Final report to Department for Environment, Food and Rural Affairs, Countryside Council for Wales and English Nature (CR0322)

Targeted Monitoring of Air Pollution and Climate Change Impacts on Biodiversity

M.D. Morecroft[1], A.R.J. Sier[2], D.A. Elston[3], I.M. Nevison[3], J.R. Hall[4]
S.C. Rennie[2], T.W. Parr[2] and H.Q.P. Crick[5]

April 2006

Address for communication:
Dr. M.D. Morecroft
Centre for Ecology and Hydrology
Crowmarsh Gifford
Wallingford
OX10 8BB

mdm@ceh.ac.uk
01491 692461

[1]Centre for Ecology & Hydrology Wallingford, Maclean Building, Crowmarsh Gifford, Wallingford, OX10 8BB

[2]Centre for Ecology & Hydrology Lancaster, Lancaster Environment Centre, Library Avenue, Bailrigg, Lancaster, LA1 4AP

[3]Biomathematics & Statistics Scotland, Macaulay Institute, Craigiebuckler, Aberdeen, AB15 8QH

[4]Centre for Ecology & Hydrology Monks Wood, Abbots Ripton, Huntingdon, Cambridgeshire, PE28 2LS

[5]British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU

Version Control

Version 1. Presented to steering committee 8 March 06
Version 1a. Additional material on birds and remote sensing, implementation plan. Additional text on soils from Sal Burgess included and some formatting problems resolved. Sent to project team and expert group 24 March (Not sent to Steering Group as they had already been circulated with additional material separately)
Version 2. Complete revision of text to reduce length and change emphasis to the presentation of proposals for the new network, rather than reporting on work carried out (change made in response to request from Defra). Remove recommendation for soil phosphorus monitoring in view of need to reduce costs and lack of a generally accepted method. Add dry deposition of sulphate and sulphur dioxide and total S deposition to list of measurements recommended for future review. Summary of results of power calculations added as Appendix 3. Sent to project team, expert and steering groups 24 April 2006
Version 3. Further revision of the text following comments and suggestions from members of the project team, expert and steering groups. Final formatting and insertion of site map. Final version, as sent to customers. Initially submitted to Defra 5 May 2006; Minor errors corrected and re-sent 12 May 2006.

Executive Summary

1. Climate change and air pollution present serious threats to the conservation of biodiversity. Policy and management strategies to reverse biodiversity loss need to be reviewed and developed in the light of these threats if they are to be effective. This assessment must be based on reliable evidence and make best use of resources.
2. The evidence-base must include the results of monitoring to detect, characterise and quantify ecological changes which are taking place. It is also important to ensure that the causes of change are correctly identified. An integrated approach to both climate change and air pollution is likely to be most effective in this, as organisms are responding to both and distinguishing their effects is a major challenge.
3. A number of major reports and studies, since 2000, have identified a need for improved monitoring of air pollution and climate change impacts on biodiversity and better integration between existing initiatives. An extension to the existing UK Environmental Change Network (ECN) provides a scientifically robust and cost effective solution to this need.
4. The ECN monitors air pollution, climate, biodiversity and biogeochemistry at 12 contrasting terrestrial sites, providing detailed information and process understanding. A larger network of less intensively studied sites would be complementary, providing a wider coverage of UK climate and air pollution conditions and better replication of habitats. This would enable statistical modelling to identify the effects of different environmental variables on changes in biodiversity with a much higher degree of confidence.
5. A series of measurements are proposed for each site, covering a range of aspects of the physical environment (climate; wet deposition of pH, nitrate, ammonium, sulphate; atmospheric ammonia concentration; aspects of soil chemistry) and selected aspects of biodiversity (vegetation, butterflies, birds). Land management records and remotely sensed data for phenology are also recommended to improve understanding of processes driving change and strengthen confidence in attribution of cause and effect.
6. Total atmospheric nitrogen deposition should be estimated on the basis of models combining data collected on site with interpolated national data and physical characteristics of the site (e.g. vegetation height).
7. Climate should be recorded using a combination of existing meteorological stations on or near sites and by installing automatic weather stations with data downloaded centrally using mobile telephone technology where possible.
8. Soil chemistry and biology is proposed to be recorded at six year intervals at six locations at each site, linked with vegetation monitoring plots. A rolling programme should be established, with a proportion of the sites sampled each year. The provisional list of measurements is: bulk density, pH, soil organic carbon, total-N, base saturation, PLFA, microarthopods and extractable nitrate and ammonium. It is recommended that this is reviewed before implementation to maximise comparability to Countryside Survey 2007 and the recommendations of the Soil Indicator Consortium (which has yet to report), where this can be achieved without compromising the aims of this project.

9. An ECN protocol for vegetation monitoring (the ‘coarse grain’ protocol) is recommended for recording the species composition of approximately 50 permanently marked plots, with a recording interval of three years. A rolling programme is recommended so that one third of the sites are recorded each year. Bryophytes and lichens, as well as vascular plants, should be recorded if possible. In addition, epiphytic lichen recording and measurements of tree height and diameter at breast height (DBH) are recommended for woodland sites.

10. The Butterfly Monitoring Scheme (BMS) and Breeding Bird Survey (BBS) methods are recommended for butterfly and bird monitoring to maximise use of existing data at many of the sites and ensure compatibility with the BMS and BBS, and with ECN, which uses both methods.

11. Monitoring would be carried out by a combination of specialist teams visiting sites on an occasional basis (for example, to record vegetation or service the weather station) and site-based staff (or potentially volunteers or contractors) carrying out regular tasks.

12. Analysis of biological data would make use of indices and aggregated data where possible (for example mean plant community Ellenberg values or indices of the latitudinal distribution of species) rather than individual species data. This avoids problems associated with the patchiness of many species’ distributions and allows more general conclusions to be drawn.

13. The proposal is based on sites defined by the boundaries of land holdings, following the pattern of ECN and Common Standards Monitoring; most selected sites are National Nature Reserves (NNRs).

14. The range of habitats to be included in the network has not been tightly defined as many sites will include more than one type. The following Broad Habitats have been prioritised: acid grasslands, dwarf shrub heath, broadleaved mixed & yew woodland, calcareous grassland, bogs, montane habitats, neutral grassland.

15. A short scoping study was carried out to assess the possibility of including coastal sites – particularly sand dunes and salt marsh. Some adjustments would be necessary, but there was a compelling case for monitoring these habitats. A workshop to consider this in more detail and seek the views of a wider group of specialists is recommended.

16. Power calculations estimated the chance that biologically significant differences in trends in biodiversity between two groups of sites with contrasting climate or pollution conditions would be detected as statistically significantly different. These calculations indicated that between approximately 40 and 90 new monitoring sites should be established and data analysed together with those from existing ECN sites.

17. Ninety sites would give greatest confidence. Additional benefits of a larger network include: (i) a broader geographical base, (ii) less restriction to particular habitats, (iii) less dependence on the continuation of monitoring at all sites, (iv) increased capacity to distinguish between the effects of the different drivers of change, (v) less sensitivity to perturbations due to the differences between the anticipated and true site-specific values of the environmental variables.

18. A minimum of 40 new sites (in addition to the existing ECN sites) is recommended to achieve the aims of the network. Once the full range of data are available for each site, allowing different causes of variation to be estimated, the

chances of detecting significant differences in trends between groups of sites should be increased compared to the power calculations. However, with a 40 site network, there is a higher degree of risk of failing to detect differential trends in a given time interval as compared to a 90 site network. It may also be necessary to focus on a more limited range of habitats to allow habitat-specific analyses.

19. It is recommended that power analyses should be repeated using actual network data, after an initial 4 year period, to review whether network size is appropriate given the emerging degree of environmental conditions sampled and variation of biodiversity measures within the network.

20. A 'long list' of sites was compiled and environmental information for each collated from spatial datasets (for example climate data and nitrogen and sulphur deposition on a 5km grid). A subset of these, comprised of NNRs, ECN sites and selected experimental sites (where climate and air pollution regime are manipulated) were subjected to cluster analysis, to group them on the basis of predicted climate change and air pollution conditions. The inclusion of experimental sites will be important to differentiate between drivers of change that are spatially correlated and provide cross-validation in attributing changes to climate change or air pollution.

21. Conservation agency staff rated the suitability of each NNR on the basis of practical considerations and existing monitoring work on sites, and were requested to try to avoid giving a low rating to all sites within a cluster. The most highly rated sites in each cluster form a provisional short list of 90 sites for inclusion in the new network across the UK. Further work will be required to refine the list and gain agreement for participation, especially for Northern Irish sites.

22. Data management should follow the ECN model and be done by the ECN data centre; a strategy for implementing this has been developed. It is recommended that open access arrangements to the data be agreed if possible.

23. The programme would be managed by a coordinator reporting to a steering committee representing network sponsors. Coordinators would also probably be nominated within the conservation agencies to manage their involvement.

24. Costs of initiating monitoring at each site are estimated at approximately £11,000, with ongoing costs of approximately £7,000 per annum (excluding overheads applied as a percentage of salary). This would be reduced where some of the monitoring is already taking place. It could also be reduced by the use of volunteers, where this can be arranged. The total annual running cost (excluding salary overheads) of a network with 40 new sites is estimated at approximately £417k; for 90 new sites it would be approximately £818k.

25. It is recommended that the next steps are:

    a. Establish the organisational framework, in particular formal agreements, such as Memoranda of Understanding between participating parties and identify the level of funding available. This will entail a considerable amount of promotion within the partner organisations and sufficient time, approximately one year, must be allowed.

    b. Resolve a number of outstanding issues, in particular finalise the list of sites. This cannot be done before agreement is reached on the number of sites, which in turn is likely to depend on the level of resources available. It will also need more detailed consultation with site managers over the habitats present on each site, ongoing monitoring and the availability of staff and volunteers.

26. This project has demonstrated the current interest in assessing and distinguishing the impacts on biodiversity of climate change and atmospheric pollution. It is strongly recommended that this proposal is used as the basis to decide whether or not to pursue and implement the new network. It has provided recommendations and options for an implementation plan and estimated costs. It has also shown that it will be most important to establish the right organisational framework, obtain agreement between parties and sufficient funding. It is likely that these preparations could take approximately one year, which will also allow time to resolve some outstanding issues, such as refinement of some of the measurement protocols and to finalise the list of sites.

Contents

List of figures

List of tables

1. Introduction

Atmospheric pollution and climate change present major threats to biodiversity, both globally and within the UK. National and regional governments have commitments to address these issues. Responding to the threats posed by air pollution and climate change requires an understanding of the nature and extent of their impacts. Monitoring allows changes in biodiversity to be detected and quantified and therefore provides objective evidence on which to develop scientific understanding, policy and management responses.

A wide range of monitoring programmes cover different aspects of UK biodiversity. Changes in the populations of some animal groups, such as bird (Eaton *et al*., 2005), moth (Woiwod, 1997) and butterfly (Thomas, 2005) species over recent decades have been reported as a result of large scale monitoring programmes conducted each year. Surveys repeated over longer intervals, especially the Countryside Surveys (Haines Young *et al*., 2000), have detected changes in the composition of plant communities since the 1970s.

The underlying causes of change in biodiversity must be identified before an appropriate response can be made. However this presents problems because ecological interactions are complex and the impacts of different environmental pressures are not always easy to disentangle.

The impacts of climate change and air pollution are particularly difficult to identify with a high degree of confidence. One of the main reasons for this is that climate and air pollution are rarely measured at sites where biodiversity is monitored so potential relationships can only be assessed by using interpolated national data. These interpolated values can be reliable in some circumstances (for example nitrogen dioxide deposition or temperature in flat terrain) but can be very unreliable in others (for example ammonia deposition or precipitation in sites with varied topography). The effect of uncritically using explanatory variables measured with error in regressions is to underestimate the effect of the explanatory variables. Whilst it is possible to correct for this bias, the correction process introduces additional uncertainty. The use of statistical techniques to compare trends at sites with contrasting environmental conditions would give best results if physical data have been measured on site. This would be particularly powerful in a network where sites were selected to maximise the contrast in air pollution and climate change regimes.

This report presents a proposal to monitor aspects of biodiversity alongside climate and air pollution across a network of conservation sites, spanning the widest possible range of air pollution conditions and predicted climate changes. It is a proposal which builds on and complements existing monitoring work and would operate as an extension to the UK Environmental Change Network.

1.1. Background

Most biodiversity monitoring has concentrated on particular groups of species, such as the Breeding Bird Survey and Butterfly Monitoring Scheme. The monitoring of air pollution and climate have generally been carried out under separate programmes at different sites. There are however three major schemes that monitor both biodiversity and aspects of the physical environment across a range of sites. The Environmental Change Network (ECN) has monitored 12 terrestrial and 45 freshwater sites in this way since 1992. The ICP Forests Level 2 Programme also monitors a wide range of variables relating to air pollution and climate and their impacts on 20 forest sites, managed for timber production. The Acid Waters Monitoring Network includes both physical and biological variables to investigate the effects of acidifying atmospheric deposition on freshwater systems and their catchments. Whilst these programmes are effective in detecting change and investigating the ecological and biogeochemical processes that are causing it, relatively few terrestrial sites are included and not all of these include important habitats for biodiversity conservation. In practice, statistically robust comparisons between areas with similar terrestrial habitats, but contrasting climate change or air pollution regimes, currently can only be made for production forests.

There is therefore a 'gap' between wide scale but relatively superficial monitoring programmes and those which are very detailed but geographically restricted (Fig. 1.1)

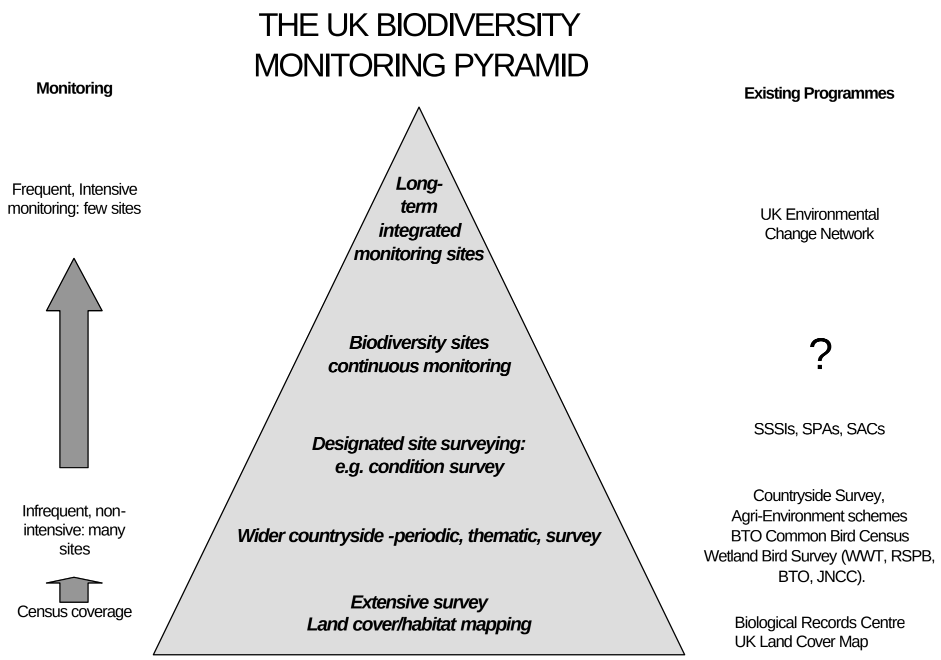


Fig. 1.1 Diagram to illustrate the trade-off between detail and coverage in monitoring programmes and the lack of intermediates between the detailed and the broad-scale

This project has been preceded by a series of reports and initiatives, which have recognised a need for further monitoring in the areas of climate change and air pollution impacts on biodiversity.

Three major reports on the effects of climate change on biodiversity recommend further monitoring in this area. A review by Hossell *et al.* (2000) advocated the 'development of methodologies for monitoring and assessing the status and quality of designated sites and key species affected by climate change'. It also suggested the extension of existing monitoring and assessment techniques to 'recognise and detect the impact of climate change on species and habitats.' Harrison *et al.* (2001), in reporting on the MONARCH (Modelling Natural Resource Responses to Climate Change) programme, also highlighted the need for more monitoring work to detect the effects of climate change, in particular the need for more sites to be located in the areas of greatest sensitivity. Riley *et al.* (2003) reviewed existing UK surveillance and monitoring schemes for their ability to detect climate-induced changes in biodiversity, with a particular emphasis on the situation in Scotland. They catalogued the range of information available to detect changes in species and habitats, including a wide range of schemes mapping the distribution of different taxa. The report recommended that more information could be derived from existing schemes if there was an overarching framework to bring data together, but also identified a need for more monitoring to fill taxonomic and habitat gaps.

One initiative has already begun to address the need for further monitoring of climate change impacts. The ECN Central Coordination Unit, working with the national conservation agencies, has developed plans for a network of sites to monitor the effects of climate change on biodiversity at designated conservation sites, using a subset of ECN measurements. An initial pilot study of ten upland sites in England, Scotland and Wales was adopted as a practical first objective given the limited resources available (Sier, 2005a and b) and two initial sites (Creag Meagaidh NNR and Ingleborough NNR) have started operating in the last two years.

A parallel process has taken place for air pollution impacts. The 2001 review by the National Expert Group on Transboundary Air Pollution (NEGTAP, 2001) provided a definitive overview of air pollution impacts. It identified a need 'to establish new monitoring programmes designed specifically to detect the biological effects of atmospheric deposition, using a range of appropriate sites'. It also recognised a need to ensure that data from existing monitoring were used effectively. A series of studies (Sutton *et al.*, 2004; Leith *et al.*, 2006) have recently reviewed biomonitoring techniques for detecting nitrogen deposition and its impacts, and developed new ones. Recommended approaches included the use of nitrogen concentrations in moss tissue, species composition of epiphytic lichen communities and characterisation of vascular plant communities using Ellenberg fertility scores (Hill *et al.*, 1999). A scoping study on monitoring the impacts of air pollution on terrestrial habitats (Morecroft *et al.*, 2005) reviewed existing schemes and methodologies for detecting the impacts of air pollution, particularly nitrogen deposition (but also including acidification and ozone). A series of options for new monitoring initiatives were presented: (1) a relatively large 'extensive network' based on a stratified random sample of sites to give nationally representative data, (2) a smaller 'intensive' network, with more emphasis on detailed process understanding, (3) a combination of intensive and extensive networks and (4) a network focused on monitoring ozone impacts.

Recent years have also seen an increasing emphasis on monitoring the condition of designated conservation sites, with the introduction of Common Standards Monitoring (CSM) across the various national agencies (JNCC, 1998). CSM provides a standardised framework for assessing whether the features of interest on designated sites are in 'favourable' condition or not. Surveyors are asked to record possible reasons for features being in unfavourable condition, but it is impossible for them to be able to identify the impacts of climate change or air pollution with any degree of confidence. Often, CSM assessments are based on short site visits, sometimes less than a day in duration. Under CSM, it is intended that each feature is monitored at least once every six years. This rapid assessment approach is inevitable given resource constraints, and there is a need to underpin these rapid assessments with more detailed, scientific measurements at a subset of sites. English Nature has conducted a pilot study for a 'validation network' to provide this function (Bealey & Cox, 2004), using quadrat-based sampling of vegetation communities.

This proposal represents the convergence of these separate strands and brings together a range of different organisations and scientific specialisms. In particular it combines the monitoring of climate change and air pollution impacts. This is both good science and wise management of limited resources. Plant and animal communities are responding to both factors at the same time and distinguishing their effects is a major challenge. In practical terms, similar biological response variables need to be monitored and there is a common need for data management and analysis; a combined network represents a considerable cost saving compared to two parallel networks. The proposed network is thoroughly integrated with existing programmes, using established methodology as far as possible and maximising the use of existing monitoring sites. It is designed to operate as an extension to the existing ECN.

The proposal is the result of a project, funded by Defra, English Nature and Countryside Council for Wales, which ran from October 2005 to March 2006. It was carried out by a consortium led by CEH, drawing on statistical input from Biomathematics and Statistics Scotland and on an expert group which included staff from the British Trust for Ornithology, Oxford University, Rothamsted Research, Forest Research, Macaulay Institute, Liverpool University, York University, Institute of Grassland and Environmental Research in addition to staff from CEH and BioSS (see Appendix 1). A steering group incorporating staff of Defra, the statutory conservation agencies, Environment Agency, Scottish Environmental Protection Agency and Scottish Executive Environment and Rural Affairs Department advised and reviewed the project.

