Briefing for Defra: Article 8/Annex V of the proposed revised National Emissions Ceilings Directive: Monitoring of Ecosystem Impacts

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1. Summary

This briefing concerns the requirements for monitoring air pollution impacts on ecosystems as required by Article 8 and specified in Annex V of the proposed revised National Emission Ceilings Directive (NECD). Taking into account current impacts and trends of pollutants, the paper provides a brief overview of information required from monitoring which will be helpful in this policy context, focussing on biodiversity impacts only. It concludes that monitoring impacts (and recovery from) nitrogen deposition, which contributes to eutrophication and acidification of freshwater and terrestrial habitats, is the priority. The paper documents relevant current and recent monitoring schemes, considers the extent to which these meet the requirements set out in Annex V and how policy relevant the outputs are likely to be in the future. It sets out options for monitoring impacts in order to meet the policy objectives.

We conclude that it would be more beneficial and cost effective to ensure that ecosystem impacts monitoring is outcome orientated, rather than prescribing a rigid set of parameters as currently proposed in Annex V.

JNCC recommends the following points:

- **Defra encourage that Annex V be reworded to be less prescriptive and more outcome based.**
- **Defra encourage that Annex V remove the need for monitoring impacts on biodiversity from ozone.**

In the time available for this briefing, it was not possible to undertake a complete review of the extent to which existing monitoring exactly meets the specific requirements of Annex V, or alternatively how it meets more broadly the requirements for policy relevant evidence of impacts of air pollution on ecosystems. We advise Defra that, depending on the outcome of negotiations for Annex V, a more extensive exercise is likely to be necessary to consider the extent to which current monitoring schemes or a combination of them deliver the agreed requirements.

Additional investigations would be needed to:

- Further investigate existing freshwater surveillance mechanisms, e.g. monitoring by the country environment agencies, and the potential to adapt them, in order to assess whether it would be more cost effective to use these, or to utilise the UK Upland Waters Monitoring Network for this purpose, or to use a combination of the two approaches.
- Consider the value of each of the detailed requirements currently specified in Annex V for freshwater and terrestrial ecosystems in order to check for parameter redundancies in providing policy relevant information.

For monitoring air pollution impacts on biodiversity in the UK we should:

- Make use of existing/planned broad-scale vegetation schemes with high sample sizes but less detailed monitoring.
- Ensure there is sufficient soil monitoring, providing a more intermediate response parameter, to show biogeochemical recovery as a consequence of nitrogen deposition (whilst vegetation response may be slower).
- Maintain, or enhance if necessary, air pollution deposition and concentration monitoring in order to support deposition modelling (e.g. UKEAP network, with consideration of how to reduce uncertainties in the modelling and further investigate what will be able to be detected from the Sentinel satellites) in order to support the modelling and mapping of deposition, which are essential for the analysis of broad-scale vegetation datasets.

- Ensure that relevant analyses of the datasets are scheduled for provision of timely information.

2. Introduction

The proposal for the revised NECD[1] seeks to reduce impacts on the natural environment from eutrophication (nitrogen deposition); acidification (sulphur and nitrogen deposition) and ozone, towards the European Union's long-term objective for air policy, "to achieve levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment". In order to assess the effectiveness of the national emission reduction commitments, the proposal sets out that Member States should monitor, where practicable, the effects of such reductions in terrestrial and aquatic ecosystems, in accordance with internationally established guidelines and report these effects. The requirements are set out in Article 8 and Annex V (reproduced in Appendix 1).

This briefing considers the NECD monitoring requirements and the extent to which this is met by current monitoring in the UK. It considers what information from monitoring is required, for each pollutant, to inform the overall goals for the revised NECD and potential monitoring approaches. It considers the extent to which the provisions in Annex V would meet these requirements as well as what would be required if the UK were to meet the current specific proposed monitoring requirements set out in Annex V. We note the wording in Article 8 "Member States should monitor, where practicable.....". Our advice relates to Annex V, and we have not attempted a consideration of what impact the term "where practicable" would have. This wording could be considered to provide the UK with the option to reduce the number of sites monitored to that which is "practicable" and hence less costly; however this appears at odds with the wording of Annex V and it may not provide an effective approach for gaining policy-relevant information. Further, the scope of the briefing document is restricted to considering monitoring of biodiversity impacts as opposed to commercial production (e.g. forestry, agriculture) or health issues. The document concludes by providing recommendations on effective and efficient means of monitoring air pollution impacts on biodiversity in the UK.

Evidence for this briefing was gathered through a literature review (see reference list), and discussion with Rick Batterbee (UCL, concerning the Upland Waters Monitoring Network), Gina Mills (CEH/ICP Vegetation, concerning ozone impact monitoring), Ed Rowe (CEH, concerning soil indicators for nitrogen deposition impacts) and Christine Braban (CEH, concerning the UKEAP). The briefing was subject to internal peer review by Anna Robinson, Clare Whitfield and Chris Cheffings (JNCC), and circulated for comment around the air pollution leads at the statutory nature conservation bodies (or a representative in their absence) (Gordon Wyatt (NE), Keith Finegan (NIEA), Dylan Lloyd (NRW), Alison Lee (SNH)).

3. Background context

3.1. Overview

The main air pollutants affecting biodiversity in the UK which are covered by the proposed NECD, are summarised in table 1. A more detailed account of the impacts is given below the table.

[1] http://ec.europa.eu/environment/air/pollutants/rev_nec_dir.htm

Table 1. Summary of main sources and biodiversity impacts of air pollutants.

Pollutant	Main Source	Biodiversity Impact
Sulphur Dioxide SO_2	Combustion sources (e.g. power stations) and shipping.	Acidification of freshwaters and terrestrial systems – habitats becoming more acidic, with increases in toxic labile aluminium, and associated impacts on acid-sensitive species. Direct effects of gaseous SO_2 now very rare.
Oxides of nitrogen NO_X	Combustion sources, road transport and shipping.	Eutrophication – habitats becoming more nutrient rich – leading to changes in species communities and loss in species richness. Acidification of freshwaters and terrestrial systems. Direct effects of NOx (only in limited areas e.g. close to major roads and in some urban areas).
Ammonia NH_3	Agriculture (particularly livestock production)	Eutrophication – habitats becoming more nutrient rich – leading to changes in species communities and loss in species richness. Acidification of freshwaters and terrestrial systems. Direct effects of NH_3 on vegetation.
Ozone (ground level) O_3	Secondary Pollutant. NOx and VOCs are precursors.	Reduction in growth and yield of sensitive species. Species of semi-natural habitats have shown varying levels of sensitivity, suggesting likely impacts at the community level. However, biodiversity impacts in the field are unknown. There are widespread impacts on arable and horticultural crops in the UK.

The relationship between national pollutant emissions and biodiversity impacts is not straight forward due to factors including transboundary movement of air pollutants, chemical interactions, accumulation of pollutants in the soil and consequent lag times between changes in emission levels and biodiversity effects. We therefore need to be conscious of trajectories of emission and deposition, and of timescales of impacts and recovery, to set the context for what we need to monitor in order to inform and evaluate policy.

Over the last 30 years, sulphur emissions and concentrations in the UK atmosphere have reduced greatly. Emissions of oxides of nitrogen have also declined substantially (manifest as a proportionally greater relative reduction of transboundary exports). There have been smaller declines in ammonia emissions and the level of nitrogen deposition in the UK over the last 20 years has changed little (ROTAP, 2012).

Peak ground level ozone concentrations in the UK have declined by about 30% over the last 20 years due to stricter controls on emissions in the UK and other EU Member States.

