Nitrogen Impacts and Vegetation Surveillance workshop

JNCC, Peterborough
15th to 16th April 2009

This PDF contains two documents:

1. Background document
2. Minutes of workshop

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Background Document

1. Introduction

Nitrogen deposition remains a threat to sensitive semi-natural habitats in the UK (NEGTAP 2001; Hall *et al*., 2006a). Large areas of the country exceed the critical loads for nutrient nitrogen and critical levels for ammonia, and are predicted to continue to do so in 2020 despite reductions in emissions of reactive nitrogen gases (Hall *et al*., 2006b).

Despite substantial research evidence, there remain many questions concerning the influence of nitrogen deposition on biodiversity, and further evidence (or further analysis of existing evidence) of impacts is required for policy advocacy and setting objectives.

Recognising, and building on, the considerable research and review effort on the subject of nitrogen deposition impacts on biodiversity, this workshop focuses on agreeing key datasets and analyses required to provide a collation of surveillance data which provides evidence of these impacts on biodiversity in the UK. It follows a recommendation from experts at a vegetation sampling workshop held by JNCC in 2008. When discussing analysis of surveillance data, consideration should be given to comparison of biodiversity impacts with critical load exceedance and deposition rates. Such an approach could potentially lend support to the application of critical loads and add weight to their use in policy development. In addition, the workshop will consider dynamic modelling of nitrogen impacts on vegetation and will discuss defining measures of biodiversity loss, or decline in condition, to which to apply the models.

2. Context – UK Surveillance Strategy

Surveillance is of paramount importance in assessing the state of biodiversity and in identifying the impacts (and potential future impacts) of environmental pressures, thereby guiding conservation action and policy. JNCC has recently published a UK Terrestrial Biodiversity Surveillance Strategy[1] to help ensure that surveillance is undertaken in a strategic manner, integrating needs for evidence and making best use of existing surveillance data. This workshop is set in the context of implementing the Surveillance Strategy, in particular addressing a specific recommendation made in the Surveillance Framework document[2]: ‘Collate evidence at different scales, including both research and wider countryside sampling to identify aspects where evidence [of the impacts of pollution] is insufficient’.

The Surveillance Strategy aims to ensure that sufficient surveillance is in place to meet three objectives: measuring status and trends of a framework of species and habitats, detecting the impacts of pressures affecting biodiversity, and meeting reporting requirements, for example Habitats Directive reporting. As a part of strategy development, JNCC has collated

[1] http://www.jncc.gov.uk/page-4409
[2] http://www.jncc.gov.uk/page-4421

information on approximately 100 biodiversity surveillance schemes, and considered how they contribute to meeting the strategy objectives. The Surveillance Framework document identifies specific surveillance requirements, analyses the current surveillance in place to meet these requirements, whether there are gaps and/or overlaps in surveillance activity, and makes recommendations. There is an explicit analysis of the biodiversity surveillance requirement for air pollution, identifying key questions and issues which need to be answered and considered in relation to this pressure.

A key principle of the strategy is that sampling should be made as efficient as possible; one dataset should be used to answer many questions. Disparate datasets should be drawn together and if possible used to provide evidence in a wider context than the original investigation for which the data were collected. Therefore, the workshop is proposing collating datasets that show nitrogen impacts on vegetation. Once the collated datasets have been analysed it will be easier to see where further evidence is required and where existing surveillance schemes need to be modified or new surveys commissioned.

An important issue is the need for evidence of change over time in the impacts of nitrogen deposition on biodiversity, both on sites considered to be of high biodiversity value and in the wider countryside. In particular there is a need to support the predictions of air pollution impact produced by critical load/level exceedance mapping that is used extensively in policy development and reporting. The workshop should begin to address these issues.

3. Aims of the Workshop

- To bring together experts to identify relevant datasets and recommend an approach to collation and analysis of the results, in order to provide evidence of nitrogen impacts on biodiversity objectives.
- To summarise what relevant surveillance datasets are telling us so far, identify inconsistencies in results, and consider whether they are consistent with risk assessment approaches such as critical loads.
- To begin to highlight gaps where surveillance evidence is insufficient.
- To discuss how dynamic modelling can be developed to make predictions in relation to biodiversity objectives and targets, by recommending targets/measures of biodiversity which can be used as a ‘metric’ in dynamic modelling of nitrogen impacts on biodiversity.