1.2. Aims, objectives and requirements

The overall purpose of the project is summarised as:

> *'Working with a multi-agency partnership, [to] design, cost and make recommendations for an extended site network, linked to the terrestrial Environmental Change Network, that provides targeted monitoring of atmospheric pollution and climate change impacts on biodiversity.'*

The proposal has been developed to meet this objective, based on an initial project specification and subsequent discussions with funders and stakeholders. Table 1.1 summarises the requirements of the new network.

Table 1.1 Requirements for the proposed network

1. Identify changes in biodiversity that are attributable to climate change and/or air pollution on the basis of robust scientific evidence.
2. Underpin policy and management decisions across a range of government departments and agencies.
3. Operate as part of the ECN with network and data management by the ECN Central Coordination Unit, but a project with a distinct remit and its own steering committee.
4. Inform and complement CSM, by identifying where climate change or air pollution may be preventing the achievement of 'favourable condition'.
5. Monitoring methodology should mostly follow ECN protocols, but new techniques should be considered where they offer substantial advantages.
6. Links with existing monitoring networks should be maximised, by, for example, sharing sites and data to give added value and better value for money.
7. Comparisons between similar habitats in contrasting regions, climates and pollution regimes must be possible. If necessary the range of habitats can be limited.
8. The network should be statistically representative of the UK. Representation of separate countries within the UK is secondary and dependent on devolved administrations. Interpretation of data for individual sites should be possible.
9. Compatibility with emerging European initiatives should be maximized as far as possible within the framework provided by UK needs.
10. The network should focus on designated conservation sites but need not be restricted to them. It is anticipated that the majority of sites will be National Nature Reserves.
11. Conservation NGOs with substantial land holdings should be approached but their sites may not be included in the early phases of network establishment.
12. The network initially should be restricted to terrestrial habitats, but opportunities subsequently to include coastal habitats (saltmarshes and sand dunes) should be investigated.
13. Interpreted results should be presented in a range of different formats appropriate to varied audiences, including: (a) policy makers, (b) site managers, (c) the scientific community, (d) other participants in biodiversity conservation, including NGO's and the voluntary sector, (e) educational audiences and (f) the wider public.
14. A pilot study, analysing the data from the new network, should be completed by 2010.
15. Raw data to be easily available to the wider community.
16. A phased introduction of the new network is acceptable, with new sites and habitat types included over a period of years.

2. Measurements

2.1. Development of proposal

A wide range of potential measurements were reviewed for inclusion. These included:

1. all existing ECN measurements (Sykes & Lane, 1996; www.ecn.ac.uk);
2. recommended techniques for nitrogen deposition biomonitoring (Leith *et al.* 1996);
3. remote sensing opportunities using airborne and satellite techniques;
4. suggestions made by the steering group or expert group over the course of the project.

The review drew on information from a number of sources:

1. evaluation of existing ECN protocols by site managers using a questionnaire;
2. a workshop (held at University College London, November 2005) attended by members of the project team, expert group and steering group, with participants completing a questionnaire at the end of the day;
3. discussions in Steering Group meetings;
4. papers prepared by members of the project team or expert group with specialist knowledge of particular areas;
5. one-to-one discussions between the project leader and experts in relevant fields;
6. costs of measurements derived from information from site managers, price lists and quotations from suppliers of equipment and services.

The criteria used to assess measurements are summarised in Table 2.1. Full details are not presented here but have been documented and are available on request (Appendix 2). On the basis of the assessment, proposals were presented in December, January, March and April and reviewed by all project participants (steering group, expert group, project team).

The wide range of interests and responsibilities of participants meant that an element of compromise was essential, given realistic expectations of resource availability. However, there was consensus on many issues and agreement that the recommended list of measurements provides a good basis for the new network.

A list of core measurements is proposed, which can be introduced from the start of the network. A small number of these require methodological details to be finalised, but there is no reason why these issues cannot be resolved within a few months. There is another group of measurements, which are not suitable for early introduction, but are desirable and show promise that they may become viable in the next few years. A watching brief should be kept on developments in these areas and stakeholders may wish to commission specific studies to address priority needs.

Table 2.1 Criteria used for assessment of potential measurements

Criterion	**Explanation**	**Basis of assessment**
Relevance	Measurements of change in biological communities; aspects of climate and pollution demonstrated to impact on community composition or species distribution or providing important explanatory information	(1) Expert opinion based on scientific literature (2) site manager questionnaire
Data Quality	An assessment of whether the data collected have proven to be reliable and consistent	(1) site manager questionnaire (2) expert opinion
Ease of implementation	Can new monitoring work be implemented quickly and easily, given appropriate guidance, equipment and knowledge?	ECN site manager questionnaire
Specialist input	To what extent is training or active involvement by specialists required, beyond providing written guidance and instructions?	Expert judgement
Established methodology	Are measurements already made for ECN or other national monitoring schemes, or are well-established techniques available?	Monitoring scheme documentation and expert judgement
Support	Level of interest from stakeholders and independent experts	Workshop, questionnaire & steering group discussions
Cost	Initial establishment and ongoing costs of equipment, analyses and personnel	Site manager questionnaire, price lists and quotations

2.2. *Recommendations*

2.2.1. Overview

The following core measurements are proposed for all sites and should be introduced from the start of the network. Further details are provided in the following sections.

- Climate;
- Air pollution;
    - Wet deposition - pH, nitrate, ammonium, sulphate;
    - Ammonia concentration - diffusion tubes;
    - Total nitrogen deposition (combination of measurements / mapped data);
- Soil chemistry and physical description characteristics;
- Vegetation composition;
- Butterflies;
- Birds;
- Satellite remote sensing of phenology;
- Site management.

A number of other measurements are proposed at more limited subsets of sites.

- Tree height and diameter – addition to vegetation monitoring at woodland sites;
- Epiphytic lichens – additional to vegetation monitoring at woodland sites or sites with trees;
- Ground-based phenological measurements.

There are a number of other measurements that are not recommended for immediate introduction, but they should be reviewed for possible future inclusion, once the network has become established.

- Foliar nitrogen concentration;
- Ozone;
- Soil mineralization and nitrification;
- Carabid beetles;
- Bats;
- Invertebrate suction samples;
- Vertebrate herbivores and / or their impact ;
- Atmospheric sulphate and sulphur dioxide concentrations and total sulphur deposition.

2.2.2. Climate

Rationale

A good climate dataset for each site is a prerequisite for detecting relationships between biological variables and climate and for comparing contrasting trends at different sites. Some sites will have existing climate recording equipment, or records will be available from a nearby station; where possible we recommend using these sources to keep costs down and take advantage of long runs of data. Some meteorological variables are prone to substantial variation over distances of a few kilometres or less; this is particularly the case with precipitation measurements and with mountainous terrain. These local variations could prove particularly valuable in separating the effects of different environmental variables. In many cases it will be necessary to install climate monitoring equipment.

The use of automatic weather stations (AWSs) is recommended, as these are becoming standard tools for environmental monitoring and are well-established technology. The ECN now has 14 years of experience of their operation (Sykes & Lane, 1996). The use of dedicated AWSs allows a standard data format to be used, reducing the time requirement for data management compared to using a mixture of formats from other programmes. If near real-time data can be made available over the internet, there are a number of other advantages, for example the suitability of weather conditions for fieldwork at remote sites can be assessed and opportunities for educational outreach can be developed.

Proposed methodology

At the implementation phase, each site should be investigated for existing sources of potential data. In the event that none are available, an Automatic Weather Station should be installed to measure the following.

- Total Solar Radiation
- Air temperature
- Relative Humidity
- Wind speed
- Wind direction
- Soil water content
- Soil temperature
- Rainfall

Mobile telephone technology should be used (where coverage allows this) to automatically download data centrally, followed by automated QA checks and input to a database. Data should be made available over the internet, updated on at least a daily basis.

Locally based staff should visually check systems at least once a month and make a preliminary investigation of any anomalous results. Calibration and basic maintenance must be carried out during an annual visit by specialist staff.

Installation and site characteristics should follow ECN protocols (Sykes & Lane, 1996).

Constraints

Start-up costs are relatively high where new automatic weather stations are required. Good QA systems are necessary to detect drifting calibrations or other problems.

Requirements for preparatory work

1. Assessment of sites which do not require installation of an AWS.
2. Procurement of new AWS systems, including negotiations with manufacturers and detailed review of technical specifications.
3. Development of central automated system for downloading and handling data (note: the elements of this are already available and telemetry equipment is a standard option with all major manufacturers).

2.2.3. Air pollution

Rationale

As with climate, quantitative air pollution data for at each site are essential for testing for associations with biodiversity responses and making comparisons between sites with contrasting conditions. There are a wide range of different variables which may potentially have biological effects but the following were identified as highest priority by the Steering and Expert Groups.

- Total nitrogen deposition
- The balance between oxidised and reduced nitrogen
- Acid deposition
- Sulphur deposition
- Ozone concentration

It is recommended that core measurements address the first three of these pollutants. Sulphur deposition is partially addressed but could potentially be addressed more comprehensively at a later stage if resources and techniques were available. Ozone concentrations are likely to rise in coming decades; methodological considerations prevent including it in the core measurement set at this stage, but ongoing review of the opportunities is recommended.

Total nitrogen deposition comprises a number of different components and varies greatly with location and habitat characteristics. Monitoring all components directly is difficult, expensive and rarely carried out. However a combination of field measurements for the most variable measurements and interpolation of national data can give a good estimate suitable for quantitative inter-site comparisons. Ammonia deposition is the largest component of total nitrogen deposition in many circumstances. It is also highly variable, depending on proximity to point sources, especially intensive livestock rearing units and the nature of habitat, particularly the height and aerodynamic roughness of vegetation. It is therefore particularly important to make field measurements of atmospheric concentrations in order to allow estimates of deposition using habitat information (deposition rates depend on land surface characteristics such as vegetation height).

Wet deposition of nitrate and ammonium can be measured at the same time as sulphate and pH using a standard precipitation collector used by ECN (Sykes and Lane, 1996) and the acid deposition monitoring networks and is cost effective on this basis. It also allows an assessment of the ratio of oxidised (nitrate) to reduced nitrogen (ammonium).

Acid deposition has been declining in recent years – by more than 50% over large areas of the UK between 1985 and 1999 (NEGTAP, 2001) – and detecting the anticipated recovery of soils and plant communities is important for demonstrating the value of emissions controls and understanding ecosystem processes which may modify the impacts of other variables. It is recommended that estimates of two other sources of atmospheric nitrogen inputs, nitrogen dioxide and nitric acid, are derived from interpolated national statistics. This is acceptable for NO_2 because its concentration is relatively unaffected by local factors and it is a relatively small component of total nitrogen deposition. Nitric acid concentration is technically difficult to measure and requires use of an active measurement system using mains power.

Sulphur deposition is partly being addressed through wet deposition measurement. A suitable method for monitoring sulphur dioxide concentration at remote sites, which does not involve disproportionate costs of installing mains power, is not currently available. (An ECN pilot study showed that concentrations are frequently too low for reliable use of diffusion tubes). Consultations with the steering group show a mixed response to the issue of sulphur deposition. Most participants did not rank the issue high in priority but the EA and SEPA favoured its inclusion in order to assess recovery of ecosystems and hence assess the effectiveness of control measures. It would be possible to investigate alternative options and perhaps develop new techniques if funding for this were available at the implementation phase.

Ozone presents difficulties. It is an important issue which may grow in importance in the future if, as anticipated, concentrations rise, but the only acceptable way of monitoring it at remote locations, without a power supply, is diffusion tubes. These have been used in the ICP Forests Level 2 programme, but do not give values for peak ozone incidents, which are believed to cause visible ozone symptoms. Vegetation change in plant communities has been shown to be related to the AOT40 exposure index, which cannot be derived directly from diffusion tube data, and studies would be needed to establish whether relationships between mean concentration and AOT40 can be applied at different sites. Morecroft *et al.* (2005) discuss the options for an ozone impacts monitoring network in more detail. It is recommended that ozone should initially be considered an 'additional measurement' which is implemented if funding is available or there is a site-specific need. This situation should however be kept under review.

Proposed methodology

Ammonia concentration should be measured using passive sampling techniques – either the 'Alpha' samplers used by the Ammonia Monitoring Scheme or commercially available diffusion tubes (e.g. those supplied and analysed by Gradko Ltd.).

Wet deposition should be collected using a standard precipitation collector (Sykes & Lane, 1996) and analysed for NO_2^-, NH_4^+, SO_4^- and pH. It is recommended that collectors are deployed at one month intervals, rather than the current one week (ECN) or two week (precipitation composition monitoring network) intervals, using a biocide such as thymol. Studies have shown (Cape *et al.* 2001) that biocides can prevent major changes in chemical composition over this period of time.

Routine deployment of field sampling equipment can be carried out by non-specialist local staff following written instructions. Laboratory analysis should be carried out by specialist staff at a recognised laboratory compliant with the Joint Code of Practice for Environment Research.

Modelling total nitrogen input for all sites can be carried out at CEH Edinburgh, using existing techniques and an input of approximately 10 days time at the outset.

Constraints

Chemical analysis is often expensive (of the order of thousands of pounds per site per year), as is equipment for continuous monitoring in the field. Costs must be minimised to enable a sufficiently large network to be established.

Mains power is not available at many sites.

Direct measurements of dry deposition are expensive and require specialist skills and rates of dry deposition are usually inferred from concentration data.

Requirements for preparatory work

Standard models need to be applied to each site, taking account of habitat characteristics, once network operation commences.

2.2.4. Soil

Rationale

Soil communities are important aspects of biodiversity and they are involved in many important ecosystem processes, particularly nutrient cycling. Soil chemistry is neither an aspect of biodiversity nor one of the primary causes of change addressed by this project. Nevertheless, understanding mechanisms of change and correctly attributing effects to causes are central to the project, making it necessary to understand the soil chemistry at sites. For example, a change in the proportion of acidophilic species in a plant community may be attributed to changing pH of rainfall. However it is possible that this correlation results from other factors, such as an association between plant species' tolerance of acidic conditions and adaptation to low nutrient levels. Furthermore, a change in pH of rainfall does not necessarily cause a change in soil pH, as many soils (particularly calcareous ones) have a capacity for buffering pH change. Similarly the timescale of change in soil pH and related parameters may well be different from that of rainfall chemistry. Evidence of causation is therefore strengthened if a change in soil pH is detected.

There are many aspects of soils which could be measured, but the priority must be on those which contribute most to understanding the mechanisms by which climate change and air pollution cause changes in ecological communities. In particular it is important to test for the following:

1. Evidence of recovery from acidic deposition. pH provides this evidence but NEGTAP (2001) recommended base saturation as a more reliable indicator in view of the UK's oceanic climate and potential short-term effects of sea salt deposition events prior to sampling.
2. Changes in soil nitrogen supply as a result of nitrogen deposition or impacts of climate change on mineralization and nitrification rates (e.g. Jamieson *et al.*, 1998). Change in extractable NH_4^+ and NO_3^- suggests inputs of nitrogen sufficient to change microbial functioning and/or uptake by plants. C:N ratio is essential for many models linking biogeochemistry and biodiversity. Changes in total pools are very slow and the use of NH_4^+ and NO_3^- and their ratio will provide additional information on shifts in microbial functioning. They may also be linked to shifts in plant species due to preferential usage of NH_4^+ or NO_3^- by plants.
3. Changes in soil carbon and bulk density reflecting the balance between plant productivity and carbon lost through respiration. This would be expected under various climate change scenarios and indicates a general shift in ecosystem processes; it would also help in the evaluation of semi-natural habitats as sinks or sources of atmospheric CO_2. This may be an important factor in weighing up the advantages and disadvantages of different biodiversity conservation strategies under climate change.
4. Changes in soil biodiversity and soil health. PLFA is a biochemical marker for key bacterial and fungal functional groups and microbial biomass. Microarthropods are a direct aspect of biodiversity for which standard methods of analysis are available and also have an important role in soil food webs and nutrient supply.

A secondary consideration is that, where possible, measurements should be comparable with those recommended by the Soil Indicator Consortium and those undertaken for the forthcoming Countryside Survey in 2007. Both of these have yet to be finalised, but will report before implementation of this network; it is essential to review the proposals for soil measurements once methodological approaches for these other initiatives are determined. The recommendations for soil measurements given here reflect advice from participants of these other initiatives and the basic approach and the costs are likely to remain appropriate. It would be beneficial if monitoring effort could be combined where both the potential Soils Monitoring Network and the new targeted monitoring network coincide in terms of space and parameters to assess. Where both networks had measurements in common, it would be sensible to agree on Standard Operating Procedures between the two. Comparability with existing ECN monitoring is also important and the basic sampling design achieves this, but it also includes a wider spatial sampling at each site.

Proposed method

It is recommended that the soil measurements follow the principal of sampling outlined for ECN, with modifications to ensure a sufficient sample for all analyses required. There should also be a change in location of the six permanent blocks so that, rather than being located within a single 1 ha block, they are spread across the site in representative vegetation types and adjacent to vegetation monitoring plots.

The sampling design is six permanent blocks with a permanent grid set of 16 cells. Cells are separated into subcells and two samples are taken from each. Subcells are not to be re-sampled again. The depth of sampling would be determined by the sensitivity of the indicator, the process required for analysis and compatibility with other monitoring programmes, and is outlined in Table 2.2. Samples would be bulked for each replicate block prior to analysis. Bulk density would also be measured and the profile described.

Table 2.2 Sampling and analysis of soil samples

Core	Depth	Analyses	Number of samples/site	Compatibility with other monitoring programmes
A	0 – 5cm and 20 – 30cm	pH, soil organic carbon, total-N, base saturation	6	ECN
B	0 – 5cm and 20 – 30cm	Exchangeable NH_4^+ & NO_3^-	6	ECN (sampling only – analyses not in protocol)
C	0 – 8cm	PLFA, microarthopods	6	SIC

Constraints

Soil phosphorus plays an important role in controlling plant nutrient relations, for example where it limits plant growth it may alter plant community response to nitrogen deposition (Carroll *et al.*, 2003; Morecroft *et al.*, 1994). Analysis of P is not recommended because there is no reliable, generally applicable analytical method for determining plant available P or P limitation.

Nitrogen mineralization and nitrification are better indicators of nitrogen supply to plants than spot measurements of NH_4^+ & NO_3^-, but they are substantially more expensive. In order to standardise the analysis, the work would require laboratory rather than field conditions, which may not be realistic. It is recommended that both of these issues be kept under review, taking into account preparation work currently underway for Countryside Survey, which may help inform this review process.

Requirements for preparatory work

Review proposal in light of final decisions by the SIC and plans for the Countryside Survey 2007 to ensure that proposed monitoring complements, rather than duplicates, other schemes.

2.2.5. Vegetation

Rationale

Species composition is an important aspect of biodiversity, and it is also important in providing the habitat for animal groups. The use of Ellenberg numbers (Hill *et al.*, 1999) allows a straightforward assessment of the composition of plant communities in terms of species nutrient requirements and this has been found to be an effective bioindicator of nitrogen deposition by Leith *et al*. (2006).

The recording of epiphytic lichens could also easily be included by vegetation surveyors visiting woodland sites and other sites with trees. It is recommended that this is included, but the technique is currently being refined and published by Dr. Pat Wolseley (NHM) so detailed recommendations are deferred until this has been done.

The determination of tissue nitrogen concentrations, whether total N or soluble ammonium, has been developed by Leith *et al.* (2006), as a surrogate for recording nitrogen deposition by focussing on bryophytes, which are most directly dependent on atmospheric deposition of N. As this project proposes to determine N deposition for each site, the analysis of tissue N is not recommended, but it is necessary to test the relative importance of atmospheric N in comparison to other sources. Total nitrogen has been used in many experimental studies (Cunha *et al.* 2002) and surveys of N deposition impacts and could potentially be an aid to attribution of change to nitrogen deposition. Interpretation is not simple since foliar nitrogen depends on a combination of factors:

1. N supply from atmosphere / soil / mycorrhizae / N fixation;
2. growth and any limitation by climate or supply of other nutrients;
3. seasonal patterns (most concentrations rise steeply to a peak in early summer and then slowly decline;
4. allocation to different plant parts.

The selection of species will require detailed consideration before embarking on a major long-term monitoring programme – species need to be present at a wide range of sites.