However, background levels have been increasing steadily due to increasing ozone precursor emissions throughout the Northern Hemisphere (ROTAP, 2012).

3.2. Sulphur dioxide and acidification

At peak emissions, sulphur dioxide was responsible for widespread damage to vegetation, particularly lichen species. However, concentrations have now reduced to a level that no longer poses a risk, except in possibly a very few localised situations. Recovery is evident from, for example, recolonisation of sensitive lichens over large parts of the country formerly experiencing high SO_2 concentrations. Emissions of SO_2also contribute to acidification together with nitrogen pollutants (NOx and NH_3). The reductions in sulphur and nitrogen emissions have led to some recovery from acidification, although exceedance of critical loads is still widespread (largely due to nitrogen deposition).

Soil acidity has declined widely in response to acid deposition reductions. There is also widespread evidence from ongoing chemical and biological recovery of UK freshwaters. Considerable uncertainty remains with respect to the future behaviour of nitrogen in catchments, and the extent to which further accumulation of nitrogen within soils, and the interactions with climate change, may affect the transport of nitrate to surface waters.

3.3. Nitrogen deposition impacts

Nitrogen deposition has caused widespread changes to species distribution and to the quality of natural and semi-natural habitats in the UK (Emmett *et al*, 2011) and is a threat to the Conservation Status of many habitats listed under the Habitats Directive[2].

There is strong evidence from national surveys that nitrogen deposition has reduced plant species richness or composition in a range of habitats, and has negatively affected plant species distribution (Emmett *et al*, 2011). Many of these impacts are expected to have occurred before the 1980s (Maskell *et al*, 2010; ROTAP, 2012; Emmett *et al*, 2011). However, current nitrogen deposition is associated with further declines in sensitive species (Emmett *et al*, 2011).

Some reductions in faunal diversity have been linked to nitrogen deposition, but knowledge of effects on fauna is still limited (Dise *et al*, 2011).

Nutrient nitrogen critical loads were exceeded in over 65% of the area of semi-natural habitat in the UK in 2010-2012 (data from UK NFC under Defra contract AQ0826, Jane Hall *pers comm.*) and only a small decline in exceedance is likely by 2020 (ROTAP, 2012). Nitrogen accumulates in ecosystems so impacts depend on not only current but past levels of N deposition. This is an important factor when considering the monitoring requirements for showing the effects of nitrogen emission reductions. Reductions in nitrogen deposition can have delayed effects, due to persistence of nitrogen in soil and vegetation and delays to re-colonisation by species. Although reductions in current deposition are likely to rapidly decrease plant exposure to nitrogen, stored nitrogen will result in a sustained release of plant-available nitrogen, so cumulative deposition needs to be taken into account. Recovery of impacts from nitrogen deposition is dependent on the amount of nitrogen accumulated in the system (from previous nitrogen deposition), the amount by which nitrogen deposition declines and the level to which it declines to, and the composition of the ecological community. Recovery is possible within 1-4 years for some sensitive lichens and bryophytes and between 5-20 years for some soil processes, plant growth and some plant species. However, because nitrogen can persist in ecosystems full recovery may take many decades or may not be achievable.

[2] http://jncc.defra.gov.uk/page-6563

Nitrogen deposition is comprised of both oxidised and reduced forms of nitrogen. The gases ammonia and oxides of nitrogen, which contribution to nitrogen deposition, can cause eutrophication, acidification, and also directly affect vegetation. Critical levels for NOx are only likely to be exceeded close to major roads and in some urban areas (although they are not apparent from concentration maps at 5km resolution). There is widespread exceedance of NH_3 critical levels (data from UK NFC under Defra contract AQ0826, Jane Hall *pers comm*.).

Evidence suggests that nitrogen deposition is also affecting productivity in some nitrogen-limited upland lakes (ROTAP, 2012).

3.4. Ozone

Exposure to elevated concentrations of ozone can result in visible leaf injury, reduced growth of sensitive species and reductions in yield, alterations of response to other environmental stresses such as drought stress and enhanced susceptibility to pests and diseases.

Flux based models estimate significant reductions in crop yields as a consequence of current ozone concentrations in the UK. The loss of total national wheat yield in 2000 was approximately equivalent to 7% of production (ROTAP, 2012). Flux-based critical levels for forest trees are widely exceeded, as are AOT40 concentration based critical levels for semi-natural vegetation. There is evidence from experiments that ozone adversely impacts some species of semi-natural habitats. For example, experiments have shown there is a wide range in sensitivity to ozone of grassland species, suggesting that elevated ozone conditions could contribute to changes in species composition. However, it is difficult to identify ozone impacts in the field. Hence, the extent of community level changes in semi-natural habitats in the field from ozone is unknown (ROTAP, 2012).

Visible injury is an indicator that ozone concentrations have caused physiological “damage”, but it is not directly related to plant growth/yield nor ecosystem/habitat level effects. It is also hard to identify for non-experts, so its usefulness as a field indicator of impacts on natural or semi-natural habitats is limited.

Unlike nitrogen and sulphur pollutants, ozone concentrations are not showing a downward trend. Although there has been a reductions in peak concentrations of ozone, mean background concentrations are increasing (ROTAP, 2012). There is also an increase in winter and spring values episodes. Concentrations show substantial year to year variation because of the role of sunlight in ozone production. This means the extent of damage will vary annually, and this may have different implications for annual *vs* perennial species. Climate change is likely to reduce the benefits of controls on ozone precursor emissions. These factors should be considered when formulating ozone monitoring options.

4. What information from monitoring do we need to inform policy

Monitoring of pollutant concentrations and deposition will show the change in this environmental pressure as a consequence of emission reductions. This can be compared with critical loads and levels to show the change in risk to ecosystems. Additionally, monitoring the impacts on ecosystems will be useful to show the effectiveness of the policy in reducing impacts and to provide evidence of recovery. Evidence that demonstrates continuing impacts where deposition levels are high will inform the need for further reduction in emissions.

Data from ecosystem impacts monitoring can also be related to other policy objectives and obligations. For example, many habitats and species that are protected by other EU directives (e.g. the Water Framework Directive (WFD) and the Habitats Directive) have been impacted by nitrogen deposition, and the UK has an obligation to monitor these and report on their conservation status on a regular basis. A secondary benefit would be that the monitoring may help inform our understanding of critical loads and levels and hence their future benefit.

4.1. Freshwaters (acidification and nitrogen impacts).

The substantial reduction in sulphur emissions over recent decades has led to some chemical and biological recovery in sensitive freshwaters. However, recovery has not been full and there is a need to continue to assess recovery and understand the factors limiting it, in order to inform future policy. For example, the delay in recovery may be due to a number of factors, including a legacy of sulphate in catchment soils; continuing high nitrogen deposition loads resulting in many soils being nitrogen saturated and hence delaying the reduction of nitrate in surface waters; and climate change influences, such as sea salt events (from winter storms) which reduce pH and ANC. The current Upland Waters Monitoring Network[3] (UWMN) is capable of attributing the relative influences in order to understand the biological and chemical responses and hence inform emissions policy.

4.2. Terrestrial (acidification and nitrogen impacts)

Nitrogen is the pollutant where further monitoring impacts on biodiversity would be the most helpful in informing policy. Sulphur emissions are declining and soils are showing signs of recovery (ROTAP, 2012), although acidity critical load exceedance continues to be widespread (largely due to nitrogen deposition). Evidence to date suggests that nitrogen deposition is having a large and long term impact, and that reductions in nitrogen deposition will reduce the harm to biodiversity (Defra project AQ0823, draft final report). This suggests that a monitoring scheme should be particularly focussed towards nitrogen.

