has a profound effect on marine pathways and processes, and can be highly sensitive to natural environmental forcing and human pressures. Our knowledge of the functional significance of marine biodiversity is, however, extremely limited. A much more rigorous understanding is needed to develop the generic models and other tools that will not only reliably detect and predict ecologically-important changes, but will also assist in achieving sustainable bioresource use, soundly-based marine spatial planning, and national compliance with statutory requirements for 'good environmental status' in UK waters[1], from coasts and estuaries to the depths of the open ocean.

1.2 The Oceans 2025 programme, a partnership of seven NERC-supported Centres, addresses this complex challenge through a Biodiversity component (Theme 4) strongly linked to other programme elements. The scale of the marine environment — providing 97% of the global biosphere, with its organisms mostly unknown[2] — makes it crucial to coordinate Oceans 2025 effort with other relevant research activities, maximising the return from current investments in skills and capabilities. In particular, the development and delivery of NERC's Biodiversity Theme Action Plan provides a unique opportunity to accelerate scientific advances at a national scale, by fostering synergies, supporting ambitious large-scale initiatives, and complementing terrestrial and freshwater research effort.

2. Biodiversity research in Oceans 2025

2.1 Theme 4 of the Oceans 2025 programme, Biodiversity and Ecosystem Functioning, is jointly implemented by Plymouth Marine Laboratory (PML), the Scottish Association for Marine Sciences (SAMS), and the Marine Biological Association (MBA). Total effort is ~11 FTE pa. Its objectives are:

- to identify the critical species-level processes needed for next-generation ecosystem models that will characterise the effect of marine biodiversity on ecosystem functioning
- to understand how resilient and predictable marine ecosystems are in response to environmental change, including habitat modification, species loss and species invasions, in realistic physical environments
- to determine the role of trophic interactions in controlling energy flow, and in contributing to the diversity and structure of marine ecosystems and their response to change
- to identify the important temporal and spatial scales of variation in coastal marine biodiversity
- to describe links between biodiversity and ecosystem function at different levels of biological organisation and complexity.

2.2 The delivery of the above is intimately connected to other Oceans 2025 work at PML, SAMS and MBA and at the National Oceanography Centre Southampton (NOCS), Proudman Oceanographic Laboratory (POL), Sea Mammal Research Unit (SMRU), and the Sir Alister Hardy Foundation for Ocean Sciences (SAHFOS). Thus there are biodiversity-related activities in seven other Oceans 2025 themes: Climate, circulation and sea level change (Theme 1), Marine Biogeochemical Cycles (Theme 2), Shelf and Coastal Processes (Theme 3), Continental Margins and the Deep Ocean (Theme 5), Sustainable Marine Resources (Theme 6), Next Generation Ocean Prediction (Theme 9), and Sustained Observations (Theme 10). Two Oceans 2025-supported national facilities are also directly involved: the British Oceanographic Data Centre (BODC) and the Culture Collection of Algae and Protozoa (CCAP)[3].

[1] The EU Marine Strategy Framework Directive requires that (by 2020) "1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions. 2) Non-indigenous species introduced by human activities are at levels that do not adversely alter ecosystems. 3) Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution indicative of a healthy stock. 4) All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity....".

[2] The World Register of Marine Species (WoRMS, part of the Census of Marine Life) has estimated that only ~25% of marine species are known to science; see www.marinespecies.org/news.php?p=show&id=349. However, this estimate does not take account of prokaryotes, archaea and viruses, that in metagenomic analyses provide the overwhelming majority of marine genetic diversity.

[3] Note that ~65% of CCAP holdings are non-marine, isolated from freshwater and soil. This is reflected in CCAP's current research.

2.3 In addition, the Strategic Ocean Funding Initiative (SOFI) and the Sustainable Marine Bioresources programme (SMB) support biodiversity-related collaborations between the Oceans 2025 researchers, university groups and other partners, through 8 research grants, 3 studentships and (to date) 3 workshops in this topic area. A summary of biodiversity research in Oceans 2025 is given at Annex 1; further details of the programme are available at www.oceans2025.org.

2.4 It should be noted that marine Centres in the Oceans 2025 programme receive funding from a range of non-NERC sources for biodiversity-related research, and participate in many national and international activities and networks, e.g. Census of Marine Life (CoML, www.coml.org), and the EU Marine Biodiversity and Ecosystem Functioning network of excellence (MarBEF, www.marbef.org).

3. Why biodiversity research needs to be multi-scale, multi-disciplinary and technologically-sophisticated

3.1 Spatial and temporal scaling issues are fundamental to a functional approach to marine biodiversity. Most research to date has been limited to a sub-set of the biota — such as benthic invertebrates, zooplankton, or fish — usually in the mm-cm size range, and with experimental studies typically at the 1 – 10 m scale. However, ecologically-significant interactions occur across the full taxonomic spectrum and size range, from viruses to whales; 'invisible' organisms dominate energy flows and elemental cycling in most marine ecosystems; population processes, habitat landscapes and hydrodynamic structuring operate on relatively large scales (from 10 m to 1000 km); behaviour may determine genetic differentiation within geographically-distinct biomes; and the problem of invasive, non-native species requires comprehensive knowledge of both their original and new environments.

3.2 Temporal scaling considerations are similarly broad, covering the range from diurnal to seasonal variability in gene expression and species' abundance; historical patterns of human impacts; the geological time scales that have shaped phylogeny and present-day distributions (e.g. Arctic – Antarctic differences); and the need to predict responses to management actions (both conservation and exploitation) and interactions with climate-driven regime shifts that may already be underway.

3.3 As indicated from the above, the importance of non-biological influences on biodiversity necessitates a multi-disciplinary approach. Thus what-lives-where is a function of *inter alia* lateral and vertical water movements; mean, seasonal and extreme temperatures; salinity and other aspects of water chemistry; and sediment/substrate characteristics. For photosynthetic organisms, light and nutrients are also key parameters. This need for supplementary data on many physico-chemical factors requires additional effort; nevertheless, it assists in giving strategic context, focusing attention on the responses of populations, species and trophic interactions to environmental change (e.g. ocean acidification; temperature-induced stratification or mixing) and associated biogeochemical feedbacks.

3.4 Technologically-sophisticated sampling platforms and analytical technologies are also increasingly needed for marine biodiversity work. Whilst most inshore and coastal ecosystems can be accessed relatively easily and reasonably frequently, open ocean studies require either the sampling and experimental facilities of a well-equipped research vessel, or *in situ* instruments on towed gear, autonomous vehicles, landers or moorings. Ships-of-opportunity have an important role for plankton surveys and other upper ocean measurements, although constrained by sampling depth and the range of organisms that can be collected and preserved for subsequent identification.

3.5 Molecular-based methods are now standard tools for analysis of genetic structure and, increasingly, the definitive descriptor of species identity[4] (e.g. GenBank/EBI accession numbers for rDNA sequences and other molecular markers are now provided with CCAP strain information). A barcode system is being developed to characterize protistan biodiversity by CCAP, with international collaborators. In addition, metagenomic libraries provide a way to link function with phylogeny, thereby facilitating the discovery of novel biochemical processes and products with biotechnological applications. Several other technologies, e.g. image analysis, flow cytometry and HPLC-based chemical taxonomy, also offer new opportunities for sample sorting and characterization, although are not yet fully practical for routine species-level identification.

[4] Identification problems have bedevilled biodiversity research. The 2008 WoRMS analysis [footnote (2)] demoted 56,400 marine "species" to alias status, almost a third of all names culled from 34 national and international inventories. Some species are morphologically very different under different conditions, e.g. genotypically-identical algae that are unicellular in freshwater whilst filamentous in the marine environment; others may only have a single species name, yet encompass very wide genetic diversity.

3.6 For both shelf sea and deep water work, multi-spectral satellite remote sensing and physical modelling (e.g. using particle tracking techniques) are now near-essential for scaling-up from point measurements or transects to synoptic habitat, biome or ocean-basin scales. All expertise need not be within the same institution; however, biodiversity researchers, remote sensing experts and physical modellers need to be aware of each others' needs, capabilities and limitations.

4. Strengths and weaknesses of Oceans 2025 biodiversity research

4.1 *Strengths*. Biodiversity work within Oceans 2025 involves a very wide range of taxonomic expertise (molecular and traditional) and covers diverse habitats, over a wide spatial range. It benefits from well-studied sites (several with globally-unique historical records), excellent experimental facilities and culture collections; in addition, it is strongly linked to modelling, biogeochemistry, remote sensing and other technologies. Within the biodiversity theme, there is no single 'approach' and effort is directed at the following issues (each as a separate Work Package):

- The characteristic scales of variation in biodiversity in coastal and shelf seas
- Linkage between benthic dynamics and pelagic ecosystem functioning in shallow seas
- The influence of biodiversity on ecosystem functioning at different levels of organisation
- Contrasting roles of predators and prey in energy flows
- Microbial mediation of primary productivity and algal biodiversity
- Linkages between habitat complexity, size diversity, and invasion-related changes in species diversity to the delivery of ecosystem services
- Functional responses of intertidal assemblages to environmental change.

4.2 *Weaknesses.* The above WPs and the programme objectives (para 2.1) can be considered over-ambitious, with the different marine Centres arguably tackling too broad a range of scientific problems, in too many different ways – and lacking an overall theme. Whilst the Oceans 2025 programme will undoubtedly advance understanding in these areas, it is unlikely to definitively answer the scientific questions posed. However, it should be remembered that the Oceans 2025 was developed as a coordinated programme, not an integrated one; furthermore, there are many linkages to other programme elements, making the problems more tractable than might appear.

Annex 1 Summary of biodiversity expertise and interests at Oceans 2025 Centres

Centre	**Main biodiversity interests and activities** *not all funded via O2025*	**Main groups**	**O2025 Themes**
MBA	Recruitment and survival in intertidal assemblages; coccolithophore genomics and biogeochemistry ; virus genetics and ecology; fish genetics and distributions ; benthic invertebrates; non-native species. Co-lead for WCO; host for Marine Environmental Change Network (MECN), Marine Life Information Network (MarLIN) and Data Archive Centre for Seabed Species and Habitats (DASSH)	Macro- and micro-algae, viruses, fish, invertebrates	T2, T4 T6, T10
NOCS	Deep sea benthos, including continental margin canyons, mid-ocean ridges, vents and seeps; chemosynthetic ecosystems; 'twilight zone' midwater fauna; acidification effects on calcareous phytoplankton; ecosystem modelling. Lead for PAP observatory, co-lead for AMT	Benthic and planktonic invertebrates, micro-algae	T2, T5 T9, T10
PML	Benthic-pelagic interactions; effects of microbial biodiversity on biogeochemistry; molecular characterisation; biotechnology; zooplankton dynamics; ocean acidification effects; remote sensing; ecosystem modeling; links to socio-economics. Co-lead for WCO and AMT	Bacteria, viruses, micro-algae, zoo-plankton, benthic invertebrates	T2, T3 T4, T6 T9, T10
POL	Ecosystem modeling; linkage between physics and plankton production in shelf seas. Lead for Irish Sea coastal observatory, host for BODC		T3, T6 T9
SAHFOS	Basin-wide plankton surveys and data analysis, using ships of opportunity	Zoo- & phytoplankton	T10
SAMS	Predator-prey relationships, intertidal fauna, fish population dynamics, bacteria-algae interactions, algal productivity, molecular taxonomy, habitat complexity, aquaculture impacts, artificial reefs, deep sea benthos incl cold-water corals, regime shifts. Lead for Arctic shelf time series; host for CCAP (marine, freshwater and terrestrial) and Euro-CoML.	Phytoplankton, macro-algae, protozoa, benthic invertebrates, zooplankton, fish	T1,T3 T4, T10
SMRU	Distribution and abundance of sea mammals, trophic dynamics	Seals, other marine mammals & their prey	T10

Annex 2 How a large-scale study of (marine) biodiversity might be developed

i) The proposed focus on either 'ecosystem function', 'ecosystem services' or 'sustainability' for a large-scale, experimental approach has attractive features as the central idea, emphasising the importance of the biodiversity-environment relationship. However, those concepts are all highly complex, potentially involving a wide variety of science questions, and, depending on their prioritisation, requiring very different experimental designs. Even if ecosystem services are considered only from a human perspective, more than a dozen issues are potentially involved[5].

ii) Large-scale (and hence high-cost) biodiversity studies that are limited to academic considerations are difficult to justify in current national economic conditions. 'Sustainability' implies that the biological components have resource (human use) value and are subject to external forcing. We therefore suggest that the first question to be considered by the workshop is whether the dominant forcing to be investigated is climate change or marine management — noting that both these approaches provide opportunities for freshwater and terrestrial comparisons.

Option A: Focus on climate change

iii) Empirical analyses of latitudinal diversity patterns — and their temporal changes — among different functional groups, trophic levels and across major environmental gradients can suggest possible mechanisms for the climatic regulation and role of biodiversity. 'Data mining' of distributional and abundance information collected over long time periods and large spatial scales (e.g. the Continuous Plankton Recorder survey, CPR), has provided many insights in this regard. However, correlations are not always causal: definitive understanding must be obtained by hypothesis-testing, typically through relatively small-scale experiments embedded within a wider observational network. Critically, the experimental work should inspire and drive the production of large-scale system models that allow further testing of the climatic mechanisms driving large-scale biodiversity patterns and ultimately deliver ecosystem-level understanding.

ii) A latitudinal-based approach could productively be based on:

- Ongoing information provided by the Western Channel Observatory (designated as National Capability within Oceans 2025, and chosen as a prime Long Term Biodiversity Research site in a new EU Concerted Action, Biomare; www.westernchannelobservatory.org.uk).
- A second northern temperate coastal/shelf sea site, such as the fjordic system of western Scotland near Oban, with existing data on fishery recruitment, intertidal invertebrates and macroalgae, sediment dynamics and benthic processes and anthropogenic impacts
- Two polar coastal sites, one in the Arctic (e.g. Kongsfjord, Svarlbard as studied by SAMS since 2002) and another in the Southern Ocean (e.g. at Rothera, planning to be led by BAS).
- A deep ocean site, such as the Porcupine Abyssal Plain observatory (PAP, at 46°N 16.5°W), supported by NOCS under Oceans 2025 There are existing PAP seasonal and multi-annual data for pelagic and benthic communities, and additional mooring-based automated instrumentation will be deployed in 2009. Wider deepwater comparisons would be achieved via the EuroSITES network.

iii) Experimental and observational studies at the above sites would be complemented by basin-wide sampling and data gathering, through the CPR study (mostly North Atlantic but some Pacific and Southern Ocean data, and new Arctic routes); the Atlantic Meridional Transect (AMT), with underway biotic sampling linked to biogeochemistry, physical oceanography and remote sensing.

Option B: Focus on marine management

iv) The main science issue would relate to maximizing the benefits (in terms of biodiversity and biodiversity-based ecosystem services) for marine protected areas, applicable to both shelf seas and deep water. Many opportunities for experimental work related to marine renewable energy developments, fishery management and marine conservation are developing in these areas. Additional information on such ideas will be presented in informal discussion by Oceans 2025 representatives at the workshop.

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[5] These include gas and climate regulation; nutrient cycling; bioremediation of waste; provision of food and raw materials; leisure and recreation; resilience and resistance; biologically-mediated habitat; disturbance prevention; cognitive values, cultural heritage and identity; and non-use and option-use values.

Contribution to the Ecosystem Sustainability Scoping Workshop

PGP Mesocosm Experiment May 2006

Background

The PGP Thematic Programme funded a project on the role of marine microbes in biogeochemical cycling. In the proposal, we identified an experiment to assess the potential impact of ocean acidification on marine microbial diversity and function. This idea of a large project experiment was influenced by my experience from many NERC directed programmes in marine science, where grant holders worked together on a research cruise, usually on different aspects of a particular environmental problem. Each of those experiments was a success and I felt that it would be a good way to bring together the different groups involved in the PGP project to study a significant ecological problem.

Objectives

This was a single site, single experiment to investigate how elevated carbon dioxide concentrations might affect marine microbial diversity in the future. Within 100 years, the CO_2 concentration in the surface ocean is projected to be 750ppm; this increase in pCO_2 will reduce pH from the current value of 8.1 to ~7.8. This is a significant change that will influence chemical speciation as well as resulting in the dissolution of calcium carbonate shells of coccolithophores and corals. The effect on diversity of other phytoplankton and bacteria are not known. Mesocosms offer many advantages over small-scale laboratory experiments. By enclosing large volumes of seawater, we could easily manipulate pCO_2 (and hence pH) by bubbling for a few hours with CO_2 enriched air. Large water volumes ensure that most of a complex ecosystem can be captured (in this case, phytoplankton, bacteria, archaea, viruses, protozoa and zooplankton).

Facilities

We did the experiment at the Large Scale Mesocosm research facility of the University of Bergen, Norway. I had previously been involved in an experiment at this facility so I knew the advantages and disadvantages; I had a good idea of whether or not we would be able to do the experiment that we planned. Briefly, the facility is self-contained, with laboratories and accommodation (self-catering) on the site. Importantly for our needs, there was a fully serviced raft (boats, electricity and water) permanently moored in the middle of the fjord, with floatation collars from which to attach our mesocosms (basically large polyethylene bags of ca. 12000L capacity). So we were following a long line of mesocosm experiments on marine microbes that have been done at Bergen.

Success of experiment

The experiment was successful at many levels.

- There was a high level of ‘buy-in’ from the grant holders and 5 of the PI’s each spent at least 1 week at the facility (2 were there for the whole 4 week period of the experiment). Every group, with the exception of one (out of 13), sent post-docs and students (the group that did not participate was working on benthic microbiology and the experiment was not relevant to their project).

- It was scientifically successful; since we were a large group (always at least 20 people at the facility at any one time) we were able to measure a large number of parameters and processes.
- We were able to attract other research groups to participate in the experiment. So for example, the biogas groups at PML and UEA were able to take samples from our experiment for their own projects that were not directly related to microbial diversity. We also had international participation with Bergen and a group from Germany.
- There was a high degree of interaction and integration between the different Universities and laboratories that are funded by the PGP grant. Because people were working closely together, strong and lasting collaboration was developed between most of the groups that participated in the experiment. In my experience, this is one of the greatest benefits of a large experiment.

Costs and management aspects

1. The cash cost of the actual experiment was about £50000 but there were additional costs such as metagenomic sequencing that are of an equivalent scale. So in planning an experiment, it is important to know how much it will cost to analyse the samples. In my experience, you should not that these costs will be found out of standard grants.
2. I had to commit a very large amount of my time to organising this experiment. NERC refused a request in the grant application for money to provide administrative support for the whole project. So I had to do most of the administration, as well as doing my own research. Do not underestimate the time it will take to plan a large experiment. In our case, the bureaucracy included obtaining customs carnets to allow every participating research group to send their equipment to Norway (outside the EU), arranging transport of equipment, ordering of chemicals and radiochemicals for delivery in Norway (since it is difficult to ship chemicals from one country to another), liaising with staff at Bergen etc. etc. Any large experiment planned by NERC in the future should be funded appropriately and supported by a relevant level of funding for administrative support.
3. We could not have done the experiment without the support of the PML. I was able to call on technical support to help with tasks such as designing effective bubbling systems to rapidly increase pCO_2 in large seawater volumes. PML also provided a wide range of sophisticated equipment, such as flow cytometers and nutrient analysis equipment, vehicles to transport equipment to Norway etc., etc. Make sure that whoever is planning a large experiment has the infrastructure necessary to carry out the experiment and see it through to the end.
4. Do not underestimate the level of commitment that will be required by the person leading the experiment.

Ian Joint

6 November 2008

Input from the NERC Centre for Ecology & Hydrology: NERC BD Theme scoping study on large scale biodiversity, environmental gradients and ecosystem sustainability; Terrestrial and freshwater communities, December 16 2008. This document provides 1) A brief description of our programme/initiative(s), our aims, objectives and methodologies (e.g. single large site, multiple smaller sites, virtual), 2) a concept for a large scale experiment including an assessment of the strengths and weaknesses of our approach?, and 3) an indication of the costs and programme/initiative management associated with the work.

Contact Mark J. Bailey (mbailey@ceh.ac.uk) / Sarah L. Turner (sltu@ceh.ac.uk).

1. Brief description of CEH activities. CEH have a history of undertaking multi-scale, long-term monitoring and experimentation to detect, predict and understand the drivers of environmental change on species, communities and ecosystem processes. CEH is structured into three Science Programmes, Biodiversity, Biogeochemisty and Water all supported by the Environmental Information Data Centre (EIDC) to facilitate the interpretation of findings, and the gathering and dissemination of data of national and international importance.

CEH Programme research is enhanced by the interdisciplinary coordination of activities that draw on a range of expertise in ecology, genetics, hydrology, informatics, biogeochemistry, atmospheric sciences, land use, ecosystem science, remote sensing and earth observation coupled to stakeholder engagement. Our research is typically undertaken with Universities, Research Institutes and NGOs; it scales from highly controlled laboratory and microcosm studies to national and ever international scales. CEH has four sites, enabling our expert staff access to field sites representative of a range of habitats spanning environmental gradients at different scales. Working across scales is also achieved through extensive modelling expertise enabling CEH to implement systems approaches to environmental research.

CEH provides, in partnership, internationally recognised surveys and the operation of Environmental Observatories (e.g. **Countryside Survey**, **Environmental Change Network (ECN), Lakes Monitoring, UK-Phenology Network, Plynlimon, UK-Atmospheric Chemistry and Air Quality Monitoring Network, Isle of May Long Term Study, LOCAR, Carbon Catchments**, etc.). In addition, CEH provides extensive spatial and temporal datasets and integrated data products (e.g. **Biological Records Centre, Non-Native Species Portal, National River Flow Archive, NERC Bioinformatics Facility, Nutrient Flux and Deposition Maps, Land Cover Map & CORINE**, **Soils Carbon & Soils Moisture Assessments,** etc.). These underpin our curiosity led research, and model development for prediction testing and understanding by providing 'baseline' data, of the status and trends in dynamics of biota and the environmental factors influencing them.

CEH also undertakes hypothesis driven field studies on 88 lowland, 44 upland and 33 freshwater sites that encompass most broad habitat types including forests, heaths, lakes, rivers and wetlands. These experiments span the range under consideration at the Ecosystem Sustainability Workshop.

1. **Long-term, large-scale single site** experiments that study land use change impacts on biodiversity, water quantity, water quality, soil moisture, pollutant inputs, etc
2. Manipulation of **multiple smaller scale sites**, a few examples include the Large Blue reintroduction and restoration sites; EU upland warming and droughting experiments at Clocaenog and Peaknaze; assessments of different land management scenarios (e.g. Pontbren, RELU projects, Somerset Levels) including a 1000 ha replicated experiment with Natural England to quantify the effectiveness of Entry Level Agri-environment Schemes.
3. The EIDC is leading an initiative to provide access CEH data sets and establish **virtual** linkages among these to enable us to exchange ideas and expert interpretation to identify novel patterns of biodiversity stock and change, their causes and the likely societal implications.

Having experience of all three experimental systems, CEH appreciate the strength and weaknesses of each, ranging from issues associated with (pseudo)replication, or lack their of, and issues to do with the extrapolation / relevance of detailed results from a single site vs the ability to detect common responses when experiments are undertaken across a range of geographical/habitat contexts. Similarly we are aware of the resource needs to gather suitable data associated with each approach.