Proposed method

The ECN ‘Coarse grain’ method (Sykes & Lane, 1996) should be adopted. This is a series of approximately 50 permanently marked 2m x 2m quadrats, randomly located on a grid system. 2m square plots are also consistent with a number of other recording schemes, including some of the habitat plots used for Countryside Surveys and the recommendations for the National Vegetation Classification (Rodwell *et al.*, 1991). Each quadrat is sub-divided into 25 ‘cells’ of 400mm x 400mm and presence/absence of each species is recorded in these cells, to give an index of frequency within the plot. Where the plot falls in woodland a 10m x 10m plot is used to record tree species and the height and Diameter at Breast Height (DBH) of up to 10 trees per plot are recorded. It is also recommended that species cover and vegetation height be recorded. Ideally the whole community, including bryophytes and lichens, should be recorded.

The existing ECN protocol specifies recording of plots to be carried out every nine years, but it is recommended that a three year interval is adopted for this programme because:

1. vegetation can change on a time scale of one or a few years and nine years would run a serious risk of missing impacts of extreme events and give little information on rates and nature of change (e.g. rapid vs. steady);
2. it would take a long time to give information about change;
3. the recommendation of the expert group was that a short time interval was desirable;
4. Common Standards Monitoring by the Conservation Agencies takes place on a six year cycle, so three years would give good complementarity.

It is recommended that vegetation surveyors be contracted centrally, either at the UK level by the central coordination unit for the project or within each of the country conservation agencies. It is also recommended that vegetation and soil monitoring are coordinated so that they take place as close to each other as possible in space and time.

Constraints

Identification of bryophytes and lichens is a specialist task, and there are few expert surveyors available. Even expert surveyors may fail to record very small specimens in some habitats, such as dense grassland. Analysis should therefore focus on species for which data are most reliable (note that it is recommended that surveyors collect as complete a record as possible from each plot).

In the event of financial constraints, it would be possible to record on a six year rather than a three year cycle. This would not necessarily represent better value, since it would take longer to detect change and it would give less information about response to extreme climatic events (e.g. droughts) or pollution episodes.

Requirements for preparatory work

There may be a need to train surveyors to record bryophytes and lichens of interest.

2.2.6. Butterflies

Rationale

Butterflies are probably the best-studied invertebrates in relation to climate change and shifts in their distribution have been reported in recent years (e.g. Parmesan *et al.*, 1999). As mobile organisms, with short generation times, they would be expected to be amongst the first indicators of change. In common with most terrestrial animal groups, the butterflies have rarely been studied in relation to air pollution impacts. However, many species of butterfly adults and larvae are dependent on specific food plants, and the proposed network offers the potential to investigate the extent to which a decline in a food plant may affect butterfly species. The Butterfly Monitoring Scheme (Pollard & Yates, 1993) has been operating since 1976 and its methodology has proved capable of detecting long term trends, year-to-year variations and the effects of extreme events (Morecroft *et al.*, 2002). Butterflies are a relatively small group (58 resident or common migrant species in the UK) for which identification is relatively easy and good field guides are available; non-experts can be easily trained and are reliable with a few weeks' or months' experience.

Many existing BMS transects are on National Nature Reserves and these reserves will be preferentially included within the new network. Preparatory work for a new extended butterfly monitoring programme in the wider countryside has developed a new methodology which would only involve two sites visits per year (D. Roy pers. comm.). This would not be suitable for this project as the method is not intended to give reliable, site-specific data, which is important for relating butterfly populations to the physical driving variables. It would be possible to develop an intermediate level of monitoring which would provide reliable site-based data. This would require statistical analysis and expert interpretation to assess the optimum number, timing and frequency of visits. This option is not recommended at this stage because maximum consistency with existing recording is desirable and many proposed sites already have ongoing transect recording. It is clear that, where the situation permits, conservation agency staff and volunteers are willing to carry out transect walks and enjoy doing so (particularly at species-rich sites). The options should be reviewed if problems in finding staff and/or volunteer resources are encountered at some sites.

Proposed method

The Butterfly Monitoring Scheme method (Pollard & Yates, 1993), which is also used by ECN, is recommended. This is a weekly transect count carried out from April to September, inclusive, under defined weather conditions (dry, with temperature over 17°C unless there is greater than 60% sun in which case a temperature threshold of 13°C is used in lowland areas or 11°C in the northern uplands).

Constraints

There is a substantial time commitment over the whole summer, although each transect only takes approximately 1 hour.

Very remote sites should not be included in the network as it is difficult for recorders to respond flexibly and take advantage of suitable weather conditions.

In some upland areas butterfly numbers are low. Nevertheless, these sites must be included since change in response to climate change is anticipated, and these sites may provide some of the best evidence of changing distribution patterns.

Requirements for preparatory work

There may be a need to train surveyors.

2.2.7. Birds

Rationale

The monitoring of bird populations is a valuable component of any general programme to monitor ecosystem health (Furness & Greenwood,1993), and will be informative as part of the proposed extended network to monitor the impacts of climate change and air pollution on biodiversity. Birds have a number of advantages as biomonitors compared to other taxa: they are relatively easy to identify; they have been well studied, so that there is a wealth of background knowledge to aid in the interpretation of population changes; they tend to occur high in food chains and therefore tend to integrate the changes that may occur at lower levels; they have been widely used as biomonitors already, for example in the UK with respect to pollution (e.g. Shore *et al.,* 2005), land-use (e.g. the UK Government's Headline Quality of Life Indicator of farmland bird populations http://www.bto.org/research/indicators/index.htm) and climate change (e.g. three of Defra's suite of Climate Change Indicators: Cannell *et al.* 1999). They are currently the subject of a wide range of national monitoring schemes, carried out using volunteer observers.

Birds have been proven as sensitive to climate change, with respect to their phenology (e.g. Crick & Sparks 1999, in press) and changes in breeding performance, survival, abundance and distributional range (reviewed in Crick, 2004). There is also evidence that bird distribution, abundance and breeding performance is affected by acid deposition (e.g. Chamberlain *et al.,* 2000). Inclusion in the proposed network would also provide added benefits with respect to the interpretation of the broader-scale, national monitoring of bird abundance carried out on 2,500 1-km squares as part of the BTO/JNCC/RSPB Breeding Bird Survey (BBS) (Raven *et al.*, 2005).

Proposed method

The Breeding Bird Survey line transect census method should be adopted (Raven *et al.* 2005). The observer makes two visits each breeding season to count all the birds seen and heard along each transect. Birds are recorded in 200m sections of each transect. The use of three distance bands enable detectability to be assessed and species density calculated. An additional survey is made to record habitat using standardised habitat codes based on Crick (1992). The method is fully described in the standard ECN protocols. The standard method is for two parallel 1-km transect to be walked at least 500m apart within a randomised 1-km square of the national grid. Within the proposed network, the transects will need to be adjusted to fit within the configuration of the site, but the key will be to record in the standard 200m sections. On small sites, the total distance covered may be less than 2km, but this will not pose a problem for analysis.

For individual site trends, the easiest way to analyse the data would be to use numbers of registrations for each species per year to measure population change. It would be possible to use distance sampling methods to estimate population densities per sites, but this only provides limited extra information. For the measurement of trends across sites, the data would be most efficiently analysed by the BTO using its standardised analytical programs. Subsets of sites may be analysed according to habitat type or region depending on the number of sites available for analysis. In general at least 30 sites are required to produce reliable trends. Depending on the level of analysis required and the number of sites involved, the analysis of trends should require approximately five days of processing time at BTO per annum. If distance sampling methods are used to produce density estimates on a per site basis or over the network or subset of sites, then there will be an initial set up cost of c. six weeks analytical time and c. three weeks analytical time per annum.

Constraints

The standard method will not monitor nocturnal species, unless specific nocturnal surveys are undertaken, but such an addition is not considered necessary as part of this programme because the number of species involved is small and will not add greatly to its monitoring capacity.

A small proportion of species may have large territories (especially raptors) so that the individual birds may be influenced by factors outside the monitoring plots. Although this may limit the value of the results for those species, most species will have the majority of their populations wholly within the monitored plots. Species that only occur on the boundaries will be readily identifiable from the recording sheets. Waterbirds may not be monitored effectively by the standard method; other similar methodology is available for them, but the network as a whole has not been designed to address aquatic habitats.

Requirements for preparatory work

A small amount of development time will be required in the first year of operation.

2.2.8. Phenology

Rationale

Phenological recording does not directly measure any aspect of biodiversity, but it can provide a mechanistic link between meteorological variables and biological processes, which have the potential to drive change in communities. For example, the earlier onset of growth in the spring with rising temperatures may disrupt synchrony between plants and pollinators or within food chains (Fitter & Fitter, 2002; McCleery & Perrins, 1998) and drought may cause premature senescence in sensitive tree species (Coultherd, 1978).

Ground-based recording of phenology has a long history and has become re-established in the UK in recent years through the UK Phenology Network. Where staff are based on sites or visit at weekly intervals or less, the time commitment is minimal; all that is required is simply noting down first occurrences of certain species, and this method is recommended. In many cases, however, this will not be possible for various reasons, and it may be necessary to adopt a different, objective approach that covers the whole network.

Satellite remote sensing can detect many aspects of the phenology of vegetation, such as date of onset of new vegetation growth, rate of greening up, date of maximum greenness, onset of senescence and length of growing season. It also enables these aspects to be monitored objectively across the whole network. Current satellite capabilities allow daily imaging of the whole of the UK at 250 metre spatial resolution in red and near-infrared channels that relate to vegetation chlorophyll absorption through the Normalised Difference Vegetation Index (NDVI). The raw satellite data has been archived at the Dundee Satellite Receiving Station since May 2000. The infrastructure to receive, and process daily satellite data from the Dundee Satellite Receiving Station at CEH Monks Wood is already being set up through CEH Science Programme funds and by NERC. Processing of data for sites in the proposed network can be achieved very cost effectively (approximately six days per year for the whole network).

Proposed method

Once the CEH National Vegetation Phenology Observatory (NVPO) has been established and becomes operational, a GIS-based system should be set up to extract cloud-cleared NDVI values for every 250 metre pixel covering sites and summary statistics of the phenology extracted and summarised. Offline back processing of the archive of data from May 2000 should also be carried out. Sites for which conventional ground-based recording is possible should be encouraged to do this, using UK Phenology Network methodology (www.phenology.org.uk).

Constraints

The data link and processing chain will be completed during 2006 for operational daily delivery of data to CEH Monks Wood.

Results will depend on the ability to provide sufficient cloud-cleared images to follow the phenological cycle.

Requirements for preparatory work

A GIS based system will need to be set up to extract data for ECN sites and generate statistics (estimated 15 days work). As data are already stored and can be retrospectively processed, this does not need to be carried out before the network is established.

2.2.9. Land management

Rationale

The impacts of climate change and air pollution can be easily obscured by the effects of management. It will be important to check that past, present and future management of sites which are included in the network is stable and consistent. It will nevertheless be necessary to record management, for example, grazing by livestock, culling of deer or controlled burning. These records will allow the impacts of these management operations to be identified and if necessary controlled in analyses.

Proposed method

The ECN has recently adopted a new protocol* for recording management operations for defined management units (for example fields or woodland compartments) in a format which is suitable for storage in a database. It is recommended that this is also adopted by the new network.

*http://www.ecn.ac.uk/protocols/Terrestrial/LU.pdf

Constraints

It is not possible to record literally all management operations on a site (for example the repair of a stile or small scale stock movements where grazing is let) and a degree of judgement needs to be exercised by site-based staff.

Requirements for preparatory work

None.

2.3. Measurements for potential future inclusion

There are a number of measurements that could be included in this network, but for which standard methods are not immediately available. Table 2.3 lists these with notes. It is recommended that the introduction of the network is not delayed whilst these measurements are investigated further, but that the opportunities for their inclusion should be reviewed on a regular basis.

Table 2.3 Measurements for potential future inclusion

Measurement	Notes
Foliar nitrogen concentration	Potentially useful bioindicator of nitrogen deposition. **Recommendation**: Once vegetation recording has been carried out, suitable species, present at a large number of contrasting sites, should be selected for investigation at time of 2nd vegetation recording and funding sought.
Ozone	Rising ground level ozone concentrations are a potentially significant threat to biodiversity. Measurements of mean concentration possible but difficult to relate to vegetation response. Two options proposed: 1) Carry out diffusion tube survey for baseline survey of mean concentrations and accept lack of information on peak concentrations. Further work on relating mean concentrations to relevant exposure indices such as AOT40 could also be commissioned. 2) Monitor reliability of new 12v instruments to assess potential use. **Recommendation**: Ongoing review of methodology (and funding) for ozone measurements
Soil mineralization and nitrification	Important to understanding total nitrogen supply available to plants. No universally agreed technique and expensive. **Recommendation**: Periodically review methods.
Carabid beetles	Major invertebrate group monitored successfully by ECN and giving useful information relevant to project. Methodology is time consuming and requires expert input. **Recommendation**: consider developing less intensive method if requirement for increasing invertebrate monitoring.
Bats	**Recommendation**: Consider exploring opportunities with Bat Conservation Trust.
Invertebrate suction samples	**Recommendation**: Consider if need for more invertebrate sampling across a wide range of groups or quantitative measure of biomass is identified. NB Sorting and identification of samples is very time consuming and expensive.
Vertebrate herbivores and / or their impact	Herbivory is a major factor affecting habitats and the biodiversity they support. Interaction with climate change and air pollution and may mask their impacts. No generally suitable methodology. **Recommendation**: Exploit local exclosure experiments and review opportunities after 4 years.
Atmospheric sulphate and sulphur dioxide and total S deposition	Priority for EA and SEPA to detect recovery from S deposition but not for other sponsors. **Recommendation**: investigate options for filter pack system or other lower power active sampler, subject to funding availability.

2.4. Programming

The individual measurements need to be efficiently scheduled for maximum scientific value, operational efficiency and cost effectiveness. This is true both within and between years. Table 2.4 indicates the programming of core measurements within a year.

Table 2.4 Timing of core measurements through the year. Grey bars indicate measurements which would be made at different sites in rotation. Phenology does not require on site recording.

Measurement	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Climate	Continuous monitoring; quick monthly check + annual maintenance											
Air pollution	Continuous monitoring; monthly change-over of sampling equipment											
Soil												
Vegetation												
Butterflies				1 hour per week if suitable weather								
Birds				2 visits								
Land management	Occasional recording when operations take place											

Soil and vegetation recording are recommended for repeat at six and three year intervals respectively. A rolling programme is recommended, with different sites recorded in different years on a rotation. This allows more consistent budgeting and the use of a smaller pool of more skilled surveyors. It also provides some information on inter-annual variability.

2.5. Framework for analysis and interpretation of data

At the design stage, it is important to identify the types of statistical analysis which are likely to be required, to meet the aims of the network, so that the selection of measurements and sites is appropriate. Time series analysis and the detection of temporal trends are fundamental to any monitoring programme and these techniques are well-established (e.g. Diggle, 1990). Additionally, the intention is for the proposed network to be able to test the causation of change and this is less straightforward.

The proposed network design is based on allowing the comparison of trends (essentially the analysis of covariance) in measured biodiversity variables between contrasting groups of sites, for example comparing changes in Ellenberg N values in sites with high and low atmospheric nitrogen deposition. This will be powerful in this network because on-site monitoring will allow accurate determination of climate and air pollution regimes for each site. In practice this would be developed with a flexible approach, using different groupings of sites to address different issues and multiple regression techniques to test relationships to more than one variable. The common need is for a sufficiently large network of sites, covering the widest possible range of climate conditions and air pollution conditions. The specific issues surrounding this are addressed in Section 3.

Testing whether species associated with particular climate or nutrient conditions are increasing or decreasing at sites is a well established approach for identifying the impacts of environmental change. This is unlikely to work effectively using single species, because distributions are frequently patchy and site-to-site variability is intrinsically high. In most circumstances a better technique is to use indices which can be applied to whole groups of species, for example the Ellenberg indices for characteristics such as fertility and water availability based on geographical distributions. The PLANTATT dataset (Hill et al., 2004) provides these data for all UK higher plant species together with mean climate conditions under which the species occur. This approach has been less commonly used for animal groups, but birds and butterflies are amongst the best understood and most practical to develop appropriate techniques (see, for example, Morecroft *et al.*, 2002).

Long term changes in community composition can be compared with relationships between species abundance and weather patterns. ECN data on changes in invertebrate populations (butterflies, moths and Carabid beetles) are already being used in this way to provide a climate change indicator within the England Biodiversity Strategy.

Testing the output of models of climate impacts and/or nitrogen deposition against monitored changes will be an important function of the new network. For example changing species distribution patterns predicted on the basis of the climate envelope approach used in the MONARCH programme can be used to generate hypotheses which can be tested at sites. The recommended biodiversity measurements have all been used in modelling work.

Comparison of changes monitored within the network with the results of experimental manipulations in field experiments will also substantially strengthen the evidence base provided by the network. No monitoring scheme by itself can directly test the effects of different variables entirely separately and in a controlled way, which is what an experiment does. For this reason, sites with long-running field manipulation experiments on climate change and air pollution effects have been identified for possible inclusion in the new network. This also adds value to the experiments, by allowing the generality of their findings to be tested across a wide range of sites with contrasting conditions.

3. Sites

3.1. General principles and approach

This is a proposal for a site-based monitoring network. There are other ways of monitoring climate change and air pollution impacts, for example changes in species distributions can be detected from Biological Records Centre data. However, a site-based approach has important advantages. Principally, physical and biological variables can be monitored together, on site, on compatible timescales. This strengthens the ability to attribute correctly the causes of change and allows the relationships between different aspects of biodiversity (e.g. plants and invertebrates) to be investigated. It also allows an efficient, cost-effective system to be developed where the monitoring of different variables can be combined, and allows the local knowledge of site managers to be used to best effect.

In this project, a 'site' is defined by the boundaries of a land holding or management unit, such as a nature reserve. Other models were considered, but this approach ensures compatibility with the existing ECN and the condition assessment of designated sites, particularly National Nature Reserves (NNRs). Informing policy and management of designated sites and other areas of high biodiversity value is an important part of the proposed network's remit and these therefore form the basis of the network. This is not a network to monitor change in the wider countryside, as provided by the Countryside Survey.

Site selection is clearly very important and must balance statistical and practical considerations. Power analysis was used to inform the decision on how many sites should be included to ensure that a degree of change could be detected. A range of techniques was used to characterise the air pollution conditions and climate change scenarios for a wide range of potential sites, using national mapped data. From this information, a network of potential sites was identified that (a) maximised the range of environmental conditions (and hence the chances of detecting significant relationships), and (b) separated (as far as possible) the effects of different variables. The practicality of carrying out monitoring work at the potential sites was assessed, considering issues such as the remoteness of sites, existing monitoring work and availability of suitable staff.

One of the aims of the new network design and site selection process was to include terrestrial habitats of conservation interest. The priority was to include habitats for which the application of the measurement methodology was most suitable and where impacts of climate change and air pollution were believed to be largest. A degree of flexibility was included and many sites possess a mosaic of different types. Coastal sand dunes and salt marshes were not included in the main proposal as the issues and measurement techniques differ from those for terrestrial habitats in some important respects. A scoping study was carried out to examine their suitability for inclusion in a subsequent extension to the network or a parallel scheme.

The network has been developed as a UK-wide initiative and the conservation agencies for England, Scotland and Wales have been actively involved in all aspects of its development. Sites in Northern Ireland are also included in the proposal, and the Department of Environment, Northern Ireland, has made an input to the process. It is anticipated that more direct involvement will be possible as the project develops.

3.2. *Methodology*

3.2.1. Statistical power analysis

Power calculations were carried out based on three datasets – butterflies, birds and vegetation. In each case the basic approach was to consider the properties of tests for comparing differences in mean trends of two groups of sites. The key objective was to estimate the probability that tests for a difference between groups in mean trend would give a statistically significant result (for a one-sided test at the 5% significance level), given an hypothesised genuine difference in trend and size of monitoring network. Examples of such comparisons that the network may be able to establish are: a comparison of the mean trend in Ellenberg N values for those sites experiencing relatively high nitrogen depositions with the mean trend in Ellenberg N values for those sites experiencing relatively low depositions; or a comparison of the mean trend in BMS butterfly indices in sites experiencing summer droughts with the mean trend in sites not experiencing summer droughts.