We also advise that monitoring focuses on responses in vegetation together with biogeochemical response (e.g. in soils) as an indicator of effects on biodiversity more generally. There is a strong evidence base for vegetation; relationships with nitrogen deposition and nitrogen availability are well understood from experimental studies and habitat associations. Whilst other components of biodiversity may be impacted by nitrogen deposition, either directly or via changes in habitat structure and function, the evidence base is less developed.

Monitoring should aim to show the effects of nitrogen deposition on vegetation to detect where impacts are ongoing and whether recovery is commencing in some areas and how this is manifest. Nitrogen deposition has driven changes in plant communities and species distribution via both eutrophication effects and acidification effects and monitoring may help attribute the mechanism of impact.

Recovery in response to a future decrease in nitrogen deposition will vary spatially depending partly on historic nitrogen inputs and where reduction measures are targeted. Rates of biogeochemical recovery in terrestrial ecosystems are likely to be faster than recovery of vascular plant communities, which may be slow. Therefore, any monitoring would usefully include intermediary measures, such as nitrogen availability in soils, as well as vegetation response. Furthermore, lichen and bryophyte communities (particularly epiphytes) may also show signs of recovery before other ecosystem elements.

4.3. Ozone

The evidence of damage to arable and horticultural crops and the economic and food security implications of this mean that any impacts monitoring programme should include these systems. Similarly, ozone reduces tree growth and hence has implications for forestry. In respect of natural and semi-natural habitats, experimental evidence suggests

[3] http://awmn.defra.gov.uk/

there is an impact on plant communities from ozone, but this has not been translated into any understanding of broad-scale effects. In the same way as nitrogen deposition, it would be useful for a monitoring programme to demonstrate the extent of impacts on natural and semi-natural habitats and how this is changing over time. However, measures or indicators of growth and visible injury cannot be related to changes in structure and function of habitats. It may be worth exploring the feasibility of an analysis of broad-scale vegetation data to detect ozone driven changes in species, but, at this stage, this remains a research question not a monitoring consideration.

5. Role of evidence

5.1. Overview

There are several potential approaches to collecting the required evidence, ranging from small scale controlled experiments, to intensive study at a small network of sites, to less intensive survey at a larger number of sites, and making more use of modelled data. All approaches have various strengths and weaknesses. The most appropriate choice is based on a range of factors such as the outcome being tested, the level of certainty required, the cost and ease of survey methods etc.

To date a variety of approaches have been used, with a variety of different levels of certainty in each approach. It is important to consider the level of certainty required, the cost and ease of survey methods, and whether it is possible to make use of surveys that are already being carried out for other purposes. Ultimately a range of different methods may be needed to complement each other and provide more robust evidence.

Note, geographical variation in a pollutant is often used as a proxy for temporal changes in a pollutant, e.g. comparing snapshots of two areas with different levels of nitrogen deposition rather than monitoring a site over time with changing levels of nitrogen deposition. The former approach is easier because it does not require a long term dataset with changes in the pollutant but care is needed to check that other factors are not influencing for the results. Also, some detailed temporal studies are required to improve our understanding of trends of decline and recovery with changing levels of pollution, as using simple geographical comparisons may not take into account cumulative impacts and lag effects.

5.2. Existing sources of evidence from monitoring and surveillance

The main sources of evidence surrounding air pollution impacts and/or vegetation changes are summarised in the table 2.

Table 2: Existing monitoring and evidence sources in the UK. Showing the extent to which these correspond with the requirements of Annex V (in terms of measure and periodicity) and the extent to which these sources have provided policy relevant information.

Source of evidence	**What it records**	**Scale/frequency**	**Match with Annex V requirements**	**Extent to which it provides policy relevant information**
ECN – Environmental Change Network	*Freshwater*: Surface water chemistry and quality (inc. major ions and heavy metals. Continuous pH, temperature, conductivity and turbidity at some sites. Temperature and dissolved oxygen profiles measured in lakes) Surface water discharge Phytoplankton Aquatic macrophytes Epithilic diatoms Zooplankton Macro-invertebrates *Terrestrial*: Meteorology measurements Nitrogen dioxide concentration Ammonia concentration Water chemistry (eg pH, conductivity, alkalinity, Na, K, Ca, Mg, Fe, Al, phosphate-P, ammonium-N, nitrate-N, sulphate-S, Chloride, Dissolved Organic Carbon.) Stream flow Soils (inc carbon concentration and chemical constituents) Vegetation Animal populations Site Management http://www.ecn.ac.uk/measurements	There are 12 terrestrial and 45 (some are coincident) freshwater sites in the UK ECN network covering a variety of habitats. http://data.ecn.ac.uk/sites/sites.asp Sites are monitored intensely, with different frequencies for different parameters. Some parameters measured continuously or daily.	*Freshwater*: *Parameter coverage*: Fairly high coverage of Annex V parameters including micro- and macrophytes, diatoms, invertebrates, pH, various ions, and invertebrates. Does not cover fish, and the specific match of chemicals recorded needs further investigation. *Frequency:* ECN sites have high frequency of coverage. *Representativity:* Fairly representative of habitats, but not randomly located. UK wide. *Terrestrial:* *Parameter coverage* Fairly high coverage of Annex V parameters including biodiversity loss, soils and water chemistry. The specific match of chemicals recorded needs further investigation. *Frequency* Parameters recorded more frequently than specified in NECD. *Representativity:* Fairly representative of habitats, but small number of sites, and not randomly located. UK wide.	Detailed co-located sampling is designed to answer detailed questions about functioning of sites. However, the low sample number, particularly for terrestrial sites, limits the value that can be obtained in showing UK level trends and attribution to air pollution.

Source of evidence	What it records	Scale/frequency	Match with Annex V requirements	Extent to which it provides policy relevant information
Upland Water Monitoring Network (originally "Acid Water Monitoring Network")	Records a wide range of water chemical parameters. See http://uwmn.defra.gov.uk/methods/chemistrymethods.php Parameters also recorded include: • Fish • Invertebrates • Aquatic macrophytes • Diatoms • Chironomids • Zooplankton • Sediment • Temperature	UK scale. Set up in 1988 to monitor the response of upland waters to UK's planned reduction in the emissions of sulphur and nitrogen gases. In 2013 the network expanded to cover all upland surface water not just those sensitive to acid. The network currently comprises 25 sites, 12 lakes and 13 streams. Chemical analysis at streams is monthly, and at lakes is quarterly. Flora and fauna are mostly recorded annually, but vegetation on lakes in now sampled triannually.	*Parameter coverage:* Fairly high coverage of Annex V parameters including aquatic macrophytes, diatoms, invertebrates, fish, and various chemical parameters. The specific match of chemicals recorded needs further investigation. *Frequency:* UWMN sites have high frequency of coverage. *Representativity:* Fairly representative of sensitive upland habitats, but not randomly located.	Network has good sensitivity to provide information on acidity in freshwater. This has been highly successful in showing chemical and biological response to reductions in sulphur emissions, but further monitoring is still useful to track recovery and monitoring impacts in relation to N.
Integrated Co-operative Programme (ICP) forests	Single species plantation stands. A large range of soil and vegetation parameters are recorded at Level II plots. For full list see: http://www.icp-forests.org/DocsMonitoring/parameters.doc	ICP Forests monitors the forest condition in Europe. Level I is based on around 6000 observation plots on a systematic transnational grid of 16 x 16 km throughout Europe. Level II intensive monitoring level has comprised around 500 plots in selected forest systems in Europe. Numbers of Level II plots are declining throughout Europe. Parameters have different recording frequencies ranging from continuous to every 10 years.	*Parameter coverage:* High level of overlap of parameters for Level II plots. Level I plots would not provide relevant data. *Frequency:* High frequency of coverage (more than required by Annex V) *Representativity:* There are currently only 5 Level II sites in the UK, and this is likely to fall further, possibly to just one for the UK (Alice Holt), plus 2 new Future Research plots in Wales and Scotland. The plots are not representative of semi-natural woodland ecosystems.	The limited number of sites combined with their location within managed single species stands constrains the relevance of the data for understanding ecosystem impacts.
EA/SEPA/NIEA/NRW monitoring of rivers and lakes	In Environment Agency surveillance monitoring for Water Framework Directive, a wide range of biological, hydromorphological and physico-	Environment Agency surveillance monitoring is carried out on a fixed network of sites, covering about 10% of identified water bodies (lakes	*Parameter coverage:* Monitoring is fairly comprehensive, although the specific match of chemicals recorded with Annex V needs further investigation. Also note	Monitoring useful for meeting WFD requirements. However, in terms of detecting air pollution impacts, detection levels are not sensitive enough (Rich