2. CEH Concept for a large scale experiment to assess ecosystem functioning.

- **Overarching question:** *How can we manipulate landscapes to allow biodiversity to respond to climate and land use change?* (**More details and an example are provided in Annex A**).

Our concept describes a generic approach for large scale experimentation, built on practical and relevant hypothesis testing. The approach we describe **is adaptable**; it is based on the study of one or more **Broad Habitat Types** (BHT) within a defined 'landscape' area e.g. 10km by 10km. The responses within a treatment area will be compared with those in a paired untreated area. Working across a 'landscape' block will provide information at different scales - from consideration of responses within local 'patches' up to the interactions between patches within the 'landscape' block and, if replicated, it will have broader relevance up to national scales. This builds on the success of the Farm Scale Evaluation approach and provides a conceptual framework for national activity. An initiative of this type will draw additional benefits from international LTER and LifeWatch initiatives and underpin LWEC.

This approach is based on a **large-scale multi site approach**, which has its good and bad points. We recognise the value of specific targeted, single site experiments but believe that a distributed system is essential to provide a platform on which to coordinate the study of ecosystem function and sustainability in the managed landscape of the UK, and for the results to have national relevance.

Strengths and Weaknesses. These are difficult to judge until the question has been identified and the experimental system and design developed. However, one strength is that it will operate at a landscape scale which is relevant for many of the most important processes that will influence climate change impact and adaptation. Smaller scale systems have considerable virtues; they are easily modified to contain internal controls to address specific issues but they rarely address multi-scale processes or drivers which act over whole landscapes. Landscape-scale studies can address these issues, but are difficult to design and manage; they require complex agreements with land-holders and consistent implementation of manipulations over time. To be successful policy direction and national coordination will be necessary. Replication may be a challenge. Environmental Observatories and experimental platforms are needed for the UK. These 'landscapes' would provide a platform into which other manipulations could be integrated e.g. affecting a different BHT. This ability to add in new treatments and experiments would require a highly coordinated and structured data management system, that might in effect evolve into an expanding virtual experiment. In many areas the use of shared data portals and knowledge transfer is an established international practice. However, data sharing and universal cooperation remains patchy. To be successful long term funding is required to establish and maintain such a system, this directly complements actions within the NERC SUNR Theme.

The long term benefits of large scale, coordinated national actives are obvious and link across all NERC Themes, LWEC and international initiatives. They provide the only means of quantifying the complex impacts of environmental change and the only true test of the effectiveness of possible adaptation strategies across landscape and catchment scales. They also provide invaluable platforms for smaller-scale, habitat-specific mechanistic studies of key ecosystem processes and services Working across scales will require the development of remote sensing technologies and ground-truthing of existing interpretation methodologies for sustainable land management.

3. Cost. To deliver a study of the type described we anticipate that a programme of 30 FTE/yrs of PDRA time and 10 students would be required over a 5 year period. This could be extended or contracted depending on scale, outcomes and the evolution of questions. In addition we anticipate that NERC Centres (CEH and BGS) would provide expertise, data and knowledge in the form of National Capability to align monitoring and survey. The objective is to establish recognised Environmental Observatories for manipulation and scenario testing, the ERFF (EOF) have a direct role to play. Such an initiative would be a national initiative and would require direct involvement with policy makers (Defra, NE), land owners, land managers, the utilities, UKRC etc.; all essential for long term planning, funding, communication and interpretation. Critically landscape scale manipulations include the urban environment and further coordination with the social sciences and environment and health are essential.

Annex A:

A Large-Scale Experiment (LSE) to address the question: *How can we manipulate landscapes to allow biodiversity and associated ecosystem functions to respond to climate and land use change?*

Summary

We propose a new Large-Scale Experimental approach which uses manipulations of landscapes and the habitats within them to allow biodiversity and related ecosystem services to respond to climate and land use change. It will test the potential for new policy approaches to re-connect habitats, increase landscape permeability and make ecosystems more resistant and resilient.

The Problem: Habitat destruction has resulted in highly fragmented landscapes.

- Fewer, smaller patches of ecosystems of high quality for biodiversity and a range ecosystem services are interspersed with poor quality patches that deliver only specific services (e.g. crops).
- The remaining high quality fragments often continue to degrade through impacts of pollution, eutrophication, invasive species, etc.
- Climate change will exacerbate these impacts as habitat becomes unsuitable for resident species, leading to cascading effects on linked species, ecosystem processes and services.
- A fragmented landscape forms a barriers which prevent species migrating (e.g. north) from newly-unsuitable to newly-suitable habitat.

The Solutions

- Novel management methods to increase the resilience (ability to recover from) and resistance (ability to withstand) of ecosystems to degrading factors; e.g. grazing to counter nitrogen deposition.
- New ecosystems can be created to replace those lost: methods have been developed to restore most UK ecosystems, but further work is needed to link this to restored function.
- Well-managed and restored ecosystems can form links (stepping stones) in landscapes to allow species to migrate to newly-available habitat.
- Ecosystems can be linked further with habitats and processes which aid species' dispersal.

Current Experiments

- Current & new experiments are designed to investigate in more detail the impact of certain drivers on *loss* of biodiversity and ecosystem services.
- Few consider methods for *countering* these losses: CEH has demonstrated capability in experiments to restore biodiversity and services at the farm-scale (e.g. Big Bee, RELU-FarmCAT, Hillesden-AES, The Farm Scale Evaluations, Large Blue, WEBs, RELU-Biofuels, Pontbren).

The Large-Scale Experiment:

The main hypothesis: ***Policy instruments can be targeted over landscapes to allow biodiversity to respond to climate and land use change, with a resulting enhancement of ecosystem function.***

The basic unit of the LSE is proposed a minimum of two 'landscape units' (size tbc - 10 x 10 km ?).

- One remains managed by existing landowners under a '**business as usual model**'. This undergoes continuing changes in biodiversity and services under environmental change.
    - This will represent the current fragmentary and 'free-market' approach to environmental land management, i.e. the business as usual landscape.
- The second a '**manipulated model**', uses existing and new (e.g. currently under development at CEH) local approaches but targets (using models) the location of management, restoration and corridors to maximise the linking up of ecosystems by:
    - Enhancing habitat connectivity by management of 'stepping-stone' habitats and by strategic introduction of habitat strips ('corridors') in intensively-used land and along linear features.
    - Strategic positioning of treatments to enhance resilience and resistance.
    - Strategic management to reduce species loss and enhance services across the landscape.
- Using modifications of existing land management policy, especially Environmental Stewardship (ES) and habitat protection (NNRs, SSSIs) schemes will ensure that:
    - Other approaches/organisations are linked in: e.g. non-statutory conservation bodies; other Government agencies such as the Highways Agency (HA), Network Rail, Defence Estates and Environment Agency (EA).
    - Targeting will involve brokered coordination among the organisations described, so should involve minimal extra cost.

    - The LSE will link to ongoing ‘landscape restoration’ projects: e.g. by the Wildlife Trusts, RSPB and the National Trust. By applying science-based spatial planning, hypothesis testing and detailed measurement of biodiversity and services, it will build on these.
    - It will add to existing datasets: Countryside Surveys, Agri-Environment Assessments, NNR, etc.
- The LSE will focus on defined ‘landscape’ areas comprising mixed habitat mosaics which together provide biodiversity value via ecosystem function and service provision such as water quality and flow (inc flood defence) within catchments (boundary flux measures), climate regulation, food provisioning and recreation.

  Two examples might be:
    - Lowland agricultural comprising; arable fields, calcareous grassland, scrub, patches of broadleaf woodland and rivers.
    - Upland moorland comprising; heather moorland, bog, coniferous plantations, improved grassland, lakes and streams.
- Within these the LSE can focus on management of one or more specific BHT (see Box).

An example for one UK habitat type: Calcareous Grassland (CG)- but can be modified to other BHT.

- A calcareous landscape comprises fields of arable and improved grass, fragmented woodland/scrub areas built-up areas, roads, rivers, etc.
- CG has high biodiversity value (‘the rainforests of the temperate zone’) and provides ecological functions such as food provisioning, pollination, pest control and maintaining water quality.
- Remnant CG are highly fragmented. Some are managed by different organisations (Nat Eng, the County WT, RSPB) and others are SSSI managed by farmers.
- Management of the remnants is coordinated by a brokered agreement among the land owners/managers to facilitate resistance and resilience (e.g. extensive grazing).
- Certain arable and grass fields – selected to maximise the connectivity among remnants – are restored to CG using refined Environmental Stewardship methods.
- The margins of selected arable and grass fields are restored to a mixture of CG (high effort) and grass containing key functional species (low effort) to provide corridors between remnant and restored CG.
- Features owned by other organisations are managed and restored to provide CG and corridors: road (Councils) & highway (HA) verges, riverbanks (EA), amenity areas (councils).
- Quantifiable ecosystem benefits include: enhanced biodiversity resilience through increased good quality habitat patches, increased population sizes, increased migration opportunity, etc
- Quantifiable ecosystems losses include: reduced arable productivity, potential for weedy invasions, etc

Measurements and discussion points

- Within targeted ecosystems, changes in: species composition, dynamics of selected (keystone) species, ecosystem processes and species interactions (webs), soil water, C content and other properties.
- Across the landscape: species movement among patches and along corridors (including genetic methods); over time, patterns in changing composition in relation to climate change; large-scale fluxes and flows of nutrients and pollutants in air and water, ecosystem service provision including value in relation to cost of targeted management.
- Develop spatially explicit models of climate change impacts.
- Earth Observation technologies to measure land-cover, fluxes, emissions, etc.
- Economics and social science to measure value of enhanced services *vs* extra costs.
- A platform for grants to study the system at scales from within-field to the whole landscape.
- Discussion points: the level of replication; the landscapes to use, project management.

Linking the LSE to monitoring (the first step in establishing a virtual biodiversity ‘experiment’

- Current UK monitoring schemes are designed to assess changes in:
    - Structure and composition, and ecosystem function of the wider countryside: Countryside Survey (inc. Integrated Assessment and Land Cover Map), vegetation, water quality, quantity and supply (NRFA), soils moisture assessment, soil carbon, soils microbial, pollutant deposition maps etc.
    - Distribution of plant and animal species: Biological Record Centre.
    - Ecological and environmental process in key ecosystems: ECN.
- The LSE will map onto these monitoring schemes by:
    - Carrying out manipulations at a scale which matches that of the monitoring.
    - Manipulating the exact processes detected by these schemes, at the relevant scales.
    - Data management and analysis which links the LSE directly to data from these schemes.

Input to NERC's Ecosystem Sustainability Scoping Workshop

NERC Centre for Population Biology (CPB), Imperial College London.

This is the input from the CPB to the Natural Environmental Research Council's scoping study on "Large-scale biodiversity, environmental gradients and ecosystem sustainability".

I. The CPB Research Programme

Our research programme has three themes, each with a goal:

1. Biodiversity and ecosystem function in a changing environment: To assess the direct and indirect effects of environmental change on ecosystem processes and functions, including the maintenance of diversity and the structure of communities.
2. Patterns and processes in diversity and distributions: To link biodiversity patterns and processes to predict biodiversity across scales of both space and time.
3. Ecology and evolution of diseases and disease vectors: To understand the ecological and evolutionary processes underpinning disease and to develop strategies for disease management.

II. Methodological approaches

We use a range of methodologies which we classify here into two broad types following the questions posed to us in the request for input. In practice almost all our work includes components of both types which are mutually reinforcing.

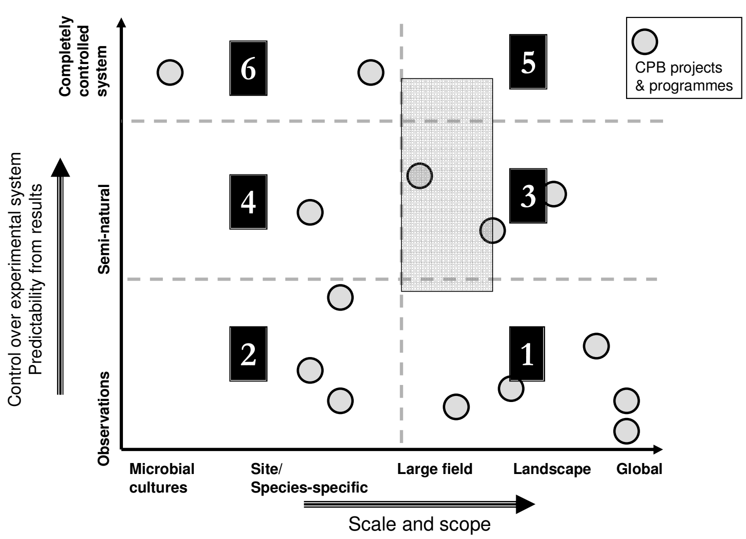
1. Observational including *in vivo* and *in vitro* controlled experiments, at scales from Petri dishes to fields, through to large-scale observations and analyses on populations, communities and ecosystems at scales from fields to global assessments.
2. Virtual/modelling based on simulations or analyses including entirely theoretical (without fixed parameters) through to fully-parameterised site and context-specific models concerning biodiversity and ecosystem processes, from genes to ecosystems, and at scales from populations to global biodiversity.

Our projects/programmes (indicated by circles in the diagrams below) cover a range of different study systems and methodological types. Rather than reviewing these in detail we discuss general approaches and the broad questions we address using them.

III. Broad questions addressed by Observational studies

The major questions can be organised according to the scale and scope of the study system and the extent to which the observations occur under controlled or experimental conditions (see Figure 1). We understand that NERC is intending to focus in areas 5 and 3 of this scheme.

Figure 1*: Approaches to empirical/observational studies. Small circles represent CPB programmes or projects. Numbers in black boxes refer to the discussion below. The grey box is the area we understand NERC is considering***.**



The numbered boxes in Figure 1 each denote a major area of study:

Area 1. What determines the distribution and abundance of species, assemblages and traits? Projects here are largely pattern-based analyses supported by analysis and models. The next steps here should link species and populations (Areas 2,4,6) with large-scale biogeographic and dynamic vegetation processes.

Area 2. What drives local-scale variation in communities and functions? This work is supported by modelling and next steps are to upscale to ecosystems, and to large scale processes and patterns (area 1).

Area 3. How does ecosystem functioning (e.g. biogeochemistry and community processes such as resistance to invasion) respond to human impacts (e.g. climate change, invasive species, nitrogen enrichment, land-use change)? The next steps are to replicate systems across sites to extend spatial scales and understand generalities as a means to approach Area 5.

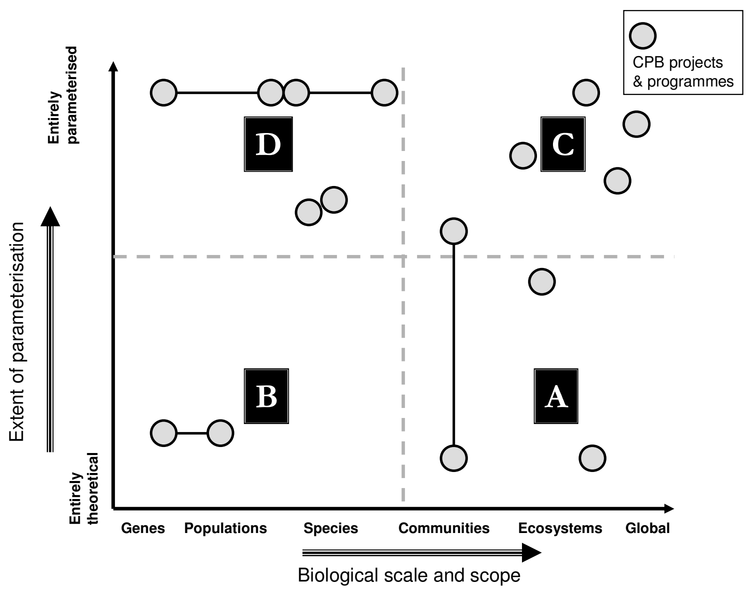
Area 4. Experimental field assessment of basic ecological principles. This is the domain of traditional ecology which is now informing larger scale/scope studies.

Area 5. How does ecosystem functioning respond to human impacts? This is similar to Area 3, but major problems with further control at this scale include the high costs and the likelihood that further control will disturb the system and render it unrealistic.

Area 6. What mechanisms and processes (including adaptation and interactions) determine populations, communities and species structure and dynamics? Future goals will include up-scaling and linking to larger scale patterns and processes and further application to studies of soil processes (Area 1).

IV. Broad questions addressed by Virtual/modelling studies

Figure 2. *Approaches to Virtual/Modelling studies. Small circles represent CPB programmes or projects. Letters in black boxes refer to the discussion below*



The lettered boxes in Figure 2 each denote a major area of study:

Area A. What determines the stability and diversity of interaction webs? How do ecology and geography influence evolutionary patterns and processes? This work links to experimental and field studies as in Figure 1: Area 2

Area B. How do genetic and demographic models scale up spatially? Under what circumstances will introduced individuals and genes spread through populations?

Area C. What are the expected outcomes of global environmental change on ecosystem processes, biogeographic patterns, community composition and species extinctions? This work has strong links to observations in Figure 1: Area 1.

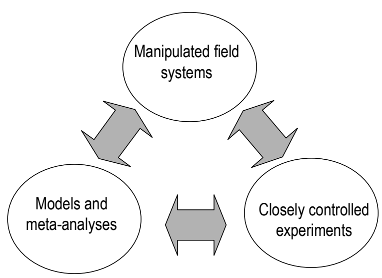
Area D. How do environmental factors influence evolutionary processes within populations, species distributions, species diversity and spatial phylogenetic patterns? Strong links to Figure 1: Area 2.

V. Conclusions on large-scale ecosystem experiments

We understand that NERC is seeking to develop systems in the area of the shaded grey rectangle on Figure 1.

1) We note that Area 5 on Figure 1 is intrinsically hard to do because large scale systems where there is enough control to deduce processes reliably will be very expensive. Additionally, the level of control may confound the processes being studied.
2) Area 3 in Figure 1 is less controlled but more feasible. Many good examples exist in Europe[1] and there is potential to exploit the existing network of LTER sites in the UK[2]. Our own work in this area, such as the field scale manipulations in the DIRECT project[3], illustrate the unavoidable trade-offs between replication for experimental design and the complexity of the question that can be studied. We recommend that this issue be addressed by an experimental approach which incorporates multiple sites across landscapes or environmental gradients, each of which has replicated plots.
3) Other work that addresses questions in this area comes from bringing together closely controlled experimental work with modelling work (e.g. stability of interaction webs, parallel field-controlled environment studies in the Ecotron such as the Lake Vyrnwy project; model development and testing in the Ecotron such as the SCALE project[4]).
4) Much of our work on large-scale biodiversity and environmental gradients is however not in areas 3 or 5. Rather we consider that successful and economic approaches bring together modelling and observations, between Areas A and C of Figure 2 and Area 1 of Figure 1. Thus there can be very useful interplay between field-based experiments, controlled environment studies and analyses (Figure 3).

Figure 3 *Interactions among modelling, closely controlled systems and field experiments may add value to each, depending in the questions being addressed.*



5) We note the current lack of studies that effectively link genetic processes up to large scale and think this is a research gap that urgently needs attention since phenomenological studies and ecological model systems may not allow good predictions beyond observed conditions.
6) We also recommend further consideration to UK involvement in integrated research infrastructures, including closed-controlled experimental systems across Europe[5]. In combination with field and modelling studies, a network of closed ecological systems can allow exploitation of synergies between different approaches (see Figure 3):

NERC Centre for Population Biology
November 2008
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[1] see http://www.biodiversity-exploratories.de/entry-page-2?set_language=en&cl=en
[2] see http://www.ecn.ac.uk
[3] see http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_26-9-2008-14-0-13?newsid=44714
[4] See http://www3.imperial.ac.uk/cpb/research/biodiversityandecosystemfunction/theecotron/research/scaleproject
[5] see http://www.anaee.com/anaee/anaee

The UK Environmental Change Network

(www.ecn.ac.uk).

Contact: Don Monteith, Centre for Ecology and Hydrology, donm@ceh.ac.uk

Aims, objectives and methodologies

The Environmental Change Network (ECN) (http://www.ecn.ac.uk) is the UK's long-term ecosystem monitoring network and aims to aid in the detection, attribution and forecasting of environmental change and its impacts resulting from natural and human causes. It is a multi-agency initiative and currently consists of 57 terrestrial and freshwater sites, spanning several environmental pressure gradients. Regular measurements are made of the main drivers of change (e.g. climate, atmospheric chemistry, land use) and ecosystem responses (e.g. water quality, soil and biota). The ECN has been in operation since 1993 and is producing a wealth of data and information of value to users in research, education and policy.

The long term purpose of the ECN is to:
(i) Provide monitoring protocols and maintain a network of monitoring and research sites and its database to deliver quality-assured data on the environment to a wide range of stakeholders.
(ii) Develop database and analytical tools and procedures to provide early indicators of change from expected norms, and identify and quantify cause-effect relationships.
(iii) Provide research and analysis that underpins the development and assessment of UK policy related to environmental change, particularly in relation to climate change, biodiversity, water quality and sustainable development.

All 12 ECN terrestrial sites are monitored by dedicated site managers, funded by one of the ECN's 14 sponsors. The monitoring of the 45 freshwater sites is undertaken more regionally, predominantly by the UK environment agencies. ECN operations are coordinated by a Central Coordination Unit (CCU), based at the Centre for Ecology & Hydrology, Lancaster Environment Centre. The CCU provides network coordination, monitoring protocols, maintenance of a central database, regular checks on the quality of the developing environmental time series. In addition it facilitates the production of annual data reports, Site Manager meetings, data dissemination, data analysis, publications in the scientific literature, and communication of the Network to a wider audience of researchers, policy makers and schools.

Strengths and weaknesses

The key strength of the ECN is that it is unique in the UK in conducting “integrated” ecosystem monitoring, i.e. monitoring of a wide range of physical, chemical and biological components from a range of UK ecosystems according to clearly defined protocols. Measurements are taken at relatively high frequency and many records are now over fifteen years in length. ECN sites therefore provide a detailed fine-resolution picture of how and why) UK ecosystems may be changing, but in addition they represent Long Term Ecological Research (LTER) platforms, where shorter term experiments and additional monitoring is encouraged. As concern grows over how policy is best applied to conserve or enhance biodiversity and Ecosystem services, the ECN provides unique national capability to address emerging research and policy needs.

The main weaknesses lie currently:
1) in the relatively limited number of terrestrial sites, that constrain network-wide analysis of responses along pressure gradients. This is currently being addressed with the development of a proposal for an extension of spatial coverage under the Environmental Change Biodiversity Network (ECBN). The ECBN will focus on sites within Natural Nature Reserves, and the ECN would therefore still benefit from a further expansion of a sites covering more representative of typical UK habitats;

2) in the availability of funding and mechanisms to maximise the use of ECN sites by Universities and Research Institutes for research purposes.

***Costs and programme/initiative management*.**
The full annual cost of the ECN, shared among its 14 sponsors, is approximately £1,600,000. One third of the cost is met by NERC while Defra contribute around 5% directly to support the activities of the ECN CCU. The Devolved Administrations, conservation agencies, Forestry Commission and the Biotechnology and Biological Sciences Research Council between them cover approximately half of the costs, through site management, sampling and sample analysis.