In practice a range of different analyses will be carried out on real data from the new network, including for example, multiple regressions in which the interaction between an environmental variable and time will provide information about the influence of environmental factors on trends. Within this setting it will also be possible to control for some sources of extraneous variation and so increase the precision with which desired relationships are estimated using site-specific environmental data.

It was not possible to cover all potential analyses and the construction of more complex models in the power analysis would have involved making less transparent assumptions about future data, with very little justification. The adopted approach provides both a clear and a realistic, if slightly conservative, guide to inform decision making and should be treated as such.

For butterflies, annual species indices for each site in the BMS between 1984 and 2004 were used. For birds, a stratified sample of BBS data consisting of estimated annual numbers of breeding pairs on each site between 1994 and 2004 were used. For vegetation, vegetation survey data from seven ECN sites consisting of annual records of the vegetation composition in between nine and eleven fixed plots per site from 1997 to 2000 were used.

A first order auto-regressive model was fitted, allowing for correlations between years within sites. For the bird and butterfly data, site effects were also included. For the vegetation data, correlation between years within plots was also allowed for but it was not possible to fit plot and site main effects as well, due to the limited number of years in the data set.

Powers were estimated assuming data collection starts in year 0 and continues for a further 12, 24 or 48 years (thereby allowing sampling every 1, 3 or 6 years). For butterflies and birds, year-on-year changes of 0.5% to 10% have been allowed for. For the vegetation indices, we considered changes in mean values ranging from 0.05 to 0.25 for Ellenberg Wetness (W), Light (L), Soil Reaction (R) and Fertility (N) values (Hill et. al., 1999) and from 0.05 to 0.45 for Grime Competitor (C) values (Grime *et al.*, 1988) over the observation interval to ensure the boundaries on index values were respected.

3.2.2. Site selection

The process of site selection involved a number of steps, summarised in figure 3.1 and described in this section. Full details of the statistical and data extraction methods are given in a technical report which is available on request (Appendix 2).

Preparation of the long list of sites

The ‘long’ list principally comprised groups of sites, such as National Nature Reserves (NNRs) and those in existing long-term monitoring networks, selected either because of their conservation value and management by the conservation agencies (e.g. NNRs) or because relevant monitoring was already being undertaken at the sites (e.g. Butterfly Monitoring Scheme or Forest Level II sites). Some experimental sites were also included, particularly where the impacts of atmospheric pollution or climate change were being investigated. The long list consisted of approximately 880 sites. The long list was generally restricted to those sites for which organisations represented on the Steering Group were responsible. This decision was taken for practical reasons: (1) these organisations are most likely to provide the initial sites in the network and (2) it was necessary to obtain geographic reference information or digital shape files for each site in a short period of time to meet the project deadline. Additional sites could potentially be added at a later stage.

For each site, a range of information was obtained, where possible, including location, details of existing monitoring and major habitats. Land Cover Map 2000 gave a good indication for large continuous habitat blocks, but not small fragmented ones.

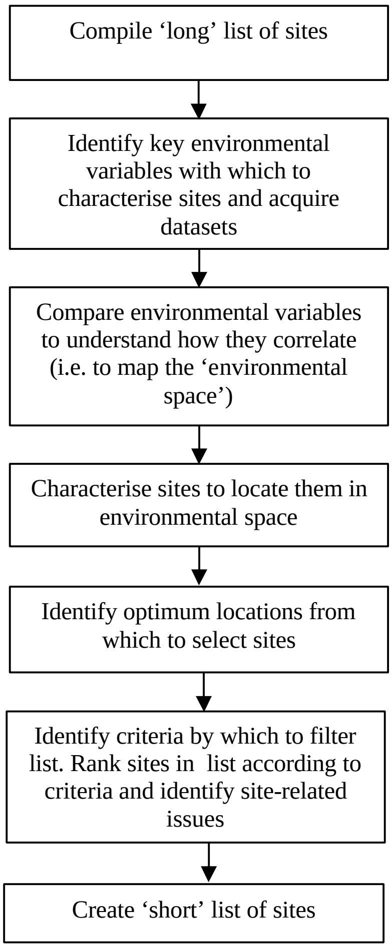


Fig. 3.1 Steps involved in selecting potential sites for the network

Characterisation of sites

Sites were characterised using a geographic information system (GIS) to extract information from national spatial datasets of key climate and pollution variables, and land cover, in particular:

- UK nitrogen and sulphur deposition estimates (5km grid) (CEH)
- UK meteorological baseline data (dates (UK Meteorological Office)
- Climate change data for Baseline, 2020, 2050 and 2080 (low and high scenarios) from HADCM3 (UKCIP / Hadley Centre)
- Land cover data from Land Cover Map 2000 (CEH)

Where only a point location was known for a site, the value at the point location was used. Digital shape (boundary) data were available for some sites, but for consistency, values were sampled at a single point selected at random from within the site boundary.

Defining the environmental envelope: Investigating correlations between variables

Preliminary investigations indicated a high degree of correlation between the climate and air pollution variables. The following five design variables were adopted as ones which summarised the main variations in the data in a way that was relevant to the aims of the network and were used in subsequent analyses:

1. **logN**: log-transformed current nitrogen deposition (sum of oxidised N and reduced N);
2. **logNSratio**: log(Current nitrogen deposition) – log(Current sulphur deposition);
3. **surain%**: percentage change in summer rainfall by 2050 from the baseline;
4. **restrain%**: percentage change in rest of year rainfall by 2050 from the baseline;
5. **sutempdiff**: change in summer temperature by 2050 from the baseline.

The definitions used were:

- summer rainfall: the sum of rainfall in the months of June, July and August;
- rest of year rainfall: the sum of rainfall for the months of September to May;
- summer temperature: the mean daily maximum during June, July and August.

Whilst variables (1) and (2) used baseline (interpolated current) values, (3)-(5) were derived by combining baseline values with predicted values for the year 2050 under a high greenhouse gas emissions scenario (UKCIP/Hadley Centre HADCM3 model). Other prediction dates and scenarios were investigated and found to correlate closely with the scenario selected.

It was originally anticipated that it would be possible to design a network with a high degree of orthogonality, meaning that the effects of different variables could be estimated independently of one another. However, the correlations are such that some combinations of high and low values are missing from the UK (Fig. 3.2). In particular, predicted temperature increase and predicted nitrogen deposition are highly correlated. It should also be noted that the data used for these analyses are based on 5km grid data as site specific data are not currently available for most sites. These predicted averages even out local scale variations and therefore underestimate the range of conditions which would be sampled by the network itself. This may be particularly important for nitrogen deposition, which is heavily influenced by point sources of ammonia.

Optimal site selection must balance the desire to maximise the variation in these variables, hence maximising power with respect to each variable in isolation, and the desire to obtain orthogonality in which causality can be attributed with less ambiguity.

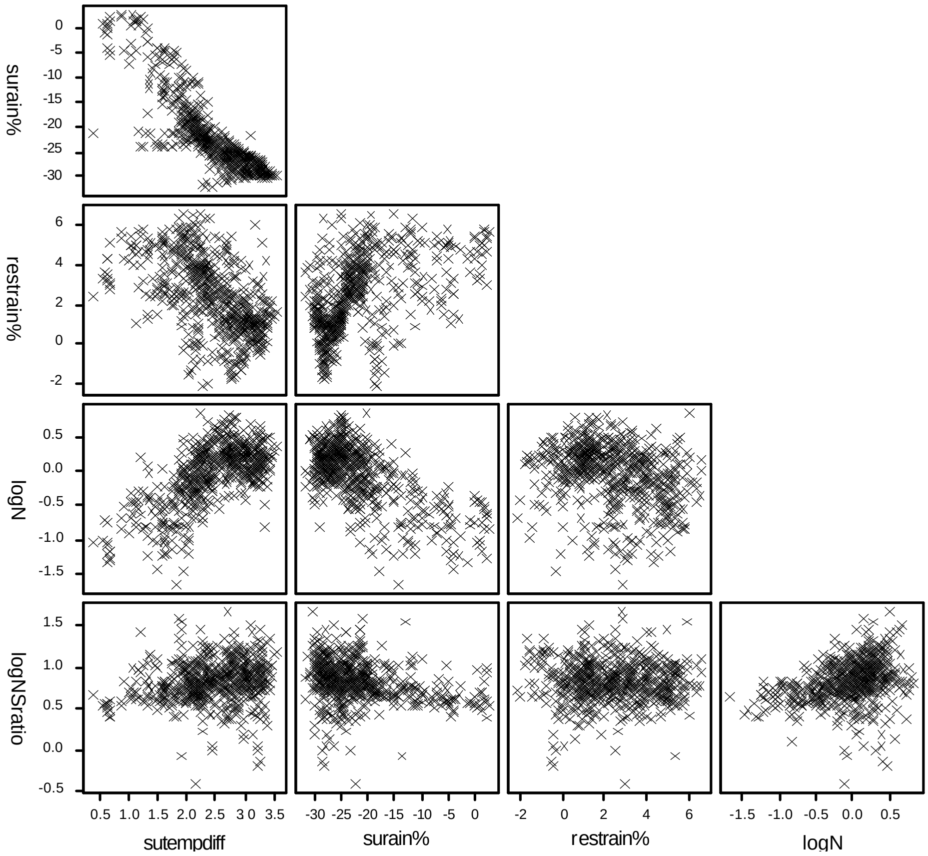


Fig. 3.2 Scatter plots showing the relationships between the five design variables used

Table 3.1 Correlation matrix of the five design variables

sutempdiff	1.000				
surain%	-0.859	1.000			
restrain%	-0.549	0.492	1.000		
logN	0.660	-0.662	-0.269	1.000	
logNSratio	0.174	-0.265	-0.018	0.328	1.000
	sutempdiff	**surain%**	**restrain%**	**logN**	**logNSratio**

Identifying clusters of sites

In discussion with the Steering Group, it was decided to restrict the initial set of selected sites to NNRs and selected experimental sites (existing terrestrial ECN sites were also included by default). The reasons for this are:

- The majority of National Nature Reserves are managed by the statutory conservation agencies. They are protected sites, under stable ownership and (in most cases) stable management. Some have established teams of site management staff. A range of relevant monitoring is already being undertaken at some NNRs, representing a valuable existing dataset. They contain a wide range of the most important UK habitats for conservation;

- Experimental sites provide a wealth of relevant data and information. Including them in the proposed network would give substantial added value both to the monitoring and to the long-term experiments that are being undertaken;
- Limiting the sites (and therefore, the organisations involved) facilitates the early establishment of an initial network.

Since it is inevitable that there are good reasons why some sites are inappropriate for the proposed monitoring, a mechanism was devised to allow the country agencies to indicate these without being presented with a completely unstructured list of sites. The aim was to identify sites that would enable sampling in as wide a range of the 'environmental space', as defined by the five design variables, as possible. This was achieved by performing a cluster analysis using Ward's method (Everitt, 1993) according to the five design variables, resulting in the presentation of sites in groups which were relatively 'compact' in design (environmental) space.

Target habitats and site types

The following criteria were used to prioritise UKBAP Broad Habitats for inclusion in the network:

- broad geographical spread in the UK;
- relevance to conservation interests;
- some understanding of climate change and air pollution impacts from other studies;
- sufficiently large blocks of habitat to allow proposed measurements to be carried out;
- sufficiently numerous sites to allow for adequate replication.

The broad habitats selected on this basis for inclusion at this stage were:

- Acid grasslands
- Dwarf shrub heath
- Broadleaved mixed & yew woodland
- Calcareous grassland
- Bogs
- Montane habitats
- Neutral grassland

A minimum 20 ha of at least one of these habitats per site was adopted as a criterion, (unless there were exceptional reasons) as most of the proposed measurement techniques are designed for relatively large areas (e.g. transect walks). It is not uncommon to find more than one of these at a single site, which is useful in allowing habitat specific conclusions to be drawn, by effectively increasing the size of the network.

Filtering the long list through consideration of key criteria

Statutory conservation agencies were provided with the clustered list of sites. They were asked to consider each site with respect to a set of criteria (available on request – see Appendix 2), and to rank the site as:

1.	**Include**	Site completely or substantially meets all the criteria. There are no major reasons not to include in the network
2.	**Possibly include**	Site meets some of the criteria. Some issues would need to be resolved before the site could be included in the network
3.	**Don't include**	Site fails most or all of the criteria. Major, insurmountable issues make the site unsuitable for inclusion.

Agencies were asked to try and ensure that wherever possible each cluster included at least one site scoring 1.

Agency contacts were asked to provide, for each site, additional information:

- Any relevant information, particularly in support of the ranking. Brief notes were specifically requested to explain the reasons for a site being ranked 2 (possibly include), rather than 1 (include);
- Brief details of the major habitats at the sites;
- Brief details of existing relevant monitoring being undertaken at the sites.

3.3. Results and recommendations

3.3.1 Power analysis and network size

Results from the statistical power analysis are summarised in Appendix 3 (full details are available on request). Power (here the chance of detecting as statistically significant, using a one-sided t-test at the 5% significance level, a difference in mean temporal trends between two groups of sites) is affected by the size of difference in trend to be detected, the number of sites in the network, and the length of time series used to estimate the difference in trends. These influences are demonstrated by Figures 3.3, 3.4 and 3.5. Compared to a small network, a large network will be more likely both to detect smaller differences and to detect differences more quickly.

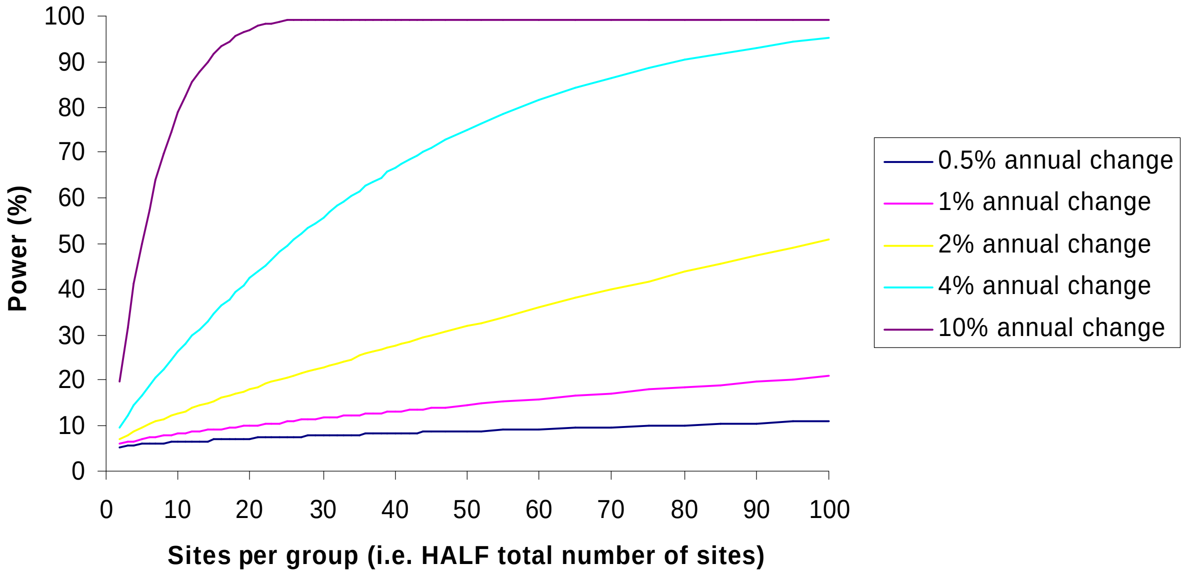


Fig. 3.3 Power to detect differences in trend in total butterfly indices. Curves are shown for five scenarios in differences of mean trends (annual change 0.5%, 1%, 2%, 4% and 10%). Power to detect differences in trend in total butterfly numbers between two

equally sized groups of sites over a 12 year interval increases as the number of sites in each group increases under each of the scenarios.

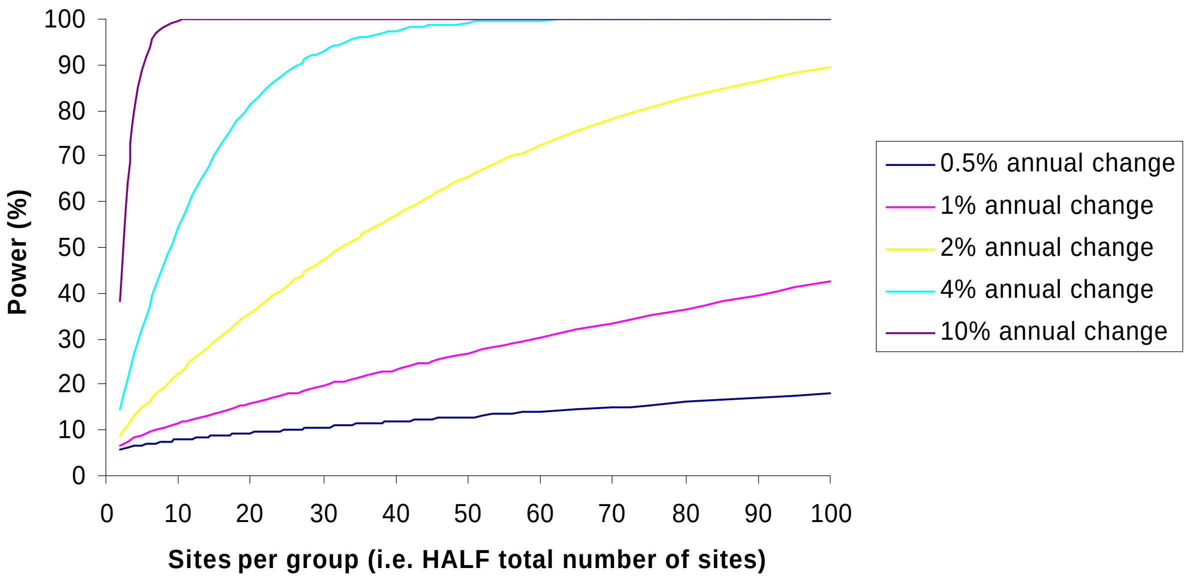


Fig. 3.4 Power to detect differences in trend in total bird indices. It is evident that for any given number of sites per group a smaller difference in trends (percentage annual change) is needed in total birds than total butterflies to attain similar statistical power.

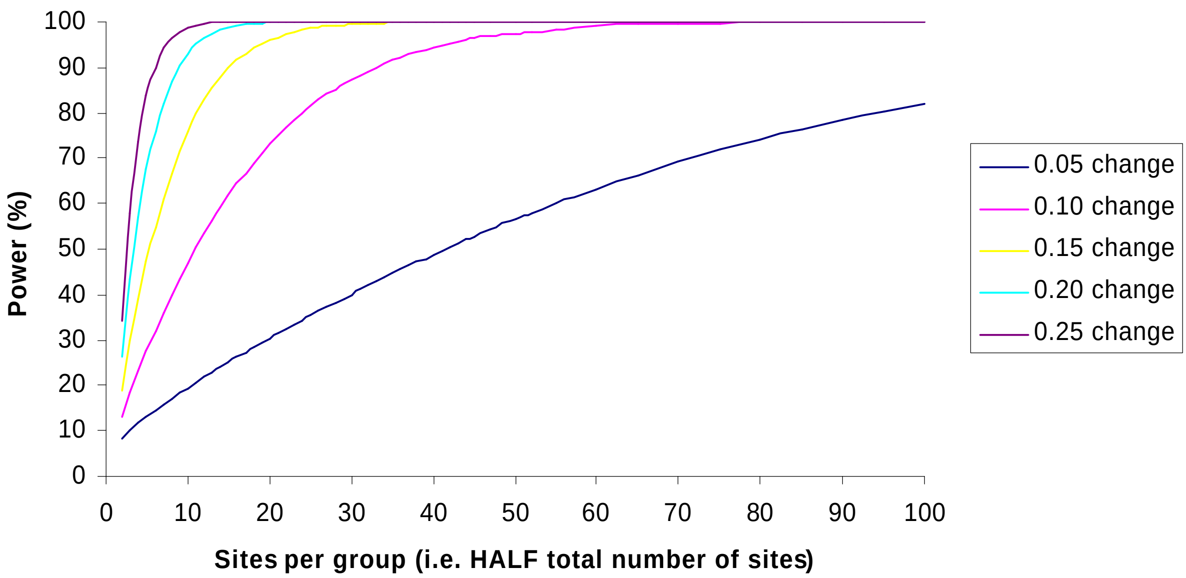


Fig. 3.5 Power to detect differences in trend in mean Ellenberg N of plant community. Powers have been calculated for changes over a 12 year period (note: this is different to birds and butterflies for which annual percentage changes have been considered). For comparison, Countryside Survey 2000 detected significant changes of the order of 0.05 to 0.15 in this index over an 8 year period, 1990-1998 (Haines-Young *et al.*, 2000).