Source of evidence	What it records	Scale/frequency	Match with Annex V requirements	Extent to which it provides policy relevant information
	chemical parameters are monitored, as well as priority and priority hazardous substances. Similar monitoring carried out in Wales, Scotland and NI. Monitoring for Water Framework Directive is carried out on 'water bodies' = all rivers (with a catchment greater than 10 sq km) and all lakes (larger than 0.5 sq km). (Includes all parameters mentioned above.) In Wales, NRW will shortly be commencing a review of their monitoring which could impact on the range, scale and frequency of monitoring	and river catchments), in a three year rolling programme. There is additional 'operational monitoring' for high risk areas, and 'investigative monitoring' following incidents.	the detection levels used by the environment agencies are not sensitive enough for the levels of concern in softwaters to show air pollution impacts (Rich Batterbee, *pers comm.*). *Frequency:* The recording timescale (every 3 years) is less frequent than some recommendations in Annex V. *Representativity:* Good	Batterbee, *pers comm*). Furthermore, WFD monitoring is confined to 'water bodies' and the size cut-off for these means that small (often upland) lakes and streams (often in the most acid-sensitive areas) are not routinely monitored for WFD assessments.
Common Standards Monitoring/Site Condition Monitoring.	This is a quick method used by the country agencies to assess condition of sites. There are different methods for different habitats, but only factors that are able to be assessed in the field. It involves considering vegetation type and structure. Recent guidance attempts to allow surveyors to attribute impacts to air pollution based on a combination of deposition modelling and field indications.	Countries aim to assess all features on A/SSSIs/SACs on a rolling 6 year cycle,	*Parameter coverage:* Limited match. Chemical parameters not usually recorded and for habitats features only vegetation is assessed. Exception is for freshwater habitats where pH and ANC and P form part of the chemical attributes. Data for these is normally based on monitoring by the environment agencies rather than additional sampling. Some monitoring of species interest features is also done. *Frequency:* Frequency of biodiversity recording is not specified in Annex V *Representativity:* Covers range of habitats. All on protected sites.	There is potential value in CSM in that it help defines a desired state. This enables divergence from an established state to be identified. Provides an indication of site condition, but attribution to air pollution has been limited in the past. CSM data was heavily used in Article 17 reporting in combination with modelled critical load information. Attribution of impacts to air pollution should improve in the future but it will still rely on (in part) critical loads exceedance.

Source of evidence	What it records	Scale/frequency	Match with Annex V requirements	Extent to which it provides policy relevant information
Natural England's Long Term Monitoring Network	A wide range of environmental parameters are monitored, including climate, ammonia concentrations and precipitation chemistry, vegetation, and above-ground fauna and soil parameters. Soil parameters recorded include: • pH in water • pH in CaCL2 • Loss on ignition at 375oC1 • Total C and total N • Cation Exchange Capacity and exchangeable cations (Mg, Ca, Na, Mn, K, Fe, Al, exchangeable acidity) • "rain extractable" mineral N and N mineralisation • Physical and biological characteristics http://www.naturalengland.org.uk/ourwork/evidence/register/ltmn.aspx	The network has 40 sites, mainly on National Nature Reserves, in England. Between 6 and 9 sites are sampled each year.	*Parameter coverage:* Fairly high overlap, biodiversity, and several soil parameters, eg pH, total N, Cation Exchange Capacity and exchangeable cations. The specific match of chemicals recorded needs further investigation. *Frequency:* Frequency is less than specified in the Annex for some parameters. Only 6-9 sites are sampled each year.. *Representativity:* Covers range of terrestrial habitats. Not randomly located – sites mainly on NNRs. Only includes England (although originally designed as part of a UK ECBN, sites have only been progressed in England (and to a lesser extent Wales –see below).	Fairly high value for investigating air pollution impacts, but network only just being set up so no results are available yet.
Environmental Change Biodiversity Network (ECBN) – Wales	Standard meteorological data. (There have been some test runs for recording vegetation, NH3 (diffusion tubes), birds, butterflies for a limited number of sites, but no systematic programme. Precipitation chemistry was measured formerly but this has recently been discontinued)	13 sites located on national nature reserves in Wales. Regular monitoring is only for meteorological data.	No match – currently only records standard meteorological data. *Representativity* *Only sites in Wales. Need to consider how representative these are of a range of semi-natural habitat types*	Currently little value for investigating air pollution impacts.

Source of evidence	What it records	Scale/frequency	Match with Annex V requirements	Extent to which it provides policy relevant information
Countryside Survey field survey	Soil and vegetation parameters, e.g. • Vegetation data from repeat plots • Pond survey data • Veteran tree survey data • Soil cores. Soil properties analysed include pH; soil organic matter (SOM); soil organic carbon (SOC); bulk density; hand texture; total-N; soil C:N (by calculation); Olsen-P; potential mineralisable N; invertebrate diversity by main taxa; metals. • Freshwater parameters including aquatic plant community, macroinverts and indicative sample of water chemistry - analysed for pH, conductivity, alkalinity, Soluble Reactive Phosphorous (SRP) and Total Oxidised Nitrogen (TON).	291 random 1km squares in GB in 2007 survey. Survey has been carried out at approx 6-9 year intervals since 1978. NI does a similar survey.	*Terrestrial ecosystems:* *Parameter coverage:* Some overlap. CS parameters recorded that match up with Annex V include: biodiversity, pH, total N, and soil C:N. Some indicators mentioned in Annex V are not covered by CS, eg exchangeable fractions of base cations (base saturation), exchangeable aluminium in soils, and sulphate. *Frequency:* The timescales mentioned in Annex V for some parameters are more frequent than CS has been. *Representativity:* Good. Random stratified by land class. *Freshwater ecosystems:* *Parameter coverage:* Some overlap. Parameters recorded by CS required in Annex V include: aquatic plant community, invertebrates and pH. Annex V parameters that are not covered by CS parameters include: acid neutralising capacity, dissolved sulphate (SO4), nitrate (NO3) and dissolved organic carbon. *Frequency:* Annex V requirements are for survey ranging from yearly to monthly which is much higher frequency than CS. *Representativity:* Good. Random stratified by land class.	CS has been used to address a number of policy questions, for example extensive use of data in the National Ecosystem Assessment. Frequency of survey is not enough for some uses.