4. Why is a new collation needed and how could it be used?

A range of large scale surveys have provided support for the role of nitrogen affecting biodiversity. A number of studies in the UK and Europe have linked increasing nitrogen deposition, or nitrogen critical load exceedance, to a reduction in species richness (Stevens *et al*., 2004; Bobbink, 2008 and Van Hinsberg *et al.*, 2008) and an increase in Ellenberg fertility score (Haines-Young *et al*., 2000; Preston *et al*., 2002). However, despite the considerable research effort on the subject, there remain questions concerning the impacts on biodiversity objectives and ecosystem services, not least differentiating the sources of nitrogen and explaining the sometimes inconsistent results from surveys (e.g. the trends of fertility score in CS2000 and CS2007 data). Furthermore, an important issue to inform conservation policy and objectives for recovery is the need to understand and provide evidence of temporal change.

There have been a considerable number of collations of impacts of nitrogen deposition on vegetation and other biodiversity components; indeed the setting of empirical critical loads for nitrogen deposition was based on such a collation. However, there has tended to be a focus on either research-scale studies in which there is high confidence in the attribution of the impact to deposition, or a focus on indicators with a view to assessing impacts to sites, habitats or species which are considered to be of 'high biodiversity value'. **This means that we currently lack a collation that attempts to integrate the research studies with the broad-scale surveillance of biodiversity**, and hence we are missing valuable signals, which have a lower confidence of attribution, but which are capable of showing changes occurring in the wider countryside. Furthermore, the focus on high biodiversity value means that we lack a full picture of the impact of air pollution mediated through vegetation change on the wider countryside. This includes effects on ecosystem services, such as the impacts of vegetation change on public enjoyment of the countryside.

Much of air pollution policy is focussed on setting appropriate emissions ceilings and the consideration of critical load exceedance, and hence is focussed on measurements of the pressure and state (in terms of air quality) (within a DPSIR[3] framework). To support policy, evidence from surveillance needs to be used to 'add weight' to the critical loads exceedance maps (i.e. provide a stronger link between biodiversity changes and critical load exceedance). In addition, policy advocacy requires that this pressure is linked to biodiversity state and impact, and this can be considered both broadly in the wider countryside and narrowly on sites, habitats and species for which other biodiversity targets have been set. Whilst there remain policy/legislative obligations, and thus evidence needs, for the latter (i.e. Habitats Directive Conservation Status, SSSI condition), convincing evidence of broad impacts, particularly if linked with changes to the provision of ecosystem services, is increasingly required. The proposed collation of evidence would link well to other projects such as BICCO-Net[4], which will collate data on climate change impacts on species distributions, populations and communities on a broad scale.

The workshop will seek to agree:

- the contents and scope of the collation
- the datasets to collate
- the analyses required (these could include analyses of large and complex datasets)
- the form of the conclusions
- a work plan

5. Defining a metric of biodiversity loss for application in dynamic modelling

The concept of critical loads and exceedance mapping is now widely used in air pollution policy development, and the more sophisticated concept of dynamic modelling is being developed. Empirical critical loads are a 'steady-state' tool, meaning they do not change over time. They do not incorporate any consideration of temporal aspects, in terms of when impacts will have occurred and recovery. Dynamic models, on the other hand, can help answer questions about setting target loads for recovery by set dates.

Dynamic models for predicting effects of nitrogen deposition on plants are being developed in the UK, principally by CEH, funded by Defra research programmes. The approach uses

[3] Drivers; Pressures, State, Impact, Responses
[4] Biodiversity Impacts of Climate Change Observation Network

biogeochemical models to predict changes in soil chemistry, such as N content, C/N ratio and pH, in response to deposition inputs. These models are coupled to models of environmental suitability for individual plant species. The approach used in the UK is to use regression models that predict plant species occurrence from environmental factors, either directly, e.g. from soil measurements, or via mean 'Ellenberg' score of the species present. However, predictions of occurrence of individual species are not easily related to habitat quality. Terrestrial habitats are typically defined by the occurrence of a set of plant species, which may be grouped as dominants, associates and rare species. Some of these will be considered as positive and some as negative indicators of habitat quality. The modellers need to translate forecasts of changes in environmental suitability for individual plant species into a measure of habitat quality.

As dynamic modelling develops it will likely play a greater role in air pollution policy development (Posch *et al.*, 2008). It is therefore important for the biodiversity surveillance community to engage with the modellers at CEH in order to help define some kind of indicator or metric (perhaps an amalgamation of a number of measures) of biodiversity loss i.e. what measure should they use to represent a loss of biodiversity (should they focus on individual species, assemblages, or habitats or a combination of these etc.?)