Given that a power of approximately 70% is typically regarded as a sound basis on which to establish a new project, a number of conclusions can be drawn from these analyses.

1. **Statistical power differs between variables**. In general terms, the estimated powers were higher for vegetation than for birds, which in turn were higher than those for butterflies.
2. **For birds and butterflies**, differences in trends of less than 2% per annum between groups are unlikely to be detected even with networks of several hundred sites over a period of 12 years.
3. **For birds and butterflies**, large differences of approximately 10% per annum could be detected by networks of approximately 20 sites over 12 years (but are unlikely in reality)
4. **For birds and butterflies**, differences of approximately 2-4% per annum could reasonably be expected to be detected by networks of approximately 50 sites over a 12 year period but a network of 100 sites would make this much more likely.
5. **For plant communities**, some ecologically realistic differences in Ellenberg indices of different groups can be expected after 12 years, even with a network of less than 50 sites. (It should however be noted that there is likely to be more demand for habitat specific analyses for plants than for the other groups, which effectively reduces the size of the network).

It is important to evaluate this information in an ecologically meaningful way. For example, although larger differences in trend are required to achieve high statistical powers for butterflies than for plants, butterfly populations are far more variable and capable of rapid change than plant populations, so a larger difference in trends is more likely. It is also important not to over–interpret this information: there is no clear right or wrong answer and the relative variabilities of actual data may prove to be different to those underpinning the power analysis.

The power analysis has demonstrated that a network of approximately 100 sites is likely to be capable of detecting biologically meaningful differences in trends between contrasting groups of sites in about 12 years. A network of approximately 50 sites may also be able to do this, but either with less certainty over 12 years or with the same certainty over a longer period. A network of approximately 20 sites is unlikely to detect a difference between groups for all but the largest changes and consequently adds little to what the existing ECN can already do.

There are many additional benefits in adopting a large, rather than a small, network. In particular, with a larger number of sites, the results will (i) have a broader geographical base, (ii) be less specific to particular habitats, (iii) be less dependent on the continuation of monitoring at all sites, (iv) be better able to distinguish between the effects of the different drivers of change, (v) be less sensitive to the perturbations due to the differences between the anticipated and true site-specific values of the environmental variables.

On this basis, it is recommended that the best option would be to establish a network of approximately 100 sites, made up of approximately 86 new sites, 12 existing ECN terrestrial sites and the two current ECN Biodiversity Network sites. This would strike a satisfactory balance between the chances of detecting biologically meaningful changes and incurring the additional costs of an unnecessarily large network. However, we recognise that this may present problems in that (i) obtaining sufficient funding may not be possible and (ii) it may be difficult for a small coordinating unit to facilitate the establishment of such a large number of new sites in the first few years of operation. Given that the power analysis may be somewhat conservative, it is also possible that, in reality, an intermediately sized network will deliver sufficient information to detect change. A compromise option would therefore be to establish the network with approximately 40 new sites (in addition to the existing ECN) and then review the situation, using actual network data to provide more accurate power analyses after, say, four years of operation. Costs would also be known from actual experience at this time, allowing a rigorously based cost-benefit analysis. If this option is adopted it would, however, be desirable to further reduce the number of habitats incorporated, if some habitat specific outputs are required.

3.3.2 Screening of long list to short list suitable sites

Screening of the clustered sites by conservation agency staff has produced a priority list of 106 potential sites, including existing ECN and Biodiversity Network sites (Table 3.2; Fig. 3.6). Suitable sites have been identified for 27 out of the 30 clusters. The three remaining clusters are: Cluster 12 (15 sites, primarily in England); Cluster 23 (three sites, all in Scotland); Cluster 29 (three sites, all in England). All three sites in cluster 23 have been ranked as unsuitable. The clusters were however only intended as a guide to site selection and the present list represents a good coverage of the range of UK conditions.

This should not be treated as a final definitive list. All agencies have emphasised that a series of negotiations will need to be conducted at national and local level which is likely to take a number of months and could not be undertaken within the present project. The suitability of each site will also need to be evaluated more closely in association with local site managers to determine, for example, exactly which habitat types are present and the feasibility of conducting monitoring. The viability of proceeding with all the habitat types listed above will also need to be reassessed once this information is available. Additional sites owned and/or operated by other organisations (as in the original 'long' list, for example) could also be considered for inclusion in the network, such as selected ICP Forest Level II sites (Fig. 3.6).

The process of clustering the sites prior to consideration by the Country Agencies should be seen as a mechanism for simplifying the assessment of sites by Agency staff relative to the provision of an unstructured list of candidate sites. Once additional investigations have taken place into the suitability of the highest ranked sites for inclusion in the network, additional statistical work is required to assess the appropriateness of the candidate sites, or a subset thereof, in combination to form a monitoring network. Any weaknesses identified at this stage may need to be rectified by the inclusion of sites of a lower ranking.

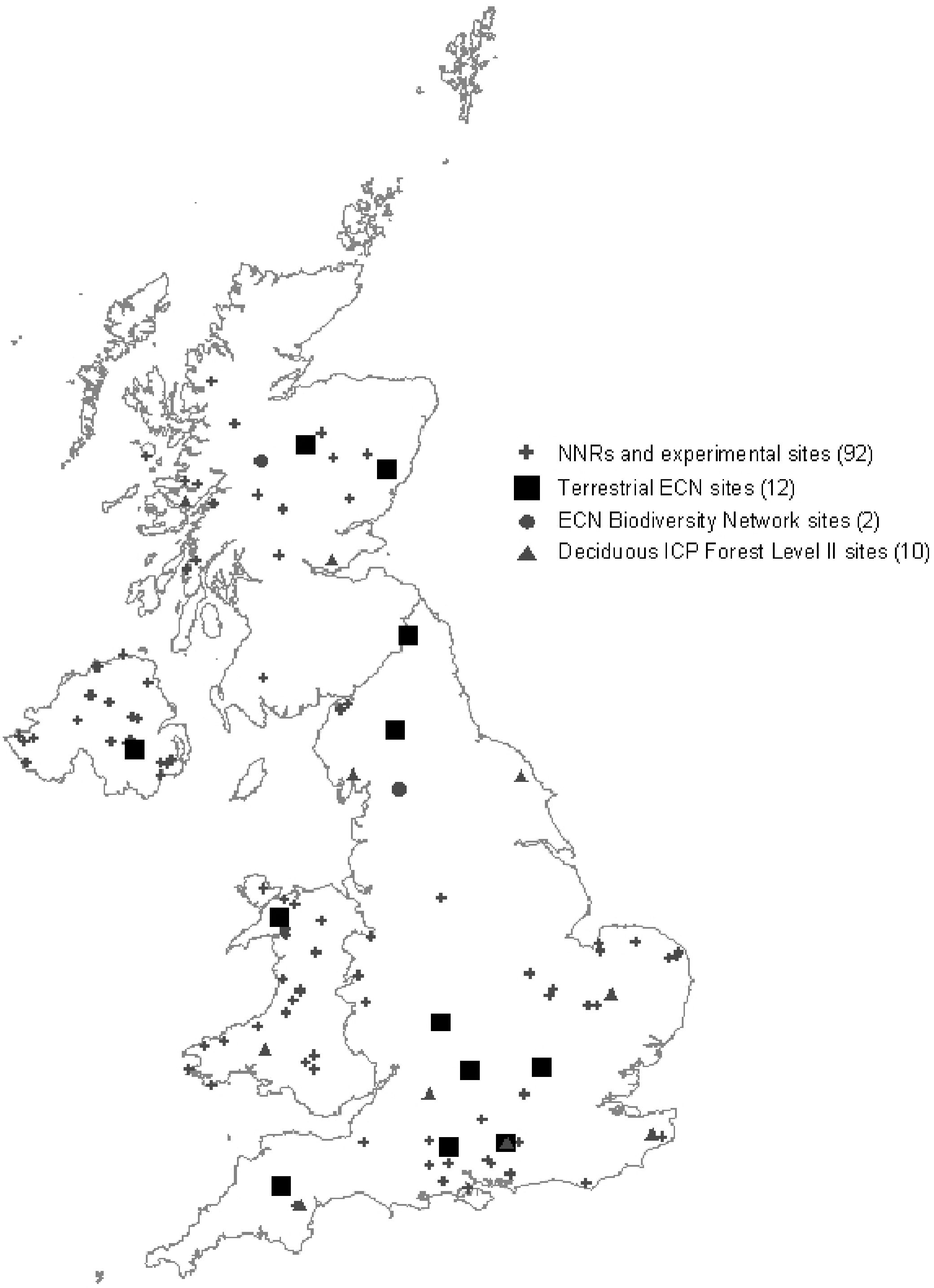


Fig. 3.6 Map of proposed sites. Existing terrestrial ECN sites are shown. In addition, the map indicates locations of ICP Forest Level II sites with plots in deciduous woodland, which may also be suitable sites for inclusion in the proposed network.

Table 3.2: Provisional list of sites ranked as suitable for inclusion

[1]Indicates terrestrial ECN sites (•) and pilot ECN Biodiversity Network sites (♦)
[2]Sites with relevant long-term experiments
[3]These sites added after the clustering exercise

Sitename	NNR	ECN[1]	Exptl[2]	Country	Major Habitats	Cluster
1. Flanders Moss	•			Scotland	Raised bog	1
2. Morrone Birkwood	•			Scotland	Birchwood and acid grassland	1
3. Coed Camyln	•			Wales	Semi natural broadleaved woodland	1
4. Coed Cymerau	•			Wales	Semi natural broadleaved woodland	1
5. Coed Y Rhygen	•			Wales	Semi natural broadleaved woodland	1
6. Coedydd Maentwrog	•			Wales	Semi natural broadleaved woodland	1
7. Cors Erddreiniog	•			Wales	Fen/Lowland raised bog with marshy grassland	1
8. Ogof Ffynnon Ddu	•			Wales	Dry heath/acidic grass mosaic & Marshy grassland	1
9. Bohill Forest NR	•			N. Ireland	Mixed Woodland	2
10. Hollymount Forest NNR	•			N. Ireland	Mixed woodland	2
11. Turmennan	•			N. Ireland	Reedbed, neutral grassland	2
12. Glensaugh		•		Scotland	Semi-natural vegetation, short-term and permanent grassland and woodland	2
13. Corsydd Llangloffan	•			Wales	Valley Mire and Fen	2
14. Ty Canol	•			Wales	Semi natural broadleaved woodland with bracken	2
15. Ariundle Oakwood	•			Scotland		3
16. Claish Moss	•			Scotland		3
17. Moine Mhor	•			Scotland	Raised bog	3
18. Rum	•			Scotland		3
19. Taynish	•			Scotland	Oak woodland	3
20. Dersingham Bog	•			England	Rhynchosporion, Valley bog	4
21. East Dartmoor Woods & Heaths	•			England	Dwarf shrub heath, deciduous woodland	4
22. North Wyke		•		England	Lowland grassland and deciduous woodland	4
23. Roydon Common	•			England	Mixed valley mire (M21, M3, M25, M16)	4

Sitename	NNR	ECN[1]	Exptl[2]	Country	Major Habitats	Cluster
24. Swanton Novers Woods	•			England	Lowland broad-leaved woodland; Ponds	4
25. Cors Caron	•			Wales	Lowland bog with marshy grassland	4
26. Craig Cerrig Gleisiad a Fan Frynych	•			Wales	Acidic dry dwarf shrub heath with acidic unimproved grassland	4
27. Cyff			•	Wales	Acid grassland (under ESA agreement) + some deep peat. Areas of improved grassland	4
28. Plynlimon (Afon Gwy: AWMN)			•	Wales	Acid grassland + deep peat (molinia) + wet heath. Very small areas of improved pasture and small area of coniferous woodland	4
29. Pwllpeiran			•	Wales	Acid grassland	4
30. Banagher Glen Extension	•			N. Ireland		5
31. Banagher Glen NR	•			N. Ireland	Mixed Woodland	5
32. Mullenakill & Annagarriff NRs	•			N. Ireland	Raised Bog	5
33. Glasdrum Wood	•			Scotland	Oak and ash woodlands	6
34. Fenn's, Whixall & Bettisfield Mosses	•			England	Active raised bog, Degraded raised bog	7
35. Stiperstones	•			England	H8, H12	7
36. Climoor			•	Wales		7
37. Glenariff Waterfalls Forest NR	•			N. Ireland	Mixed woodland	8
38. Giant's Causeway NNR	•			N. Ireland	Geology, Acid grassland	9
39. Den of Airlie	•			Scotland		9
40. Stackpole	•			Wales	Sand dune system with woods and scrub, calcareous grassland	9
41. Finglandrigg Woods	•			England	Broadleaved mixed and yew woodlands, acid grasslands	10
42. South Solway Mosses	•			England	Bogs	10
43. Binevenagh NR	•			N. Ireland	Montane, mixed woodland	10
44. Correl Glen Forest NR	•			N. Ireland	Mixed woodland	10
45. Murrins Forest NR	•			N. Ireland		10
46. Ashford Hill	•			England	Neutral grassland on London Clay with acidic and calcareous elements and swamp	11
47. Kingley Vale	•			England	Yew woodland, chalk grassland	11

Sitename	NNR	ECN[1]	Exptl[2]	Country	Major Habitats	Cluster
48. Kingston Great Common	•			England	Heathland, valley mire within the New Forest	11
49. Langley Wood	•			England		11
50. Shapwick Heath	•			England	Reed Bed, Wet Woodland, Open Water, Acid Grassland	11
51. Thursley	•		•	England	Lowland heath, valley mire	11
52. Wytham		•		England	Woodland (unmanaged ancient and secondary woodland, plantations and small areas of semi-natural grassland) and farmland (producing a variety of livestock and crops)	11
53. Ben Lawers	•			Scotland	Dry heath; wet heath; tall herbs; montane scrub; calcareous grassland	13
54. Rannoch Moor	•			Scotland		13
55. Coed Dolgarrog	•			Wales	Semi natural broadleaved woodland	13
56. Coedydd Aber	•			Wales	Semi natural broadleaved woodland and bracken	13
57. Yr Wyddfa	•	•		Wales	Acidic unimproved grassland with acidic dry dwarf shrub heath	13
58. Hickling Broad	•			England	Fen (Flood-plain, basic), wet woodland, open water	14
59. Ludham Marshes	•			England	Lowland wet grassland with ditches	14
60. Lydden Temple Ewell	•			England	CG2, CG4	14
61. Bure Marshes	•			England	Fen (Flood-plain, basic), wet woodland, open water	15
62. Ingleborough	•	♦		England	H12-18, M15, M17-19	15
63. Moor House - Upper Teesdale	•	•		England	Blanket bog (M18b, M19a,b) with deciduous woodland and herb-rich meadows at lower altitudes	15
64. Sourhope		•		Scotland	Rough grazing, permanent pasture and woodland	15
65. Rhos Llawr Cwrt	•			Wales	Marshy grassland	15
66. Derbyshire Dales	•			England	Upland limestone grassland, woodland & rivers	16
67. Y Berwyn	•			Wales	Bog and flush system with acidic dry heath	16
68. Abernethy Forest	•			Scotland	Caledonian woodland	17
69. Cairngorms	•	•		Scotland	Altitudinal sequence of communities, from Caledonian pine woodland at 300m up to arctic-alpine vegetation at 1100m	17
70. Creag Meagaidh	•	♦		Scotland	Native Woodland, Carex bigelowii-Rhacomitrium heath, snowbed vegetation and ungrazed ledge vegetation. Substantial areas of blanket bog and Molinia dominated grassland	17
71. Glen Affric	•			Scotland	Native pine and mixed woodland	17

Sitename	NNR	ECN[1]	Exptl[2]	Country	Major Habitats	Cluster
72. Alice Holt		•		England	Coniferous and deciduous woodland	18
73. Beacon Hill	•			England	CG2b&c, CG3	18
74. Burnham Beeches	•			England	Beech woodland & wood pasture; Dry & wet heathland; Valley mire	18
75. Chippenham Fen	•			England	Peat fen over chalk, wet meadows, chalk grassland & woodland	18
76. Collyweston Great Wood & Easton Hornstocks	•			England	Small-leaved lime, W8/W10 woodland	18
77. Drayton		•		England	Mixed farmland	18
78. Monks Wood	•			England	Ancient ash-oak woodland	18
79. Old Winchester Hill	•			England	CG2 grassland	18
80. Rothamsted		•		England	Agricultural research station with long-term ‘Classical Experiments’ designed to cover cereal growth, grassland management and woodland regeneration	18
81. Wicken Fen	•			England	Peat fen	18
82. Woodwalton Fen	•			England	Fen (Flood-plain, basic)	18
83. Cairngorms	•	•		Scotland	Upland heath	19
84. Beinn Eighe	•			Scotland	Montane and dwarf shrub heaths; bog and wet heath, Scots pine woodland	20
85. Dyfi	•			Wales	Estuarine complex with intertidal flats, saltmarsh, raised mire, grazing marsh/ fen and sand dune system	21
86. Castle Archdale Islands Forest NR	•			N. Ireland	Mixed woodland	22
87. Castlecaldwell Forest NR	•			N. Ireland	Mixed woodland	22
88. Marble Arch NR	•			N. Ireland	Semi-natural woodland	22
89. Montiaghs Moss	•			N. Ireland	Bog	22
90. Randalstown Forest NR	•			N. Ireland	Mixed woodland	22
91. Altikeeragh NNR	•			N. Ireland	Montane	24
92. Ballynahone Bog NNR	•			N. Ireland	Raised Bog	24
93. Banagher Glen Extension	•			N. Ireland	Mixed Woodland	24
94. Murlough NR	•			N. Ireland	Sand Dune Dry Heath	25
95. Glen Tanar	•			Scotland		25

Sitename	NNR	ECN[1]	Exptl[2]	Country	Major Habitats	Cluster
96. Silver Flowe	•			Scotland		25
97. Martin Down	•			England		26
98. North Solent	•			England	Coastal, estuarine, asnw, neutral grassland, acid grassland, heathland	26
99. Parsonage Down	•			England		26
100. Porton		•		England	Woodland and semi-natural chalk grassland with successional scrub	26
101. Downton Gorge	•			England	Broadleaved mixed woodland	27
102. Lullington Heath	•			England	CG2, others? (U1/4?)	28
103. Lough Neagh-Oxford Island NNR	•			N. Ireland	Mixed woodland	30
104. Lough Neagh-Rea's Wood Forest NR	•			N. Ireland	Mixed woodland	30
105. Cwm Cadlan[3]				Wales	Wet Grassland	
106. Skomer[3]				Wales		

4. Data and information management

4.1. Overview

Good management of the data and information generated by the network is essential. Because of the long-term nature of the monitoring, careful consideration needs to be given to the way in which data are stored and maintained and to the kinds and amount of meta-data that are stored alongside measurement datasets. It is also necessary to ensure that methods of data collection and transfer are simple and efficient, to facilitate rapid transfer of data from sites to the central coordination unit staff, and to reduce the potential for errors. Quality control is an important consideration, so appropriate data validation processes must be utilised to identify potentially erroneous data. The true value of data are only realised if they are used, therefore the provision of means to access the data and associated information, appropriate for the intended users, is essential. The data stored also need to be compatible with proposed methods of reporting and analysis. ECN data and information management procedures are tried and tested and provide a cost effective framework which it is proposed to adopt as far as possible for the new network (Fig. 4.1). In future an alternative approach may be to use a series of distributed databases and a Grid system, but this technology is not yet sufficiently advanced to consider this. It is also possible that some of the key participants in the proposed network, such as the conservation agencies would prefer not to be responsible for their own databases and would rather use a centralised facility.