Source of evidence	What it records	Scale/frequency	Match with Annex V requirements	Extent to which it provides policy relevant information
Bunce resurvey	Data was collected on plant species composition in the canopy and ground flora, soil pH and Soil Organic Matter, habitat management	A one-off repeat survey. Originally surveyed in 1971, resurveyed 2001-2003. 103 sites resurveyed. 16 200m2 sample plots located at random within each site.	*Parameter coverage:* Only overlap includes pH *Frequency:* It was a one-off repeat survey *Representativity:* Woodlands only.	Analyses looked at effect of atmospheric deposition of S and N. Bunce resurvey showed that attributing change to N effects is particularly difficult for woodland, with a dominant effect of the clearance / regrowth stage on the ground flora
PondNet	Variety of optional components: • Amphibians • Aq. Inverts • Wetland plants • Dragonflies • S41 plants/inverts • Birds • Environmental data, including physical characteristics, connectivity and pH.	Scheme under development. Target of 550 1km survey squares in England recorded annually (combination random/stratified by GCN and/or common toad). All ponds in squares will be recorded.	*Parameter coverage:* Limited match. Only overlap includes pH, wetland plants and invertebrates. Note, in 2012-2013 pilot study, only a small number of volunteers recorded pH. *Frequency:* Planned to be annual – frequency required in Annex V is not specified. *Representativity:* Random stratified squares should give good representativity of ponds in different areas.	Designed to enable reporting on status and trends of protected species, and should give a broad overview of state of pond environments. Results could be overlaid with modelled pollution data and analysed. Many ponds are in areas in which N status will be dominated by groundwater effects, and hence there will be low sensitivity for measuring air pollution impacts and recovery.
National Plant Monitoring Scheme including Wildflowers Count	Vascular plant species abundances in quadrats within known semi-natural habitats. Data are collected annually.	Scheme under development, but incorporates former Wildflowers Count survey. Target is to be representative of semi-natural habitat types across the whole of the UK, and to provide annual reporting and analysis. Current Wildflowers Count survey includes over 1000 1km survey squares.	*Parameter coverage:* will provide a measure of biodiversity loss in terrestrial environments, though this is described as required without an associated key indicator. *Frequency:* annual is likely to be more than sufficient to monitor this, but is not specified by the Annex. *Representativity:* good.	Designed to be representative of semi-natural habitat across the UK, and hence will sample across the nitrogen deposition gradient. Recording is within known habitats so should have good analytical power, when analysed against deposition data.

Source of evidence	**What it records**	**Scale/frequency**	**Match with Annex V requirements**	**Extent to which it provides policy relevant information**
BSBI Plant Atlases	Vascular plant distribution data designed to be representative at the 10km square level across the UK. There have been two atlases so far, with a third in preparation, with 30 years between the first two, and 20 years to the third.		*Parameter coverage:* will provide a measure of biodiversity loss in terrestrial environments, though this is described as required without an associated key indicator. *Frequency:* probably too low, although distributional change processes tend to be slow. *Representativity:* good, but individual habitats not differentiated.	Spatial analysis of the most recent Atlas has provided good evidence of species losses associated with high N deposition. A similar analysis could be undertaken when the next Atlas is complete, but the new NPMS should provide a more sensitive measure.
Local Change survey	Vascular plant presence data in a sample (811) of 2km squares across the UK. There have so far been two surveys, repeated after 16-17 years.	Unknown when the next survey period will be.	*Parameter coverage:* will provide a measure of biodiversity loss in terrestrial environments, though this is described as required without an associated key indicator. *Frequency:* probably too low, although distributional change processes tend to be slow. *Representativity:* good, but individual habitats not differentiated.	Spatial analysis has provided good evidence of species losses associated with high nitrogen deposition. Similar analyses could be repeated if the survey is repeated in the future. The new NPMS should provide a more sensitive measure.
British Bryological Society Database	Bryophyte distribution data designed to be representative at the 10km square level across the UK.		*Parameter coverage:* will provide a measure of biodiversity loss in terrestrial environments, though this is described as required without an associated key indicator. *Frequency*: probably too low, although distributional change processes tend to be slow. *Representativity*: good, but individual habitats not differentiated.	Spatial analysis of the most recent Atlas has provided good evidence of species losses associated with high nitrogen deposition. A similar analysis could be undertaken when the next Atlas is complete.

Source of evidence	**What it records**	**Scale/frequency**	**Match with Annex V requirements**	**Extent to which it provides policy relevant information**
British Lichen Society Database	Lichen distribution data across the UK.	Representativity and spatial resolution varies across the UK.	*Parameter coverage:* will provide a measure of biodiversity loss in terrestrial environments, though this is described as required without an associated key indicator. *Frequency*: probably too low, although distributional change processes tend to be slow. *Representativity*: good, but individual habitats not differentiated.	Spatial analysis has provided good evidence of species losses associated with high nitrogen deposition.

The continuation of at least three of the schemes in Table 2, which measure some of the parameters required by Annex V, is uncertain. For example, Defra funding for the UWMN is currently in the region of £200K per annum. This only partially funds the network (around 7-8 sites, out of a total of 22 sites), with additional contributions from Forestry Commission, NRW, SNH, SEPA and contributions in kind from CEH and UCL. Future funding is not certain and the current funding model may not be sustainable. The cost of the last Countryside Survey in 2007 was around £10.7m and the future of the scheme is currently under review, as funders work to identify the most efficient and effective means of gathering evidence priorities. For ICP forests, Forest Research will be reducing the Level II plots. Clearly this has implications for Defra, as to the extent to which current monitoring can deliver the requirements of Annex V into the future.

Note, many of the approaches above rely on deposition data from models (e.g. Defra funded CBED model), particularly when nitrogen deposition is not co-sampled at the site alongside other biodiversity parameters. To date there has been a network of rural stations (UKEAP[4]) that monitor pollution air concentrations and deposition levels. CBED uses the pollution data to predict concentrations and deposition levels across the whole of the surface of the UK. This method provides an estimate of the uncertainty from the mapping process (Smith and Fowler, 2001). The deposition data can be analysed statistically with other data, such as vegetation data, in order to look for relationships.

The number of air pollution sampling stations has a large impact on the accuracy of air pollution models. There are currently 38 sites in the current deposition monitoring network (Precip-Net network) for 2011, reduced from the original 59 sites when the network was established for this work in 1987.There are currently large standard errors around modelled deposition levels in low deposition areas, e.g. over 100% uncertainty (expressed as twice the coefficient of variation (cv) of the value). However, the predictions are better in higher deposition areas, and overall predictive air pollution models have been accurate enough to use in investigations to show air pollution impacts on biodiversity. Defra are proposing to significantly cut the number of monitoring sites in the UKEAP from 2014. A recent report to Defra by Smith, Braban, and Banin (2013) looked at the impact on prediction accuracy of reducing sites from the sample network. They concluded that reductions of the network size by more than 10 sites will substantially increase uncertainty estimates, particularly for ammonium and nitrate in rainfall. Any reduction in the size of the sample network would have implications on the value that can be obtained from the different surveillance schemes described in table 2.