This approach was discussed by CEH with members of JNCC Air Pollution Lead Co-ordination Network in late 2007 and the researchers have since explored an approach providing a single measure of habitat quality derived from Common Standards Monitoring (CSM) guidance[5].

At the workshop, an introduction to the UK approach to dynamic modelling for predicting nitrogen impacts on vegetation will be given. Examples of the approach using a metric derived from CSM will be presented. This will then lead to a discussion on different approaches which could be used to define a metric.

The workshop will seek to:

- introduce dynamic modelling of nitrogen impacts on vegetation
- introduce the reasons for and concepts of defining a single metric
- facilitate the discussion of appropriate biodiversity measures/targets
- agree a way forward – recommend further work and consultation

6. Outputs from the Workshop

The workshop outputs will be written up and circulated to participants for further comment. The work plan for the data collation and analysis will be agreed, and ultimately, possibly following a research contract, a report will be published. The report will allow identification of where further surveillance is required to provide evidence to meet policy needs. Options for defining biodiversity targets for dynamic modelling will be proposed and recommendations put forward for further development work and/or consultation.

[5] Further information is available in a workshop paper: Rowe *et al.* (2008), Forecasting Air Pollution Impacts on Biodiversity and Habitat Quality: A British Study. See pages 62 – 68 on the PDF linked to below.
http://www.rivm.nl/bibliotheek/digitaaldepot/PBL_CCE_Berne2008_sverdrup_etal.pdf

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Present at the workshop: Isabel Alonso (Natural England), Chris Cheffings (JNCC), Iain Diack (Natural England), Chris Ellis (RBGE), Bridget Emmett (CEH), Clive Hurford (CCW), Keith Kirby (Natural England), Zoe Masters (Natural England), Vicky Morgan (JNCC), Chris Preston (CEH), Anna Robinson (JNCC), Simon Smart (CEH), Carly Stevens (Open University), Ian Strachan (SNH), Kevin Walker (BSBI), Clare Whitfield (JNCC), Tim Wilkins (Plantlife), Marcus Yeo (JNCC) (part).

Summary of workshop

During the workshop an overview was given of the main vegetation surveillance datasets in the UK and what they are telling us about the impact of nitrogen on vegetation. The need for clear evidence to support advocacy and guidance of air pollution policy was discussed, and possible future analyses of these surveillance datasets were identified as a means of providing this evidence. The workshop also included a discussion of conservation objectives, both to guide design of data collection and analysis, and for use in dynamic modelling of nitrogen impacts. It was concluded that we should analyse the vegetation surveillance datasets against nitrogen deposition data (as has been carried out for Countryside Survey data) to identify whether they show similar spatial and temporal correlations. A synthesis of information from these new analyses should be made for use in air pollution policy advocacy. The analyses should produce a range of possible metrics of nitrogen impacts, which can be tested with habitat specialists, and then used to inform future monitoring and modelling work.

Evidence from vegetation surveillance schemes

Presentations were given on vegetation surveillance datasets. Speakers were asked to focus on the spatial and temporal scales of the survey, whether it is possible to extract a nitrogen signal from the survey, the confidence in attributing the signal to nitrogen deposition, further analyses that may be helpful, and how the results compare to those of other surveys. There was also an overview of research scale evidence on the effects of nitrogen deposition on vegetation.

The surveillance schemes presented were fairly consistent in showing a eutrophication signal over time. The Plant Atlas showed that there has been a shift in the countryside from species with low Ellenberg N to species with high Ellenberg N since the 1950s. The BSBI Local Change survey showed a shift to more eutrophic communities between 1988 and 2004 if species analyses were grouped by habitat. Plantlife's Common Plants Survey showed declines in some of the same species that research-scale experiments in acid and calcareous grasslands measured (*e.g. Campanula rotundiflora*). The eutrophication signal was also seen in Countryside Survey, although the shift to more eutrophic communities stabilised in the last (2007) survey. Countryside Survey showed more significant results in correlations between nitrogen deposition and average Ellenberg N at a spatial scale than at a temporal scale, suggesting that responses to cumulative nitrogen deposition had already occurred by 1978 (the first Countryside Survey).