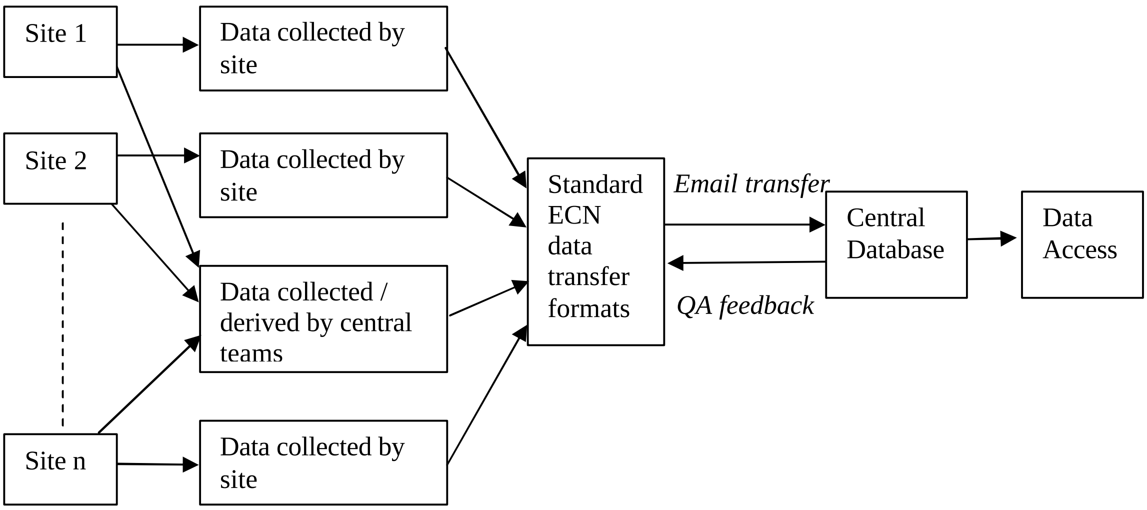


Fig. 4.1 Proposed data management structure for the new network

4.2. Metadata

Meta-information is an essential part of the database, particularly as there may often be little contact between data users and data providers. A meta-information system needs to hold descriptions of data values, their derivation, measurement parameters and quality criteria, as well as information about the sites and personnel involved in the network.

4.3. Data capture

Data capture will mainly be through manual methods, using standardised field forms. The use of ruggedised laptops or field computers could, however, be considered. Automated methods are also proposed, for example automatic weather stations to monitor climate. Where possible and appropriate, existing data capture methods should be adopted to maintain comparability with data from ECN and other networks, such as the Butterfly Monitoring Scheme, which uses standard recording forms.

4.4. Data Transfer

Sites (or agency coordinators) and centrally coordinated research teams, will be responsible for sending the data to the ECN data centre in machine-readable form (quarterly for frequent measurements and annually for seasonal measurements). Standard data transfer formats must be developed to describe how this should be done. The data transfer formats should include specifying a means to record data quality. E-mail will be the preferred medium for data transfer. It is proposed that automatic weather stations be automatically downloaded centrally using mobile telephone technology, wherever network coverage allows. This system is already being used successfully at some existing ECN sites (Cairngorms, Glensaugh and Sourhope), and this has enabled near real-time data to be made available on the ECN web site (www.ecn.ac.uk/online_aws/index.asp).

4.5. Data Verification

Datasets received by the ECN Data Centre will be logged in a meta-database and a receipt notification sent. Data loading and verification programs will be used to check the datasets prior to entry in the database. They should check, for example, whether the data are within an agreed range, and that valid species codes have been used. The time taken to process a dataset is strongly determined by the type and number of errors it contains. Where possible, problems should be solved through communication via e-mail. A cautious approach must be adopted to discarding data on the principle that apparent errors may be valid outliers.

4.6. Data access

The current ECN information management system has a two-tiered approach with summary data freely accessible over the Internet (www.ecn.ac.uk) and raw data accessible through a licensing system. A data licensing system has the advantage of allowing the owners of the data to maintain control over who uses data they have collected. However it is costly (in terms of staff time) to run and maximising freedom of information is likely to be a higher priority for this network. Intellectual property rights and licensing issues will have to de discussed and agreed by the Steering Group during the formal establishment of the network and it is recommended that as open a policy as possible be adopted.

Table 4.1 Database Development – task list

Tasks	New Protocols	Existing Protocols
Specification of data for measurement protocols	Draft protocols from expert groups.	Existing ECN Protocols.
	if changes	*if same*
	Define data specification e.g. units, precision etc.	Use existing data specification.
QA and data verification	Identify or create necessary code lists.	Use existing QA procedures.
Develop ECN data model	Define and create data and meta-data structures Discover and import metadata.	Create data structures; Discover and import metadata.
Develop mechanisms for transfer of data	Develop suitable mechanisms and formats for data transfer.	Use existing data transfer formats.
QA and data verification	Develop appropriate range checks in collaboration with expert groups; Set up data loading programs; Set up data verification programs.	Use existing QA procedures.
Summary database (used by web interfaces)	Define and create data and meta-data structures; Import metadata.	Create data structures; Import metadata.

5. Programme Management

A proposed structure for the network is presented in Fig. 5.1 with different roles and responsibilities defined in Table 5.1. Some important points to consider are:

- A Steering Committee formed from the sponsoring organisations, the network coordinator and any other key, invited stakeholders would be responsible for governing the overall direction of the network.
- A Central Coordination Unit (CCU) would coordinate the operation of network and be responsible for data management, communication and outreach, links with other key initiatives and would provide the secretariat for the Steering Committee. The CCU would be responsible for the development of the network, working with the Steering Committee. It would be headed by a Network Coordinator.
- Monitoring would use a combination of local staff (and/or volunteers) based close to the site and specialist teams who would visit at intervals of a year or more.
- Some measurements, for example counts of butterflies and birds, need regular short periods of work, which would not be practical for centralised staff to carry out. It would be important to make sure that local staff have the necessary skills or undertake appropriate training. It would be necessary to ensure that there is a named individual who takes responsibility for - and an interest in - the monitoring at each site and ensures that quality is maintained and any problems are noted and reported at an early stage.
- Other measurements, such as vegetation and soil survey are carried out at long, predictable time intervals. Some may also require specialist skills which are not necessarily available locally. In these situations, it is more efficient to train specialist teams to visit a number of sites.
- Unlike the existing ECN network, it is recommended that central survey teams and analytical facilities report directly to the coordinator of the network or a national coordinator within country conservation agencies and supply data directly to the database manager, rather than site managers. It is also recommended that provision is made for automatic, centralised downloading of weather stations.
- A flexible arrangement should be adopted for communication between the Central Coordination Unit and site staff. The proposed network will consist of more sites than the current ECN terrestrial network, it would be more appropriate for the CCU to liaise with one or a few representatives of the sponsoring organisations, who would be responsible for overseeing the monitoring and associated activities at their sites. The CCU should also be able to communicate directly with site staff when necessary.

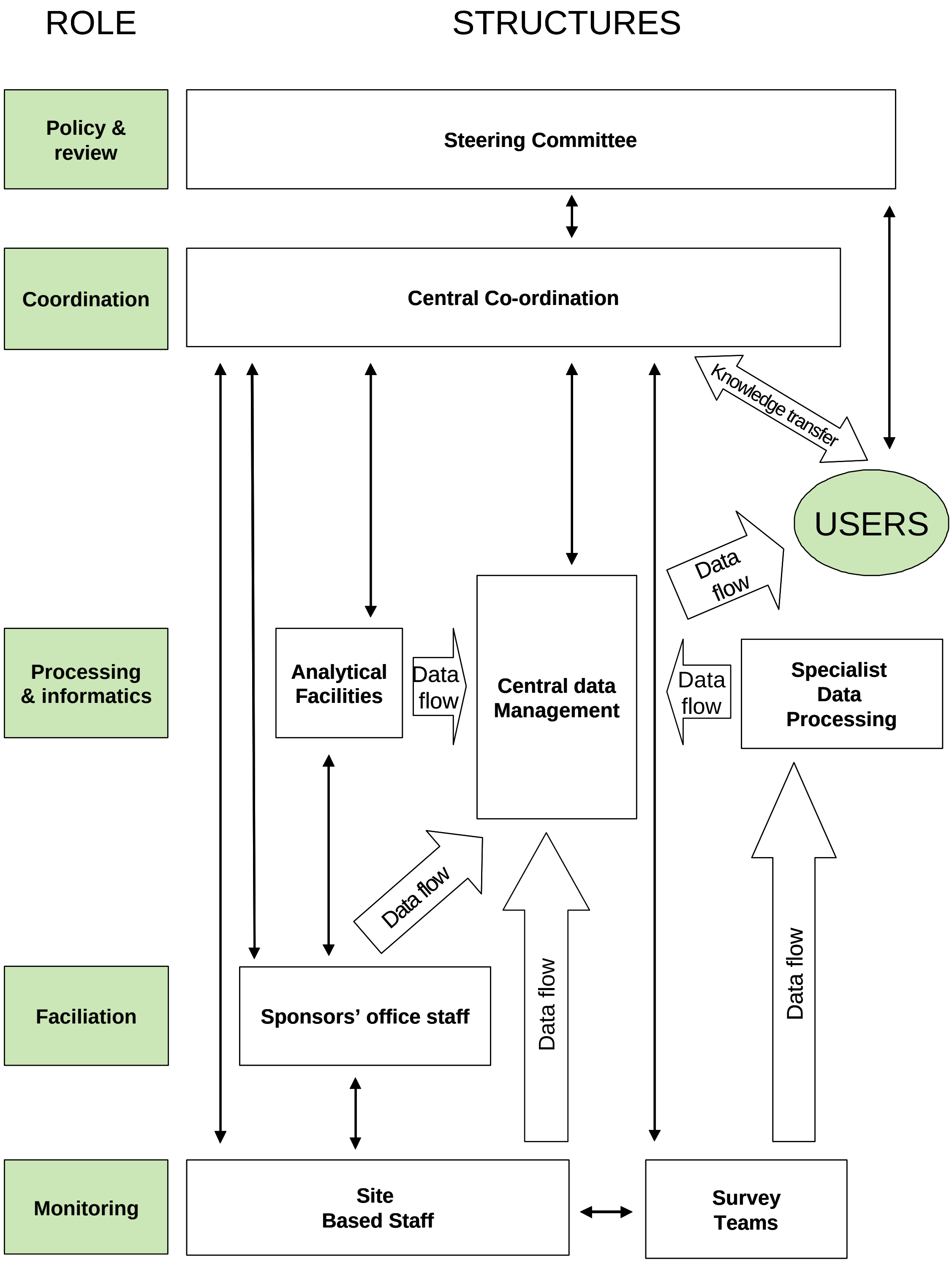


Fig. 5.1 Organisational chart for proposed targeted monitoring network

Table 5.1 Summary of organisational structures and roles

Role	Structure	Tasks	Resources and notes
Policy and Review	Steering Committee	• Review of project; • Funding; • Providing feedback on policy and management needs; • Strategic developments e.g. new sites / measurements.	Project sponsors and key stakeholders.
Coordination	Central Coordination Unit – Network management team	• Coordination of network; • Secretariat to Steering Committee; • Field QA and training coordination; • Liaison with sponsors; • Analysis and interpretation of data (statistician and biologist); • Dissemination of results.	Probably approximately 1.5 full time equivalent (fte) posts co-located with ECN Central Coordination Unit. Resources required depend to some extent on number of sites.
Processing & informatics	Central Coordination Unit - Data Management Team	• Development of database; • Development of systems for automated data input; • Data quality assurance; • Input of data to database; • Development of system for remote AWS data downloading; • Development of web interface for data and information access.	Probably co-located with network management group. Resources required depends on number of sites and measurements.
Processing & informatics	Specialist Advice and data processing	• Development and monitoring of atmospheric deposition estimates[1]; • Processing of butterfly data to produce indices[2]; • Processing of bird data[3]; • Provision, processing and interpretation of remote sensing data.	[1]CEH Edinburgh; [2]CEH Biological Records Centre; [3]BTO.
Analytical services	Analytical Facilities	• Analysis of precipitation samples; • Analysis of soil samples; • Analysis of diffusion tubes[1]; • Data input for above.	[1]Probably commercial labs.
Facilitation	HQ and/or regional office staff of sponsoring organisations	• Assist with effective communication between sites and CCU; • Oversee day-to-day activities at their sites; • Assist with data compilation and transfer.	Project sponsors.
Monitoring	Site based staff, volunteers and contractors)	• Routine tasks such as: precipitation collection, changing over diffusion; tubes, basic checks of AWS, downloading AWS[1]; • Butterfly monitoring and initial data input; • Bird monitoring and initial data input.	[1]If telemetry is not an option.
Monitoring	Centrally managed field teams	• Vegetation and data input; • Soil sampling; • AWS maintenance and calibration; • Sampling for nitrogen bio-monitoring techniques.	

6. Communications

6.1. Introduction

To ensure uptake and support for the new network, it is essential that there is effective communication with stakeholders in the network at all phases of implementation and network operation. Organisations and individuals involved in establishing and running the network need to have clear communication channels, and need to recognise the need to share information in an appropriate and timely manner. It is also important that the existence and purpose of the network, and the data and other outputs arising from it, are communicated to an external audience.

A Communication Plan (available on request – see Appendix 2) has been prepared in order to guide communications. The plan addresses communication in the following phases of activity: Initial project leading the current report, post-project interim period, assumed network implementation phase and assumed network operation phase. A summary of the key points of the Communication Plan is given here.

6.2. Aims of the communication

There are many reasons to communicate effectively. These will vary depending on the audience and the phase of activity. The Communication Plan lists in detail the aims of communication, and can be summarised as:

- to ensure key individuals are well-informed, so that implementation and network operation activities are effective and efficient;
- to raise awareness of the existence and purpose of the network;
- to publicise the outputs of the network, such as datasets, publications and interpretations of results, and to receive feedback on these.

6.3. Key messages

It is important to be clear what it is that should be communicated. The Communication Plan sets out a number of anticipated key messages for each phase of activity. They include: ‘Why should a potential sponsor support the network?’ and ‘How can data and other outputs be accessed?’.

6.4. Anticipated outputs

The likely outputs from or related to network are:

- the present report, which sets out the rationale and background for the network;
- additional material to aid in building support for the network (these might include outputs from the existing ECN network);
- annual reports during a defined implementation phase, aimed at building wider support by demonstrating the successful operation of the network and the likely uses of the data;
- a final contract report from the implementation phase summarising any pilot work, including a case study application of the data to the requirements of

CBD (before 2010), and costed recommendations for the continuation of the network;

- summary and raw datasets from the network, and possibly one or more presentations (e.g. in web-form) of interpreted results, such as indicators that utilise the data;
- regular material, in a variety of forms, aimed at maintaining and increasing awareness of the network and its outputs.

6.5. Audiences

It is essential to be aware of the primary audiences for communication. The Communication Plan lists the anticipated audiences, which will vary from phase to phase. It also assigns a priority to each audience group. The primary audiences are:

- people involved in the establishment and/or operation of the network;
- key people involved in the existing ECN network;
- researchers in relevant disciplines (potential data users/research partners);
- Government, EU and other policy development staff (potential data users/funders);
- conservation agency staff (potential data users/collaborators/funders);
- people responsible for other sites, networks and monitoring programmes; (potential data users/collaborators/funders);
- people involved in other national/international long-term ecosystem research and monitoring programmes (potential data users/research partners).

Different forms of communication will be appropriate for each audience. The Communication Plan indicates suitable methods of communication (e-mail, letter, web page, etc.) for each situation.

6.6. Specific actions

Specific communication actions are listed in the Communication Plan. As work on the network progresses, more detail will be added, and a clearer time schedule will be developed.

6.7. Major obstacles and risks

Consideration has been given in the plan to major obstacles to communication and the risks associated with communication. These help focus attention on where particular thought and care needs to be given when contacting audiences. Actions to reduce risks or overcome obstacles are also listed. A failure to communicate effectively could delay or prevent the transition to an implementation phase, for example, if sufficient commitment cannot be established as a result poor or absent communication. Similarly, a failure to properly communicate the results of the network could jeopardise its operation.

6.8. Evaluation and review

It is important continually to evaluate and review communication activities to ensure that they are effective, and to enable improvements to be made if necessary. The Communication Plan identifies suitable forms of evaluation, such as recording communication activities (e.g. the dates letters or key e-mails are sent and the recipients or website visitor activity), and seeking and listening to feedback.

The Communication Plan is not intended as a static document: it should be regularly reviewed and updated. In particular, if implementation and eventual operation of a working network go ahead, the plan should be amended to provide more detail in these areas.

7. Implementation

Consultations with the Steering Group and others, such as the ECN Steering Committee have shown that there is strong support for the network from all of the major participants and a feeling that the time is right to introduce it (subject to availability of resources). As described in Section 1, a number of initiatives and reports, over several years, have prepared the ground and the ECN Biodiversity Network effectively provides a pilot study.

It is strongly recommended that a decision to proceed with the project is taken while interest is high. Some issues remain to be resolved, and some cannot be resolved until initial decisions are made so a decision should not be delayed because of minor issues which are not critical to the establishment of the network. For example, the list of sites cannot be finalised until the size of the network is agreed and site managers cannot be expected to devote a lot of time to evaluating practicalities, until it is clear that the programme is going ahead. Although an early commitment to the network is desirable, it will take some time to put in place all the necessary arrangements and it is important that sufficient time is allowed for this. It is anticipated that approximately one year will be required before it will be possible to begin to implement the monitoring itself, but there can be no guarantee of this.

Once implementation begins, it is recommended to initiate the new network with a relatively small group of sites. This will allow various unforeseeable problems to be identified and addressed, without inconveniencing more site-based staff than necessary or overwhelming the central coordination unit. It is proposed that these 'initial sites' would start a year earlier than the others and would be selected mainly on the basis of the experience and enthusiasm of staff. They should include existing ECN biodiversity sites (Creag Meagaidh and Ingleborough) and others with substantial ongoing monitoring programmes (e.g. Burnham Beeches). Data from these sites should not be analysed separately from the main body of sites, so no statistical sampling techniques are necessary for their selection; but they would be selected to represent a range of different regions and habitats. It has been assumed that the remaining sites would be established the following year and this is also assumed in the cost estimates presented in Section 8. An alternative approach would be to introduce sites over a longer period of time, if, for example, it was necessary to spread costs over several financial years. This might be the most attractive option to funding bodies and partners for a large network.

Vegetation and soil sampling should be carried out by centrally managed teams. They should not commence in the first year of operation for any site as local staff would be better able to support and facilitate their visits once the initial establishment of the site has been completed and staff are familiar with the programme.

Table 7.1 provides an overview of the main tasks that are required for implementation. It indicates timings that would apply if a decision to establish the network is made sometime in the middle of Financial Year 2006/7 and that a major report is published in late 2010, which will form the basis for developing future plans. Any differences to this timescale would require a revision to this outline. It should be noted that because of the seasonal nature of much of the field work, this may not be a simple matter of adding or subtracting a fixed number of months. Once a decision is taken, an early priority will be to develop a detailed implementation plan.

Table 7.1 Proposed outline implementation strategy – tasks by financial year, assuming commencement in the middle of FY 2006/7. Ongoing tasks are noted in the year they commence but not subsequently.

Organisational Tasks	Scientific Tasks
Year 0 (2006/7) 1. Agree relationships between participating organisations, e.g. by memoranda of understanding; 2. Secure funding; 3. Build awareness and support at all levels in the conservation agencies; 4. Appoint steering committee and coordination staff; 5. Identify approximately 15 sites for initial implementation (to include existing ECN biodiversity network sites); 6. Develop detailed implementation plan; 7. Hold workshop and review options for coastal sites; 8, Develop relations with Northern Ireland and incorporate Northern Irish sites.	1. Agree number of sites to be established; 2. Refine details of methodology for measurements to be implemented from outset - where necessary; 3. Review list of sites, for habitats and practicality in consultation with site managers and revise if necessary; 4. Check representation of environmental space by selected sites; 5. Start to develop documentation (protocols etc.) for site managers.
Year 1 (2007/8) 1. Finalise list of sites; 2. Appoint data management staff; 3. Nominate site contact / manager for each site; 4. Organise meeting and training for site managers; 5. Begin procurement processes for equipment and services.	1. Complete first draft documentation for site managers; 2. Commence monitoring at initial sites; 3. Develop protocols for data transfer and start to design new database structures.
Year 2 (2008/9) 1. Routine management of network operation begins; 2. Establishment of routine communication procedures.	1. First complete year of monitoring at initial sites; 2. Begin soil and vegetation monitoring at initial sites; 3. Revise documentation in light of feedback from site managers; 4. Commence monitoring at majority of sites; 5. Develop procedures for initial processing of air pollution, remote sensing, butterfly and bird data; 6. Database structures finalised (at least in provisional form).
Year 3 2009/10 1. Establishment of requirements for reporting and publication in 2010/11.	1. First complete year of monitoring at majority of sites; 2. Data start to be entered into database; 3. Development of data access tools; 4. Development of QA checks.
Year 4 (2010/11) 1. Publication of major report; 2. Review of programme establishment; 3. Agree plans for next five years.	1. Preliminary analysis of data for spatial trends; 2. Statistical review of network effectiveness and power to detect trends.