5.3. How successful have high intensity studies at a low number of sites been in providing policy relevant evidence?

The ECN contains 12 terrestrial sites with a wide variety of parameters monitored on a regular basis (see Table 2). Eight of the sites have been monitored since 1992, and the remaining four joined in the following 6 years (Morecroft *et al*, 2009). Many of the sites are based at major research sites, e.g. Rothamsted, Porton Down, and Alice Holt. The sites include co-sampling of air pollution data and meteorological data with biodiversity data e.g. vegetation, butterflies and beetles. Management activity at sites is also recorded. A review of the network in 2009 (Morecroft *et al*, 2009) confirmed other national measurements showing reductions of sulphate and nitrate in precipitation over this time period at all sites and some sites respectively. There was a reduction in NO_2 concentrations at some sites but no consistent trend in ammonia concentrations. The sites confirmed decreased acidification (increased pH) over this period, but no evidence of any consistent trend of NH_4^+ or NO_3^- levels in soil solution, consistent with no clear evidence of reduction of nitrogen deposition inputs.

[4] http://uk-air.defra.gov.uk/networks/network-info?view=ukeap

In terms of biodiversity changes, the trends were different between sites, and likely linked to a combination of meteorological and site management factors as well as air pollution. As it is not a controlled experiment and there is a small sample size, it is hard to know exactly what is responsible for any changes seen. There were changes in mean plot species richness Ellenberg and CSR vales of plant communities detected, but with contrasting trends at different sites. When looking at trends in specific habitat types the sample size for analysis was reduced because not all of the 12 sites contain the same habitats. For example, only three of the sites contain fertile grassland, five contain lowland woodland, seven contain moorland grass/mosaic and eight contain heath/bog. These are small sample sizes for looking for significant patterns across sites, either temporally or spatially. This network does not appear to be sufficient to demonstrate widespread changes in vegetation response to air pollution across the UK, particularly when bearing in mind that the level of change we want to detect is often quite small.

IPC Forests[5] has been used to investigate the affects of air pollution across Europe, but there are very few sites in the UK and these are in single species plantation stands, so it is not representative of semi-natural woodlands. The Bunce resurvey shows that there was no overall shift in species towards more eutrophic assemblages and no change in mean Ellenberg fertility score. With the exception of epiphytes, woodland is likely to be particularly slow to react to changes in nitrogen deposition (Kirby *et al*, 2005; Emmett *et al*, 2011). Thus, woodland habitats may not be the most useful habitat to focus on when investing money in monitoring to provide evidence to influence policy in the short term.

The UWMN is the main network that focuses monitoring on upland freshwater ecosystems sites in detail (12 lakes and 13 streams). There are also 45 wetland sites in the ECN network (some co-located with UWMN). This is a larger sample size than for terrestrial ECN sites, so has greater potential for detecting air pollution impacts and trends at a UK scale. Results have demonstrated reduction in sulphur and a corresponding reduction in acidification, although there are still further reductions needed, and nitrogen deposition, which has not declined as much, is contributing to acidification. The UWMN has helped show that the increase in Dissolved Organic Carbon (DOC) (a major issue for water companies) is a response to recovery from acidification, not so much land use management and extent of burning and grazing as was thought originally. The network largely meets the requirements of Annex V in respect of freshwater and over the years has produced highly relevant evidence for policy and more widely for research studies. However, it is not certain whether it is the most cost-efficient means of answering policy questions, or whether perhaps modifying routine monitoring by the environment agencies could be an alternative approach provided there was some adaption to monitoring programmes. For example, options may include an increase in sample site coverage to areas most at risk from acidification and eutrophication, higher frequency of sampling occasions and improved capability in terms of 'limits of detection' for water quality parameters.

5.4. How successful have broad-scale vegetation survey schemes been in providing policy relevant evidence?

Over recent decades there have been several datasets that include vegetation records from across the UK. Many of these are from structured surveillance schemes (e.g. BSBI Local Change survey) or repeated complete distributional studies (the Plant Atlases) which make it easier for the results to be used to show change in plant communities. These datasets cover many sites over a large area, but do not generally have associated data on air pollution, deposition, or soil composition (Countryside Survey is the exception with some soil data (see Table 2)). However, the data have been used in large scale correlative studies with modelled nitrogen deposition data, for example, Emmett *et al*, (2011) and Stevens *et al*, (2011).

[5] http://www.forestry.gov.uk/pdf/fcin088.pdf/$FILE/fcin088.pdf

Stevens *et al* (2011) analysed eight national scale vegetation datasets (the Vascular Plant Database (1930-1969 and 1987-1999), Botanical Society of the British Isles (BSBI) Local Change Survey (1987-1988 and 2003-2004), British Bryological Society (BBS) Database, British Lichen Society (BLS) Database, Plantlife Common Plant Survey, Countryside Council for Wales Grassland Database, Scottish Natural Heritage National Vegetation Classification (NVC) survey, and Natural England Grassland Database) and considered impacts in four different habitats (acidic and calcareous grassland, heathland and bogs). The results indicated significant responses in the cover and presence of 91 plant and lichen species in relation to nitrogen deposition, indicating a change in habitat structure. These included two BAP priority species, four species (or species groups) mentioned in Annexes of the Habitats Directive and 24 positive indicator species used in Common Standard Monitoring. The results also revealed significant impacts on habitat function, shown by changes in both species and ecosystem function indices (such as Ellenberg N). Changes were shown to occur at low levels of nitrogen deposition (<10kgN/ha/yr), sometimes below the established critical load (the nitrogen deposition level below which damage is not supposed to occur). The study also showed that further change occurred progressively at levels above the critical load, suggesting that there are still benefits from reducing nitrogen deposition even if it cannot be brought to below the critical load. The results from this study have been used to inform the UK mapping value for nitrogen critical loads.

The Countryside Survey has shown an increase in soil pH, associated with reductions in sulphur deposition. It has shown topsoil (N) concentration has decreased in many habitats despite continued N deposition. A concomitant increase in C:N ratios implies that either N loss has increased or the at the N signal has been diluted by increased C fixation by plants. In terms of vegetation response, the Countryside Survey has shown reduction in species richness across a range of habitats (Maskall *et al*, 2010)

The certainty from this type of study (reliant on a modelled nitrogen deposition surface) is not considered as robust as taking pollution recording from the same location as the vegetation surveillance took place. However, the ability to have a much larger sample size compensates for this. Results have to be interpreted with care since they highlight correlations that should not automatically be considered to be causal. However, other variables which could have an effect (e.g. climate) can be added as co-variables in the analysis to account for them, as was done in the Steven’s *et al*. (2011) study.

This type of analysis using broad-scale vegetation surveys is particularly dependent on modelled nitrogen deposition data accuracy.

One challenge faced when analysing plant datasets, is that records in many schemes are not assigned to habitat types, which may be required for the desired analysis. Steven's *et al* (2011) used a post survey method to assign records to habitat, but it would be more accurate if habitat types were recorded at the point of data capture. JNCC are currently working with partners to establish a new plant surveillance scheme (the NPMS in Table 2), which will be based on recording within identified habitat types, and hence the assignment to habitat will be achieved at source.

6. Overarching advice on monitoring approach

The revision to the NECD will replace the 2001 NECD (2001/81/EC) in order to “address the highly significant remaining health risks and environmental impacts posed by air pollution in the Union.” The proposal is one of the main legislative pillars to achieve emission reductions to work towards the European Union's long-term objective for air policy, “to achieve levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment”.

We need to ensure our monitoring can show the impacts of pollution on biodiversity in order to inform future emissions policy. We need to monitor impacts over time and consider trends of change so that we have a better idea of progress against the Directive's objective, and the timescales and extent of recovery. This will feed into reporting on the status of habitats and species of conservation concern under the Habitats Directive, and could indicate if mitigation action is required.