Concerning lichens and bryophytes, there have been severe historic declines in epiphytic species due to high air concentrations of SO_2 and NO_X, but they have recently been showing recovery (albeit, many of the recolonising lichens are nitrophiles). Emissions of SO_2 and

NO_X have reduced substantially since their peak in 1970s and early 1990s respectively, whilst ammonia has shown a small decline in emissions in the last decade. Recovery has largely been in response to decreasing SO_2 concentrations and reductions in acid deposition. However, the continuing role of high ammonia concentrations and nitrogen deposition, which have shown little decrease, remains a major concern and is influencing the nature of the recovery response.

Major nitrogen eutrophication impacts (changes in species composition) are likely to have already happened in areas of high deposition but large changes in species composition are still being seen in areas that have experienced low levels of nitrogen deposition in the past, *e.g.* large parts of Scotland. Although surveillance has detected recovery in relation to S deposition (*e.g.* the return of lichens and bryophytes, and reduced acidity levels), we are not expecting to see recovery from the effects of nitrogen deposition where nitrogen input remains greater than nitrogen outputs. Although, in many cases the response to high nitrogen deposition appears to have slowed down (as changes have already occurred), evidence from research and the experience of other countries, for example the Netherlands, suggests that the continued gradual build up of nitrogen will eventually lead to conditions where the soil will become very acidic leading to further serious declines in species.

Brief summaries of the different datasets and their results are given in Appendix 1, with links to further information.

What are the advocacy needs?

Participants at the workshop were asked to consider the policy advocacy needs in relation to nitrogen deposition impacts. The discussion is reported here, but this is supplemented with further information for contextual purposes.

JNCC and the country conservation agencies require evidence of air pollution effects (including recovery) in order to inform evidence-based advice and policy advocacy. Policy advocacy and advice is targeted at Government, the pollution regulators and planning authorities (local and regional), as well as at the European level. The need for advocacy (and raising awareness) is also relevant internally, within the agencies, to support the case for nitrogen deposition/air pollution being a significant issue for conservation (and subsequently for consideration of implications for management, assessment of effects in relation to setting conservation objectives and meeting legislative/policy commitments, and for policy and casework advice). It was also suggested that there was a need to raise awareness of the issue amongst the general public and natural history groups, so they have acceptance of, and support for, air pollution policy changes.

This section describes some of the policy areas that JNCC is trying to influence. Much of the legislation and policy implemented by the UK Government is derived from European obligations, as set out under the Thematic Strategy on Air Pollution. Proposals for the revision of the National Emissions Ceilings Directive are due to be published sometime this year. It sets emissions limits, for each Member State, for pollutants including SO_2, NO_X and NH_3. The 'recast' of the IPPC (Integrated Pollution Prevention and Control) directive which addresses emissions from industrial (including intensive agriculture) installations is also relevant. JNCC's advocacy role seeks to influence the UK Government's position on these European policies by providing evidence of the effects of air pollution on conservation 'commitments' and the influence of policy options on this. Since policy is generally going in the 'right direction', *i.e.* driving down emissions, our role is to challenge the level of ambition where ecosystem protection is not being fully met and to advocate that measures are targeted appropriately to deliver conservation policy objectives. Furthermore, since human health is currently the primary focus, it is important that the co-benefits are realised and the potential conflicts (*i.e.* pollutant priorities) do not compromise requirements for ecosystem protection.

JNCC also provides advice on the UK's domestic policy, such as the UK Air Quality Strategy. Since 2001, JNCC has consistently advocated the extension of the strategy to incorporate a more holistic consideration of impacts on ecosystems and has identified anomalies in the strategy regarding protection of sites in 'exclusion zones' (5km from industrial point sources, major roads or built up areas and 20km from large urban agglomerations) where objectives for the protection of vegetation do not apply. Similarly, JNCC and the country agencies have advocated that a strategy is required to address ammonia emissions and impacts, incorporating an integrated policy on nitrogen emissions, since there are currently no regulatory mechanisms (as opposed to target ceilings) to address the majority of ammonia emissions. A sound evidence base is required to support this policy advocacy.

The country conservation agencies are statutory consultees under Pollution Prevention and Control (Scotland) Regulations and Environmental Permitting Regulations and provide advice to the pollution regulators regarding the impacts to protected sites from emissions to air from industrial and agricultural point sources. The risk assessment approach for assessing impacts from regulated point sources utilises critical loads. However, increasingly the regulators are requiring evidence of damage on sites before they will take action over and above application of Best Available Technology (BAT). In addition, to justify measures above and beyond current commitments and to advocate more targeted measures (*i.e.* geospatially or sector specific), evidence is required that specifically relates effects of air pollution to impacts on the UK's ability to meet legislative and policy obligations *i.e.* favourable conservation status under the Habitats Directive, SSSI condition (and related PSA targets in each country), BAP, and increasingly on ecosystem services.