The ECN is overseen by a Steering Committee, comprising representatives of the 14 network sponsors. The Steering Committee sets priorities for research and development and provides an interface with key policy and research communities. They are encouraged to provide regular feedback to the CCU on priorities and opportunities. Scientific and technical development of the ECN is provided by a small group of experienced environmental scientists and statisticians known as the Scientific and Technical Advisory Group (STAG). STAG is tasked with developing R&D plans covering priority issues for ECN and ensuring that appropriate links and collaborative research projects are established with complementary monitoring and research programmes in the UK and internationally. STAG also monitors and evaluate progress on R&D implementation plans and advises the Steering Committee on progress and any necessary modifications to improve network design, techniques and procedures.

Potential for addressing questions
ECN data make significant contributions to a national evidence base contributing to our understanding of environmental processes and environmental change. These include: the provision of supporting data for large-scale ecosystem assessments, such as the Countryside Survey (providing a short term variability context); support for assessments of key impacts and predictions of responses to future scenarios, e.g. Defra's Review of Transboundary Air Pollutants (RoTAP) (information on changes in soil water chemistry and evidence for vegetational change); support for natural resource management, e.g. through provision of data on biodiversity to other monitoring programmes and data on fluxes and controls on organic carbon in peatlands; and, early warning of environmental change impacts and their consequences (providing climate change indicators). In terms of European policy assessment and development, ECN science is highly applicable to the further development and implementation of European Directives on biodiversity, soil and water.

Environmental monitoring often provides the earliest evidence of change in the environment, provides crucial data for developing process understanding, and also allows for process-based models to be tested in the "real" environment. However, experiments are also paramount in hypotheses testing, and the ECN strives to facilitate the use of its sites and its data for experimental purposes. To date most ECN-related experiments have been restricted to individual sites, but the ECN is keen to develop the use of its full spatial coverage to host cross-network experiments. The Network is well placed in this respect as a result of the presence of site managers who can facilitate and participate in new research. Several potential projects are currently under discussion. These range from: process-based studies across environmental gradients, such as assessments of key environmental controls on organic carbon processing, invertebrate growth rates, or grazing pressure; studies of new threats to human health, e.g. a network-wide identification and quantification of specific mosquito vectors and pathogens in the environment, or implications of rising dissolved organic carbon in water suppplies; to cross-site manipulative experiments, such as the use of exclusion cages to assess grazing effects on biodiversity.

Background document from the Ecological Continuity Trust for the NERC Ecosystem Sustainability Scoping Workshop

www.EcologicalContinuityTrust.org

Aims & relevance of the Ecological Continuity Trust

The ECT is a registered charity that has been established by a broad coalition of ecological scientists and conservation practitioners supported by the British Ecological Society and the Esmée Fairbairn Foundation. We believe that long-term ecological experiments (LTEs) are essential to understand the future impacts of global change upon ecosystems and to obtain the sound scientific evidence upon which political and corporate policy development should be based.

We have conducted a review of LTEs in the UK to determine their scope and relevance to climate change and its interactions with other ecological drivers. Out of 44 long-term experiments for which data were available, only 6 have survived beyond 20 years and none has a guaranteed future. Fewer than five manipulate any climate-related variables, none manipulate UVB and very few manipulate CO_2, temperature or hydrology. The two most commonly applied treatments are nutrient manipulation and grazing, reflecting previous research priorities. There are only 4 experiments which attempt to measure interactions between multiple global change drivers (of which only 2 include climate-related treatments).

As with treatments, the coverage of habitats largely reflects the past focus on agricultural production, with the best represented habitat being grassland (70% in neutral grassland). Habitat types with little or no representation are coastal, montane, fen meadows and boundary features (e.g. hedgerows and river banks). This analysis illustrates how few experiments address climate change and its interactions, and identifies several habitat types for which there is no current long-term experimental research at all.

We have identified the core problem to be a **lack of continuity of funding**, linked to changing priorities and the absence of a long-term strategic perspective. With this in mind, the aims of the ECT are to:

- **devise and maintain long term experiments as <u>platforms</u> for present and, especially, future research.** Experimental manipulation of temperature and rainfall will be used to anticipate the effects of expected changes in climate.
- **support other long-term ecological research** (wherever possible)
- **analyse and disseminate the information** obtained in a way which is accessible to policy-makers, opinion-formers and decision-makers in government, commerce and non-profit institutions
- **raise awareness of the evidence** and its implications among the general public
- **provide a beacon of best practice** that may be copied elsewhere
- **raise funds for an endowment** in order to ensure continuity and security of dedicated and independent funding.

Experimental platforms: our vision

Our vision is to develop a network of financially secure global change experiments in a range of key UK ecosystems, focusing on interactions between climate and other key drivers of change. These experimental platforms will enable scientists and stakeholders to work together for the delivery of new and important findings that will be fundamental to ecosystem management in the future. We are committed to sharing data from ECT experiments and all participants would sign up to making their data available to the wider community.

Design of the experimental platforms

As a first step towards this aim, we are working towards the establishment of one large-scale experiment located in a species-rich calcareous grassland site, a habitat recognised as of key importance and vulnerable to future global change. The factorial treatments will be **temperature** (ambient vs. elevated) X **rainfall** (ambient vs. summer drought) X **sheep grazing** (at two levels of intensity). Other treatments will be nested within this basic design and could include: nutrient manipulation to simulate elevated atmospheric inputs; litter removal to look at carbon sequestration; manipulation of species composition; rainfall addition (winter or summer). At least fifty percent of the space inside the top-level treatments will be reserved for future experimental manipulations. To accommodate this, plots will be large (ideally of the order of 20m X 25m) and spare plots will be incorporated into the basic design for future use. The total area required for this experiment, including guard areas and access routes, is 16 ha.

Logistics and funding

Site selection

It is essential that once established the experimental site is protected indefinitely from competing uses (e.g. housing, roads, agriculture). We have therefore started strategic discussions with the National Trust whose very large landholdings are uniquely protected by act of Parliament. A shortlist of 12 possible calcareous grassland sites owned by the NT has been identified and we are working through them. The ideal site will have existing buildings nearby that could be re-purposed for use as a field laboratory and workshop, a permanent archive for samples and a visitor centre where the general public could learn about the experiment and the science of global change in general.

Funding

The costs of the basic infrastructure for the experimental platform are currently being calculated based upon known costs from existing experiments. A strength of the proposal is that the complete package would be suitable for mixed funding from NERC, other governmental sources, Heritage Lottery Fund and private foundations. The ECT's constitution provides for establishment of an endowment to support the proposed experimental platform and we currently employ an experienced fundraising consultant who is advising us on our long-term fundraising strategy. A weakness is that the current global financial crisis makes the immediate prospect of raising a privately-funded endowment difficult. However, climate change is now at the very top of the agenda for many philanthropists and the medium-term prospects for fundraising are more promising. At least some potential donors and their advisers recognise that private funding has a unique role to play in guaranteeing long-term initiatives like the ECT. Short-term funding is clearly within the remit and capability of government/public funding organisations and the provision of some NERC funding at this stage would complement and "underwrite" the science value of the ECT and assist in the seeking of other sources of finance for the endowment.

Issues for discussion at the scoping workshop

1. There is a trade-off between large-scale and long-term. However, can expenditure on a large-scale experiment be justified if it is not *also* long-term enough to recoup the initial investment?
2. What exactly is meant by large-scale or long-term? What are the relevant yardsticks?
3. Grazing is a permanent feature of most semi-natural habitats in the UK. How can this be incorporated into new experimental designs?
4. Herbaceous plant communities that are rich in plant species tend to occur in ecosystems that have relatively low carbon storage (e.g. on thin calcareous soils) and *vice versa*. Do we therefore need separate ecosystem experiments to study the impacts of climate change on biodiversity and on the carbon cycle?
5. Which ecosystem ought to be top priority for study? Is it reasonable to select only one? If not, how can a range of ecosystems be included?
6. What can be learned from the successes and failures of other LTEs?
7. How can existing LTEs, such as the one at the Buxton Climate Change Impacts Laboratory which has been running for 15 years, be protected and integrated with plans for new experimental facilities?

Contact: J.Silvertown@open.ac.uk
06.11.08

LIFEWATCH

LifeWatch

A European e-Science and Technology Infrastructure for biodiversity data and observatories

(www.lifewatch.eu).

UK Contact: Terry Parr, Centre for Ecology and Hydrology, twp@ceh.ac.uk

1. Rationale

LifeWatch is a European biodiversity research infrastructure programme that will bring together high quality scientific data information, knowledge and expertise from a variety of sources including a system of observatories with wide and long-term coverage and through integrated access to (genetic, species-level and ecosystem) data. These data will be combined in a virtual environment offering offering analytical and modelling tools providing customized services for biodiversity research and policy.

The scale and complexity of the challenges related to the sustainable use of biodiversity and ecosystems can only be solved by multi-scale, interdisciplinary research based on a combination of observational, experimental, theoretical and modelling approaches. LifeWatch will provide the infrastructure necessary to bring these components together within a virtual system operating across Europe.

LifeWatch could provide the observational and informatics frameworks required to underpin large scale experimental approaches in the UK.

2. Overview of the Structure

LifeWatch will bring into operation the facilities, hardware, software and governance structures required to make biodiversity data available to research and policy users across Europe. It is part of the ESFRI (European Strategy for Research Infrastructures) and is currently under development through an EC/FP7 funded preparatory phase.

LifeWatch will be a major European component of the GEO Global Earth Observation System of Systems (GEOSS) and in particular the GEO Biodiversity Observation Network. Its main components will cover:

- Data generation and data processing: including biodiversity observatories.
- Data integration and interoperability: data standard and processing facilities to link information from different sources
- Virtual laboratories: use of grid technology to promote collaborative working and modelling
- Service Centre: dealing with marketing, access rights, user support, training.

3. Research and policy priorities

The fundamental aim of LifeWatch is to make data and information readily available to researchers, policy makers and citizens with an interest in biodiversity and ecosystems. Its main areas of application will be in relation to:

(i) the discovery of biodiversity;
(ii) biodiversity patterns in e.g. mapping of hot spots and changes in distribution and abundance of species;
(iii) biodiversity processes – understanding patterns of change over time;
(iv) systems biology – understanding multi-state dynamics of genes, species, populations and ecosystems and their responses to abiotic changes;
(v) nature conservation and management;
(vi) valuation and maintenance of ecosystem services; and
(vii) specific questions related to particular issues and capability (e.g. see Section 4).

4. Biodiversity Observatories in LifeWatch

LifeWatch will access data from distributed data sources, such as biological collections, field surveys and site based studies and promote the development of new data collection methods. A key component of the LifeWatch infrastructure will be biodiversity and ecosystem observatories covering terrestrial, freshwater and marine systems. These will include marine reference sites and terrestrial and freshwater observatories such as Long-term Ecosystem Research Sites (LTER).

Long-term Ecosystem Research Sites (LTER) in Europe provide platforms for observations, experiments and research on biodiversity and ecosystem processes. The LTER-Europe Network (www.lter-europe.net) now has access to over 200 sites in 18 European countries and is linked to a further 22 countries world-wide as part of ILTER. The UK Component of LTER-Europe is the UK Environmental Change Network (ECN, www.ecn.ac.uk. LifeWatch will promote the process of bringing these sites together into a single multi-functional research platform for Europe.

The aim of LTER-Europe is to address continental scale questions related to ecosystem change including:

- How are ecosystems across Europe affected by changes in climate, atmospheric pollution, land use, and invasive species over time?
- Can we identify and provide early warnings of thresholds or tipping points in ecosystem structures and functions?
- What are the effects of changes in ecosystems on the provision of ecosystem services and how do socio-ecological systems respond?
- How should we structure and manage multi-functional landscapes in order to maintain biodiversity and ecosystem services?
- How can society adapt to environmental change, particularly climate change?
- What policies and management approaches are required to promote ecosystem resilience and ensure the long-term sustainability of socio-ecological systems?

European LTER sites provide an extensive network of research platforms for distributed experiments on ecosystem processes making used of a combination of natural gradients and controlled experiments or perturbations to test hypotheses related to the above questions.

5. Strengths and Weaknesses of LifeWatch

The strengths of the approach include:

- It is feasible: makes use of recent technological developments in e-Science and existing data sources;
- It has a flexible design: enabling it to make use of new technologies and address a range of new and emerging research and policy questions;
- It brings together many different parts of the biodiversity research community[2] including the biological collections, genomics, terrestrial, freshwater and marine communities
- It builds on previous work such as the Global Biodiversity Information Facility (GBIF) and the International Long-Term Ecological Research Network (ILTER);
- Strong European Partnerships: these include 7 Networks of Excellence[2] and links with related infrastructure projects (eg ICOS (carbon flux observatories), NOHA (hydrological observatories) and ANAEE (ecotrons and experimental platforms)).
- UK Partnership: LifeWatch already has a strong UK focus including the Centre for Ecology and Hydrology, the Marine Biological Association, the Natural History Museum and the Cardiff e-Science Centre.

Weaknesses of the approach include:

- Currently 18 countries are involved in the preparatory phase (including the UK) which is developing the legal, governance, and operational plans are being developed. The construction phase (2010-) will require support from the scientific and policy communities across Europe.
- It is a long-term programme: full implementation of the system will take at least 10 years.
- Early development of the LifeWatch infrastructure in the UK (and in Europe) would benefit from a problem solving focus aligned to short term research questions. These have not yet been agreed.

6. Costs

The LifeWatch preparatory phase is funded by the EC (€ 5,000,000) and national contributions (€ 4,600,000). The overall cost of the construction phase (as estimated in the ESFRI proposal) is € 370,000,000. The UK contribution is undecided.

Footnotes

[1] ESFRI (European Strategy for Research Infrastructures) aims to help improve the competitiveness of the European scientific community by starting a process to establish new large-scale research infrastructures. In 2006 ESFRI published its first "Roadmap" of the most promising next generation large-scale Research Infrastructures - this included "LifeWatch".

[2] Major European Networks already involved in LifeWatch include ALTER-Net (A Long-term Biodiversity, Ecosystem and Awareness Research Network); BioCASE (Biological Collection Access Service for Europe); EDIT (European Distributed Institute of Taxonomy); ENBI (European Network for Biodiversity Information; EUR-OCEANS (Ocean Ecosystems Analysis); MarBEF (Marine Biodiversity and Ecosystem Functioning); MGE (Marine Genomics Europe) and SYNTHESYS (Infrastructure network of biological collections).

Briefing note on UKPopNet's pilot experimental platform

1 Brief description of the programme

The UK Population Biology Network (UKPopNet) is funded by the Natural Environment Research Council (NERC), English Nature and more recently Natural England. The major funder is NERC. UKPopNet is a network of scientists in Universities and Institutes and our research programme aims to integrate population, community and ecosystem biology and researchers, practitioners and policy-makers. UKPopNet commenced activities on 1 April 2004 and has funding till March 2010.

One of the three overarching themes within our current programme is a pilot experimental platform for research, a large-scale experiment at RSPB's Lake Vyrnwy Reserve in North Wales, aimed at evaluating the impacts on ecosystem processes and services of alternative futures for the uplands. This can only be done using a rigorous experimental design protocol.

By working closely with the land-managers (RSPB) and the LIFE Active Blanket Bog in Wales Project (http://www.blanketbogswales.org/), it has been possible to explore the effects of different management interventions on key ecosystem processes using a replicated plot (sub-catchment) design. The treatments include heather mowing and re-wetting of the landscape by blocking drainage channels (grips). Control plots are left untouched. Each of the 5 replicate plots is matched with a control plot to provide a balanced experimental design. The large size of each replicate plot (c. 30Ha) will help to provide meaningful landscape-scale answers to landscape scale questions.

A key focus is on carbon storage, measuring the loss or gain of carbon dioxide (CO_2) and methane (CH_4) with the aim of developing models to predict the impacts of moorland habitat restoration and potential future climate change on C-storage and greenhouse gases. Predictions will be scaled-up from experimental plots to the landscape scale, to derive estimates for both the reserve and region. Impacts of the treatments on hydrology, vegetation structure and biodiversity of invertebrates and microbes are also being considered.

Thus, the platform is an extensive single site, with smaller (30Ha) treatment and control plots.

The platform is managed on a day-to-day basis by a Platform Co-ordinator, who has responsibility for ensuring that all work carried out of the site meets the requirements of both UKPopNet and the site managers (RSPB) with respect to health and safety, environmental impact, liaison and co-ordination with other team members, data bases and field equipment maintenance. The Platform Co-ordinator works very closely with the RSPB at the site.

The experiment was initially set up as a pilot platform in order to test out ideas and protocols required for carrying out such experiments and how best to design platforms. It has always been UKPopNet's intention to use these lessons to design activity at a broader range of sites, including Vyrnwy.

2. Strengths and Weaknesses

The *strengths* of our approach are as follows:

- large scale of plots, relevant to landscape-scale questions.

- rigorous experimental design incorporating balanced control and treatment areas.
- willingness of the land manager (RSPB) to design management interventions in a manner which is appropriate to the above and an appreciation of the need to have matched treatment and control areas for an extensive period (up to 15 years).
- presence of a Platform Co-ordinator to ensure that all work done at the site, within the experiment, is co-ordinated and managed appropriately.
- ability to muster a large-scale and diverse programme comprising many individual PIs, PhD studentships and institutions through UKPopNet funding (competitive, not directed), which has encouraged funding from other sources.
- funding of sister programmes on scaling issues, relating measurements of ecological and environmental variables measured at a range of spatial scales within the plots, from the core-scale to the landscape scale, and involving mesocosm-based work, including the Ecotron.

The *weaknesses* are:

- To date, all our effort has been largely focused on one location (Vyrnwy), mainly to take advantage of the opportunities listed above. However, the lessons learned over the past few years about how to make platforms work are intended to be translated to a wider range of upland (and other ecosystems). To this effect, UKPopNet currently has 4 funded working groups exploring the potential for extending platforms across a range of sites and environmental issues. Full details of these can be found on the UKPopNet site.

- The site provides excellent opportunities for cutting-edge research on the effects of management interventions on a range of ecological processes, as well as for exploring governance and science management practices for the successful establishment of a platform approach. However, this particular site offers limited opportunities for exploring social and economic dimensions to environmental management due to the restricted group of stakeholders.

Costs of the platform

The research programmes underway within the platform are funded from competitive calls within, and outwith, UKPopNet. The scale of activity is large, and we have able to take advantage of the habitat restoration works undertaken by the LIFE Active Blanket Bog project, amounting to considerable in-kind costs. This has enabled UKPopNet's own relatively limited resources (~£1M allocated to this theme) to fund two major projects, four PhD studentships and a number of smaller projects (c.£15-20kk each). A further competition for UKPopNet funds is in progress (each bid probably in the range £30-60k) and it is expected that several of the applications will be for work to be carried out at the platform site.

However, there are significant costs in establishing such a platform. In addition to the direct co-ordination by UKPopNet (platform co-ordinator post) and the contribution in-kind from the RSPB, UKPopNet funded a proof-of-principle research grant several years ago in order to establish the feasibility of designing such a platform, taking advice and evidence from the research community. If platforms are to be established as a future NERC initiative as part of the Biodiversity TAP, then our experience shows that such exploratory and co-ordination activity would need to be in place well in advance of the start of any research *per se*.

Dave Raffaelli, Director UKPopNet, University of York, 17th November 2008

Observations on flora fauna in the Netherlands – a coordinated action between the national government, field ecologists and scientists

E.E. van Loon and Judy Shamoun, Universiteit van Amsterdam (vanloon@uva.nl)

A short history

In 2005 the Universiteit van Amsterdam (UvA) and a group of private organisations[1] that manage observational flora and fauna data started an intensive cooperation to build a virtual data base containing all the observations collected by the organizations and conduct research with this data.

This project was successful in the sense that a central data base the National Database Flora and Fauna (NDFF) with one generalized data model was developed and very different data sets were converted to the new data model. EcoGRID is the software infrastructure to access and interpret the data, as well as the data model itself. The project also contributed to the Netherlands bird avoidance model BAMBAS[2], the results of which are available online at http://www.bambas.ecogrid.nl. This initial phase can be seen as a pilot project for the more extensive NDFF/EcoGRID project which started in 2007.

Three persons worked on it full time for 2 years, and in addition there was a genuine commitment by the participating PGOs to contribute by delivering and converting data sets, providing explanations of the data and participating in discussions. The total time invested into this sums approximately to four persons over two years (distributed over 15 individuals).

In 2007 the Dutch ministry for agriculture, nature conservation and fisheries (LNV) decided to build a central facility to store all the observational data which can be relevant for legislation, policy making and making large-scale decisions with respect to nature management or conservation. The system by UvA and the VOFF was the only system that came close to support the aspirations by LNV, so the consortium was approached to extend the work to deliver the functionality desired by the central government.

Characterisation of the data that is being collected

The data being collected is field data on the occurrence of species, often observed visually. The majority of the data is collected by volunteers and professionals, who are members of a PGO which concentrates on a certain species group (like birds, butterflies, mammals, higher plants, etc.). In cases where it is difficult to establish the observation to the species level, determination is done at the genus or family levels. Much of the data is collected within a certain project that has a professional coordinator who is employed by one of the PGOs, a protocol that has been communicated and written down, and some level of data validation after volunteers have sent their data to the PGO-office. The observation locations are not distributed homogeneous over the Netherlands. There is f.i. a bias to observe in nature reserves while urban areas are under represented. Qualitatively, the best monitoring is done for a selection of species within a project called NEM (‘Netwerk Ecologische Monitoring’), conducted by PGOs and supervised by Statistics Netherlands (CBS), see http://nemweb.ipo-rivm.nl/.

[1] These organizations are PGO’s (‘Private Gegevensbeherende Organisaties’) such as Sovon – The Dutch Center for field Ornithology, Vlinderstichting, Floron, united in the VOFF foundation, see www.voff.nl

[2] Shamoun-Baranes, J., W. Bouten, L. Buurma, R. DeFusco, A. Dekker, H.Sierdsema, F. Sluiter, J. Van Belle, H. Van Gasteren and E. Van Loon 2008. Avian Information Systems: Developing Web-Based Bird Avoidance Models. Ecology and Society 13 (2): 38 http://www.ecologyandsociety.org/vol13/iss2/art38/

In most NEM monitoring projects the observation locations are revisited every year. The placement of the observation locations in the Netherlands is stratified (based on expert insights) according to main landscape types (around 10 for the Netherlands). The 15.000 volunteers from the 10 PGOs in the Netherlands collect around 5 million records every year.