Ultimately it is important that the outcomes of the NECD are met and that evidence is available to inform air pollution related policy decisions. The question of what is the most effective and efficient approach to use to achieve this will probably vary between Member States depending on what surveillance mechanisms are already in place for other purposes, and on the volunteer and professional resource capacity. The review above demonstrates that there are multiple ways of carrying out surveillance that will provide credible evidence to inform air pollution policy.

We consider it more beneficial and cost effective to ensure that monitoring of ecosystem impacts is outcome orientated and reflects the overall policy objective. We strongly recommend that Annex V takes a less prescriptive approach and gives Member States the flexibility to decide on the most effective and efficient way for them to provide this evidence.

One approach to ensure that a less prescriptive nature of Annex V could still provide robust evidence, would be to request Member States to present monitoring plans to the Commission for approval.

The following section outlines some options for providing this evidence in the UK, and provides a brief analysis of their costs and benefits.

7. Options for gaining further evidence

7.1. Freshwater ecosystems

Monitoring of freshwater ecosystems, including chemical parameters, is useful because they respond relatively quickly to changing air pollution levels.

There are probably a sufficient number of sample sites in the freshwater environment to show air pollution impacts through the UWMN and ECN freshwater sites. These networks collect data on a wide variety of parameters which have a high overlap with the requirements of the proposed Annex V. If the UWMN is to be main delivery mechanism for this obligation then future funding will need to be secured (see section 5.2).

However, it should be noted that it has not been investigated if this approach is the most efficient means of obtaining the evidence. Another approach to consider would be to use the broad-scale freshwater monitoring schemes that are routinely carried out by EA/SEPA/NIEA/NRW. There are currently concerns over the sensitivity of monitoring detection limits, as they are less sensitive than required to demonstrate air pollution impacts in softwaters. In addition, the WFD monitoring programme covers rivers and lakes, but not small lakes (less than 0.5 km^2) or smaller streams (with a catchment area less than $10km^2$). However, it would be sensible to consider whether it would be more cost effective to modify this sampling, whether the most efficient approach is to maintain a relatively small but more detailed network such as the UWMN, or to consider a combination of the two approaches.

It would also be advisable to further investigate if the full suite of parameters requested in the proposed Annex V is necessary in providing evidence to answer policy questions, or whether there is any redundancy of parameters listed.

7.2. Terrestrial Ecosystems (nitrogen deposition and acidification)

Monitoring of terrestrial ecosystems to show nitrogen impacts and acidification is critically important to show ongoing damage and/or recovery in some habitats and therefore the benefits of emissions reductions and what further action is required.

We note that although the Annex V specifies that a network should be representative of a country's natural and semi-natural as well as forest ecosystems types, some habitats are more responsive than others to changes in nitrogen and it may be cost effective to focus more resource on habitats where it is likely to be easier to obtain evidence that will influence policy. We also note that the proposed Annex V presumes that the same network of sites will need to be used to record all parameters, including biodiversity. This is one approach, but we do not think that this is essential in order to provide the required evidence.

Two broad approaches that we could follow to obtain evidence for terrestrial ecosystems for nitrogen deposition and acidification are outlined below:

i) An intensive survey model at relatively few sites.

The first approach is to use an intensive survey model comprising multiple measurements at the same location. The costs of this approach mean the number of sites will be generally be low. An advantage is that co-location of deposition monitoring removes the problems of uncertainties in the deposition model.

In order to meet the objectives of monitoring in the NECD, we would need to extend the size and representativeness of the ECN network.

Currently there are just 12 terrestrial sites in the ECN, which has not been sufficient to detect and confidently attribute trends across the UK. More sites would be needed to give a better chance of detecting statistically significant patterns in changes across sites. The ECN network could be combined with the LTMN network, to ensure the combined schemes together cover the required parameters (chemical and biodiversity) at the specified sampling frequency where we think this would be of value and that they are representative. Again, it would be sensible to further investigate the list of parameters to assess what is essential to inform policy decisions, and if there are any redundancies of measures showing similar responses, or unnecessarily frequent sampling timeframes.

There are several issues to consider relating to this option:

Firstly, it would likely be very expensive. The ECN costs approximately £90,000[6] per site, plus approximately £100,000[7] a year for a central co-ordination unit[8]. The expense would limit the number of sites that could be included in the network. There is always going to be a compromise needed between the level of detail recorded at sites and the number of sites in the network. As for freshwater, it would be worthwhile to further investigate if the full suite of parameters requested in the proposed Annex V is necessary in providing evidence to answer policy questions, or whether there is any redundancy of parameters listed. A shorter list of parameters could reduce per site costs,

[6] This is for a full site. Any expansion of the ECN for the current purpose could use a reduced set of measurements, therefore reducing the costs.

[7] This also includes data management for the ECBN and LTMN.

[8] http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=ProjectList&Completed=0&Keyword=Environmental%20Change

but might be less attractive to co-funding from academic research. These high costs can be contrasted with the lower costs associated with the broad-scale option.

The LTMN sites are restricted to England (the ECBN in Wales only measures meteorological data currently) and consideration of geographic coverage representative of the whole of the UK and pollution gradient would needed.

Finally, note, the current ECN and LTMN sites are not randomly chosen sites and this introduces some bias in results. The sites are based on National Nature Reserves, where in some cases local mitigation might make impacts of pollution less severe than in other areas of the country. It would be difficult to introduce randomised sites to the network, and hence reduce bias, due to the need for the sites to be regularly accessed and to contain considerable instrumentation.

ii) Utilise a broad-scale survey approach

The second option is to utilise broad-scale vegetation surveys, probably supplemented with a soil sampling component. Broad-scale surveys have been demonstrated previously as capable of producing policy-relevant information, and the National Plant Monitoring Scheme, currently being established, has been designed to be more effective in analyses against environmental pressures (see Table 2). It is likely to be possible to get a much bigger sample size for this scheme than the sample size that is easy to obtain through an ECN type approach (e.g. the scheme has a target of two thousand, compared to the current 12 terrestrial ECN sites). The much higher sample size is possible because the scheme will be largely reliant on volunteers and there will be lower sample intensity needed through the year – i.e. only two visits (taking ½ day each) required. The NPMS is envisaged to cost approximately £120,000 per year[9].

To obtain value from this approach for air pollution purposes we would need to ensure continued and sufficient monitoring of pollution air concentrations and deposition, e.g. through the UKEAP network, in order to maintain a national deposition model with sufficient accuracy. This would enable analysis of the results in relation to air pollution parameters, for example as was carried out in the Stevens *et al.* (2011) analysis[10]. Maintaining/strengthening this network is likely to be cheaper than increasing the number of sites in an ECN type network (e.g. the UKEAP network (excluding super sites) is in the region of £300k per annum, but faces a 25% cut). It should also be noted that there may be other ways of monitoring pollution concentration and deposition levels other than a site based network. Some of the new Sentinel satellites due to be launched soon by the European Space Agency has sensors on it to monitor pollution (e.g. 'Sentinel-4 is a payload devoted to atmospheric monitoring that will be embarked upon a Meteosat Third Generation-Sounder (MTG-S) satellite in geostationary orbit; Sentinel-5 is a payload that will monitor the atmosphere from polar orbit aboard a MetOp Second Generation satellite'[11]). Obviously, this has an extremely high up-front cost, but the decision to launch this has already been made and resultant data will be made freely available.

Monitoring changes in plant communities in response to pollution concentrations and deposition would be meeting the objectives of the NECD, despite not covering the

[9] Figure commercial in confidence until end August 2014.