Current approaches and their limitations

Critical loads

Much of the current assessment of air pollution impacts on ecosystems is based on critical loads/level exceedance. These have been developed and mapped for broad habitats across the UK and 'feature-relevant' critical loads have been applied to European sites and A/SSSIs. Broad habitat critical loads exceedence is a UK 2010 biodiversity indicator and a headline indicator for sustainable development. Critical loads exceedance is used by Government (and the European Commission) for policy analysis and optimisation. The air pollution assessment carried out for the UK's assessment of conservation status of Annex I habitats under Article 17 of the Habitats Directive, was primarily based on critical load exceedance, since the assessment includes a consideration of future prospects/habitat viability. Critical loads exceedance maps show that a substantial area of semi-natural ecosystems and protected sites exceed critical loads for nutrient nitrogen and acidity, and backing this up, UK research experiments and broad scale surveys provide convincing evidence of the effects of nitrogen deposition. Indeed, the presentations at the workshop reinforced how much nitrogen research and assessment is available in the UK.

Although critical loads can be used to identify sites at risk from nitrogen deposition impacts, they do not tell us which sites are impacted currently, since they do not include a temporal aspect. Exceedance of a critical load tells us whether damage will occur, not when. When considering 'impacts' on sites or habitat more generally, there are four scenarios which could exist:

1) No damage.
2) Unknown damage - damage exists but we do not know it or measure it, *i.e.* site appears fine, but missing the species that it may have had in the past when in pristine condition.
3) Potential damage - the site is accumulating nitrogen in the soil - currently not enough to be a problem, but will be in future if continued inputs of nitrogen above critical loads.
4) Realised damage - sites with explicit nitrogen deposition damage, *e.g.* acidification, loss of sensitive species.

Surveys, research, and/or dynamic modelling of nitrogen impacts are required to show us the timescale of when sites or habitats will become damaged. (However, it would be wise not to wait until all sites reach 'realised damage' before critical load exceedance is acted on - once it gets to realised damage it will be very difficult to remove the problem.)

Evidence from protected sites

In support of the UK's ability to meet legislative and policy obligations, the conservation agencies undertake monitoring of the condition of protected sites based on Common Standards Monitoring (CSM) Guidance. A current policy focus, in England, is the PSA target for SSSI condition (95% of SSSIs, by area, to be in favourable condition by 2010). Similar targets apply in Wales, Scotland and Northern Ireland. In England, the associated 'remedies project' aims to identify and address the adverse factors affecting condition and seeks to implement management or policy action to address them. This currently represents a major policy driver. However, the 2006 JNCC CSM report only identifies 30 records of air pollution being listed as an adverse factor affecting feature condition (UK-wide). This result is anomalous with the evidence from research and broad scale surveys and predictions from critical loads. This is of major concern since it presents a very mixed message to stakeholders and is undermining the current policy advocacy.

It is acknowledged that our reporting of SSSI condition and the adverse factors affecting condition is likely to significantly underplay the importance of air pollution: CSM is not designed to assess these impacts and will fail to detect and attribute the effects of air pollution in a consistent and auditable manner. However, both the assessment of impacts and the attribution of air pollution as a contributory cause of unfavourable condition of terrestrial SSSIs are extremely challenging. Often, air pollution effects will be as a result of complex interactions with other abiotic or biotic stresses, for example climate and grazing.

It should be emphasised that a site being recorded as 'favourable' does not necessarily mean that it is not being impacted by air pollution. One reason why CSM is limited in its ability to detect nitrogen deposition impacts is that it only monitors those features that the site was designated for against conservation objectives. For instance, if a site were designated for a particular mammal, bird or invertebrate, it would not be necessary to monitor vegetation, and therefore it might be impossible to see the effect of nitrogen deposition. Another problem is that an interest feature could be managed to be kept in 'favourable' condition despite being affected by air pollution. For example, nettles and brambles could be weeded out of the site, if these were negative attributes. The fact that the interest feature can be maintained at high management cost does not mean that the problem of nitrogen deposition should not be addressed. It may not be economically viable to manage sites forever, and the wider countryside, which cannot be managed in the same way as protected sites, will be still affected if the cause of the problem is not addressed.