The Dutch Authority for Nature Data (GAN)

A first important step in organising the new EcoGRID project was the establishment of a neutral governmental body outside the ministry with an independent budget. This organisation was established in 2007 and named GAN ('Gegevens Autoriteit Natuur'). The aim of the GAN is to facilitate trustworthy information on the distribution of flora and fauna in the Netherlands and make this available to everyone. It aims at stimulating and facilitating the cooperation between data collectors, administrators and users via a stable ICT infrastructure. It operates independently and approaches all stakeholders in a neutral way. Currently the main activities by the GAN are:

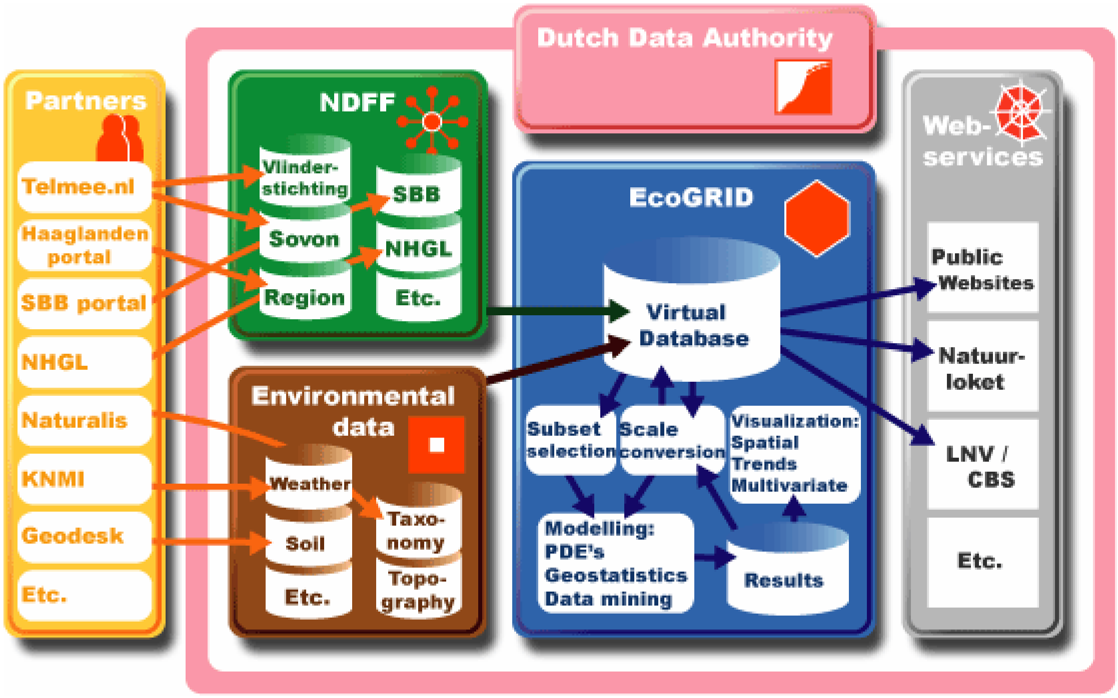
- Involving many governmental bodies and terrain managing organisations in the Netherlands to contribute to and/or make use of the system
- Setting up the ICT infrastructure (EcoGRID) to further complete, enhance and manage the NDFF, jointly with UvA and VOFF.
- Directing the data collection process (GAN has a budget to pay PGO's for this)
- Controlling quality of the data in the NDFF by establishing protocols together with Statistics Netherlands (CBS, http://www.cbs.nl)

The ambitions of GAN rely on a well organised software infrastructure and a large and continuously maintained set of observational data. UvA designs the software infrastructure while the process of collecting, validating and storing flora and fauna observations being taken care of by the PGOs (as well as other organizations in the future). To turn the software architecture and prototypes into operational systems and also to manage the production-version of the NDFF, Geodan (www.geodan.nl), a company specialized in geo-data, has been contracted by GAN.

The foreseen timeline to achieve the above mentioned goals is four years (mid 2007 – mid 2011), and a total budget of 20 million euro is available for this purpose. From 2011 onwards GAN should be a non-profit semi-governmental body which finances itself.

EcoGRID

The National Databank Flora en Fauna (NDFF) has been set up as a distributed system (a collection of databases) that behaves as one virtual database. The different databases are managed by various organizations, but all databases share the same EcoGRID data model as their core. The data model is defined for a spatial data base. This is relevant because it allows the storage of any object in space (point, line, polygon). Due to this property a wide range of different types of flora and fauna observations can be stored in a single data model. In addition, the model stores uncertainty information about time, space, abundance explicitly in the form of bounds and taxonomic information can be specified at different levels in the taxonomic hierarchy. The description of the data model is currently only available in Dutch but will be available in English soon (www.ecogrid.nl). A schematic idea of how the system works, with a rough indication of all the analysis steps that will be required to convert the 'raw' observations into useful knowledge is shown below.



In addition to a central data model, communication interfaces are defined so that external databases can connect to the NDFF for input or output purposes. Also several web-portals are being constructed for data input directly into and out of the NDFF virtual database; and a workflow system is implemented to conduct reproducible research and produce outputs in a traceable manner. The approach in this project is to allow any organization (in addition to the PGOs) to connect to the system (after agreeing on certain conditions of use) in order to deliver or extract data. In summary: EcoGRID comprises three parts: 1) A generic data model, 2) A workflow environment consistent with the data model containing a number of relevant and tested analytical techniques, and 3) Software components that can be used to execute the workflows on a distributed system. All the parts of the NDFF/EcoGRID system are built out of open source software components. The participants in the EcoGRID team employ this technology for the following four activities:

1. **Identification** - retrieving information (observations, meta-data, modelling results) about a particular type of species or a particular point or region in space or time.
2. **Communication -** the exchange of data, information or knowledge between two or more users.
3. **Integration -** the combination of observations or modelling results beyond the borders of a single type of species and the tight integration with abiotic information.
4. **Analyses** – exploratory analyses, summary statistics, visualisation and concept driven ecological modelling. EcoGRID aims especially at spatially predicting occurrences and abundances of flora and fauna at the national scale.

The EcoGRID project will run for 4 years and has a capacity of 4 people full time (2 scientific programmers, one researcher at the post doc level, and smaller inputs from several scientists with expertise in GIS, statistics, etc.). In addition there is a similar capacity by the counterpart Geodan available for converting prototypes to production software and maintain the system.

Strengths and weaknesses of the programme

A clear strength of the program is the governmental commitment to build and use the NDFF/EcoGRID system for practical purposes. It ensures a sustainable source for funding, and an interest from a large user community (both those that will provide data and use data).

Another strength of NDFF/EcoGRID is that it did start from an existing (pilot) project and data collection infrastructure that already existed. Setting up national inventories of field data from scratch takes many years (if not decades). The aim is to streamline it, make it more professional and furthermore enhance quality by standardisation.

The focus on the data integration and conversion first (the green box in the figure) rather than on analysis tools (blue box), is considered a strength. Many similar ecological or ict-projects in other countries seem to focus a lot on the latter. This results frequently in analysis tools that are not appropriate for the data or a lack of time to actually collect or prepare the observational data required as input for the analysis tool.

Weaknesses can only be described from the perspective of a certain partner. Here only the perspective of UvA is provided, i.e. the perspective of a scientists interested in macro-ecological questions and ecological modelling.

From the perspective of a scientific ecologist a weakness of the NDFF data is that it is strongly biased (in space, time, certain species groups, etc.) and it is sometimes hard to correct for these. With the many stakeholders involved and the large reliance on volunteers to collect field data, there are only limited possibilities to influence the way in which or location where certain observations are collected. However, this seems not to be unique to NDFF/EcoGRID but rather a general characteristic of the observational data underlying species distribution studies.

A second weakness is that it takes a lot of effort to agree with all the stakeholders in the project about the technologies that are being implemented. And when new technologies are implemented in NDFF or EcoGRID it takes a big effort to explain and educate all users. This time could otherwise be spent on ecological research.

Ecosystem Sustainability Scoping Study Workshop – Terrestrial and Freshwater
Defra Innovation Centre, Reading
Tuesday 16th December

09 December 2008

Dear Delegate,

We are pleased to confirm that you have registered for the workshop on Terrestrial and Freshwater ecosystem sustainability scoping study workshop on the 16th December.

Registration will take place between 9.30 and 10am, and refreshments will be available on arrival. Please note that talks will start promptly at 10am, so please register early. The workshop will aim to finish by 4pm.

We attach the following information to ensure that we make best use of the time.

1. **Workshop Briefing Note** – Summarising the objectives of the workshop and the rationale for undertaking this action

2. **Evidence** – Collected from inviduals or organisations working on relevant programmes and initiatives

3. **Map and travelling instructions** for the Defra Innovation Centre.

We would greatly appreciate it if you could read the briefing notes and evidence documents before arriving at the workshop, so that we can optimise the valuable time that we have together.

If you have time between now and the 11th December, could you send me what you consider **to be the top three priority research questions that require a large-scale, long-term platform for delivery (maximum 50 words each).** These will be collated and used as a starting point for the workshop sessions.

We hope that you will have time to read this information and to think about the questions from the perspective of your organisation and from your own experience in studying ecosystems. You should also consider the needs of others in the community and seek opportunities to understand each other's viewpoints.

If you would like to claim for travel and subsistence to and from the workshop, please contact me and I will send you the NERC guidelines on T&S and a claim form.

To contact the innovation centre on the day of the workshop, please call: 0118 955 7800.

We look forward to meeting you at the workshop

Nichola Badcock

NATURAL ENVIRONMENT RESEARCH COUNCIL

Ecosystem Sustainability Scoping Study Workshop – Terrestrial and Freshwater
Defra Innovation Centre, Reading
Tuesday 16th December

Briefing Note

We are delighted that you have applied up to attend the workshop on the 16th December. We have about 50 confirmed delegates from a wide range of organisations and backgrounds. It promises to be an interesting workshop. We are also aware that each of you will have a different starting point and knowledge of the ecosystem suitability scoping study.

Workshop Objectives

This scoping exercise will identify and outline options for future planned activities in developing an unprecedented cross-scale biodiversity experiment of global significance to inform our understanding of biodiversity functions and processes across scales and systems. The programme options should be world-leading and integrated within the context of other national and international activities in this area. The purpose of the scoping activities is to:

(i) determine what the priority research questions are that require a large-scale, long term platform for delivery,

(ii) consider the advantages and disadvantages of different approaches to achieving the desired science outcomes (e.g. a single site approach vs multiple experiments vs a virtual observatory), and

(iii) determine the resources required to deliver a programme of this kind that will contribute to global initiatives in ecosystem sustainability.

Background Information

This scoping exercise directly relates to delivery of the NERC Strategy, in particular the Biodiversity theme. A greater understanding of the factors dictating ecosystem sustainability addresses the main Biodiversity theme challenge, “biodiversity in ecosystems, processes resilience and change”. It is also relevant to specific challenges within the Biodiversity theme, challenges 2 (“detailed study of a single system to demonstrate a systems biology approach”), 4 (“biodiversity for life support), and 5 (tools for valuing the environment. There are also links with the Virtual Observatory action that would facilitate comparisons with distributed small-scale ecosystem projects, which has emerged from the Sustainable Use of Natural Resources theme.

This action would be the first large-scale, multidisciplinary investigation of the stability of ecosystems that are linked across major environmental gradients and the associated functional role of biodiversity at both the landscape and ecosystem level. This is an exciting opportunity to develop the essential paradigms that are currently lacking. Whilst the UK biodiversity research community is recognized as possibly the best in the world, much of the community has not been accustomed to working at cross-ecosystem landscape scales in multidisciplinary teams to identify the interdependencies between ecosystems, traditionally pursuing independent, focused research at small scales. This action will also demand new approaches and ways of working for the biodiversity research community. Specifically, many of the questions will need to be tackled at spatial and temporal scales in which society has a stake as well as bridging the sub-disciplines within natural sciences and working at the interfaces between the natural, physical and social sciences. It is proposed to harness this intellectual capacity to achieve new synergies to facilitate major science advances by allowing the community to work with a large-scale, integrated experimental platform at the landscape scale. The benefits of multi-disciplinary, large team efforts in field campaigns are well established in the marine and atmospheric sciences and the proposed experimental platform will deliver similar benefits for NERC's biodiversity programme. The action should run for enough time to allow incorporation of significant environmental variation into models (e.g. cold, warm and low and high precipitation years). This work will also put us in line with the highly successful US LTER programmes. It will also make a major contribution to providing policy makers with evidence needed to develop strategies to mitigate impacts of climate and other environmental change on biodiversity and ecosystem services.

This scoping exercise will outline options for a world-leading research programme aimed at improving our understanding of biodiversity, environmental gradients and ecosystem sustainability at large scales by providing (i) a step improvement in understanding of the role of biodiversity in ecosystems (ii) marked improvement in understanding of effects of change on biodiversity and ecosystems with concomitant enhancement of ability to predict future response scenarios, and (iii) a significant improvement in quality of advice to stakeholders.

NATURAL ENVIRONMENT RESEARCH COUNCIL

Ecosystem Sustainability Scoping Study Workshop – Terrestrial and Freshwater

Defra Innovation Centre, Reading

Tuesday 16th December

Evidence

Marine

- PML GLOBEC (Global Change and Marine Ecosystems) - Manuel Barange
- MarBEF (Marine Biodiversity and Ecosystem Functioning) – Carlo Heip
- MBA MECN (Marine Environmental Change Network) – Matthew Frost
- Oceans 2025 – Phil Williamson
- PGP Mesocosm Experiment – Ian Joint

Terrestrial and Freshwater

- CEH (Centre for Ecology and Hydrology) – Mark Bailey
- CPB (Centre for Population Biology) – Georgina Mace
- ECN (Environmental Change Network) – Don Monteith
- Ecological Continuity Trust – John Silverton
- LifeWatch – Terry Parr
- UKPopNet – Dave Raffealli

Virtual

- EcoGRID – Emiel van Loon

GLOBEC (Global Change and Marine Ecosystems)

A core project of the International Geosphere-Biosphere Programme, co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission of UNESCO (IOC)

GLOBEC, a study of Global Ocean Ecosystem Dynamics, was initiated by SCOR and UNESCO-IOC in response to recommendation of a joint workshop which identified the need to understand how global change, in its broadest sense, will affect the abundance, diversity and productivity of marine populations comprising a major component of oceanic ecosystems. The programme has four specific objectives:

1. To better understand how multiscale physical environmental processes force large-scale changes in marine ecosystems
2. To determine the relationships between structure and dynamics in a variety of oceanic systems which typify significant components of the global ocean ecosystem, with emphasis on trophodynamic pathways, their variability and the role of nutrition quality in the food web
3. To determine the impacts of global change on stock dynamics using coupled physical, biological and chemical models linked to appropriate observation systems and to develop the capability to predict future impacts
4. To determine how changing marine ecosystems will affect the global earth system by identifying and quantifying feedback mechanisms

GLOBEC was globally implemented in 1999[1], with a mandate to run until December 2009. It is therefore in its integration and synthesis phase. GLOBEC is coordinated through an International Project Office, based at the Plymouth Marine Laboratory. The IPO is co-funded between NERC and PML, and receives funding for its activities from USA-NSF, SCOR, IGBP, IOC, and had hoc support from a number of funding agencies.

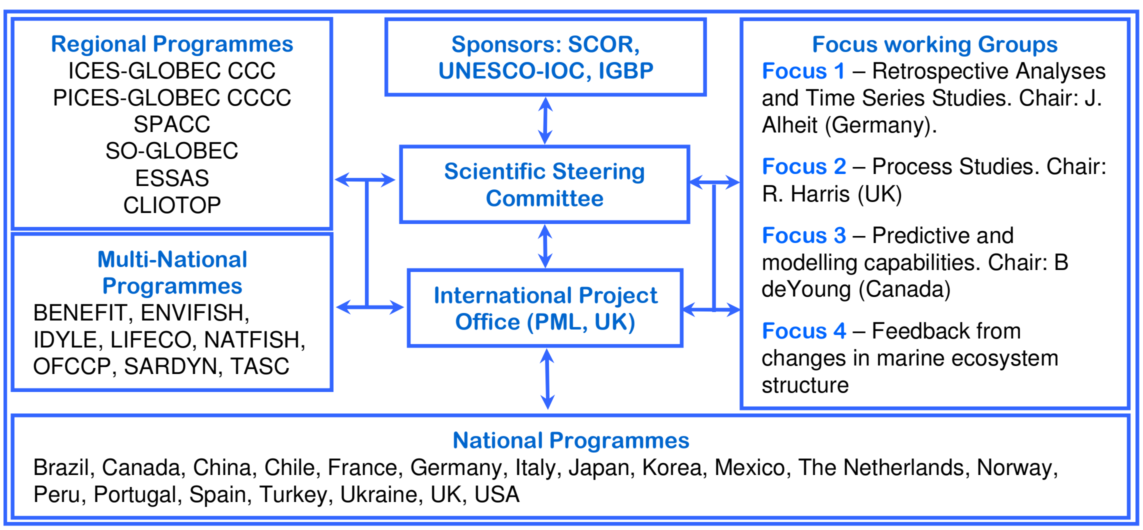


Figure 1. Programmatic structure of GLOBEC. See text for explanations.

GLOBEC has been implemented on the basis of national and multi-national field programmes (Figure 1). In addition, a number of regional programmes have been set up, to cover most marine ecosystem types and to recognise the basin-scale nature of many global change impacts. These are:

- ICES-GLOBEC Cod and Climate Change (CCC)
- PICES-GLOBEC Climate Change and Carrying Capacity in the North Pacific (CCCC)

[1] GLOBEC 1999. Global Ocean Ecosystem Dynamics. Implementation Plan. IGBP Report 47 and GLOBEC Report 13. 207p.

- Small Pelagic fish And Climate Change (SPACC)
- Southern Ocean GLOBEC (SO)
- Ecosystem Studies of Sub-Arctic Seas (ESSAS)
- CLimate Impacts On marine Top Predators (CLIOTOP)

Some national programmes (e.g. USA) and most regional programmes have there own support office that works closer with the IPO. Most of them also have there own steering committees or executive committees. In the case of regional programmes, these committees respond to the GLOBEC SSC and receive funding through it. Approximately 30 countries contribute to the research conducted at national, multinational and regional level. The North and South Atlantic and Pacific Oceans, the Southern Ocean and the equatorial Indian Ocean are the main implementing regions.

In addition, GLOBEC runs four working groups, designed to extract information from the field programmes and conduct activities conducive to integration and synthesis. The membership of working groups tends to reflect the national and regional programmes. Their mandates are:

- Focus 1 – Retrospective Analyses and Time Series Studies.
- Focus 2 – Process Studies
- Focus 3 – Predictive and modelling capabilities.
- Focus 4 – Feedback from changes in marine ecosystem structure

The work of GLOBEC has been summarised, among others, in 26 special issues in peer-reviewed journals, over 3,000 logged publications (2,600 peer-reviewed), 4 synthesis books (3 in press) and 10 international symposia (for the period 2000-2009). The final GLOBEC Open Science Meeting will take place in Victoria, Canada, 22-26 June 2009. In the last year of the programme GLOBEC will also put together a brochure of scientific highlights (research highlights are already selected and published annually) and a summary for policymakers, to complete its knowledge transfer requirements.

As requested by the theme leader, we will briefly address the following two questions:

Strengths and weaknesses of GLOBEC's approach
Without umbrella programmes global scientific synthesis (not global assessments) would be almost impossible to achieve. They certainly would not have the credibility and influence that umbrella programmes provide, partially because these are developed by large sections of the community and with non-partisan international support. By being strongly connected to international science and policy bodies, GLOBEC does influence research planning and the delivery of knowledge to decision makers. This approach also adds considerable value to the research investments conducted at national level and helps building capacity across large regions (one of our major goals). GLOBEC has been particularly successful in implementing work at regional level, working closely with policy and science bodies at that geographical scale to identify and resolve important questions. The lack of a single "unit" (like Carbon has been for other programmes) has made our synthesis more complex, and yet much more diverse and unexpected. The work has gradually focused more on impacts of global change to human societies and has become increasingly more multidisciplinary. In this sense it has develop frameworks of interaction between the natural, social and economic sciences, of broader use. On the negative side it is difficult to keep enough rotation at the management and scientific leadership level to ensure the effort truly represents a global consensus. Also, the success of working groups depends very much on the drive and vision of a few individuals. One of the reasons for our success has been the setting of a sunset clause, to ensure focus on our delivery and synthesis, as opposed to continued efforts with no planned end and moving objectives. Sunset clauses allow the community to revisit the science after some time and design fit-for-purpose programmes.

Indication of the costs (both of the programme and its management)
Most of the funding of GLOBEC is devoted to field work and is raised through standard mechanisms by national scientists. In addition, the GLOBEC IPO generates "glue money", to support workshops, publications, conferences and travel support. It is difficult to estimate the actual investment in GLOBEC's science. The US GLOBEC programme, for example, has invested USD140 M during its life. Globally this figure probably exceeds USD250 M, but different funding mechanisms preclude an accurate estimate. The international coordination of international project offices, including manpower, workshops, committees, publications, etc., has been estimated by the International Group of Funding Agencies (IGFA) to be typically of the order of US$500-750k per year, probably less than 2% of the research funding. In addition, substantial funding is generated by IPOs, so that their central funding can be consider an investment rather than a direct cost.

For more information, contact the Director of the IPO, Dr Manuel Barange, Plymouth Marine Laboratory, m.barange@pml.ac.uk, 01752 633160; www.globec.org

MarBEF: Marine Biodiversity and Ecosystem functioning

FP6 Network of Excellence: 95 Institutes (56 full members) across 24 nations and over 600 scientists involved

Introduction

Knowledge on marine biodiversity in Europe is fragmented within and between disciplines. The approach to understanding the effects of increased anthropogenic pressure on marine biodiversity has hitherto been ad hoc and local. In particular, to understand how marine ecosystems will adapt to climate change, we need addressing especially the long-term and large-scale changes in marine biodiversity. This requires an entirely new research framework.

The network of excellence MARBEF (Marine Biodiversity and Ecosystem Functioning) aims at integrating research efforts by forming a dedicated group of marine scientists and institutes and creating a virtual European institute with a long-term research programme and dedicated links with industry and the public at large. This involves besides coordination of research the training, exchange and outreach activities in several relevant fields of science, including marine ecology and biogeochemistry, fisheries biology, taxonomy and socio-economic sciences. Better integration of research is also required to support the legal obligations of the EU and its member states and associated states for the Convention for Biological Diversity, the OSPAR and Barcelona conventions as well as several EU directives (Bird Directive, Habitat Directive, Water Framework Directive) and the future EU Maritime Policy.

The network improves links between the academic and governmental institutions and the large and growing number of industries depending on the sustainable use and exploitation of marine biodiversity. This includes tourism, fisheries and aquaculture but also new industries that explore and commercialise marine genetic and chemical products.

MarBEF's primary objectives are:

1. To develop a better understanding of marine biodiversity and ecosystem functioning.

2, To understand and minimize the negative impacts of human activities.

3. To ensure sustainable management of natural resources and marine ecosystems as well as the protection of genetic resources.

MARBEF's primary goal is to create a virtual European centre of excellence in marine biodiversity and ecosystem functioning that will deliver the top quality science needed to underpin these three objectives.

The integrated science component

The integrated science component of the NoE has three general themes:

1.To understand how marine biodiversity varies across spatial and temporal scales, and between levels of biological organisation, in order to develop methods to detect significant change.

Research activities within this theme aim to understand, and assess marine biodiversity (species and genetic levels) on a global scale in an ecosystem context, taking into account the combined effects of the main drivers (anthropogenic and natural) in determining patterns in marine biodiversity.

2. To generate theory, models and tests of the relationship between marine biodiversity (assessed at different levels of organization: genetic, traditional species, and functional groups) and ecosystem function through the integration of theoretical and modelling exercises, comparative analyses and carefully-designed experimental tests.

This theme addresses the relationship between ecosystem functioning and biodiversity, and aims to predict the consequences of changes in biodiversity to marine ecosystems in terms of their stability and functioning, and on their ability to provide goods and services

3.To understand the economic and social value of marine biodiversity by developing the research base required to support the sustainable management of marine biodiversity, the monitoring of the health of marine ecosystems, the management of aquaculture, the conservation of marine biodiversity, the history of marine resource exploitation, and the leisure use of marine ecosystems.