[10] It is noted that Defra are currently proposing cutting the funding for the UKEAP network by 25% which will have implications for the levels of uncertainty with the CBED model which uses the monitoring data to provide the UK deposition map used for generating critical load exceedance and for used for broadscale analysis of vegetation datasets (e.g. Stevens et al., 2011).

[11] http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Overview4

specific requirements of the proposed Annex V. However, changes to plant communities can be slow so it may take a while to show impacts, i.e. where critical loads continue to be exceeded and nitrogen is accumulating, even if it has not reached the stage where it affects the plant communities. On the other hand where there have been improvements in pollution levels there may be delays before recovery is seen in the vegetation communities. We therefore advise that is would be useful to have a subset of sites or separate network where intermediate response parameters, e.g. soils, are measured to show changes in chemical conditions. The sample size for soil recording would need to be larger than the current terrestrial ECN network to be able to provide policy relevant information, but it would not need to be at as broad a scale as vegetation monitoring. Practically, it would require professional sampling of a network (ideally of a similar size and coverage to the Countryside Survey), which could be co-located with vegetation surveillance, but would not need to be in order to provide useful information.

7.3. Ozone

We think that flux based CL modelling approaches are a useful approach to help with assessing risk from ozone and should be maintained. We note that this is not really a monitoring requirement i.e. in the spirit of Article 8/Annex V. We also note that flux based models are not yet available for natural and semi-natural communities.

The most well established evidence of the impacts of ground level ozone relate to growth and yield effects on arable/horticultural crops and forestry production, rather than on biodiversity. However, currently the Annex V does not specify any monitoring of impacts on arable/horticultural systems. This seems to be an omission, but we have not made any recommendations on this as our focus is on biodiversity impacts.

We do not think the monitoring approaches specified in Annex V will be helpful in providing relevant information to inform air pollution policy in respect of biodiversity impacts. Further R&D is needed to investigate the impacts of ozone at this stage, for example, analysing broad-scale vegetation datasets to show whether ozone is driving species level responses, rather than implementing widespread monitoring at this stage. We do not feel there is yet sufficient understanding of the relationship between visible injury, growth and C flux indicators and the impacts on structure and function of natural and semi-natural habitats.

8. Summary of recommended approach for UK monitoring

We conclude that it would be more beneficial and cost effective to ensure that ecosystem impacts monitoring is outcome orientated, rather than prescribing a rigid set of parameters as currently proposed in Annex V.

JNCC recommends the following points:

- Defra encourage that Annex V be reworded to be less prescriptive and more outcome based.
- Defra encourage that Annex V remove the need for monitoring impacts on biodiversity from ozone.

Additional investigations would be needed to:

- Further investigate existing freshwater surveillance mechanisms, e.g. monitoring by the country environment agencies, and the potential to adapt them, in order to assess whether it would be more cost effective to use these, or to utilise the UK Upland Waters Monitoring Network for this purpose or to use a combination of the two approaches.

- Consider the value of each of the detailed requirements currently specified in Annex V for freshwater and terrestrial ecosystems in order to check for parameter redundancies in providing policy relevant information.

For monitoring air pollution impacts on biodiversity in the UK we should:

- Make use of existing/planned broad-scale vegetation schemes with high sample sizes but less detailed monitoring.
- Ensure there is sufficient soil monitoring, providing a more intermediate response parameter, to show biogeochemical recovery as a consequence of nitrogen deposition (whilst vegetation response may be slower).
- Maintain, or enhance if necessary, air pollution deposition and concentration monitoring in order to support deposition modelling (e.g. UKEAP network, with consideration of how to reduce uncertainties in the modelling and further investigate what will be able to be detected from the Sentinel satellites) in order to support the modelling and mapping of deposition, which are essential for the analysis of broad-scale vegetation datasets.
- Ensure that relevant analyses of the datasets are scheduled for provision of timely information.

9. Risk of consequences if Annex V retained in current form

For freshwater ecosystems, following the current prescription in Annex V would likely mean a requirement to continue the UWMN. This monitoring scheme has proved successful and would be likely to provide the evidence required for air pollution policy in respect of freshwater impacts. However, it is possible there may be more cost effective ways of gathering the same information. The specific suite of parameters and recommended frequencies may be more than is necessary to inform air pollution policy, resulting in unnecessary expense.

For terrestrial ecosystems (acidification and nitrogen deposition impacts) following the current prescription in Annex V would force the UK to go down the approach of having few high intensity survey sites. In the current economic climate there is unlikely to be sufficient resource to expand the network size much, which would severely limit its ability to produce evidence of broad value to framing air pollution policy. This approach would also be very expensive and would not make good use of biodiversity monitoring planned for other purposes, e.g. the National Plant Monitoring Scheme.

For ozone, following Annex V would provide us with a set of data with little value for telling us about biodiversity impacts. The data may possibly have some use related to ozone impacts on forests in respect of commercial forestry. However, as currently prescribed it would not provide information for arable habitats; a habitat for which ozone causes high economic damage.

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Appendix 1

The proposed text for Article 8 and Annex V of the revision to the NECD.

Article 8
Monitoring air pollution impacts

1. Member States shall ensure, if practicable, the monitoring of adverse impacts of air pollution upon ecosystems in accordance with the requirements laid down in Annex V.

2. Member States shall, where appropriate, coordinate the monitoring of air pollution impacts with other monitoring programmes established by virtue of Union legislation, including Directive 2008/50/EC [AQ Directive] and Directive 2000/60/EC [WFD] of the European Parliament and of the Council.[30]

3. The Commission shall be empowered to adopt delegated acts in accordance with Article 13 in order to adapt Annex V to technical and scientific progress.

ANNEX V
Monitoring of effects of pollutants in the environment

1. Member States shall ensure that their network of monitoring sites is representative of their fresh water, natural and semi-natural as well as forest ecosystems types.

2. Member States shall ensure that the monitoring is based upon the following mandatory indicators at all sites of the network defined in paragraph 1:

(a) for freshwater ecosystems: establishing the extent of biological damage, including sensitive receptors (micro- and macrophytes and diatoms), and loss of fish stock or invertebrates:
the key indicator acid neutralising capacity (ANC) and the supporting indicators acidity (pH), dissolved sulphate (SO4), nitrate (NO3) and dissolved organic carbon with a minimum frequency of sampling from yearly (in lake autumn turnover) to monthly (streams).

(b) for terrestrial ecosystems: assessing the soil acidity, soil nutrients loss, nitrogen status and balance as well as biodiversity loss:
(i) the key indicator soil acidity: exchangeable fractions of base cations (base saturation) and exchangeable aluminium in soils every ten years and the supporting indicators, pH, sulphate, nitrate, base cations, aluminium concentrations in soil solution every year (where relevant);
(ii) the key indicator soil nitrate leaching (NO3,leach) every year;
(iii) the key indicator carbon-nitrogen ratio (C/N) and the supporting indicator of total nitrogen in soil (Ntot), every ten years;
(iv) the key indicator nutrient balance in foliage (N/P,N/K, N/Mg) every four years.

(c) for terrestrial ecosystems: assessing ozone damage to vegetation growth and biodiversity:
(i) the key indicator vegetation growth and foliar damage and the supporting indicator carbon flux (Cflux) every year;
(ii) the key indicator exceedence of flux-based critical levels every year during the growing season;

3. Member States shall use the methodologies on the Convention on Long-Range Transboundary Air Pollution and its Manuals for the International Cooperative Programmes when collecting and reporting[5] the information covered by paragraph 2.