8. Costs

This section presents estimated costs of establishing and running the network. They are based on the experience of the ECN, estimates from other project participants, quotations and published price lists. They are therefore a reliable guide, but they should not be treated in the same way as a direct tender or quotation. Overheads have not been added to salary costs, as the nature of the collaboration and the organisations carrying out the work have not been agreed.

For reference, 115% would be added to CEH salary costs, to cover overheads, unless co-funding of the project is agreed. Other organisations would have similar rates (it should be noted that most universities have recently changed their basis of charging in line with the introduction of Full Economic Costs by the research councils). This will clearly have a major bearing on the overall cost of the network and must be borne in mind. The potential to reduce costs by using volunteers for some measurements at some sites has not been considered. All costs are given at 2006/7 levels.

8.1. Central management costs

The evidence of the existing Environmental Change Network is that a full time Programme Coordinator and Database Manager will be necessary. These have not been costed on a formula based on number of sites and measurements, as some of the most time consuming elements are more or less independent of network size (e.g. designing data structures, writing documentation, analysing results and writing reports). It is possible that either or both roles could be split into two half time posts. It has been assumed that the database manager would be supported by a more junior member of staff and that this role would be expanded to cope with a larger network of sites. In the longer term (beyond the initial four year period), it is likely that the database assistant could take over more of the routine data management and that costs would reduce. There would also be a need for statistical input and other expert involvement for limited periods, amounting to approximately 15% of a senior post (Band 4, which is roughly equivalent to a civil service Grade 7). Total annual costs for this are shown in Table 8.1 on the basis of CEH staff rates.

Some of the conservation agencies have indicated that they would expect to nominate a part-time coordinator for their own sites. This role would expand as the number of sites increases. The nature of this role will depend on how much the agencies wish to develop it and accurate costs are not available at this stage (some estimates have been made, using CEH rates for consistency).

Table 8.1 Total annual costs for programme and data management

Costs for Network of 40 sites

Post	**Band**	**Annual rate (£)**	**% fte**	**Cost (£)**
Statistics Adviser / Senior manager	Band 4	60875	15	9131
Coordinator(s)	Band 5	47063	100	47063
Database manager	Band 6	37021	100	37021
Additional database support	Band 7	29521	10	2952
Total central coordination costs				**96167**
National agency coordination	Band 5	47063	60	**28238**

Costs for Network of 90 sites

Post	**Band**	**Annual rate (£)**	**% fte**	**Cost (£)**
Statistics Adviser / Senior manager	Band 4	60875	15	9131
Coordinator(s)	Band 5	47063	100	47063
Database manager	Band 6	37021	100	37021
Additional database support	Band 7	29521	50	14761
Total central coordination costs				**107976**
National agency coordination	Band 5	47063	120	**56476**

8.2. Measurement costs

The estimated costs of each measurement are given in Table 8.2, showing both the initial costs of establishing monitoring at each site and ongoing costs. Although some costs are fixed for the whole network, regardless of number of sites, most scale with the number of sites. Monitoring at each site is estimated to cost up to £11k to establish and £7k per year to operate (costs inclusive of equipment, staff time, chemical analysis etc.).

A number of assumptions have been made in estimating these costs, the most important ones are that the cost of site-based staff is £150 per day (based on information from conservation agencies) and that of science specialists (e.g. vegetation surveyors) is £171 per day (CEH band 6 / HSO rate). Some equipment, such as AWSs, is already installed at some sites or available nearby and some monitoring work is already taking place, so in many cases actual costs will be substantially lower.

The conservation agencies also hope to use volunteers for some tasks, which will again lower costs substantially at those sites where this is feasible. In some ways the critical issue for running sites at a local level is likely to be whether staff or volunteer time is available, rather than cost *per se* and it is also possible that contractors will need to be used in some cases.

The time commitment for each site is estimated as approximately 22 days per year (Table 8.2) with a further 21 days for establishment time (assuming vegetation and soil monitoring plots are identified and marked by site-based staff). The amount of travelling time necessary for a site can make a significant contribution to the staff time required, and will vary from site-to-site.

Table 8.2 Estimated costs of measurements. Total cost, including staff time, chemical analysis and equipment, for each site, unless stated otherwise.

Measurement	**Local staff time (days)**		**Total Cost (£)**	
	Start up	**Ongoing**	**Start up**	**Ongoing**
Climate	1	1	6684	492
Wet deposition	1	2	650	934
Ammonia	1	2	250	842
Soil	5		750	627
Vegetation (including epiphytic lichens and tree growth)	10		2000	1771
Butterflies	1	10	150	1500
Birds	1	4	150	600
Site management	1	3	150	450
Total nitrogen deposition measurement			85.5	0
Total	**21**	**22**	**10870**	**7216**
Additional Costs, independent of number of sites				
Remote sensing (all sites)			2565	1526
Nitrogen deposition			2565	855
Birds			1710	855
Butterflies			855	855
Total			**7695**	**4091**

8.3. Overall network running costs

In estimating the overall costs of the network, the central coordination costs and those of the measurements have been combined for two options – a 40 site network and a 90 site network. The rationale for these two options was given in Section 3. In both cases, it is intended that these sites will be additional to the 12 existing terrestrial ECN sites and potentially a small number of ICP Forests Level 2 plots, whose costs will be met from other budgets. It has been assumed that 10 sites will already have Automatic Weather Stations (AWS) and that 20% of the remaining sites will be sufficiently covered by a nearby weather station. In these cases, the costs of new AWSs have been excluded, but the same running costs, to cover costs of obtaining and using the data have been included.

Overall the cost of a 40 site network would be approximately £417k per year and that of a 90 site network would be approximately £818k (in both cases, excluding staff overheads). Fig. 8.1 illustrates the total costs for the two sizes of networks, broken down into broad categories:

1. Cost of work carried out by site-based staff and coordination of subsets of sites by national agencies. It is envisaged that this will mainly be covered by conservation agency staff time, with input by volunteers, with many people each making a small contribution;
2. Centralised monitoring costs – mostly soil and vegetation recording and chemical analysis cost. The issue of which organisations will bear which of these costs has not been resolved; they could potentially be covered from a range of different sources, for example a conservation agency may be able to

cover vegetation surveying but look to a government department to meet the costs of chemical analysis. The situation may well differ between the different parts of the UK. Careful negotiation will be required during the early stages of implementation;

3. Central costs - mostly coordination and data management. These costs have already been detailed in Table 8.1 above. The conservation agencies are unlikely to fund this other than through their own staff time and are likely to look to other bodies.

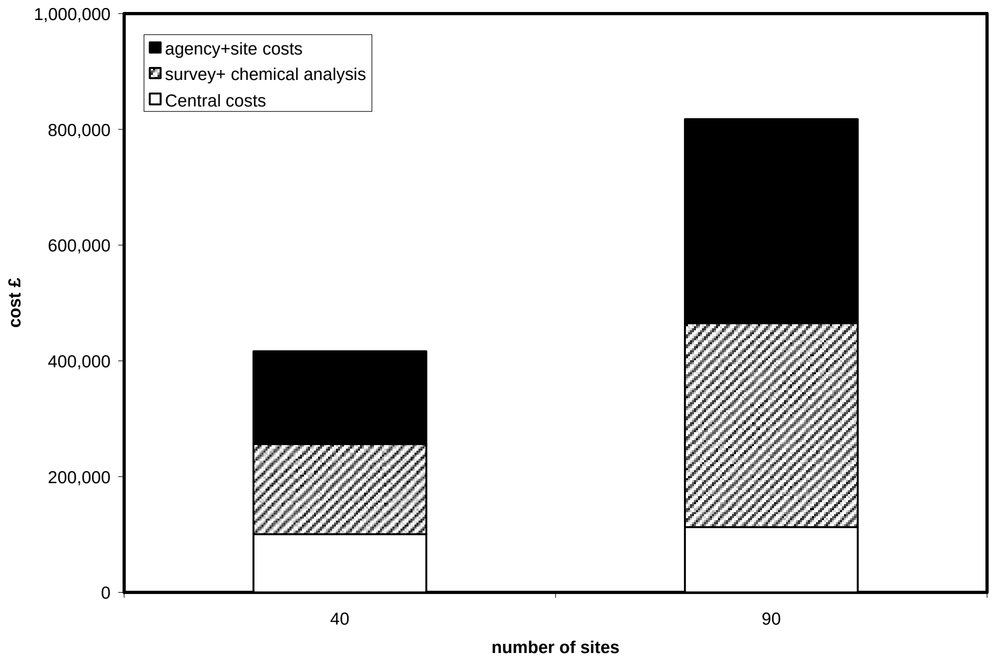
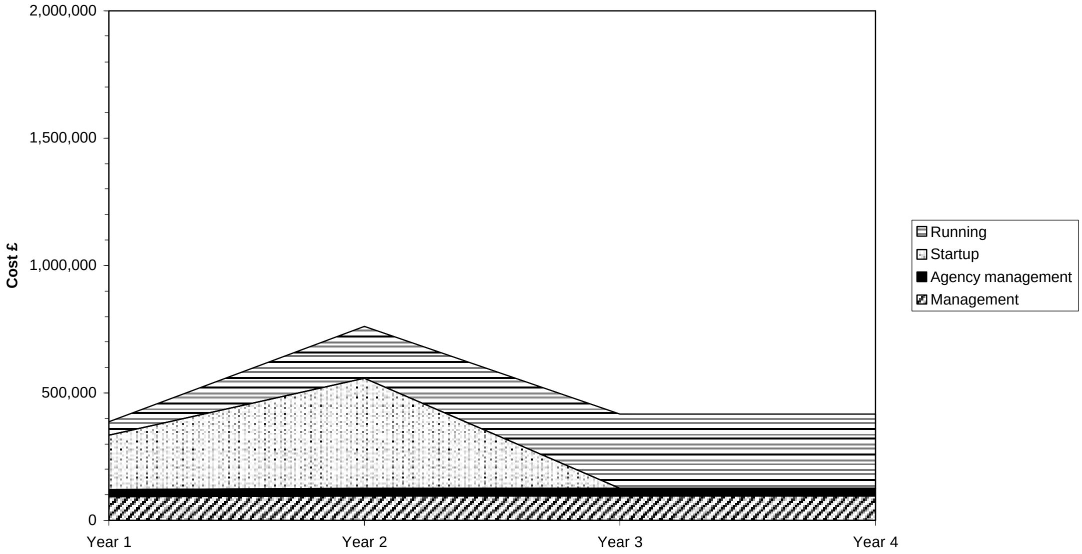


Fig. 8.1 Annual cost of running a network of 40 or 90 sites, broken down into broad categories.

8.4. Annual costs during implementation phase

Figure 8.2 indicates how total costs are likely to change over the first four years of operation for either 40 or 90 sites. Beyond this period it is possible that some costs may reduce as tasks become more routine and can be delegated to more junior staff but it is also possible that additional measurements or sites may be introduced. In both cases the cost is substantially higher in year 2 than other years and for 90 new sites it is particularly large (c. £1.8 M compared to c. £760k for 40 sites). This reflects the cost of establishing new sites and starting monitoring work; it includes the costs of equipment such as AWSs and additional staff time to establish new plots and transects. It is likely that these costs will be met mainly by the conservation agencies, who will be running the majority of sites. If this presented problems for budgeting, it could be reduced by introducing sites over a longer period of time.

(a) 40 sites



(b) 90 sites

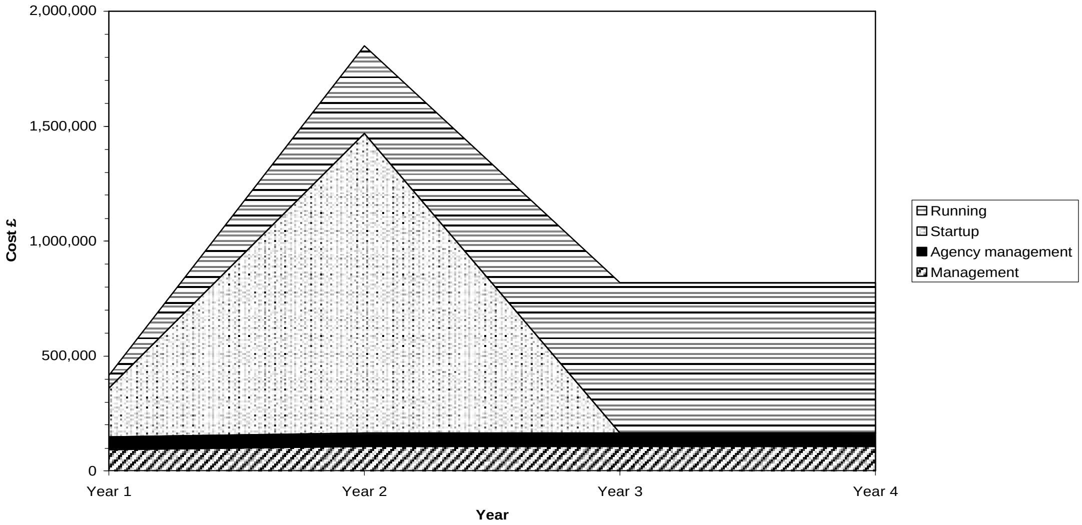


Fig. 8.2 Network costs over first four years of operation with (a) 40 sites and (b) 90 sites. Year 1 is taken to be the year in which site-based monitoring commences under this programme. It therefore corresponds to 2007/8 in the implementation strategy outlined in Section 7.

8.5 Funding of the Network

Table 8.3 lists those organisations which have indicated a potential willingness to fund or support the new network. All of the active participants in the Steering Group from the design phase are willing, in principle, to make some contribution to the network. However, funding will need to be bid for within the organisations and the amounts that are likely to be available will only become clear after completion of this report.

There are a small number of other organisations who manage NNRs, who are likely to be willing to participate in the network. For example, discussions have already been held regarding Burnham Beeches NNR which is owned and managed by the Corporation of London.

Preliminary discussions have been held with a number of other organisations, outside the present participants and managers of NNRs and a number could provide sites and volunteer participants. None were identified who are able to offer substantial amounts of funding or staff contributions. As a lack of suitable sites seems unlikely and incorporating further organisations at this stage would delay implementation, it is recommended that the network starts with the present participants. The option of expanding the network at a later stage should, however, be kept open and a willingness to explore options with potential participants should be encouraged.

Table 8.3 Potential sponsors of and support for the new network

Sponsor	Notes
Defra	Principal funder of the design study. Various departments have an interest in this project and coordination between them is likely to be important to securing sufficient funding.
JNCC	Have indicated willingness in principle to contribute to future developments. Active participant in design project.
SEERAD	Have indicated that would potentially be able to fund some aspects of future work in Scotland. Have received papers for design project.
Environment Agency	Have indicated willingness in principle to contribute to future developments. Particular interest in monitoring recovery from sulphur deposition. Active participant in design study.
SEPA	Active participant in design study. Have indicated willingness in principle to contribute to future developments. Particular interest in monitoring recovery from sulphur deposition.
English Nature	Have indicated strong support for the concept and willingness (in principle) to support monitoring work at sites. Co-funder of design project.
SNH	Have indicated strong support, in principle, for the concept. However, monitoring work at sites will need resourcing issues to be addressed. Active participant in design project.
CCW	Have indicated strong support for the concept and willingness (in principle) to support monitoring work at sites. Co-funder of design project.
EHS NI / DoENI	Have indicated interest in supporting Northern Irish sites, subject to other demands on funding. Have received papers for design project and provide comments on request.
NERC (CEH)	Principal contractor for design project. If CEH were leading the project, potentially able to cover some of the central costs, where they align with NERC priorities.
Forestry Commission (Forest Research)	Potentially willing to adjust ICP Level 2 sites and measurements to align more closely with the proposed network.
Corporation of London	Likely to be willing to support Burnham Beeches involvement in the network.
MoD (Defence Estates)	Have indicated interest in providing sites across UK, subject to other demands on funding.

9. Conclusions and Recommendations

There is a widely recognised need to improve the monitoring of the impacts of climate change and air pollution on biodiversity, to allow policy and management decisions to be based on evidence and to test and refine models and predictions of change. An extension to the ECN offers the best opportunity to ensure that a new site-based network is cost effective and complementary to existing research and monitoring work.

A suite of measurements has been identified and recommended for inclusion which will allow changes in important elements of biodiversity to be quantified alongside the aspects of the physical environment causing change. The main measurements for initial inclusion are:

- Climate;
- Air pollution;
  - Wet deposition - pH, nitrate, ammonium, sulphate;
  - Ammonia concentration - diffusion tubes;
  - Total nitrogen deposition (combination of measurements / mapped data);
- Soil chemistry and physical description characteristics;
- Vegetation composition;
- Butterflies;
- Birds;
- Satellite remote sensing of phenology;
- Site management.

A number of other measurements have also been identified, that could be introduced at a later stage depending on technical and methodological developments.

Power analyses and practical considerations were used to demonstrate that between 40 and 90 sites should be established for the new network. Forty sites would offer a substantially cheaper network and be easier to establish than 90 sites, but it would be important to review whether the data were likely to offer sufficient power to meet the aims after an initial period of approximately four years operation. In both cases data should be combined with data from existing ECN sites (and potentially some ICP Forest Level 2 plots) for analysis, giving a combined network size of at least 50 sites.

A flexible approach to the inclusion of habitats is advocated, but priority for inclusion should be given to: Acid grasslands, Dwarf shrub heath, Broadleaved mixed & yew woodland, Calcareous grassland, Bogs, Montane habitats and Neutral grassland.

Coastal habitats, particularly salt marshes and sand dunes, are important, sensitive habitats in which to increase understanding of the impacts of climate change and air pollution. Some of the measurements proposed can be implemented in such habitats, but there are sufficient differences between these and other terrestrial habitats to warrant further assessment of how these sites can be best incorporated into a wider network. A workshop is proposed to address this specific issue.

A list of approximately 90 potential sites has been compiled, maximising the range of climatic and air pollution regimes. These are mostly NNRs, amongst which priority has been given to sites with existing monitoring work and or particularly likely to be able to support a monitoring programme. Sites with relevant field manipulation experiments, such as nitrogen additions, have also been included, which will strengthen the attribution of trends in biodiversity variables to the correct cause. The list of sites will need to be refined before implementation, taking into account the number of sites agreed for the initial network, the full range of habitats present at each site and the practicalities of monitoring at each site. Local site managers will need to be thoroughly involved in decision making.

Data management and network coordination should be carried out in association with the ECN and strategies have been proposed together with one for communications.

This project has demonstrated the current interest in assessing and distinguishing the impacts on biodiversity of climate change from those of atmospheric pollution. It is strongly recommended that this proposal is used as the basis for deciding whether or not to pursue and implement the new network. It has provided recommendations and options for an implementation plan and estimated costs. It has also shown that it will be most important to establish the right organisational framework, obtain agreement between parties and secure sufficient funding. It is likely that these initial preparations could take approximately one year. This would provide time to resolve most outstanding issues, such as refining some of the measurement protocols and finalising the list of sites.

10. Acknowledgements

We wish to thank all those who contributed to this report by providing valuable help, information and advice, including the members of the Project Team and Expert Advisory Group, whose names are listed in Appendix 1, and the Project Steering Group. The project was funded jointly by the Department for Environment, Food and Rural Affairs, Countryside Council for Wales and English Nature.

11. References

JNCC (1998). *Statement on Common Standards Monitoring.* JNCC, Peterborough.

Bealey, C.E. and Cox, J. (2004). *Validation network project: upland habitats covering blanket bog, dry dwarf shrub heath, wet dwarf shrub heath, Ulex gallii, dwarf shrub heath. English Nature Research Report 564.* English Nature, Peterborough.

Cannell, M.G.R., Palutikof, J.P. and Sparks, T.H. (eds.) (1999). *Indicators of Climate Change in the UK.* DETR, London.