This third theme addresses the socio-economic implications of marine biodiversity. The aim is to approach the social and economic implications through a range of initiatives, working at the interface between marine ecology and socio-economics, promoting research exploring the societal drivers leading to biodiversity loss, and ways in which these may be reduced.

Organisation

The NoE is organised in 10 workpackages of which three address primarily the integrated research objectives of MarBEF. The work within the three research themes are organised in a two-way approach:

1. A top down organised Core Strategic Programme (CSP) ensuring that the main goals of the network are being reached, supplemented with
2. Bottom up organised (dedicated) Responsive Mode Projects (19 RMPs) that fill in the gaps of the CSP.

Methodologies (site related approaches)

Theme 1, and some of the RMPs within it, are working with a set of large integrated databases containing primary biodiversity data of a network of sites, contributed by the individual participants. IPR is an important issue.

The work of theme 2 is primarily organised around the activities of the individual RMPs. Depending on the research focus of these RMPs, the projects are focussed on a network of sites, or processes linked to spatial patterns.

The science within theme 3 is either conceptual, linked to specific case studies (sites), and/or linked to spatial patterns, or general processes (functions).

Strength and weaknesses of the approach

+ The combination of the top down and bottom up approach works very well.
+ The commitment within the RMPs is very high
+ The investment of the participants in MarBEF is very high
- The managerial burden (paperwork) for the participants (full members) is too high
- The lack of a future for large NoE’s within FP 7 and beyond complicates the development of a long lasting infrastructure for the network and the consortium commitment
- It remains difficult to get end users (policy makers, politicians) involved
- The investment of the participants in MarBEF is very high: therefore a high value for money is delivered which is not in balance with the market principle of the members involved in strategic (applied) science.

Estimation of costs

The total budget of MarBEF is 8.7 Milion €. Total management costs are maximal 7% of this budget. Because of mainly the management requirements for the EC, the management costs most probably will exceed this limit.

Marine Biological Association of the UK

The MBA has been involved in systematic observations of the marine environment for over 100 years. The MBA has an international reputation for global environmental change research based on the extensive time-series that the laboratory has collected since the start of the twentieth century, coupled with laboratory and field experimental research into the mechanisms behind species responses to both acidification and warming of the world's oceans. The MBA receives substantial funding from a variety of Research Council and other sources for both blue skies and strategic research, including the NERC Oceans 2025 marine science strategic programme. The laboratory is ideally situated in an oceanographic breakpoint region where cold boreal and warm lusitanian waters meet, and conducts monthly benthic sampling at multiple sites in this area to monitor ecosystem fluctuations in response to environmental change. The MBA has an extensive seawater aquarium with both treated and untreated seawater supplies sourced from directly below the laboratory in Plymouth Sound. Facilities include controlled environments where temperature, seawater chemistry and irradiance can be artificially manipulated for open or closed experimental seawater systems. This resource plays an integral role in research programmes investigating environmental change and impacts on marine biodiversity, providing an essential facility for long-term holding and conditioning of species in thermally and pH-controlled environments. The MBA also has a state-of-the-art cellular and molecular suite which is being used to pursue novel research into the impact on biological mechanisms of global climate change.

The Marine Biological Association has several research programmes dedicated to environmental change and biodiversity, and hosts the national Marine Environmental Change Network. It is a core member and data contributor to the Western Channel Observatory and the MECN also functions as the Knowledge Transfer and Exchange mechanism for this web-based resource. Both the MBA and the MECN are active members of the MarBEF European Network of Excellence. These programmes and organizations are interlinked within the MBA to provide an holistic approach to the detection, quantification and prediction of the effects of global environmental change on the marine environment.

Marine Environmental Change Network

In 2002 the Marine Environmental Change Network was established by DEFRA and the Marine Biological Association of the UK in response to the cross-sector recognition of the need for the continuation, restoration and enhancement of marine observations around the UK (Inter Agency Committee for Marine Science and Technology, 2001). MECN has brought together seventeen major groups from the research and university sectors responsible for maintaining long-term recording of the marine environment around the British Isles, and is expanding to incorporate government agencies with long-term monitoring programmes.

MECN's strengths lie in the cross-cutting nature of the datasets and monitoring from the partners. The time-series and long-term research programmes maintained and re-started by these MECN partners are unique due to the length of time over which measurements have been collected (many are multi-decadal) and the number of environmental and biological parameters which are measured. These cover intertidal, subtidal and nearshore benthic and pelagic systems. Multiple recording sites have been established for each parameter, enabling MECN to provide information at local, regional and national scales. MECN is a member of the FP7 Network of Excellence MarBEF, and is involved with the MarBEF LargeNet European database project. Several UK datasets have been submitted to LargeNet via MECN, and MECN in turn has access to this European database covering pelagic, soft and hard benthic systems, allowing MECN to provide information at the European scale. MECN is in the process of linking with the terrestrial Environmental Change Network to promote a large-scale, cohesive 'catchment-to-coast' approach encompassing both systems, and to integrate common data collection and archival standards across the natural ecosystems within the UK. Via links to Lifewatch, this will also be extended to the European scale. Weaknesses are focused around the multi-source funding structure of the varu

MECN also functions as a conduit between scientists and policymakers and stakeholders, with the remit, '*to ensure that information from the network is provided to policy makers and other end-users to enable them to produce more accurate assessments of ecosystem state and gain a clearer understanding of factors influencing change in marine ecosystems*'. Information on long-term trends in the marine environment has been given to the relevant government bodies to provide the context in which climate impacts (and other factors) can be assessed. MECN has also initiated scientific collaborations between the MECN network partners and meta-analyses of multiple datasets from the network to answer emergent questions regarding the state and changes to the UK coastal marine ecosystem.

Fig.1. MECN partner institutes.

Fig.2. Rocky intertidal survey sites in the UK

Marine Biodiversity and Climate Change

The MBA maintains several long-term time-series, which include some of the most temporally extensive datasets globally. A suite of parameters are regularly measured including temperature, salinity, phytoplankton, fish, rocky intertidal and soft sediment benthos. Several research projects at the MBA use these time-series as a basis for process-driven research into the impacts of climate change including behavioural, physiological, cellular and molecular responses. The rocky intertidal time-series captures data from over 400 locations around the UK coastline (Fig.2), and has been extended to coverage of the Atlantic coastline of Europe and Scandinavia. A collaborative project with the National Institute for Water and Atmospheric Sciences, NIWA has established the first biodiversity baseline in New Zealand for the monitoring of future climate-driven changes to marine biodiversity. The multi-site, temporally extensive nature of the datasets allow ecological responses to climate change to be tracked in different components of coastal and shelf ecosystems. Weaknesses again centre on the short-term nature of funding. Approximate costings for the maintenance of the time-series and the associated research are £350,000 p.a.

Large-scale biodiversity, environmental gradients and ecosystem sustainability

Oceans 2025 perspective for NERC Biodiversity Workshop: 15 Dec 2008

1. The (marine) challenge

1.1 The variety of animals, plants and microbes has a profound effect on marine pathways and processes, and can be highly sensitive to natural environmental forcing and human pressures. Our knowledge of the functional significance of marine biodiversity is, however, extremely limited. A much more rigorous understanding is needed to develop the generic models and other tools that will not only reliably detect and predict ecologically-important changes, but will also assist in achieving sustainable bioresource use, soundly-based marine spatial planning, and national compliance with statutory requirements for 'good environmental status' in UK waters[1], from coasts and estuaries to the depths of the open ocean.

1.2 The Oceans 2025 programme, a partnership of seven NERC-supported Centres, addresses this complex challenge through a Biodiversity component (Theme 4) strongly linked to other programme elements. The scale of the marine environment — providing 97% of the global biosphere, with its organisms mostly unknown[2] — makes it crucial to coordinate Oceans 2025 effort with other relevant research activities, maximising the return from current investments in skills and capabilities. In particular, the development and delivery of NERC's Biodiversity Theme Action Plan provides a unique opportunity to accelerate scientific advances at a national scale, by fostering synergies, supporting ambitious large-scale initiatives, and complementing terrestrial and freshwater research effort.

2. Biodiversity research in Oceans 2025

2.1 Theme 4 of the Oceans 2025 programme, Biodiversity and Ecosystem Functioning, is jointly implemented by Plymouth Marine Laboratory (PML), the Scottish Association for Marine Sciences (SAMS), and the Marine Biological Association (MBA). Total effort is ~11 FTE pa. Its objectives are:

- to identify the critical species-level processes needed for next-generation ecosystem models that will characterise the effect of marine biodiversity on ecosystem functioning
- to understand how resilient and predictable marine ecosystems are in response to environmental change, including habitat modification, species loss and species invasions, in realistic physical environments
- to determine the role of trophic interactions in controlling energy flow, and in contributing to the diversity and structure of marine ecosystems and their response to change
- to identify the important temporal and spatial scales of variation in coastal marine biodiversity
- to describe links between biodiversity and ecosystem function at different levels of biological organisation and complexity.

2.2 The delivery of the above is intimately connected to other Oceans 2025 work at PML, SAMS and MBA and at the National Oceanography Centre Southampton (NOCS), Proudman Oceanographic Laboratory (POL), Sea Mammal Research Unit (SMRU), and the Sir Alister Hardy Foundation for Ocean Sciences (SAHFOS). Thus there are biodiversity-related activities in seven other Oceans 2025 themes: Climate, circulation and sea level change (Theme 1), Marine Biogeochemical Cycles (Theme 2), Shelf and Coastal Processes (Theme 3), Continental Margins and the Deep Ocean (Theme 5), Sustainable Marine Resources (Theme 6), Next Generation Ocean Prediction (Theme 9), and Sustained Observations (Theme 10). Two Oceans 2025-supported national facilities are also directly involved: the British Oceanographic Data Centre (BODC) and the Culture Collection of Algae and Protozoa (CCAP)[3].

[1] The EU Marine Strategy Framework Directive requires that (by 2020) "1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions. 2) Non-indigenous species introduced by human activities are at levels that do not adversely alter ecosystems. 3) Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution indicative of a healthy stock. 4) All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity....".

[2] The World Register of Marine Species (WoRMS, part of the Census of Marine Life) has estimated that only ~25% of marine species are known to science; see www.marinespecies.org/news.php?p=show&id=349. However, this estimate does not take account of prokaryotes, archaea and viruses, that in metagenomic analyses provide the overwhelming majority of marine genetic diversity.

[3] Note that ~65% of CCAP holdings are non-marine, isolated from freshwater and soil. This is reflected in CCAP's current research.

2.3 In addition, the Strategic Ocean Funding Initiative (SOFI) and the Sustainable Marine Bioresources programme (SMB) support biodiversity-related collaborations between the Oceans 2025 researchers, university groups and other partners, through 8 research grants, 3 studentships and (to date) 3 workshops in this topic area. A summary of biodiversity research in Oceans 2025 is given at Annex 1; further details of the programme are available at www.oceans2025.org.

2.4 It should be noted that marine Centres in the Oceans 2025 programme receive funding from a range of non-NERC sources for biodiversity-related research, and participate in many national and international activities and networks, e.g. Census of Marine Life (CoML, www.coml.org), and the EU Marine Biodiversity and Ecosystem Functioning network of excellence (MarBEF, www.marbef.org).

3. Why biodiversity research needs to be multi-scale, multi-disciplinary and technologically-sophisticated

3.1 Spatial and temporal scaling issues are fundamental to a functional approach to marine biodiversity. Most research to date has been limited to a sub-set of the biota — such as benthic invertebrates, zooplankton, or fish — usually in the mm-cm size range, and with experimental studies typically at the 1 – 10 m scale. However, ecologically-significant interactions occur across the full taxonomic spectrum and size range, from viruses to whales; 'invisible' organisms dominate energy flows and elemental cycling in most marine ecosystems; population processes, habitat landscapes and hydrodynamic structuring operate on relatively large scales (from 10 m to 1000 km); behaviour may determine genetic differentiation within geographically-distinct biomes; and the problem of invasive, non-native species requires comprehensive knowledge of both their original and new environments.

3.2 Temporal scaling considerations are similarly broad, covering the range from diurnal to seasonal variability in gene expression and species' abundance; historical patterns of human impacts; the geological time scales that have shaped phylogeny and present-day distributions (e.g. Arctic – Antarctic differences); and the need to predict responses to management actions (both conservation and exploitation) and interactions with climate-driven regime shifts that may already be underway.

3.3 As indicated from the above, the importance of non-biological influences on biodiversity necessitates a multi-disciplinary approach. Thus what-lives-where is a function of *inter alia* lateral and vertical water movements; mean, seasonal and extreme temperatures; salinity and other aspects of water chemistry; and sediment/substrate characteristics. For photosynthetic organisms, light and nutrients are also key parameters. This need for supplementary data on many physico-chemical factors requires additional effort; nevertheless, it assists in giving strategic context, focusing attention on the responses of populations, species and trophic interactions to environmental change (e.g. ocean acidification; temperature-induced stratification or mixing) and associated biogeochemical feedbacks.

3.4 Technologically-sophisticated sampling platforms and analytical technologies are also increasingly needed for marine biodiversity work. Whilst most inshore and coastal ecosystems can be accessed relatively easily and reasonably frequently, open ocean studies require either the sampling and experimental facilities of a well-equipped research vessel, or *in situ* instruments on towed gear, autonomous vehicles, landers or moorings. Ships-of-opportunity have an important role for plankton surveys and other upper ocean measurements, although constrained by sampling depth and the range of organisms that can be collected and preserved for subsequent identification.

3.5 Molecular-based methods are now standard tools for analysis of genetic structure and, increasingly, the definitive descriptor of species identity[4] (e.g. GenBank/EBI accession numbers for rDNA sequences and other molecular markers are now provided with CCAP strain information). A barcode system is being developed to characterize protistan biodiversity by CCAP, with international collaborators. In addition, metagenomic libraries provide a way to link function with phylogeny, thereby facilitating the discovery of novel biochemical processes and products with biotechnological applications. Several other technologies, e.g. image analysis, flow cytometry and HPLC-based chemical taxonomy, also offer new opportunities for sample sorting and characterization, although are not yet fully practical for routine species-level identification.

[4] Identification problems have bedevilled biodiversity research. The 2008 WoRMS analysis [footnote (2)] demoted 56,400 marine "species" to alias status, almost a third of all names culled from 34 national and international inventories. Some species are morphologically very different under different conditions, e.g. genotypically-identical algae that are unicellular in freshwater whilst filamentous in the marine environment; others may only have a single species name, yet encompass very wide genetic diversity.

3.6 For both shelf sea and deep water work, multi-spectral satellite remote sensing and physical modelling (e.g. using particle tracking techniques) are now near-essential for scaling-up from point measurements or transects to synoptic habitat, biome or ocean-basin scales. All expertise need not be within the same institution; however, biodiversity researchers, remote sensing experts and physical modellers need to be aware of each others' needs, capabilities and limitations.

4. Strengths and weaknesses of Oceans 2025 biodiversity research

4.1 *Strengths*. Biodiversity work within Oceans 2025 involves a very wide range of taxonomic expertise (molecular and traditional) and covers diverse habitats, over a wide spatial range. It benefits from well-studied sites (several with globally-unique historical records), excellent experimental facilities and culture collections; in addition, it is strongly linked to modelling, biogeochemistry, remote sensing and other technologies. Within the biodiversity theme, there is no single 'approach' and effort is directed at the following issues (each as a separate Work Package):

- The characteristic scales of variation in biodiversity in coastal and shelf seas
- Linkage between benthic dynamics and pelagic ecosystem functioning in shallow seas
- The influence of biodiversity on ecosystem functioning at different levels of organisation
- Contrasting roles of predators and prey in energy flows
- Microbial mediation of primary productivity and algal biodiversity
- Linkages between habitat complexity, size diversity, and invasion-related changes in species diversity to the delivery of ecosystem services
- Functional responses of intertidal assemblages to environmental change.

4.2 *Weaknesses.* The above WPs and the programme objectives (para 2.1) can be considered over-ambitious, with the different marine Centres arguably tackling too broad a range of scientific problems, in too many different ways — and lacking an overall theme. Whilst the Oceans 2025 programme will undoubtedly advance understanding in these areas, it is unlikely to definitively answer the scientific questions posed. However, it should be remembered that the Oceans 2025 was developed as a coordinated programme, not an integrated one; furthermore, there are many linkages to other programme elements, making the problems more tractable than might appear.

Annex 1 Summary of biodiversity expertise and interests at Oceans 2025 Centres

Centre	**Main biodiversity interests and activities** *not all funded via O2025*	Main groups	O2025 Themes
MBA	Recruitment and survival in intertidal assemblages; coccolithophore genomics and biogeochemistry ; virus genetics and ecology; fish genetics and distributions ; benthic invertebrates; non-native species. Co-lead for WCO; host for Marine Environmental Change Network (MECN), Marine Life Information Network (MarLIN) and Data Archive Centre for Seabed Species and Habitats (DASSH)	Macro- and micro-algae, viruses, fish, invertebrates	T2, T4 T6, T10
NOCS	Deep sea benthos, including continental margin canyons, mid-ocean ridges, vents and seeps; chemosynthetic ecosystems; 'twilight zone' midwater fauna; acidification effects on calcareous phytoplankton; ecosystem modelling. Lead for PAP observatory, co-lead for AMT	Benthic and planktonic invertebrates, micro-algae	T2, T5 T9, T10
PML	Benthic-pelagic interactions; effects of microbial biodiversity on biogeochemistry; molecular characterisation; biotechnology; zooplankton dynamics; ocean acidification effects; remote sensing; ecosystem modeling; links to socio-economics. Co-lead for WCO and AMT	Bacteria, viruses, micro-algae, zoo-plankton, benthic invertebrates	T2, T3 T4, T6 T9, T10
POL	Ecosystem modeling; linkage between physics and plankton production in shelf seas. Lead for Irish Sea coastal observatory, host for BODC		T3, T6 T9
SAHFOS	Basin-wide plankton surveys and data analysis, using ships of opportunity	Zoo- & phytoplankton	T10
SAMS	Predator-prey relationships, intertidal fauna, fish population dynamics, bacteria-algae interactions, algal productivity, molecular taxonomy, habitat complexity, aquaculture impacts, artificial reefs, deep sea benthos incl cold-water corals, regime shifts. Lead for Arctic shelf time series; host for CCAP (marine, freshwater and terrestrial) and Euro-CoML.	Phytoplankton, macro-algae, protozoa, benthic invertebrates, zooplankton, fish	T1,T3 T4, T10
SMRU	Distribution and abundance of sea mammals, trophic dynamics	Seals, other marine mammals & their prey	T10

Annex 2 How a large-scale study of (marine) biodiversity might be developed

i) The proposed focus on either 'ecosystem function', 'ecosystem services' or 'sustainability' for a large-scale, experimental approach has attractive features as the central idea, emphasising the importance of the biodiversity-environment relationship. However, those concepts are all highly complex, potentially involving a wide variety of science questions, and, depending on their prioritisation, requiring very different experimental designs. Even if ecosystem services are considered only from a human perspective, more than a dozen issues are potentially involved[5].

ii) Large-scale (and hence high-cost) biodiversity studies that are limited to academic considerations are difficult to justify in current national economic conditions. 'Sustainability' implies that the biological components have resource (human use) value and are subject to external forcing. We therefore suggest that the first question to be considered by the workshop is whether the dominant forcing to be investigated is climate change or marine management — noting that both these approaches provide opportunities for freshwater and terrestrial comparisons.

Option A: Focus on climate change

iii) Empirical analyses of latitudinal diversity patterns — and their temporal changes — among different functional groups, trophic levels and across major environmental gradients can suggest possible mechanisms for the climatic regulation and role of biodiversity. 'Data mining' of distributional and abundance information collected over long time periods and large spatial scales (e.g. the Continuous Plankton Recorder survey, CPR), has provided many insights in this regard. However, correlations are not always causal: definitive understanding must be obtained by hypothesis-testing, typically through relatively small-scale experiments embedded within a wider observational network. Critically, the experimental work should inspire and drive the production of large-scale system models that allow further testing of the climatic mechanisms driving large-scale biodiversity patterns and ultimately deliver ecosystem-level understanding.

ii) A latitudinal-based approach could productively be based on:

- Ongoing information provided by the Western Channel Observatory (designated as National Capability within Oceans 2025, and chosen as a prime Long Term Biodiversity Research site in a new EU Concerted Action, Biomare; www.westernchannelobservatory.org.uk).
- A second northern temperate coastal/shelf sea site, such as the fjordic system of western Scotland near Oban, with existing data on fishery recruitment, intertidal invertebrates and macroalgae, sediment dynamics and benthic processes and anthropogenic impacts
- Two polar coastal sites, one in the Arctic (e.g. Kongsfjord, Svarlbard as studied by SAMS since 2002) and another in the Southern Ocean (e.g. at Rothera, planning to be led by BAS).
- A deep ocean site, such as the Porcupine Abyssal Plain observatory (PAP, at 46°N 16.5°W), supported by NOCS under Oceans 2025 There are existing PAP seasonal and multi-annual data for pelagic and benthic communities, and additional mooring-based automated instrumentation will be deployed in 2009. Wider deepwater comparisons would be achieved via the EuroSITES network.

iii) Experimental and observational studies at the above sites would be complemented by basin-wide sampling and data gathering, through the CPR study (mostly North Atlantic but some Pacific and Southern Ocean data, and new Arctic routes); the Atlantic Meridional Transect (AMT), with underway biotic sampling linked to biogeochemistry, physical oceanography and remote sensing.

Option B: Focus on marine management

iv) The main science issue would relate to maximizing the benefits (in terms of biodiversity and biodiversity-based ecosystem services) for marine protected areas, applicable to both shelf seas and deep water. Many opportunities for experimental work related to marine renewable energy developments, fishery management and marine conservation are developing in these areas. Additional information on such ideas will be presented in informal discussion by Oceans 2025 representatives at the workshop.

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[5] These include gas and climate regulation; nutrient cycling; bioremediation of waste; provision of food and raw materials; leisure and recreation; resilience and resistance; biologically-mediated habitat; disturbance prevention; cognitive values, cultural heritage and identity; and non-use and option-use values.

Contribution to the Ecosystem Sustainability Scoping Workshop

PGP Mesocosm Experiment May 2006

Background

The PGP Thematic Programme funded a project on the role of marine microbes in biogeochemical cycling. In the proposal, we identified an experiment to assess the potential impact of ocean acidification on marine microbial diversity and function. This idea of a large project experiment was influenced by my experience from many NERC directed programmes in marine science, where grant holders worked together on a research cruise, usually on different aspects of a particular environmental problem. Each of those experiments was a success and I felt that it would be a good way to bring together the different groups involved in the PGP project to study a significant ecological problem.

Objectives

This was a single site, single experiment to investigate how elevated carbon dioxide concentrations might affect marine microbial diversity in the future. Within 100 years, the CO_2 concentration in the surface ocean is projected to be 750ppm; this increase in pCO_2 will reduce pH from the current value of 8.1 to ~7.8. This is a significant change that will influence chemical speciation as well as resulting in the dissolution of calcium carbonate shells of coccolithophores and corals. The effect on diversity of other phytoplankton and bacteria are not known. Mesocosms offer many advantages over small-scale laboratory experiments. By enclosing large volumes of seawater, we could easily manipulate pCO_2 (and hence pH) by bubbling for a few hours with CO_2 enriched air. Large water volumes ensure that most of a complex ecosystem can be captured (in this case, phytoplankton, bacteria, archaea, viruses, protozoa and zooplankton).