Furthermore, CSM does not include measurements of future pressures and threats which could capture concern at sites exposed to a gradual build up of nitrogen where there could be severe problems in the future. Sites in these situations would still be recorded as favourable before the nitrogen could be seen to be having an effect, but once the effects of nitrogen deposition are seen it may be too late, and extremely hard to remove the nitrogen from the ground and recover the situation. Recognising these difficulties, Natural England has included an 'at risk' supplementary category to indicate critical load exceedance and support policy response.

The participants at the workshop reinforced that CSM cannot be adapted to assess nitrogen impacts (See Stevens *et al.*, 2009[1]). It was suggested that air pollution should be removed from the list of adverse factors affecting condition, because it cannot reliably be identified through CSM and its inclusion is therefore misleading.

Dynamic modelling of nitrogen impacts

Dynamic models differ from critical loads in that they incorporate consideration of temporal aspects and can help answer questions about setting target loads for recovery by set dates. Dynamic models for predicting effects of nitrogen deposition on plants are being developed in the UK, principally by CEH, funded by Defra research programmes. The GBMOVE model, developed by Simon Smart and Andy Scott, predicts habitat suitability for plant species based on soil chemistry characteristics. It is based on regression models of realised niches for 1130 UK plant species. It was based on very large datasets from four surveys: Key Habitats survey, Countryside Survey, Broadleaved woodland survey, and National Vegetation Classification. This model appears to make accurate predictions of vegetation change. For example, putting the Park Grass control plot at Rothamsted into the model successfully predicted the NVC community of the Rothamsted Broadbalk woodland, W8e. Dynamic models can also be used as a tool to predict historic species composition at a site.

One limitation to the use of dynamic models (and indeed conservation action generally) is the lack of clarity concerning conservation objectives. Although models can predict changes in species abundance, we need to know what this means in conservation terms. For example, should we be concerned with a predicted decrease in species X? Parameters we could be concerned with include: key plant species for habitats, 'canary' species, rare species, combinations of species that are linked to a habitat being in good quality (*e.g.* positive habitat indicator (CSM) scores minus negative habitat indicator (CSM) scores), or the suitability of the habitat for other taxa. We may also be concerned with other attributes such as vegetation height, although dynamic models will need further development before they are able to predict such attributes.

During the workshop it was agreed that we need to come up with **indicators of impacts** of nitrogen deposition on biodiversity. These indicators do not have to be a parameter that is of

[1] Stevens, C.J., Caporn, S.J.M., Maskell, L.C., Smart, S.M., Dise, N.B. and Gowing, D.J. 2009. Detecting and attributing air pollution impacts during SSSI condition assessment. *JNCC Report No. 426* (In press).

great conservation importance in itself, but they must indicate a change that is of conservation importance. For example, Ellenberg N, or Specific Leaf Area[2] are parameters that are not of conservation concern in themselves, but which inform us about species composition. It was agreed that habitat specialists need to assess the applicability of several different indicators of impacts (positive or negative indicators) for different habitats, which can be correlated against nitrogen deposition data to test suitability. Once appropriate indicators of impacts have been identified they can feed back into the design and analysis of monitoring schemes, and be used in dynamic modelling.

Linked to the issue of having clear conservation objectives is the question of what level of recovery we are aiming for. In the case of protected sites it should be noted that sites were not necessarily in favourable condition at the time of notification, and in 2007 JNCC advised the Environment Agency that "it is not the purpose of the conservation objectives, and subsequent monitoring, to enhance the special interest, but to ensure the ecosystem structures and functions are in place to maintain its special interest (which implies environmental improvement in some cases)". So our surveillance of protected sites needs to demonstrate the continuing effects on ecosystem viability in relation to notified/designated interest, rather than focus on aspirational targets for recovery to a 'pristine' environment. However, this is clearly an area of discussion and debate within the conservation agencies and is critical to informing casework advice as well as wider policy advice.

What could a new collation of evidence potentially offer?

The UK has a strong evidence base in relation to nitrogen impacts, from research scale and site based monitoring through to broad scale survey. However, limitations and/or ambiguities exist in the current approaches used in air pollution policy advocacy. This workshop identified that there is scope for further analysis of the results of some of the broad scale surveillance schemes in order to provide stronger evidence of the effects of nitrogen deposition on vegetation at all spatial scales. A consistent message shown from a consistent analysis across broad scale surveillance datasets would be very valuable for use in advocacy to demonstrate to policy makers that nitrogen deposition is having an impact across the countryside. Beyond this, a collation needs to marshal the evidence to articulate/demonstrate how it affects key conservation commitments (for example, protected sites), and address some of the questions and anomalies concerning CSM assessments, perhaps through demonstration at exemplar sites.