Cape J.N., Kirika A., Rowland A.P., Wilson D.S., Jickells T.D., and Cornell S., (2001). Organic Nitrogen in Precipitation: Real Problem or Sampling Artefact? In *Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection: Proceedings of the 2nd International Nitrogen Conference on Science and Policy. The Scientific World* 1.

Carroll J.A., Caporn, S.J.M., Johnson D., Morecroft, M.D. and Lee, J.A. (2003). The interactions between plant growth, vegetation structure and soil processes in semi-natural acidic and calcareous grasslands receiving long-term inputs of simulated pollutant nitrogen deposition. *Environmental Pollution* 121 (3): 363-376.

Chamberlain, D.E., Warren, R.F., Crick, H.Q.P., Hall, J., Metcalfe, S., Ormerod, S., Whyatt, D. and Vickery, J.A. (2000). *Acidification and Terrestrial Birds.* BTO Research Report No. 236. BTO, Thetford.

Coultherd, P. (1978). Observations on the effects of drought on tree species (with particular reference to the summer of 1976). *Quarterly Journal of Forestry* 72: 67-80.

Crick, H.Q.P. (1992). A bird-habitat coding system for use in Britain and Ireland incorporating aspects of land-management and human activity. *Bird Study* 39**:** 1-12.

Crick, H.Q.P. (2004). The impacts of climate change on birds. *In* Rehfisch, M.M., Feare, C.J., Jones, N.V. and Spray, C. (eds.) *Climate Change and Coastal Birds. Ibis*146 (suppl.1): 48-56.

Crick, H.Q.P, and Sparks, T.H. (1999). Climate change related to egg-laying trends. *Nature* 399: 423-424.

Crick, H.Q.P. and Sparks, T.H. (in press). Changes in the phenology of breeding and migration in relation to global climate change. *Proceedings of the 23rd International Ornithological Congress, Beijing.*

Cunha A., Power S.A., Ashmore M.R., Green P.R.S., Haworth B.J. and Bobbink R. (2002). *Whole ecosystem nitrogen manipulation: an updated review. JNCC report 331*. JNCC, Peterborough.

Diggle, P.J. (1990). *Time Series: A Biostatistical Introduction (Oxford Statistical Science Series, No. 5).* Oxford University Press.

Eaton, M.A., Noble, D.G., Hearn, R.D., Grice, P.V., Gregory, R.D., Wotton, S., Ratcliffe, N., Hilton, G.M., Rehfisch, M.M., Crick H.Q.P. and Hughes, J. (2005). *The State of the UK's Birds 2004*. BTO, RSPB, WWT, CCW, EN, EHS and SNH. Sandy, Bedfordshire.

Everitt, B.S. (1993). *Cluster Analysis, 3rd Edition*. Edward Arnold, London.

Fitter A.H. and Fitter R.S.R (2002). Rapid changes in flowering time in British plants. *Science* 296: 1689-1691.

Furness, R.W. and Greenwood, J.J.D. (eds.). (1993). *Birds as Monitors of Environmental Change*. Chapman and Hall, London.

Grime J.P., Hodgson, J.G., Hunt, R. (1988). Comparative plant ecology: a functional approach to common British species. Unwin Hyman, London.

Haines-Young, R.H., Barr, C.J., Black, H.I.J., Briggs, D.J., Bunce, R.G.H., Clarke, R.T., Cooper, A., Dawson, F.H., Firbank, L.G., Fuller, R.M., Furse, M.T., Gillespie, M.K., Hill, R., Hornung, M., Howard, D.C., McCann, T., Morecroft, M.D., Petit, S., Sier, A.R.J., Smart, S.M., Smith, G.M., Stott, A.P., Stuart, R.C. and Watkins, J.W. (2000). *Accounting for nature: assessing habitats in the UK countryside*. DETR, London.

Harrison, P.A., Berry, P.M. and Dawson, T.E. (eds.) (2001). Climate change and Nature Conservation in Britain and Ireland: Modelling Natural Resource Responses to Climate Change (the MONARCH project). UKCIP.

Hill, M.O., Mountford, J.O., Roy, D.B. and Bunce, R.G.H. (1999). *Ellenberg's indicator values for British plants. Ecofact Volume 2 Technical Annex*. Institute of Terrestrial Ecology/Department of Environment Transport and the Regions, pp46.

Hill, M.O., Preston, C.D. and Roy, D.B. (2004). *PLANTATT - Attributes of British and Irish Plants: Status, Size, Life History, Geography and Habitats.* CEH, Peterborough. 73 pp.

Hossell, J.E., Briggs, B. and Hepburn, I.R. (eds.) (2000). *Climate change and UK Nature Conservation: A review of the impact of climate change on UK species and habitat conservation policy. Report to DETR.* ADAS.

Jamieson N., Barraclough D., Unkovich M. and Monaghan R. (1998). Soil N dynamics in a natural calcareous grassland under a changing climate. *Biology and Fertility of Soils* 27: 267-273.

Leith, I.D., van Dijk N., Pitcairn, C.E.R., Wolseley, P.A. and Sutton, M.A. (2006). *Refinement and testing of bio-monitoring methods, and development of protocols, for assessing impacts of atmospheric nitrogen deposition or concentrations on statutory nature conservation sites.* JNCC, Peterborough.

McCleery R.H., Perrins C.M. (1998). Temperature and egg laying trends. *Nature* 391 (6662): 30-31.

Morecroft, M.D., Cape, J.N., Parr, T.W., Brown, J.C., Caporn, S.J.M., Carroll, J.A., Emmett, B.A., Harmens, H., Hill, M.O., Lane, A.M.J., Leith, I.D., Mills, G.E., Reynolds, B., Sheppard, L.J., Smart, S.M. and Wolseley, P.A. (2005). *Monitoring the impacts of air pollution (acidification, eutrophication and ground-level ozone) on terrestrial habitats in the UK: A Scoping Study. Final Contract Report to Defra, JNCC, Environment Agency, Environment and Heritage Service (Northern Ireland), English Nature*. (Ref. CPEA 20).

Morecroft, M.D., Bealey, C.E., Howells, O., Rennie, S.C. and Woiwod, I. (2002). Effects of drought on contrasting insect and plant species in the UK in the mid-1990s. *Global Ecology and Biogeography* 11: 7 -22.

Morecroft, M.D., Sellers, E.K. and Lee, J.A. (1994). An experimental investigation into the effects of atmospheric nitrogen deposition on two semi-natural grasslands. *Journal of Ecology* 82: 475 - 483.

NEGTAP (2001). *National Expert Group on Transboundary Air Pollution: Acidification, Eutrophication and Ground Level Ozone in the UK*. NEGTAP.

Parmesan, C., Ryrholm, N., Stefanescu, C., Hill, J.K., Thomas, C.D., Descimon, H., Huntley, B., Kaila, L., Kullberg, J., Tammaru, T., Tennent, W.J., Thomas, J.A., and Warren, M. (1999). Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature* 399(6736): 579-583.

Pollard E. and Yates T.J. (1993). *Monitoring butterflies for ecology and conservation*. Chapman and Hall, London.

Raven, M.J., Noble, D.G. and Baillie, S.R. (2005). *The Breeding Bird Survey 2004. BTO Research Report No 403*. BTO, Thetford.

Riley, J., Kirby, J., Linsley, M. and Gardiner, G. (2003). *Review of UK and Scottish surveillance and monitoring schemes for the detection of climate-induced changes in biodiversity. Report to Scottish Executive and Defra*. Just Ecology.

Rodwell J.S. (ed.) (1991). *British Plant Communities Volume 1*. Cambridge University Press, Cambridge.

Shore, R.F., Malcolm, H.M., Wienburg, C.L., Walker, L.A., Turk, A. and Horne, J.A. (2005). *Wildlife and Pollution: 2001-02. JNCC Report No. 352*. JNCC, Peterborough.

Sier, A. (2005). *Proposal for long-term ecosystem monitoring to detect impacts of climate change on biodiversity at protected sites: the ECN Biodiversity Network. A paper to Defra, EN, SNH, CCW, DoE(NI) and NTS*. UK Environmental Change Network.

Sier, A. (2005). *Climate change impacts on biodiversity: Developing a long-term monitoring network. A workshop to review user requirements and develop a specification and implementation plan.* UK Environmental Change Network.

Sutton, M.A., Pitcairn, C.E.R. and Whitfield, C.P. (eds.) (2004). *Bioindicator and biomonitoring methods for assessing the effects of atmospheric nitrogen on statutory nature conservation sites*. JNCC Report No. 356. JNCC, Peterborough. 230 pp.

Sykes, J.M. and Lane, A.M.J. (eds.) (1996). *The United Kingdom Environmental Change Network: protocols for standard measurements at terrestrial site*. Stationery Office, London.

Thomas J.A. (2005). Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. *Philosophical Transactions of the Royal Society B - Biological Sciences* 360: 339-357.

Woiwod, I.P. (1997). Detecting the effects of climate change on Lepidoptera. *Journal of Insect Conservation* 1: 149-158.

Appendix 1 - Members of project team and expert advisory group

Project Team

	Expertise
Dr. Mike Morecroft (CEH)	Ecological Impacts of climate change and air pollution, Long-term monitoring, plant ecology, project management.
Dr. Andy Sier (CEH)	Science communication, project management.
Dr. Terry Parr (CEH)	Long-term monitoring, science programme management (e.g., ALTER-Net, ECN), ecological impacts of climate change.
Ms. Sue Rennie (CEH)	Environmental informatics, database development.
Ms. Jane Hall (CEH)	Geographical Information systems, Air pollution and its ecological impacts.
Mr. Andrew Wilson (CEH)	Earth observation.
Mr. Ian Leith (CEH)	Air pollution impacts, plant ecology.
Mr. Angus Garbutt (CEH)	Coastal ecologist.
Prof. David Elston (BioSS)	Statistician (Director, BioSS).
Mr. Ian Nevison (BioSS)	Statistician.

Expert Advisory Group

	Expertise
Prof. Mike Ashmore (York University)	Air pollution impacts (member NEGTAP), plant ecology.
Dr. Mark Broadmeadow (Forest Research)	Climate change & air pollution impacts; Forest monitoring (manager Level 2 programme).
Dr. Pam Berry (Oxford University)	Climate change impacts. Modelling studies, especially MONARCH.
Dr. Neil Cape (CEH)	Air pollution monitoring and impacts; atmospheric physics and chemistry.
Dr. Humphrey Crick (BTO)	Avian ecology and monitoring, climate change impacts.
Dr. Peter Dennis (Macaulay Institute)	Insect ecology and monitoring.
Dr. Bridget Emmett (CEH)	Climate–nitrogen interactions; soil science; leader of Defra funded 'Terrestrial Umbrella'.
Prof. Keith Goulding (Rothamsted Research)	Soil science, air pollution impacts, Chair ECN Science and Technical Advisory Group.
Prof. Rob Marrs (University of Liverpool)	Vegetation and soil monitoring; conservation management.
Dr. David Roy (CEH)	Manager of Butterfly Monitoring Scheme.
Dr. Andy Scott (CEH)	Statistics (ECN & Countryside Survey statistician).
Dr. Jerry Tallowin (IGER)	Vegetation monitoring, land management issues.
Dr. Helaina Black (CEH)	Soil biology and monitoring.

Appendix 2 - Supporting documentation

The following papers were produced during the course of this design project and are available on request from Mike Morecroft (mdm@ceh.ac.uk) or Andrew Sier (arjs@ceh.ac.uk).

- Papers circulated in advance of workshop on 15 November 2005;
- Scoping study on including coastal sites into the proposed network. A. Garbutt);
- Decision matrix summarising advantages and disadvantages of all potential measurements considered;
- Technical report on statistical analyses;
- Results of ECN Site Manager questionnaire survey;
- Results of project participant questionnaire survey;
- Details of the criteria used for site selection;
- Communication Plan.

Appendix 3 - Summary of results of Statistical Power Analysis

D.A. Elston & I.M. Nevison (20th April 2006 Version 2)

Power calculations have been carried out based on three datasets: one for butterflies, one for birds and one for vegetation. Annual butterfly species indices for each site in the butterfly monitoring scheme (BMS) between 1976 and 2004 were used. For birds a stratified sample of BTO Breeding Bird Survey data consisting of estimated annual numbers of breeding pairs on each site between 1994 and 2004 were used. For vegetation, vegetation survey data from seven ECN sites consisting of annual records of the vegetation composition in between nine and eleven fixed plots per site from 1997 to 2000 were used.

Statistical powers (here the probability that a difference in mean trend between two equally sized groups of sites would be detected as statistically significantly different in a one-sided t-test at the 5% level) have been estimated assuming data collection starts in year 0 and continues for a further 12, 24 or 48 years (thereby allowing sampling every 1, 3 or 6 years). For butterflies and birds, year-on-year changes of 0.5% to 10% have been allowed for. For the vegetation indices, we consider changes in mean values ranging from 0.05 to 0.25 for Ellenberg W, L, R and N and from 0.05 to 0.45 for Grime C over the observation interval to ensure the boundaries on index values are respected.

In the technical report (available on request), separate power tables are presented for different classifications of butterflies (total butterflies, grassland species, woodland species, Meadow Brown, Speckled Wood, Garden/hedgerow species and species susceptible to changes in the summer temperature). Similarly separate power tables have been presented for different classifications of birds (total birds, non-passerine species, passerine species, migrant insectivores, resident insectivores, raptor and owl species, seed-eating passerines and waterfowl). Vegetation is presented in terms of numerical indices (Ellenberg W, L, R and N and Grime C).

This Appendix summarises the power tables in the technical report. Here, we present the chance (as a percentage) of observing a statistically significant difference in mean trend between two equally sized groups of 15, 30 and 50 sites per group when data collection is undertaken annually after averaging over all variables assessed for butterflies, for birds and for vegetation using only the Ellenberg scores (Tables 1-3). Similarly, Tables 4-6 contain averages across tables within taxa for the chance (as a percentage) of observing a statistically significant trend within an individual site when data collection occurs annually, every three years or every six years.

The tables were derived after fitting first order auto-regressive models to the available data on the variable of interest, allowing for correlations between years within sites. For the bird and butterfly data site effects were also included. For the vegetation data correlation between years within plots was also allowed for but it was not possible to fit plot and site main effects as well due to the limited number of years in the data set. The estimated parameters in the model for random variation were then used to estimate the variance of the difference in mean trends for a given number of sites per group and a given time period for monitoring. Powers were then derived using the hypothesised true mean difference in trends and the variance of the estimated difference assuming assessment by a one-sided t-test at the 5% significance level.

Within Tables 1 and 2, it is possible to see the increases in mean powers for detecting differences in trends that are associated with increasing the total number of sites, increasing the time interval of the monitoring, and increasing the hypothesised true difference in trends. For the butterflies, high (83%) mean power is calculated for a 4% difference in annual trends after 24 years with 100 sites, but the corresponding mean power with 30 sites is only 51%. For the birds, high (86%) mean power is calculated for a 4% difference in annual trends after 12 years with 100 sites, but the corresponding mean power with 30 sites is only 52%.

For vegetation (Table 3), the power calculations decrease with length of monitoring because they are based on hypothesised differences in change in indices over the time interval, hence the differences in rates of change decrease as the monitoring interval increases. The mean power associated with a difference of index change of 0.1 over 12 years was calculated as 84% with 100 sites, whilst the corresponding figure for 30 sites is 45%. Similar powers over a 48-year interval were calculated as being associated with a difference of index change of 0.2.

The mean powers for detecting trend within a given monitoring site were generally quite low even with annual visits (Tables 4-6). Indeed, the only mean powers calculated to be above 70% were for 10% annual changes in butterflies after 48 years and birds after 24 years. The reasons for these low powers are twofold. Firstly, the variance of each trend estimate contains a contribution from the year-to-year variation that is absent from any variance of an estimated difference in trends. Secondly, the information on trend within a particular site is adversely affected by the correlation between years within sites, which was particularly high for the butterfly data.

Table 1: Average powers for detecting differences in trends in butterflies from data collected annually, estimated using the auto-regressive model. The differences in trends (Annual % change) are assumed to be between two equally sized groups formed from the stated total number of sites.

Annual % change	Time interval (years)	Fractional change over interval	Autocorrelated errors model with total number of sites		
			30	60	100
0.5	12	1.06	6	7	7
1	12	1.13	7	9	10
2	12	1.27	11	14	19
4	12	1.60	20	31	43
10	12	3.14	58	79	90
0.5	24	1.13	8	9	11
1	24	1.27	11	16	21
2	24	1.61	22	34	47
4	24	2.56	51	70	83
10	24	9.85	91	97	99
0.5	48	1.27	13	19	26
1	48	1.61	28	43	56
2	48	2.59	59	76	85
4	48	6.57	87	94	97
10	48	97.02	99	99	99

Table 2: Average powers for detecting differences in trends in birds from data collected annually, estimated using the auto-regressive model. The differences in trends (Annual % change) are assumed to be between two equally sized groups formed from the stated total number of sites.

Annual % change	Time interval (years)	Fractional change over interval	Autocorrelated errors model with total number of sites		
			30	60	100
0.5	12	1.06	8	9	11
1	12	1.13	11	16	20
2	12	1.27	22	34	48
4	12	1.60	52	74	86
10	12	3.14	94	98	99
0.5	24	1.13	10	13	18
1	24	1.27	19	29	40
2	24	1.61	45	67	82
4	24	2.56	87	97	99
10	24	9.85	99	99	99
0.5	48	1.27	18	27	37
1	48	1.61	41	63	79
2	48	2.59	84	96	99
4	48	6.57	99	99	99
10	48	97.02	99	99	99

Table 3: Average powers for detecting differences in trends in vegetation from data collected annually, estimated using the auto-regressive model. The differences in trends (Change over interval) are assumed to be between two equally sized groups formed from the stated total number of sites.

Time interval (years)	Change over interval	Autocorrelated errors model with total number of sites		
		30	60	100
12	0.05	19	30	41
12	0.10	45	68	84
12	0.15	72	91	97
12	0.20	88	97	99
12	0.25	95	99	99
24	0.05	14	21	28
24	0.10	31	49	66
24	0.15	52	75	88
24	0.20	70	90	96
24	0.25	83	96	99
48	0.05	11	15	20
48	0.10	22	34	47
48	0.15	36	56	72
48	0.20	51	74	87
48	0.25	65	86	95

Table 4: Average powers for detecting trends in butterflies at a particular site from data collected annually, every three years or every six years estimated using the auto-regressive model.

Annual % change	Time interval (years)	Fractional change over interval	Autocorrelated errors model with no. years between visits		
			1	3	6
0.5	12	1.06	5	5	5
1	12	1.13	6	6	5
2	12	1.27	7	6	6
4	12	1.60	9	8	7
10	12	3.14	17	13	10
0.5	24	1.13	6	6	6
1	24	1.27	7	7	6
2	24	1.61	9	8	8
4	24	2.56	16	13	11
10	24	9.85	44	36	27
0.5	48	1.27	7	7	7
1	48	1.61	10	9	9
2	48	2.59	19	17	14
4	48	6.57	44	37	30
10	48	97.02	84	80	74

Table 5: Average powers for detecting trends in birds at a particular site from data collected annually, every three years or every six years estimated using the auto-regressive model.

Annual % change	Time interval (years)	Fractional change over interval	Autocorrelated errors model with no. years between visits		
			1	3	6
0.5	12	1.06	6	6	5
1	12	1.13	7	6	6
2	12	1.27	9	8	7
4	12	1.60	15	12	10
10	12	3.14	44	31	18
0.5	24	1.13	7	6	6
1	24	1.27	9	8	8
2	24	1.61	14	13	11
4	24	2.56	30	25	21
10	24	9.85	82	73	60
0.5	48	1.27	8	8	8
1	48	1.61	13	12	12
2	48	2.59	28	25	23
4	48	6.57	66	61	54
10	48	97.02	99	99	97

Table 6: Average powers for detecting trends in vegetation at a particular site from data collected annually, every three years or every six years estimated using the auto-regressive model.

Time interval (years)	Change over interval	Autocorrelated errors model with no. years between visits		
		1	3	6
12	0.05	9	8	7
12	0.10	14	12	9
12	0.15	20	16	12
12	0.20	29	22	15
12	0.25	38	29	18
24	0.05	8	8	7
24	0.10	11	11	10
24	0.15	16	14	13
24	0.20	21	19	17
24	0.25	27	25	21
48	0.05	7	7	7
48	0.10	9	9	9
48	0.15	12	12	11
48	0.20	16	15	14
48	0.25	20	19	18