Facilities

We did the experiment at the Large Scale Mesocosm research facility of the University of Bergen, Norway. I had previously been involved in an experiment at this facility so I knew the advantages and disadvantages; I had a good idea of whether or not we would be able to do the experiment that we planned. Briefly, the facility is self-contained, with laboratories and accommodation (self-catering) on the site. Importantly for our needs, there was a fully serviced raft (boats, electricity and water) permanently moored in the middle of the fjord, with floatation collars from which to attach our mesocosms (basically large polyethylene bags of ca. 12000L capacity). So we were following a long line of mesocosm experiments on marine microbes that have been done at Bergen.

Success of experiment

The experiment was successful at many levels.

- There was a high level of ‘buy-in’ from the grant holders and 5 of the PI’s each spent at least 1 week at the facility (2 were there for the whole 4 week period of the experiment). Every group, with the exception of one (out of 13), sent post-docs and students (the group that did not participate was working on benthic microbiology and the experiment was not relevant to their project).

- It was scientifically successful; since we were a large group (always at least 20 people at the facility at any one time) we were able to measure a large number of parameters and processes.
- We were able to attract other research groups to participate in the experiment. So for example, the biogas groups at PML and UEA were able to take samples from our experiment for their own projects that were not directly related to microbial diversity. We also had international participation with Bergen and a group from Germany.
- There was a high degree of interaction and integration between the different Universities and laboratories that are funded by the PGP grant. Because people were working closely together, strong and lasting collaboration was developed between most of the groups that participated in the experiment. In my experience, this is one of the greatest benefits of a large experiment.

Costs and management aspects

1. The cash cost of the actual experiment was about £50000 but there were additional costs such as metagenomic sequencing that are of an equivalent scale. So in planning an experiment, it is important to know how much it will cost to analyse the samples. In my experience, you should not that these costs will be found out of standard grants.
2. I had to commit a very large amount of my time to organising this experiment. NERC refused a request in the grant application for money to provide administrative support for the whole project. So I had to do most of the administration, as well as doing my own research. Do not underestimate the time it will take to plan a large experiment. In our case, the bureaucracy included obtaining customs carnets to allow every participating research group to send their equipment to Norway (outside the EU), arranging transport of equipment, ordering of chemicals and radiochemicals for delivery in Norway (since it is difficult to ship chemicals from one country to another), liaising with staff at Bergen etc. etc. Any large experiment planned by NERC in the future should be funded appropriately and supported by a relevant level of funding for administrative support.
3. We could not have done the experiment without the support of the PML. I was able to call on technical support to help with tasks such as designing effective bubbling systems to rapidly increase pCO_2 in large seawater volumes. PML also provided a wide range of sophisticated equipment, such as flow cytometers and nutrient analysis equipment, vehicles to transport equipment to Norway etc., etc. Make sure that whoever is planning a large experiment has the infrastructure necessary to carry out the experiment and see it through to the end.
4. Do not underestimate the level of commitment that will be required by the person leading the experiment.

Ian Joint

6 November 2008

Input from the NERC Centre for Ecology & Hydrology: NERC BD Theme scoping study on large scale biodiversity, environmental gradients and ecosystem sustainability; Terrestrial and freshwater communities, December 16 2008. This document provides 1) A brief description of our programme/initiative(s), our aims, objectives and methodologies (e.g. single large site, multiple smaller sites, virtual), 2) a concept for a large scale experiment including an assessment of the strengths and weaknesses of our approach?, and 3) an indication of the costs and programme/initiative management associated with the work.
Contact Mark J. Bailey (mbailey@ceh.ac.uk) / Sarah L. Turner (sltu@ceh.ac.uk).

1. Brief description of CEH activities. CEH have a history of undertaking multi-scale, long-term monitoring and experimentation to detect, predict and understand the drivers of environmental change on species, communities and ecosystem processes. CEH is structured into three Science Programmes, Biodiversity, Biogeochemisty and Water all supported by the Environmental Information Data Centre (EIDC) to facilitate the interpretation of findings, and the gathering and dissemination of data of national and international importance.

CEH Programme research is enhanced by the interdisciplinary coordination of activities that draw on a range of expertise in ecology, genetics, hydrology, informatics, biogeochemistry, atmospheric sciences, land use, ecosystem science, remote sensing and earth observation coupled to stakeholder engagement. Our research is typically undertaken with Universities, Research Institutes and NGOs; it scales from highly controlled laboratory and microcosm studies to national and ever international scales. CEH has four sites, enabling our expert staff access to field sites representative of a range of habitats spanning environmental gradients at different scales. Working across scales is also achieved through extensive modelling expertise enabling CEH to implement systems approaches to environmental research.

CEH provides, in partnership, internationally recognised surveys and the operation of Environmental Observatories (e.g. **Countryside Survey**, **Environmental Change Network (ECN), Lakes Monitoring, UK-Phenology Network, Plynlimon, UK-Atmospheric Chemistry and Air Quality Monitoring Network, Isle of May Long Term Study, LOCAR, Carbon Catchments**, etc.). In addition, CEH provides extensive spatial and temporal datasets and integrated data products (e.g. **Biological Records Centre, Non-Native Species Portal, National River Flow Archive, NERC Bioinformatics Facility, Nutrient Flux and Deposition Maps, Land Cover Map & CORINE**, **Soils Carbon & Soils Moisture Assessments,** etc.). These underpin our curiosity led research, and model development for prediction testing and understanding by providing 'baseline' data, of the status and trends in dynamics of biota and the environmental factors influencing them.

CEH also undertakes hypothesis driven field studies on 88 lowland, 44 upland and 33 freshwater sites that encompass most broad habitat types including forests, heaths, lakes, rivers and wetlands. These experiments span the range under consideration at the Ecosystem Sustainability Workshop.

1. **Long-term, large-scale single site** experiments that study land use change impacts on biodiversity, water quantity, water quality, soil moisture, pollutant inputs, etc
2. Manipulation of **multiple smaller scale sites**, a few examples include the Large Blue reintroduction and restoration sites; EU upland warming and droughting experiments at Clocaenog and Peaknaze; assessments of different land management scenarios (e.g. Pontbren, RELU projects, Somerset Levels) including a 1000 ha replicated experiment with Natural England to quantify the effectiveness of Entry Level Agri-environment Schemes.
3. The EIDC is leading an initiative to provide access CEH data sets and establish **virtual** linkages among these to enable us to exchange ideas and expert interpretation to identify novel patterns of biodiversity stock and change, their causes and the likely societal implications.

Having experience of all three experimental systems, CEH appreciate the strength and weaknesses of each, ranging from issues associated with (pseudo)replication, or lack their of, and issues to do with the extrapolation / relevance of detailed results from a single site vs the ability to detect common responses when experiments are undertaken across a range of geographical/habitat contexts. Similarly we are aware of the resource needs to gather suitable data associated with each approach.

2. CEH Concept for a large scale experiment to assess ecosystem functioning.

- **Overarching question:** *How can we manipulate landscapes to allow biodiversity to respond to climate and land use change?* (**More details and an example are provided in Annex A**).

Our concept describes a generic approach for large scale experimentation, built on practical and relevant hypothesis testing. The approach we describe **is adaptable**; it is based on the study of one or more **Broad Habitat Types** (BHT) within a defined 'landscape' area e.g. 10km by 10km. The responses within a treatment area will be compared with those in a paired untreated area. Working across a 'landscape' block will provide information at different scales - from consideration of responses within local 'patches' up to the interactions between patches within the 'landscape' block and, if replicated, it will have broader relevance up to national scales. This builds on the success of the Farm Scale Evaluation approach and provides a conceptual framework for national activity. An initiative of this type will draw additional benefits from international LTER and LifeWatch initiatives and underpin LWEC.

This approach is based on a **large-scale multi site approach**, which has its good and bad points. We recognise the value of specific targeted, single site experiments but believe that a distributed system is essential to provide a platform on which to coordinate the study of ecosystem function and sustainability in the managed landscape of the UK, and for the results to have national relevance.

<u>Strengths and Weaknesses</u>. These are difficult to judge until the question has been identified and the experimental system and design developed. However, one strength is that it will operate at a landscape scale which is relevant for many of the most important processes that will influence climate change impact and adaptation. Smaller scale systems have considerable virtues; they are easily modified to contain internal controls to address specific issues but they rarely address multi-scale processes or drivers which act over whole landscapes. Landscape-scale studies can address these issues, but are difficult to design and manage; they require complex agreements with land-holders and consistent implementation of manipulations over time. To be successful policy direction and national coordination will be necessary. Replication may be a challenge. Environmental Observatories and experimental platforms are needed for the UK. These 'landscapes' would provide a platform into which other manipulations could be integrated e.g. affecting a different BHT. This ability to add in new treatments and experiments would require a highly coordinated and structured data management system, that might in effect evolve into an expanding virtual experiment. In many areas the use of shared data portals and knowledge transfer is an established international practice. However, data sharing and universal cooperation remains patchy. To be successful long term funding is required to establish and maintain such a system, this directly complements actions within the NERC SUNR Theme.

The long term benefits of large scale, coordinated national actives are obvious and link across all NERC Themes, LWEC and international initiatives. They provide the only means of quantifying the complex impacts of environmental change and the only true test of the effectiveness of possible adaptation strategies across landscape and catchment scales. They also provide invaluable platforms for smaller-scale, habitat-specific mechanistic studies of key ecosystem processes and services Working across scales will require the development of remote sensing technologies and ground-truthing of existing interpretation methodologies for sustainable land management.

3. Cost. To deliver a study of the type described we anticipate that a programme of 30 FTE/yrs of PDRA time and 10 students would be required over a 5 year period. This could be extended or contracted depending on scale, outcomes and the evolution of questions. In addition we anticipate that NERC Centres (CEH and BGS) would provide expertise, data and knowledge in the form of National Capability to align monitoring and survey. The objective is to establish recognised Environmental Observatories for manipulation and scenario testing, the ERFF (EOF) have a direct role to play. Such an initiative would be a national initiative and would require direct involvement with policy makers (Defra, NE), land owners, land managers, the utilities, UKRC etc.; all essential for long term planning, funding, communication and interpretation. Critically landscape scale manipulations include the urban environment and further coordination with the social sciences and environment and health are essential.

Annex A:
A Large-Scale Experiment (LSE) to address the question: *How can we manipulate landscapes to allow biodiversity and associated ecosystem functions to respond to climate and land use change?*

Summary
We propose a new Large-Scale Experimental approach which uses manipulations of landscapes and the habitats within them to allow biodiversity and related ecosystem services to respond to climate and land use change. It will test the potential for new policy approaches to re-connect habitats, increase landscape permeability and make ecosystems more resistant and resilient.

The Problem: Habitat destruction has resulted in highly fragmented landscapes.

- Fewer, smaller patches of ecosystems of high quality for biodiversity and a range ecosystem services are interspersed with poor quality patches that deliver only specific services (e.g. crops).
- The remaining high quality fragments often continue to degrade through impacts of pollution, eutrophication, invasive species, etc.
- Climate change will exacerbate these impacts as habitat becomes unsuitable for resident species, leading to cascading effects on linked species, ecosystem processes and services.
- A fragmented landscape forms a barriers which prevent species migrating (e.g. north) from newly-unsuitable to newly-suitable habitat.

The Solutions

- Novel management methods to increase the resilience (ability to recover from) and resistance (ability to withstand) of ecosystems to degrading factors; e.g. grazing to counter nitrogen deposition.
- New ecosystems can be created to replace those lost: methods have been developed to restore most UK ecosystems, but further work is needed to link this to restored function.
- Well-managed and restored ecosystems can form links (stepping stones) in landscapes to allow species to migrate to newly-available habitat.
- Ecosystems can be linked further with habitats and processes which aid species' dispersal.

Current Experiments

- Current & new experiments are designed to investigate in more detail the impact of certain drivers on *loss* of biodiversity and ecosystem services.
- Few consider methods for *countering* these losses: CEH has demonstrated capability in experiments to restore biodiversity and services at the farm-scale (e.g. Big Bee, RELU-FarmCAT, Hillesden-AES, The Farm Scale Evaluations, Large Blue, WEBs, RELU-Biofuels, Pontbren).

The Large-Scale Experiment:
The main hypothesis: ***Policy instruments can be targeted over landscapes to allow biodiversity to respond to climate and land use change, with a resulting enhancement of ecosystem function.***
The basic unit of the LSE is proposed a minimum of two 'landscape units' (size tbc - 10 x 10 km ?).

- One remains managed by existing landowners under a '**business as usual model**'. This undergoes continuing changes in biodiversity and services under environmental change.
  - This will represent the current fragmentary and 'free-market' approach to environmental land management, i.e. the business as usual landscape.
- The second a '**manipulated model**', uses existing and new (e.g. currently under development at CEH) local approaches but targets (using models) the location of management, restoration and corridors to maximise the linking up of ecosystems by:
  - Enhancing habitat connectivity by management of 'stepping-stone' habitats and by strategic introduction of habitat strips ('corridors') in intensively-used land and along linear features.
  - Strategic positioning of treatments to enhance resilience and resistance.
  - Strategic management to reduce species loss and enhance services across the landscape.
- Using modifications of existing land management policy, especially Environmental Stewardship (ES) and habitat protection (NNRs, SSSIs) schemes will ensure that:
  - Other approaches/organisations are linked in: e.g. non-statutory conservation bodies; other Government agencies such as the Highways Agency (HA), Network Rail, Defence Estates and Environment Agency (EA).
  - Targeting will involve brokered coordination among the organisations described, so should involve minimal extra cost.

- The LSE will link to ongoing ‘landscape restoration’ projects: e.g. by the Wildlife Trusts, RSPB and the National Trust. By applying science-based spatial planning, hypothesis testing and detailed measurement of biodiversity and services, it will build on these.
    - It will add to existing datasets: Countryside Surveys, Agri-Environment Assessments, NNR, etc.
- The LSE will focus on defined ‘landscape’ areas comprising mixed habitat mosaics which together provide biodiversity value via ecosystem function and service provision such as water quality and flow (inc flood defence) within catchments (boundary flux measures), climate regulation, food provisioning and recreation.

  Two examples might be:
    - Lowland agricultural comprising; arable fields, calcareous grassland, scrub, patches of broadleaf woodland and rivers.
    - Upland moorland comprising; heather moorland, bog, coniferous plantations, improved grassland, lakes and streams.
- Within these the LSE can focus on management of one or more specific BHT (see Box).

An example for one UK habitat type: Calcareous Grassland (CG)- but can be modified to other BHT.

- A calcareous landscape comprises fields of arable and improved grass, fragmented woodland/scrub areas built-up areas, roads, rivers, etc.
- CG has high biodiversity value (‘the rainforests of the temperate zone’) and provides ecological functions such as food provisioning, pollination, pest control and maintaining water quality.
- Remnant CG are highly fragmented. Some are managed by different organisations (Nat Eng, the County WT, RSPB) and others are SSSI managed by farmers.
- Management of the remnants is coordinated by a brokered agreement among the land owners/managers to facilitate resistance and resilience (e.g. extensive grazing).
- Certain arable and grass fields – selected to maximise the connectivity among remnants – are restored to CG using refined Environmental Stewardship methods.
- The margins of selected arable and grass fields are restored to a mixture of CG (high effort) and grass containing key functional species (low effort) to provide corridors between remnant and restored CG.
- Features owned by other organisations are managed and restored to provide CG and corridors: road (Councils) & highway (HA) verges, riverbanks (EA), amenity areas (councils).
- Quantifiable ecosystem benefits include: enhanced biodiversity resilience through increased good quality habitat patches, increased population sizes, increased migration opportunity, etc
- Quantifiable ecosystems losses include: reduced arable productivity, potential for weedy invasions, etc

Measurements and discussion points

- Within targeted ecosystems, changes in: species composition, dynamics of selected (keystone) species, ecosystem processes and species interactions (webs), soil water, C content and other properties.
- Across the landscape: species movement among patches and along corridors (including genetic methods); over time, patterns in changing composition in relation to climate change; large-scale fluxes and flows of nutrients and pollutants in air and water, ecosystem service provision including value in relation to cost of targeted management.
- Develop spatially explicit models of climate change impacts.
- Earth Observation technologies to measure land-cover, fluxes, emissions, etc.
- Economics and social science to measure value of enhanced services *vs* extra costs.
- A platform for grants to study the system at scales from within-field to the whole landscape.
- Discussion points: the level of replication; the landscapes to use, project management.

Linking the LSE to monitoring (the first step in establishing a virtual biodiversity ‘experiment’

- Current UK monitoring schemes are designed to assess changes in:
    - Structure and composition, and ecosystem function of the wider countryside: Countryside Survey (inc. Integrated Assessment and Land Cover Map), vegetation, water quality, quantity and supply (NRFA), soils moisture assessment, soil carbon, soils microbial, pollutant deposition maps etc.
    - Distribution of plant and animal species: Biological Record Centre.
    - Ecological and environmental process in key ecosystems: ECN.
- The LSE will map onto these monitoring schemes by:
    - Carrying out manipulations at a scale which matches that of the monitoring.
    - Manipulating the exact processes detected by these schemes, at the relevant scales.
    - Data management and analysis which links the LSE directly to data from these schemes.

Input to NERC's Ecosystem Sustainability Scoping Workshop NERC Centre for Population Biology (CPB), Imperial College London.

This is the input from the CPB to the Natural Environmental Research Council's scoping study on "Large-scale biodiversity, environmental gradients and ecosystem sustainability".

I. The CPB Research Programme

Our research programme has three themes, each with a goal:

1. Biodiversity and ecosystem function in a changing environment: To assess the direct and indirect effects of environmental change on ecosystem processes and functions, including the maintenance of diversity and the structure of communities.
2. Patterns and processes in diversity and distributions: To link biodiversity patterns and processes to predict biodiversity across scales of both space and time.
3. Ecology and evolution of diseases and disease vectors: To understand the ecological and evolutionary processes underpinning disease and to develop strategies for disease management.

II. Methodological approaches

We use a range of methodologies which we classify here into two broad types following the questions posed to us in the request for input. In practice almost all our work includes components of both types which are mutually reinforcing.

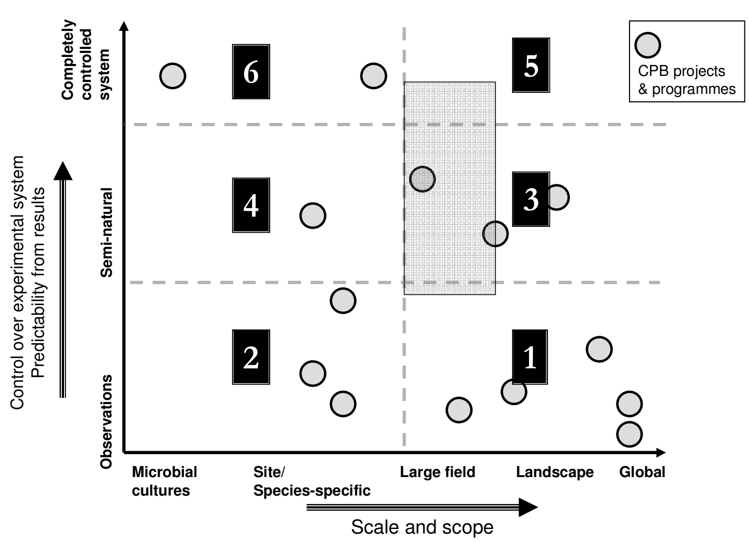
1. Observational including *in vivo* and *in vitro* controlled experiments, at scales from Petri dishes to fields, through to large-scale observations and analyses on populations, communities and ecosystems at scales from fields to global assessments.
2. Virtual/modelling based on simulations or analyses including entirely theoretical (without fixed parameters) through to fully-parameterised site and context-specific models concerning biodiversity and ecosystem processes, from genes to ecosystems, and at scales from populations to global biodiversity.

Our projects/programmes (indicated by circles in the diagrams below) cover a range of different study systems and methodological types. Rather than reviewing these in detail we discuss general approaches and the broad questions we address using them.

III. Broad questions addressed by Observational studies

The major questions can be organised according to the scale and scope of the study system and the extent to which the observations occur under controlled or experimental conditions (see Figure 1). We understand that NERC is intending to focus in areas 5 and 3 of this scheme.

Figure 1: *Approaches to empirical/observational studies. Small circles represent CPB programmes or projects. Numbers in black boxes refer to the discussion below. The grey box is the area we understand NERC is considering***.**



The numbered boxes in Figure 1 each denote a major area of study:

Area 1. What determines the distribution and abundance of species, assemblages and traits? Projects here are largely pattern-based analyses supported by analysis and models. The next steps here should link species and populations (Areas 2,4,6) with large-scale biogeographic and dynamic vegetation processes.

Area 2. What drives local-scale variation in communities and functions? This work is supported by modelling and next steps are to upscale to ecosystems, and to large scale processes and patterns (area 1).

Area 3. How does ecosystem functioning (e.g. biogeochemistry and community processes such as resistance to invasion) respond to human impacts (e.g. climate change, invasive species, nitrogen enrichment, land-use change)? The next steps are to replicate systems across sites to extend spatial scales and understand generalities as a means to approach Area 5.

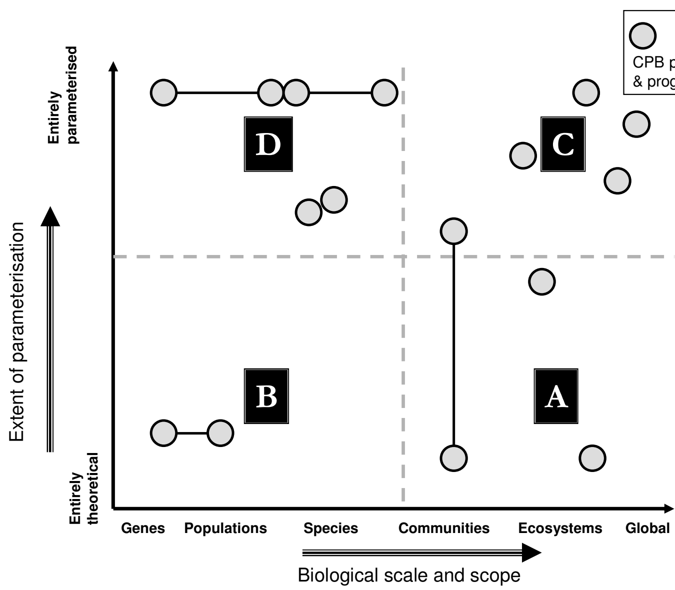
Area 4. Experimental field assessment of basic ecological principles. This is the domain of traditional ecology which is now informing larger scale/scope studies.

Area 5. How does ecosystem functioning respond to human impacts? This is similar to Area 3, but major problems with further control at this scale include the high costs and the likelihood that further control will disturb the system and render it unrealistic.

Area 6. What mechanisms and processes (including adaptation and interactions) determine populations, communities and species structure and dynamics? Future goals will include up-scaling and linking to larger scale patterns and processes and further application to studies of soil processes (Area 1).