What should a new collation include?

The collation should include an analysis of the spatial and temporal relationships between nitrogen deposition (available at a $5km^2$ resolution in the UK) and a range of possible response variables including average Ellenberg N for a selection of habitats for each of the surveillance datasets included in Appendix 1. Other factors should be statistically controlled for during the analyses, including S deposition, climate parameters, and grazing (using AgCensus data). Some indicators of impacts may only be available for certain habitats or datasets. Iteration between the data analysis and work with habitat specialists may produce a set of 'indicators' that could be used in future monitoring and dynamic modelling.

[2] Diaz, S. *et al*. 2004, The plant traits that drive ecosystems: evidence from three continents. *Journal of Vegetation Science*. **15:** 295-304.

The habitats included in the analysis should be widespread and with good levels of data, for example, heathlands, acid grasslands, calcareous grasslands, sand dunes and wetlands were proposed. Although we do not have extensive surveillance evidence of air pollution effects for all habitats in the UK, we do have fairly good coverage of the habitats mentioned above. It is not necessary to have good surveillance coverage of all habitats because if action is taken on the basis of a few, then all habitats will benefit.

The results need to be put together into a clear presentation, to present to a range of policy makers and conservation practitioners. The presentation should also simply describe the impacts of the findings for UK key conservation commitments, and clarify the limitations of other approaches, for example CSM. Photographs and information from exemplar sites should be used to illustrate the issues.

Way forward and recommendations

JNCC, in consultation with others, will produce a research specification for the proposed new collation. This will include the following:

1. Full spatial and temporal analysis of surveillance datasets against nitrogen deposition data controlling for other factors.
2. Iteration with habitat specialists to identify appropriate indicators of impacts of nitrogen deposition on vegetation to feed into design of surveillance schemes, analysis of data and dynamic modelling.
3. Collation of results into a presentation, with other relevant information for use in air pollution policy advocacy.
4. Awareness raising with a range of stakeholders including policy makers, conservation practitioners and the general public.

Appendix 1: Summary of surveillance datasets and research scale evidence.

Scheme/ what it records	Spatial scale	Temporal scale	Results	Further information
Countryside Survey Records habitat type, linear and point features, vegetation plots (presence and percentage cover) of different types, and water and soil samples.	Nearly 600 random 1 km squares, stratified according to land class, throughout GB. (285 0.5km x 0.5km survey squares in NI). The same survey squares are recorded in repeat surveys. On average, 30 vegetation sampling plots were completed within each sample square.	The survey has been repeated at roughly 10 yearly intervals since 1978. (2007, 1998, 1990, 1984 and 1978)	A range of response variables (*e.g.* mean Ellenberg N, species richness, Specific Leaf Area) have been analysed against nitrogen deposition (available at a 5 km^2 resolution in the UK, based on 2004-2006 data), whilst accounting for other factors, *e.g.* annual average rainfall, modelled SO_X deposition, intensive land use and grazing (AgCensus). Correlations have been shown to be significant, despite a relatively small amount of variation being explained. More significant results have been found in correlations at a spatial scale than at a temporal scale, suggesting that responses to cumulative nitrogen deposition were already in place by 1978.	http://www.countrysidesurvey.org.uk/
Plant Atlas This involved mapping of all vascular plant species.	Plants mapped at 10 km^2 scale throughout the UK.	First atlas was produced in 1962, and a repeat survey carried out between 1987 – 1999. Ongoing collection of data allows the mapping distributions to be kept updated on BSBI's website.	The dataset shows that species with low Ellenberg N values have declined, whilst those with high Ellenberg N values have increased between the two atlases.	Perring, F.H., and Walters, S.M., 1962, *Atlas of the British Flora*, Thomas Nelson & Sons, London. Preston, C.D., Pearman, D.A., and Dines, T.D., 2002, *New Atlas of the British and Irish Flora*, Oxford University Press, Oxford. http://www.bsbi.org.uk/html/atlas.html
Local Change (BSBI) All species present growing in the wild were recorded.	Scheme involved a sample of 2*2 km squares (tetrads) across GB. 761 tetrads were resurveyed, of which 635 were deemed to be comparable for analysis.	Surveyed in 1987-88, and again in 2003-04.	When species are grouped by habitat, about half show a significant positive relationship between mean species change and Ellenberg N value (*i.e.* shift from species with low Ellenberg N value to high Ellenberg N value). The attribution of changes to nitrogen is clear for some habitats, although it is complicated by interactions with other drivers.	Braithwaite, M.E., Ellis, R.W., and Preston, C.D., 2006, *Change in the British Flora, 1987-2004*, Botanical Society of the British Isles, London.