IV. Broad questions addressed by Virtual/modelling studies

Figure 2. *Approaches to Virtual/Modelling studies. Small circles represent CPB programmes or projects. Letters in black boxes refer to the discussion below*



The lettered boxes in Figure 2 each denote a major area of study:

Area A. What determines the stability and diversity of interaction webs? How do ecology and geography influence evolutionary patterns and processes? This work links to experimental and field studies as in Figure 1: Area 2

Area B. How do genetic and demographic models scale up spatially? Under what circumstances will introduced individuals and genes spread through populations?

Area C. What are the expected outcomes of global environmental change on ecosystem processes, biogeographic patterns, community composition and species extinctions? This work has strong links to observations in Figure 1: Area 1.

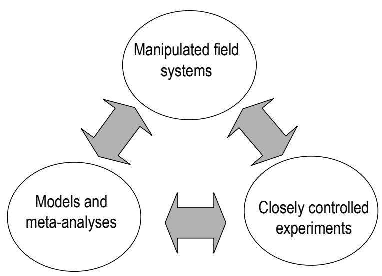
Area D. How do environmental factors influence evolutionary processes within populations, species distributions, species diversity and spatial phylogenetic patterns? Strong links to Figure 1: Area 2.

V. Conclusions on large-scale ecosystem experiments

We understand that NERC is seeking to develop systems in the area of the shaded grey rectangle on Figure 1.

1) We note that Area 5 on Figure 1 is intrinsically hard to do because large scale systems where there is enough control to deduce processes reliably will be very expensive. Additionally, the level of control may confound the processes being studied.
2) Area 3 in Figure 1 is less controlled but more feasible. Many good examples exist in Europe[1] and there is potential to exploit the existing network of LTER sites in the UK[2]. Our own work in this area, such as the field scale manipulations in the DIRECT project[3], illustrate the unavoidable trade-offs between replication for experimental design and the complexity of the question that can be studied. We recommend that this issue be addressed by an experimental approach which incorporates multiple sites across landscapes or environmental gradients, each of which has replicated plots.
3) Other work that addresses questions in this area comes from bringing together closely controlled experimental work with modelling work (e.g. stability of interaction webs, parallel field-controlled environment studies in the Ecotron such as the Lake Vyrnwy project; model development and testing in the Ecotron such as the SCALE project[4]).
4) Much of our work on large-scale biodiversity and environmental gradients is however not in areas 3 or 5. Rather we consider that successful and economic approaches bring together modelling and observations, between Areas A and C of Figure 2 and Area 1 of Figure 1. Thus there can be very useful interplay between field-based experiments, controlled environment studies and analyses (Figure 3).

Figure 3 *Interactions among modelling, closely controlled systems and field experiments may add value to each, depending in the questions being addressed.*



5) We note the current lack of studies that effectively link genetic processes up to large scale and think this is a research gap that urgently needs attention since phenomenological studies and ecological model systems may not allow good predictions beyond observed conditions.
6) We also recommend further consideration to UK involvement in integrated research infrastructures, including closed-controlled experimental systems across Europe[5]. In combination with field and modelling studies, a network of closed ecological systems can allow exploitation of synergies between different approaches (see Figure 3):

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November 2008
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[1] see http://www.biodiversity-exploratories.de/entry-page-2?set_language=en&cl=en

[2] see http://www.ecn.ac.uk

[3] see http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_26-9-2008-14-0-13?newsid=44714

[4] See http://www3.imperial.ac.uk/cpb/research/biodiversityandecosystemfunction/theecotron/research/scaleproject

[5] see http://www.anaee.com/anaee/anaee

The UK Environmental Change Network

(www.ecn.ac.uk).

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Aims, objectives and methodologies

The Environmental Change Network (ECN) (http://www.ecn.ac.uk) is the UK's long-term ecosystem monitoring network and aims to aid in the detection, attribution and forecasting of environmental change and its impacts resulting from natural and human causes. It is a multi-agency initiative and currently consists of 57 terrestrial and freshwater sites, spanning several environmental pressure gradients. Regular measurements are made of the main drivers of change (e.g. climate, atmospheric chemistry, land use) and ecosystem responses (e.g. water quality, soil and biota). The ECN has been in operation since 1993 and is producing a wealth of data and information of value to users in research, education and policy.

The long term purpose of the ECN is to:
(i) Provide monitoring protocols and maintain a network of monitoring and research sites and its database to deliver quality-assured data on the environment to a wide range of stakeholders.
(ii) Develop database and analytical tools and procedures to provide early indicators of change from expected norms, and identify and quantify cause-effect relationships.
(iii) Provide research and analysis that underpins the development and assessment of UK policy related to environmental change, particularly in relation to climate change, biodiversity, water quality and sustainable development.

All 12 ECN terrestrial sites are monitored by dedicated site managers, funded by one of the ECN's 14 sponsors. The monitoring of the 45 freshwater sites is undertaken more regionally, predominantly by the UK environment agencies. ECN operations are coordinated by a Central Coordination Unit (CCU), based at the Centre for Ecology & Hydrology, Lancaster Environment Centre. The CCU provides network coordination, monitoring protocols, maintenance of a central database, regular checks on the quality of the developing environmental time series. In addition it facilitates the production of annual data reports, Site Manager meetings, data dissemination, data analysis, publications in the scientific literature, and communication of the Network to a wider audience of researchers, policy makers and schools.

Strengths and weaknesses

The key strength of the ECN is that it is unique in the UK in conducting "integrated" ecosystem monitoring, i.e. monitoring of a wide range of physical, chemical and biological components from a range of UK ecosystems according to clearly defined protocols. Measurements are taken at relatively high frequency and many records are now over fifteen years in length. ECN sites therefore provide a detailed fine-resolution picture of how and why) UK ecosystems may be changing, but in addition they represent Long Term Ecological Research (LTER) platforms, where shorter term experiments and additional monitoring is encouraged. As concern grows over how policy is best applied to conserve or enhance biodiversity and Ecosystem services, the ECN provides unique national capability to address emerging research and policy needs.

The main weaknesses lie currently:
1) in the relatively limited number of terrestrial sites, that constrain network-wide analysis of responses along pressure gradients. This is currently being addressed with the development of a proposal for an extension of spatial coverage under the Environmental Change Biodiversity Network (ECBN). The ECBN will focus on sites within Natural Nature Reserves, and the ECN would therefore still benefit from a further expansion of a sites covering more representative of typical UK habitats;

2) in the availability of funding and mechanisms to maximise the use of ECN sites by Universities and Research Institutes for research purposes.

***Costs and programme/initiative management*.**

The full annual cost of the ECN, shared among its 14 sponsors, is approximately £1,600,000. One third of the cost is met by NERC while Defra contribute around 5% directly to support the activities of the ECN CCU. The Devolved Administrations, conservation agencies, Forestry Commission and the Biotechnology and Biological Sciences Research Council between them cover approximately half of the costs, through site management, sampling and sample analysis.

The ECN is overseen by a Steering Committee, comprising representatives of the 14 network sponsors. The Steering Committee sets priorities for research and development and provides an interface with key policy and research communities. They are encouraged to provide regular feedback to the CCU on priorities and opportunities. Scientific and technical development of the ECN is provided by a small group of experienced environmental scientists and statisticians known as the Scientific and Technical Advisory Group (STAG). STAG is tasked with developing R&D plans covering priority issues for ECN and ensuring that appropriate links and collaborative research projects are established with complementary monitoring and research programmes in the UK and internationally. STAG also monitors and evaluate progress on R&D implementation plans and advises the Steering Committee on progress and any necessary modifications to improve network design, techniques and procedures.

Potential for addressing questions

ECN data make significant contributions to a national evidence base contributing to our understanding of environmental processes and environmental change. These include: the provision of supporting data for large-scale ecosystem assessments, such as the Countryside Survey (providing a short term variability context); support for assessments of key impacts and predictions of responses to future scenarios, e.g. Defra's Review of Transboundary Air Pollutants (RoTAP) (information on changes in soil water chemistry and evidence for vegetational change); support for natural resource management, e.g. through provision of data on biodiversity to other monitoring programmes and data on fluxes and controls on organic carbon in peatlands; and, early warning of environmental change impacts and their consequences (providing climate change indicators). In terms of European policy assessment and development, ECN science is highly applicable to the further development and implementation of European Directives on biodiversity, soil and water.

Environmental monitoring often provides the earliest evidence of change in the environment, provides crucial data for developing process understanding, and also allows for process-based models to be tested in the "real" environment. However, experiments are also paramount in hypotheses testing, and the ECN strives to facilitate the use of its sites and its data for experimental purposes. To date most ECN-related experiments have been restricted to individual sites, but the ECN is keen to develop the use of its full spatial coverage to host cross-network experiments. The Network is well placed in this respect as a result of the presence of site managers who can facilitate and participate in new research. Several potential projects are currently under discussion. These range from: process-based studies across environmental gradients, such as assessments of key environmental controls on organic carbon processing, invertebrate growth rates, or grazing pressure; studies of new threats to human health, e.g. a network-wide identification and quantification of specific mosquito vectors and pathogens in the environment, or implications of rising dissolved organic carbon in water suppplies; to cross-site manipulative experiments, such as the use of exclusion cages to assess grazing effects on biodiversity.

Background document from the Ecological Continuity Trust
for the NERC Ecosystem Sustainability Scoping Workshop

www.EcologicalContinuityTrust.org

Aims & relevance of the Ecological Continuity Trust

The ECT is a registered charity that has been established by a broad coalition of ecological scientists and conservation practitioners supported by the British Ecological Society and the Esmée Fairbairn Foundation. We believe that long-term ecological experiments (LTEs) are essential to understand the future impacts of global change upon ecosystems and to obtain the sound scientific evidence upon which political and corporate policy development should be based.

We have conducted a review of LTEs in the UK to determine their scope and relevance to climate change and its interactions with other ecological drivers. Out of 44 long-term experiments for which data were available, only 6 have survived beyond 20 years and none has a guaranteed future. Fewer than five manipulate any climate-related variables, none manipulate UVB and very few manipulate CO_2, temperature or hydrology. The two most commonly applied treatments are nutrient manipulation and grazing, reflecting previous research priorities. There are only 4 experiments which attempt to measure interactions between multiple global change drivers (of which only 2 include climate-related treatments).

As with treatments, the coverage of habitats largely reflects the past focus on agricultural production, with the best represented habitat being grassland (70% in neutral grassland). Habitat types with little or no representation are coastal, montane, fen meadows and boundary features (e.g. hedgerows and river banks). This analysis illustrates how few experiments address climate change and its interactions, and identifies several habitat types for which there is no current long-term experimental research at all.

We have identified the core problem to be a **lack of continuity of funding**, linked to changing priorities and the absence of a long-term strategic perspective. With this in mind, the aims of the ECT are to:

- **devise and maintain long term experiments as <u>platforms</u> for present and, especially, future research.** Experimental manipulation of temperature and rainfall will be used to anticipate the effects of expected changes in climate.

- **support other long-term ecological research** (wherever possible)

- **analyse and disseminate the information** obtained in a way which is accessible to policy-makers, opinion-formers and decision-makers in government, commerce and non-profit institutions

- **raise awareness of the evidence** and its implications among the general public

- **provide a beacon of best practice** that may be copied elsewhere

- **raise funds for an endowment** in order to ensure continuity and security of dedicated and independent funding.

Experimental platforms: our vision

Our vision is to develop a network of financially secure global change experiments in a range of key UK ecosystems, focusing on interactions between climate and other key drivers of change. These experimental platforms will enable scientists and stakeholders to work together for the delivery of new and important findings that will be fundamental to ecosystem management in the future. We are committed to sharing data from ECT experiments and all participants would sign up to making their data available to the wider community.

Design of the experimental platforms

As a first step towards this aim, we are working towards the establishment of one large-scale experiment located in a species-rich calcareous grassland site, a habitat recognised as of key importance and vulnerable to future global change. The factorial treatments will be **temperature** (ambient vs. elevated) X **rainfall** (ambient vs. summer drought) X **sheep grazing** (at two levels of intensity). Other treatments will be nested within this basic design and could include: nutrient manipulation to simulate elevated atmospheric inputs; litter removal to look at carbon sequestration; manipulation of species composition; rainfall addition (winter or summer). At least fifty percent of the space inside the top-level treatments will be reserved for future experimental manipulations. To accommodate this, plots will be large (ideally of the order of 20m X 25m) and spare plots will be incorporated into the basic design for future use. The total area required for this experiment, including guard areas and access routes, is 16 ha.

Logistics and funding

Site selection

It is essential that once established the experimental site is protected indefinitely from competing uses (e.g. housing, roads, agriculture). We have therefore started strategic discussions with the National Trust whose very large landholdings are uniquely protected by act of Parliament. A shortlist of 12 possible calcareous grassland sites owned by the NT has been identified and we are working through them. The ideal site will have existing buildings nearby that could be re-purposed for use as a field laboratory and workshop, a permanent archive for samples and a visitor centre where the general public could learn about the experiment and the science of global change in general.

Funding

The costs of the basic infrastructure for the experimental platform are currently being calculated based upon known costs from existing experiments. A strength of the proposal is that the complete package would be suitable for mixed funding from NERC, other governmental sources, Heritage Lottery Fund and private foundations. The ECT's constitution provides for establishment of an endowment to support the proposed experimental platform and we currently employ an experienced fundraising consultant who is advising us on our long-term fundraising strategy. A weakness is that the current global financial crisis makes the immediate prospect of raising a privately-funded endowment difficult. However, climate change is now at the very top of the agenda for many philanthropists and the medium-term prospects for fundraising are more promising. At least some potential donors and their advisers recognise that private funding has a unique role to play in guaranteeing long-term initiatives like the ECT. Short-term funding is clearly within the remit and capability of government/public funding organisations and the provision of some NERC funding at this stage would complement and "underwrite" the science value of the ECT and assist in the seeking of other sources of finance for the endowment.

Issues for discussion at the scoping workshop

1. There is a trade-off between large-scale and long-term. However, can expenditure on a large-scale experiment be justified if it is not *also* long-term enough to recoup the initial investment?
2. What exactly is meant by large-scale or long-term? What are the relevant yardsticks?
3. Grazing is a permanent feature of most semi-natural habitats in the UK. How can this be incorporated into new experimental designs?
4. Herbaceous plant communities that are rich in plant species tend to occur in ecosystems that have relatively low carbon storage (e.g. on thin calcareous soils) and *vice versa*. Do we therefore need separate ecosystem experiments to study the impacts of climate change on biodiversity and on the carbon cycle?
5. Which ecosystem ought to be top priority for study? Is it reasonable to select only one? If not, how can a range of ecosystems be included?
6. What can be learned from the successes and failures of other LTEs?
7. How can existing LTEs, such as the one at the Buxton Climate Change Impacts Laboratory which has been running for 15 years, be protected and integrated with plans for new experimental facilities?

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06.11.08

LIFEWATCH

LifeWatch

A European e-Science and Technology Infrastructure for biodiversity data and observatories
(www.lifewatch.eu).

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1. Rationale

LifeWatch is a European biodiversity research infrastructure programme that will bring together high quality scientific data information, knowledge and expertise from a variety of sources including a system of observatories with wide and long-term coverage and through integrated access to (genetic, species-level and ecosystem) data. These data will be combined in a virtual environment offering offering analytical and modelling tools providing customized services for biodiversity research and policy.

The scale and complexity of the challenges related to the sustainable use of biodiversity and ecosystems can only be solved by multi-scale, interdisciplinary research based on a combination of observational, experimental, theoretical and modelling approaches. LifeWatch will provide the infrastructure necessary to bring these components together within a virtual system operating across Europe.

LifeWatch could provide the observational and informatics frameworks required to underpin large scale experimental approaches in the UK.

2. Overview of the Structure

LifeWatch will bring into operation the facilities, hardware, software and governance structures required to make biodiversity data available to research and policy users across Europe. It is part of the ESFRI (European Strategy for Research Infrastructures) and is currently under development through an EC/FP7 funded preparatory phase.

LifeWatch will be a major European component of the GEO Global Earth Observation System of Systems (GEOSS) and in particular the GEO Biodiversity Observation Network. Its main components will cover:

- Data generation and data processing: including biodiversity observatories.
- Data integration and interoperability: data standard and processing facilities to link information from different sources
- Virtual laboratories: use of grid technology to promote collaborative working and modelling
- Service Centre: dealing with marketing, access rights, user support, training.

3. Research and policy priorities

The fundamental aim of LifeWatch is to make data and information readily available to researchers, policy makers and citizens with an interest in biodiversity and ecosystems. Its main areas of application will be in relation to:

(i) the discovery of biodiversity;
(ii) biodiversity patterns in e.g. mapping of hot spots and changes in distribution and abundance of species;
(iii) biodiversity processes – understanding patterns of change over time;
(iv) systems biology – understanding multi-state dynamics of genes, species, populations and ecosystems and their responses to abiotic changes;
(v) nature conservation and management;
(vi) valuation and maintenance of ecosystem services; and
(vii) specific questions related to particular issues and capability (e.g. see Section 4).

4. Biodiversity Observatories in LifeWatch

LifeWatch will access data from distributed data sources, such as biological collections, field surveys and site based studies and promote the development of new data collection methods. A key component of the LifeWatch infrastructure will be biodiversity and ecosystem observatories covering terrestrial, freshwater and marine systems. These will include marine reference sites and terrestrial and freshwater observatories such as Long-term Ecosystem Research Sites (LTER).

Long-term Ecosystem Research Sites (LTER) in Europe provide platforms for observations, experiments and research on biodiversity and ecosystem processes. The LTER-Europe Network (www.lter-europe.net) now has access to over 200 sites in 18 European countries and is linked to a further 22 countries world-wide as part of ILTER. The UK Component of LTER-Europe is the UK Environmental Change Network (ECN, www.ecn.ac.uk. LifeWatch will promote the process of bringing these sites together into a single multi-functional research platform for Europe.

The aim of LTER-Europe is to address continental scale questions related to ecosystem change including:

- How are ecosystems across Europe affected by changes in climate, atmospheric pollution, land use, and invasive species over time?
- Can we identify and provide early warnings of thresholds or tipping points in ecosystem structures and functions?
- What are the effects of changes in ecosystems on the provision of ecosystem services and how do socio-ecological systems respond?
- How should we structure and manage multi-functional landscapes in order to maintain biodiversity and ecosystem services?
- How can society adapt to environmental change, particularly climate change?
- What policies and management approaches are required to promote ecosystem resilience and ensure the long-term sustainability of socio-ecological systems?

European LTER sites provide an extensive network of research platforms for distributed experiments on ecosystem processes making used of a combination of natural gradients and controlled experiments or perturbations to test hypotheses related to the above questions.

5. Strengths and Weaknesses of LifeWatch

The strengths of the approach include:

- It is feasible: makes use of recent technological developments in e-Science and existing data sources;
- It has a flexible design: enabling it to make use of new technologies and address a range of new and emerging research and policy questions;
- It brings together many different parts of the biodiversity research community[2] including the biological collections, genomics, terrestrial, freshwater and marine communities
- It builds on previous work such as the Global Biodiversity Information Facility (GBIF) and the International Long-Term Ecological Research Network (ILTER);
- Strong European Partnerships: these include 7 Networks of Excellence[2] and links with related infrastructure projects (eg ICOS (carbon flux observatories), NOHA (hydrological observatories) and ANAEE (ecotrons and experimental platforms)).
- UK Partnership: LifeWatch already has a strong UK focus including the Centre for Ecology and Hydrology, the Marine Biological Association, the Natural History Museum and the Cardiff e-Science Centre.

Weaknesses of the approach include:

- Currently 18 countries are involved in the preparatory phase (including the UK) which is developing the legal, governance, and operational plans are being developed. The construction phase (2010-) will require support from the scientific and policy communities across Europe.
- It is a long-term programme: full implementation of the system will take at least 10 years.
- Early development of the LifeWatch infrastructure in the UK (and in Europe) would benefit from a problem solving focus aligned to short term research questions. These have not yet been agreed.

6. Costs

The LifeWatch preparatory phase is funded by the EC (€ 5,000,000) and national contributions (€ 4,600,000). The overall cost of the construction phase (as estimated in the ESFRI proposal) is € 370,000,000. The UK contribution is undecided.

Footnotes

[1] ESFRI (European Strategy for Research Infrastructures) aims to help improve the competitiveness of the European scientific community by starting a process to establish new large-scale research infrastructures. In 2006 ESFRI published its first “Roadmap” of the most promising next generation large-scale Research Infrastructures - this included “LifeWatch”.

[2] Major European Networks already involved in LifeWatch include ALTER-Net (A Long-term Biodiversity, Ecosystem and Awareness Research Network); BioCASE (Biological Collection Access Service for Europe); EDIT (European Distributed Institute of Taxonomy); ENBI (European Network for Biodiversity Information; EUR-OCEANS (Ocean Ecosystems Analysis); MarBEF (Marine Biodiversity and Ecosystem Functioning); MGE (Marine Genomics Europe) and SYNTHESYS (Infrastructure network of biological collections).

Briefing note on UKPopNet's pilot experimental platform

1 Brief description of the programme

The UK Population Biology Network (UKPopNet) is funded by the Natural Environment Research Council (NERC), English Nature and more recently Natural England. The major funder is NERC. UKPopNet is a network of scientists in Universities and Institutes and our research programme aims to integrate population, community and ecosystem biology and researchers, practitioners and policy-makers. UKPopNet commenced activities on 1 April 2004 and has funding till March 2010.

One of the three overarching themes within our current programme is a pilot experimental platform for research, a large-scale experiment at RSPB's Lake Vyrnwy Reserve in North Wales, aimed at evaluating the impacts on ecosystem processes and services of alternative futures for the uplands. This can only be done using a rigorous experimental design protocol.

By working closely with the land-managers (RSPB) and the LIFE Active Blanket Bog in Wales Project (http://www.blanketbogswales.org/), it has been possible to explore the effects of different management interventions on key ecosystem processes using a replicated plot (sub-catchment) design. The treatments include heather mowing and re-wetting of the landscape by blocking drainage channels (grips). Control plots are left untouched. Each of the 5 replicate plots is matched with a control plot to provide a balanced experimental design. The large size of each replicate plot (c. 30Ha) will help to provide meaningful landscape-scale answers to landscape scale questions.

A key focus is on carbon storage, measuring the loss or gain of carbon dioxide (CO_2) and methane (CH_4) with the aim of developing models to predict the impacts of moorland habitat restoration and potential future climate change on C-storage and greenhouse gases. Predictions will be scaled-up from experimental plots to the landscape scale, to derive estimates for both the reserve and region. Impacts of the treatments on hydrology, vegetation structure and biodiversity of invertebrates and microbes are also being considered.

Thus, the platform is an extensive single site, with smaller (30Ha) treatment and control plots.

The platform is managed on a day-to-day basis by a Platform Co-ordinator, who has responsibility for ensuring that all work carried out of the site meets the requirements of both UKPopNet and the site managers (RSPB) with respect to health and safety, environmental impact, liaison and co-ordination with other team members, data bases and field equipment maintenance. The Platform Co-ordinator works very closely with the RSPB at the site.

The experiment was initially set up as a pilot platform in order to test out ideas and protocols required for carrying out such experiments and how best to design platforms. It has always been UKPopNet's intention to use these lessons to design activity at a broader range of sites, including Vyrnwy.

2. Strengths and Weaknesses

The *strengths* of our approach are as follows:

- large scale of plots, relevant to landscape-scale questions.