Scheme/ what it records	Spatial scale	Temporal scale	Results	Further information
Woodland (Bunce) Resurvey This survey covered vascular plants. Flora, soil and tree information was recorded.	103 broadleaved woods throughout Britain. Sixteen 200m^2 plots were used at each site.	The survey took place in 1971, and was repeated in 2001	The resurvey showed no overall shift in species towards more fertile/eutrophic assemblages. Woodland is a relatively hard habitat to show impacts of nitrogen deposition due to being naturally dynamic over decades and sometimes a naturally nutrient rich habitat. There are also interactions with other factors such as grazing and light levels. However, the Woodland resurvey has shown some effects which may be related to nitrogen inputs, *e.g.* increasing soil pH and high levels of intensive land surrounding the wood were associated with increases in Ellenberg N scores, species increasing in cover were more likely to be associated with high nutrient status condition, and some changes in abundance were correlated with increases in modelled nitrogen deposition.	Kirby, K.J., Smart, S.M., Black, H.I.J., Bunce, R.G.H.,Corney,P.M. & Smithers,R.J., 2005, *Long term ecological change in British woodland (1971-2001).* Peterborough: English Nature (Research Report 653).
Common Plants Survey Records presence/absence and estimated percentage cover category of 65 common species of vascular plants.	932 1km^2 sites have been recorded. Participants are assigned a random square near to where they live and are asked to record vegetation within a central 5m*5m plot, and the nearest 20m*1m linear feature. An additional 5 plots of each type can be recorded.	Annual survey that started in 2000. Participants survey the same square each year.	Some species shows significant changes over time. Those increasing include: *Arum maculatum*, *Ranunculus ficaria*, *Clematis vitalba*, and *Urtica dioica*, and those declining include: *Stellaria media*, *Petasites hybridus*, *Vicia cracca*, *Trifolium pratense*, and *Campanula rotundiflora*. The impact of nitrogen has not yet been analysed, but the 65 target species cover a wide range of Ellenberg N values and so have good potential for showing nitrogen impacts.	http://www.plantlife.org.uk/uk/plantlife-get-involved-common-plants-survey.html
Bryophytes	Bryophyte data have a good representation across the UK.	Data have been built up gradually over the last 50 years.	Many bryophyte species have been recovering, probably due to decline of sulphur emissions (*e.g.*, following the Clean Air Act of 1956). Climate change may also be involved, as some species, *e.g.* *Cololejeunea minutissima*, are now found in areas where it had not been previously recorded.	http://data.nbn.org.uk/datasetInfo/taxonDataset.jsp?refID=6&dsKey=GA000144&grpType=1&sgl1Key=NHMSYS0000079984&sgl2Key=NHMSYS0000080019

Scheme/ what it records	Spatial scale	Temporal scale	Results	Further information
Lichens	Lichen data have a good representation across the UK.	Data have been built up gradually over the last 50 years.	Certain lichen species have shown recovery, probably due to the decline of sulphur emissions (*e.g.*, following the Clean Air Act of 1956). However, nitrophobic lichens are not recovering at the same rate.	http://www.thebls.org.uk/content/databases.html
Research scale evidence	There have been 8 research scale surveys across a nitrogen deposition gradient: 2 in acid grassland, 2 in calcarious grassland, 2 in moorland/heath, 1 in sand dunes, and 1 of woodland epiphytes. There have been many nitrogen addition experiments with 10 experiments simulating nitrogen deposition.	Some research experiments are very long term, *e.g.* Rothampsted Broadbalk experiment has been going since 1843, and the Rothamsted Park Grass experiment since 1856.	Key findings from research scale surveys include decreased species richness, and increase in grass:forb with increasing nitrogen deposition. Nitrogen addition experiments show similar results. On heathlands nitrogen deposition causes *Calluna* growth to increase (although late winter injury was increased), and bryophytes and lichens to decrease. In grasslands, increased nitrogen deposition generally led to increased grass cover, and reductions in other species, *e.g.* bryophytes. Nitrogen deposition increased biomass in the dune habitat.	ROTAP report (due out at early 2010, and for consultations in May 2009)