- rigorous experimental design incorporating balanced control and treatment areas.
- willingness of the land manager (RSPB) to design management interventions in a manner which is appropriate to the above and an appreciation of the need to have matched treatment and control areas for an extensive period (up to 15 years).
- presence of a Platform Co-ordinator to ensure that all work done at the site, within the experiment, is co-ordinated and managed appropriately.
- ability to muster a large-scale and diverse programme comprising many individual PIs, PhD studentships and institutions through UKPopNet funding (competitive, not directed), which has encouraged funding from other sources.
- funding of sister programmes on scaling issues, relating measurements of ecological and environmental variables measured at a range of spatial scales within the plots, from the core-scale to the landscape scale, and involving mesocosm-based work, including the Ecotron.

The *weaknesses* are:

- To date, all our effort has been largely focused on one location (Vyrnwy), mainly to take advantage of the opportunities listed above. However, the lessons learned over the past few years about how to make platforms work are intended to be translated to a wider range of upland (and other ecosystems). To this effect, UKPopNet currently has 4 funded working groups exploring the potential for extending platforms across a range of sites and environmental issues. Full details of these can be found on the UKPopNet site.

- The site provides excellent opportunities for cutting-edge research on the effects of management interventions on a range of ecological processes, as well as for exploring governance and science management practices for the successful establishment of a platform approach. However, this particular site offers limited opportunities for exploring social and economic dimensions to environmental management due to the restricted group of stakeholders.

Costs of the platform

The research programmes underway within the platform are funded from competitive calls within, and outwith, UKPopNet. The scale of activity is large, and we have able to take advantage of the habitat restoration works undertaken by the LIFE Active Blanket Bog project, amounting to considerable in-kind costs. This has enabled UKPopNet's own relatively limited resources (~£1M allocated to this theme) to fund two major projects, four PhD studentships and a number of smaller projects (c.£15-20kk each). A further competition for UKPopNet funds is in progress (each bid probably in the range £30-60k) and it is expected that several of the applications will be for work to be carried out at the platform site.

However, there are significant costs in establishing such a platform. In addition to the direct co-ordination by UKPopNet (platform co-ordinator post) and the contribution in-kind from the RSPB, UKPopNet funded a proof-of-principle research grant several years ago in order to establish the feasibility of designing such a platform, taking advice and evidence from the research community. If platforms are to be established as a future NERC initiative as part of the Biodiversity TAP, then our experience shows that such exploratory and co-ordination activity would need to be in place well in advance of the start of any research *per se*.

Dave Raffaelli, Director UKPopNet, University of York, 17th November 2008

Observations on flora fauna in the Netherlands – a coordinated action between the national government, field ecologists and scientists

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A short history

In 2005 the Universiteit van Amsterdam (UvA) and a group of private organisations[1] that manage observational flora and fauna data started an intensive cooperation to build a virtual data base containing all the observations collected by the organizations and conduct research with this data.

This project was successful in the sense that a central data base the National Database Flora and Fauna (NDFF) with one generalized data model was developed and very different data sets were converted to the new data model. EcoGRID is the software infrastructure to access and interpret the data, as well as the data model itself. The project also contributed to the Netherlands bird avoidance model BAMBAS[2], the results of which are available online at http://www.bambas.ecogrid.nl. This initial phase can be seen as a pilot project for the more extensive NDFF/EcoGRID project which started in 2007.

Three persons worked on it full time for 2 years, and in addition there was a genuine commitment by the participating PGOs to contribute by delivering and converting data sets, providing explanations of the data and participating in discussions. The total time invested into this sums approximately to four persons over two years (distributed over 15 individuals).

In 2007 the Dutch ministry for agriculture, nature conservation and fisheries (LNV) decided to build a central facility to store all the observational data which can be relevant for legislation, policy making and making large-scale decisions with respect to nature management or conservation. The system by UvA and the VOFF was the only system that came close to support the aspirations by LNV, so the consortium was approached to extend the work to deliver the functionality desired by the central government.

Characterisation of the data that is being collected

The data being collected is field data on the occurrence of species, often observed visually. The majority of the data is collected by volunteers and professionals, who are members of a PGO which concentrates on a certain species group (like birds, butterflies, mammals, higher plants, etc.). In cases where it is difficult to establish the observation to the species level, determination is done at the genus or family levels. Much of the data is collected within a certain project that has a professional coordinator who is employed by one of the PGOs, a protocol that has been communicated and written down, and some level of data validation after volunteers have sent their data to the PGO-office. The observation locations are not distributed homogeneous over the Netherlands. There is f.i. a bias to observe in nature reserves while urban areas are under represented. Qualitatively, the best monitoring is done for a selection of species within a project called NEM ('Netwerk Ecologische Monitoring'), conducted by PGOs and supervised by Statistics Netherlands (CBS), see http://nemweb.ipo-rivm.nl/.

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[1] These organizations are PGO's ('Private Gegevensbeherende Organisaties') such as Sovon – The Dutch Center for field Ornithology, Vlinderstichting, Floron, united in the VOFF foundation, see www.voff.nl

[2] Shamoun-Baranes, J., W. Bouten, L. Buurma, R. DeFusco, A. Dekker, H.Sierdsema, F. Sluiter, J. Van Belle, H. Van Gasteren and E. Van Loon 2008. Avian Information Systems: Developing Web-Based Bird Avoidance Models. Ecology and Society 13 (2): 38 http://www.ecologyandsociety.org/vol13/iss2/art38/

In most NEM monitoring projects the observation locations are revisited every year. The placement of the observation locations in the Netherlands is stratified (based on expert insights) according to main landscape types (around 10 for the Netherlands). The 15.000 volunteers from the 10 PGOs in the Netherlands collect around 5 million records every year.

The Dutch Authority for Nature Data (GAN)

A first important step in organising the new EcoGRID project was the establishment of a neutral governmental body outside the ministry with an independent budget. This organisation was established in 2007 and named GAN ('Gegevens Autoriteit Natuur'). The aim of the GAN is to facilitate trustworthy information on the distribution of flora and fauna in the Netherlands and make this available to everyone. It aims at stimulating and facilitating the cooperation between data collectors, administrators and users via a stable ICT infrastructure. It operates independently and approaches all stakeholders in a neutral way. Currently the main activities by the GAN are:

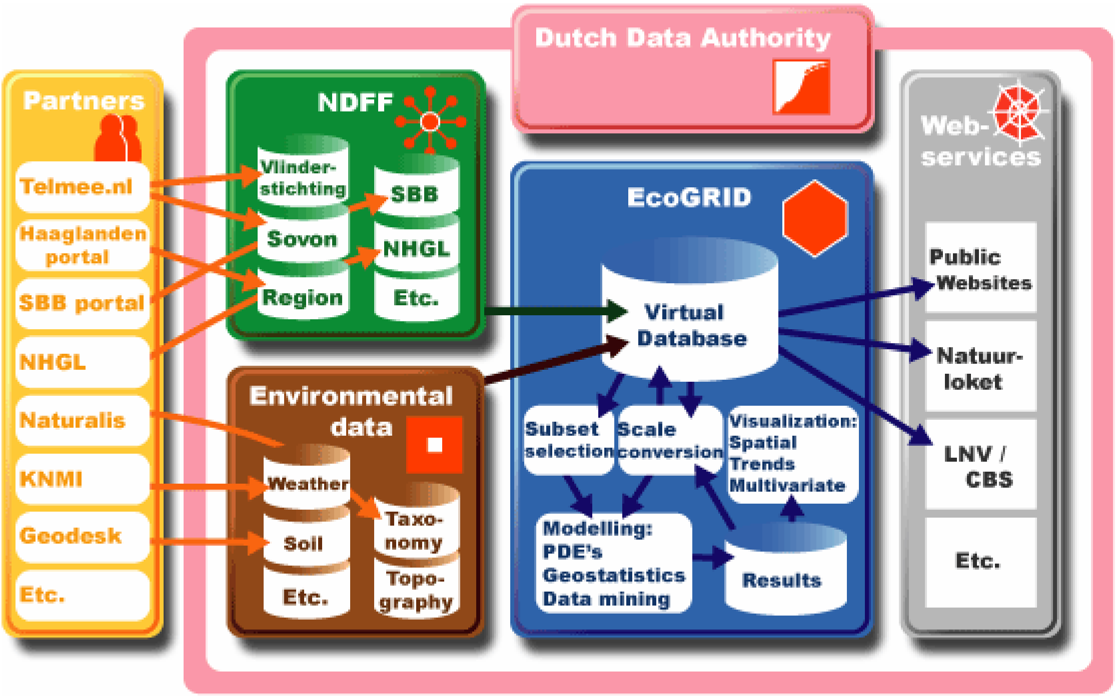
- Involving many governmental bodies and terrain managing organisations in the Netherlands to contribute to and/or make use of the system
- Setting up the ICT infrastructure (EcoGRID) to further complete, enhance and manage the NDFF, jointly with UvA and VOFF.
- Directing the data collection process (GAN has a budget to pay PGO's for this)
- Controlling quality of the data in the NDFF by establishing protocols together with Statistics Netherlands (CBS, http://www.cbs.nl)

The ambitions of GAN rely on a well organised software infrastructure and a large and continuously maintained set of observational data. UvA designs the software infrastructure while the process of collecting, validating and storing flora and fauna observations being taken care of by the PGOs (as well as other organizations in the future). To turn the software architecture and prototypes into operational systems and also to manage the production-version of the NDFF, Geodan (www.geodan.nl), a company specialized in geo-data, has been contracted by GAN.

The foreseen timeline to achieve the above mentioned goals is four years (mid 2007 – mid 2011), and a total budget of 20 million euro is available for this purpose. From 2011 onwards GAN should be a non-profit semi-governmental body which finances itself.

EcoGRID

The National Databank Flora en Fauna (NDFF) has been set up as a distributed system (a collection of databases) that behaves as one virtual database. The different databases are managed by various organizations, but all databases share the same EcoGRID data model as their core. The data model is defined for a spatial data base. This is relevant because it allows the storage of any object in space (point, line, polygon). Due to this property a wide range of different types of flora and fauna observations can be stored in a single data model. In addition, the model stores uncertainty information about time, space, abundance explicitly in the form of bounds and taxonomic information can be specified at different levels in the taxonomic hierarchy. The description of the data model is currently only available in Dutch but will be available in English soon (www.ecogrid.nl). A schematic idea of how the system works, with a rough indication of all the analysis steps that will be required to convert the 'raw' observations into useful knowledge is shown below.



In addition to a central data model, communication interfaces are defined so that external databases can connect to the NDFF for input or output purposes. Also several web-portals are being constructed for data input directly into and out of the NDFF virtual database; and a workflow system is implemented to conduct reproducible research and produce outputs in a traceable manner. The approach in this project is to allow any organization (in addition to the PGOs) to connect to the system (after agreeing on certain conditions of use) in order to deliver or extract data. In summary: EcoGRID comprises three parts: 1) A generic data model, 2) A workflow environment consistent with the data model containing a number of relevant and tested analytical techniques, and 3) Software components that can be used to execute the workflows on a distributed system. All the parts of the NDFF/EcoGRID system are built out of open source software components. The participants in the EcoGRID team employ this technology for the following four activities:

1. **Identification** - retrieving information (observations, meta-data, modelling results) about a particular type of species or a particular point or region in space or time.
2. **Communication -** the exchange of data, information or knowledge between two or more users.
3. **Integration -** the combination of observations or modelling results beyond the borders of a single type of species and the tight integration with abiotic information.
4. **Analyses** – exploratory analyses, summary statistics, visualisation and concept driven ecological modelling. EcoGRID aims especially at spatially predicting occurrences and abundances of flora and fauna at the national scale.

The EcoGRID project will run for 4 years and has a capacity of 4 people full time (2 scientific programmers, one researcher at the post doc level, and smaller inputs from several scientists with expertise in GIS, statistics, etc.). In addition there is a similar capacity by the counterpart Geodan available for converting prototypes to production software and maintain the system.

Strengths and weaknesses of the programme

A clear strength of the program is the governmental commitment to build and use the NDFF/EcoGRID system for practical purposes. It ensures a sustainable source for funding, and an interest from a large user community (both those that will provide data and use data).

Another strength of NDFF/EcoGRID is that it did start from an existing (pilot) project and data collection infrastructure that already existed. Setting up national inventories of field data from scratch takes many years (if not decades). The aim is to streamline it, make it more professional and furthermore enhance quality by standardisation.

The focus on the data integration and conversion first (the green box in the figure) rather than on analysis tools (blue box), is considered a strength. Many similar ecological or ict-projects in other countries seem to focus a lot on the latter. This results frequently in analysis tools that are not appropriate for the data or a lack of time to actually collect or prepare the observational data required as input for the analysis tool.

Weaknesses can only be described from the perspective of a certain partner. Here only the perspective of UvA is provided, i.e. the perspective of a scientists interested in macro-ecological questions and ecological modelling.

From the perspective of a scientific ecologist a weakness of the NDFF data is that it is strongly biased (in space, time, certain species groups, etc.) and it is sometimes hard to correct for these. With the many stakeholders involved and the large reliance on volunteers to collect field data, there are only limited possibilities to influence the way in which or location where certain observations are collected. However, this seems not to be unique to NDFF/EcoGRID but rather a general characteristic of the observational data underlying species distribution studies.

A second weakness is that it takes a lot of effort to agree with all the stakeholders in the project about the technologies that are being implemented. And when new technologies are implemented in NDFF or EcoGRID it takes a big effort to explain and educate all users. This time could otherwise be spent on ecological research.

Understanding critical processes and functions

How do we define and quantify relationships between biodiversity, ecosystem function and services at spatial and temporal scales that are relevant to ecosystem processes and management? Tools: manipulative experiments, examine stability, resilience and their impacts on elemental cycling, time-series data and observatories.

A1	1) What are the important characteristics (eg. variability, trajectories) of ecological change that takes place over longer timescales than those normally represented by observations, and what are the drivers?
A2	2) What are the critical dynamical characteristics that lead to nonlinear changes (eg. resilience, thresholds, irreversible), and how can they be simulated to produce realistic scenarios over decadal timescales?
A3	1) What are the key ecological processes within a landscape that contribute to a specified ecosystem service and what land uses affect these processes (either negatively or positively)? Can an integrated ecosystems approach be derived that considers a range of ecosystem services arising from a landscape and trade offs between them?
A4	3) Are ecological networks, wildlife corridors or other ecological connectivity approaches more effective ways of maintaining biodiversity and ecosystem services within landscapes than existing conservation tools of static reserves and agri-environment measures?
A5	1. [Can we] achieve a significantly better understanding of the relationship between anthropogenic pressures and the response of aquatic and wetland ecology, with sufficient precision to improve the management/protection of these systems.
A6	2) Are there key pathways/processes/interactions that are essential for ecosystem sustainability? At what level of organisation do they occur (micro, macro, mega)? How do key processes change with latitude or depth? Should we be concerned with genetic or functional diversity? Are there commonalities between types of system?
A7	2. What physical processes underpin marine biodiversity? Background: let's get away from just measuring easy scalars like temperature, and deal with the rate processes (e.g. turbulent supply of nutrients, fluctuating light regimes) that drive the ecosystems. Not so much a stand-alone question, more a plea to include these considerations in larger biodiversity questions.
A8	Is there functional redundancy in ecosystems (in time and space) with respect to environmental change? Does biodiversity matter, and at what level?
A9	Are communities adapted to their local environment, and if so, can they cope with the predicted perturbation that is likely to occur in the next 100 years? What will happen to biodiversity and ecosystem functioning in the poles?
A10	1) How will ecosystem processing of carbon in the UK be influenced by climate change, and by changes in the acidity and nitrogen content of soils?
A11	3) Does biodiversity matter: is functional capacity and stability more important than variety?
A12	2. Is functional redundancy a valid concept; how important are non-utilitarian components of the ecosystem? Reconciling the ecosystem service philosophy with traditional conservation approaches.
A13	1. How to deliver biodiversity-rich, functioning, freshwater ecosystems in the lowlands. Freshwater ecosystems form an important component of the landscape mosaic. Standing waters can contribute to obvious biodiversity (e.g. Odonata) and also less obvious (e.g. Diptera as food for songbirds). Most standing waters and almost 100% of running waters are degraded by eutrophication. The causes of this are individual farms and household septic tanks, multiplied many times over. Ecosystem processes which might mitigate eutrophication have been lost by drainage.
A14	1. How is diversity responding to environmental change? What lies behind this question is to judge whether we have in place an adequate environmental and biodiversity monitoring programme covering a full taxonomic range and range of levels, genetic to habitat.
A15	4 What is the relationship between ESS delivery and underlying marine ecosystem functions?

Understanding trends and implications

What are the consequences of variation in these relationships in the face of change at different scales (climate change, ecosystem use and management strategies)? Tools would include analysis of different large and small scale gradients, use observatories; hindcast and forecast models

B1	To what extent does biodiversity confer resilience to climate change in marine ecosystems? Sub-question: Does biodiversity play a greater role in driving the resilience WITHIN ecosystems than among ecosystems? It's likely that comparisons among marine systems would place emphasis on the type of species being important rather than biodiversity per se. However, we have good reason to believe that biodiversity is a key driver within ecosystems. I would advocate translating the outcome of a particular level of resilience into the delivery of ecosystem services.
B2	1) How will predicted climate change (e.g. nutrient supply, temperature, pH, salinity in coastal waters) impact the long-term sustainability of marine ecosystems. 'Testing' predictions arising from small-scale experiments, mesocosm studies and modelling. Suite of ecosystems e.g. deep sea, high latitude, temperate coastal. Scope for adaptation at an ecosystem level; what genetic diversity within an ecosystem might accommodate adaptation (within and between species)?
B3	3) (overlaps with 2) Is there a minimum degree of trophic redundancy required to confer sustainability in a marine ecosystem? How is this affected by changes in latitude or depth - are there commonalities? What potential is there that climate change or human impacts (fishing) will disrupt trophic redundancy?
B4	1) Spatial and temporal patterns in the biodiversity of open ocean systems, surface to seafloor, shelf to abyss. How will these systems change, and how will this affect their role in carbon fluxes etc? The obvious choice for a study area is the Celtic Sea and extending to the Porcupine Abyssal Plain, given the existing datasets for this area.
B5	2) Spatial and temporal patterns in the biodiversity of coastal systems, catchment to coast. How will changes in temperature, rainfall and land use affect marine systems, and the services they provide. The West coast of Scotland provides a range of marine study sites and land uses from agriculture to urban, and good existing datasets on the biology and physical environment.
B6	3) Migration, dispersal and connectivity in marine populations. How can we expect species and communities to be affected by climate change? What can we do to maximise the survival of species (by controlling invasive species, transplanting others, and providing reserves and suitable habitats for organisms to migrate or disperse to)?
B7	1) Understanding natural variability of biological communities (and how it effects communities, ecosystem functioning and resilience) across range of scales within the water landscape.
B8	2) How do we differentiate and measure the impacts of anthropogenic pressures on freshwater communities and functioning from the inherent natural variability.
B9	1. How sensitive are marine boundaries (e.g. properties at fronts, shelf edges) and their biodiversity to a drifting climate? Background to this: these boundaries can have high biodiversity, are regions of marked (potentially very sensitive) gradients in biodiversity, and (for coastal/ shelf seas) are usually associated with high bioresource exploitation.

B10	3. How can we model the emergent response of biodiversity to drifting climate? Background: I'm talking of a new modelling approach that allows multi-species (multi = 100s - 1000s) to compete within a realistic physical framework. The idea is viewed with some excitement at the new Hartree Computing Centre (Daresbury) where they are looking for applications to throw at several 10s of thousands of processors. I would encourage such an activity to be strongly supported by a parallel observational campaign
B11	What role does genetic diversity play in ecosystem resilience?
B12	1) How can we practically increase the resilience of ecosystems to environmental change, a) increased patch size and buffering, or b) re-linking landscapes, c) management to bring ecosystems into optimal condition?
B13	2) How important is functional diversity and trophic structure in controlling ecosystem resilience?
B14	3) How do the key drivers of environmental change interact to affect ecosystem functions at a range of scales?
B15	2) Are predictions from single local-scale experiments relevant at the landscape scale?
B16	3. What is the appropriate scale to study and manage different components of the ecosystem to maintain sustainable ecosystem function? Quantifying the importance of movement at different scales on gene flow, population structure and adaptability.
B17	3) Can we detect early warning of loss of ecosystem function in sensitive systems? Close monitoring of ecosystems (including managed) that are at risk from env change, eg peatland from drying out and loss of grazing, woodland with changing pathogens, herbivores
B18	2. To what extent is adaptation of component populations essential for an ecosystem to be resistant and resilient in the face of environmental change?
B19	3. What are the primary factors that prevent species from expanding or moving their ranges?
B20	1) How do biogeochemical cycles influence biodiversity across environmental gradients and how will changing biogeochemical cycles affect biodiversity? Would link microbial diversity/function with biodiversity of macro-organisms to address ecosystem connectivity and stability, perhaps incorporating watershed systems as platforms for study and uniting metagenomics, metabolomics and proteomics with taxonomy and biodiversity.
B21	2) How will environmental change alter organismal interactions and how will this influence sustainability? Would address whether environmental change promotes: a) differential responses of interacting organisms, and; b) new cross-ecosystem linkages (e.g. novel pathogens, competitors, predators) to create new patterns of biodiversity at the landscape level.
B22	2 In instances where we only have an aggregate measure of the benefit provided by a partcular ESS how can we better apportion this aggregate to individual landscape types?
B23	How is biodiversity maintained in an ecosystem? The number of species in an ecosystem is dependent on a huge range of variables, and will change over space time in response to climate and other forcing factors. Observatory networks, coordinated sampling strategies and quality taxonomic methods will be key to understanding these changes.
B24	3) What are the key tipping points in the function our wilder ecosystems, with respect to climate change, air pollution and land use change, and where are we now relative to them?

Developing management solutions

What are the relevant spatial and temporal scales at which management should be focussed to ensure sustainability of ecosystems, their functioning and delivery of services? Tools: development of coupled ecosystem-bio-economic models that underpin decision support systems within incorporating quantification and valuation of changes in BEF-Services and show consequences of alternative pathways, develop management strategies and operating plans

C1	3) What are the baseline, pre-impact or resilient ecosystem characteristics that could provide goals for ecosystem management/restoration?"
C2	2) Can large scale ecological restoration of landscapes recreate the ecological processes previously occurring within those landscapes or will they fundamentally differ when the original ecological assets have been lost? Can ecological restoration increase the 'resilience' of ecological processes within landscapes to impacts such as climate change?
C3	2. [Can we] achieve a significantly better understanding of the response of aquatic & wetland ecosystems to specific measures designed to restore, protect or improve these systems e.g. river restoration, reductions in pollutant or flow pressures, landscape restoration.
C4	3)How do we use this knowledge to design and undertake sustainable management and restoration measures for catchments
C5	1) Do we, and if not should we, manage connectivity at a landscape scale to enbale biodiversity and associated ecosystem functions to respond to climate and land-use change?
C6	1. What is the impact of habitat management on intra-specific diversity and what are the implications for pest management and ecosystem services (within species functional complementarily)? Hypothesis: an increasingly homogenous landscape is leading to a reduction in genetic diversity and less potential for species to adapt to new conditions.
C7	1) How can we ensure that ecosystem services will be delivered from managed land / landscapes during a period of climate and socio-economic change?
C8	2) How do we integrate the outcomes of land management decisions with regional and global environmental processes?