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CURRENT AND FUTURE POLICY OPTIONS FOR TACKLING NITROGEN DEPOSITION IMPACTS ON NATURA 2000 SITES (THEME 5)

7.1 Background document

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7.1.1 Introduction

Atmospheric nitrogen deposition represents a major anthropogenic threat to the 'Natura 2000' network and to the conservation status of habitats and species listed under the Habitats Directive. The Natura 2000 network has a central place in European conservation legislation, affording sites the highest degree of protection of any nature conservation areas under European law. Many of these habitats are naturally adapted to limited nitrogen supply, so that additional inputs can cause substantial changes in biogeochemistry and species composition. The importance of nitrogen as a key threat has been recognized through 'nitrogen deposition' being listed as one of the long-term indicators under the Convention on Biological Diversity, and, related to this, in the SEBI 2010 process of the European Environment Agency (Streamlining European Biodiversity Indicators for 2010; EEA, 2007).

In this background document, we briefly review the challenge of protecting the Natura 2000 network from nitrogen deposition, arguing that there is a need for further policy development, as well as improvement in the enforcement procedures. We then explore a range of possible policy options that could help address the concerns identified. It should be noted that the Habitats Directive uses the Natura 2000 network as part of its overall ambition to maintain and improve conservation status, including the occurrence of species outside of Natura 2000 sites. Here we deliberately focus on Natura 2000, as the flagship network with the highest degree of protection for conservation sites in the European Union. While not losing this focus, the present discussion should be seen in the context of these wider objectives.

The purpose of this document is to stimulate discussion for the COST 729 workshop. It is hoped that the ideas presented here will encourage additional suggestions. Together, these options can then be refined to provide a shortlist of approaches that merit in-depth investigation for future policy development and enforcement.

7.1.2 The nitrogen deposition threat and the need for further policy development to protect the Natura 2000 network.

The Natura 2000 network comprises all Special Areas of Conservation (SACs) and Special Protection Areas (SPAs), as designated under the Habitats Directive (92/43/EEC) and the Birds

Directive (79/409/EEC), with the Habitats Directive also including updated provisions for the management of SPAs. In aiming to provide the highest degree of conservation protection, a precautionary approach is specified, as illustrated by Article 6.3 of the Habitats Directive:

> *Any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives.*
>
> *In the light of the conclusions of the assessment ..., the competent national authorities shall agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the site concerned and, if appropriate, after having obtained the opinion of the general public.*

For this purpose, a 'plan or project' is understood to be intended to mean any activity which might potentially have an adverse effect on the integrity of one or more SACs. Apart from exceptions outlined in Article 6.4 (in the case of no alternatives and of overriding public interest), the Habitats Directive thus, in principle, guarantees a high level of protection, particularly as it explicitly notes that multiple activities should also be assessed in regard of their combined effect on the sites.

Given this precautionary approach, it is therefore of interest to note that many SACs and SPAs remain under the threat of anthropogenic nitrogen deposition. For example, Figure 7.1a shows the estimated location of critical load exceedance for nutrient nitrogen across Europe. This is the amount by which estimated total nitrogen deposition is larger than the 'critical load', the estimated amount of deposition below which effects do not occur according to present knowledge. Critical load exceedance is the indicator used by the SEBI 2010 activity, for which values have been established using extensive analysis of field observations, experiments and models (e.g., Achermann and Bobbink, 2003; ICP Modelling and Mapping, 2004). Similarly, critical levels are used for NH_3 and NO_x, which are the air concentrations above which effects do occur according to present knowledge (ICP Modelling and Mapping, 2004; Sutton *et al*., 2009b). Wherever exceedance of either a critical load or critical level occurs, adverse impacts of nitrogen on Natura 2000 site integrity may be expected. Figure 7.1a refers to 2010, assuming that the existing commitments under the UNECE Gothenburg Protocol (UNECE, 1999) and the EU National Emissions Ceilings Directive (2001/81/EC) to reduce emissions of nitrogen oxides () and ammonia (NH_3) are met. From an international perspective, there is therefore a long way to go until adverse effects of nitrogen deposition on the Natura 2000 network can be avoided.

It is important to consider spatial scale when assessing the overall threat of nitrogen deposition to sensitive habitats. Thus Figure 7.1b shows the estimated pattern of critical loads exceedance for two example habitat types in the UK, based on national models. These maps illustrate the variation in sensitivity between habitat types (through differing values of critical loads) and the fact that the rates of nitrogen deposition are also dependent on land cover type (nitrogen deposition is largest to rough forest vegetation). While Figure 7.1b shows the regional patterns using one km estimates of critical loads and five km resolution estimates of nitrogen deposition, it still does not reveal the full extent of spatial variation. Reactive nitrogen emissions can occur in the rural environment, leading to gradients in atmospheric concentrations and deposition downwind of major roads (for NO_x and NH_3, Cape *et al*., 2004), and downwind of livestock farms (for NH_3, e.g. Dragosits *et al*., 2002 and other organic nitrogen compounds). Figure 7.1c illustrates the pattern of modelled critical load exceedance that may occur in a single five km grid-square in an agricultural landscape. Major gradients of nitrogen deposition occur with distance from ammonia sources, including manure spreading, grazing, farm buildings and manure stores. These spatial patterns are extremely important and can help guide the search for nitrogen mitigation policies. In particular, they highlight two extremes to the nitrogen deposition problem:

- **Long range transport**, leading to well dispersed increases in N deposition, which only vary as a result of topographic effects on wet deposition, and on dry deposition of secondary gases (e.g., nitric acid) and secondary particulate matter.
- **Short range transport**, leading to locally enhanced increases in N deposition, which are extremely spatially variable, mainly as a result of gradients in air concentrations away from sources and ecosystem dependent rates of gaseous dry deposition (especially ammonia and to a lesser extent nitrogen oxides).

Rather different strategies are needed to combat these two extremes, though both are important in contributing to the nitrogen threat to Natura 2000 sites.

Of course, critical loads and levels exceedances only provide an indicator of the threat to sites. Nevertheless, in the case of empirical critical loads, the values have been derived from a combination of experiments and field observations where effects are seen in practice (e.g., Bobbink and Achermann, 2003). The result is that these maps give a good indication of the areas in Europe and the extent of spatial variability of where Natura 2000 sites can be considered under threat from nitrogen deposition.

Where a SAC or SPA is located in an area with exceedance of a critical load or level, it is therefore anticipated that adverse impacts on site integrity will follow. This may include both damage and

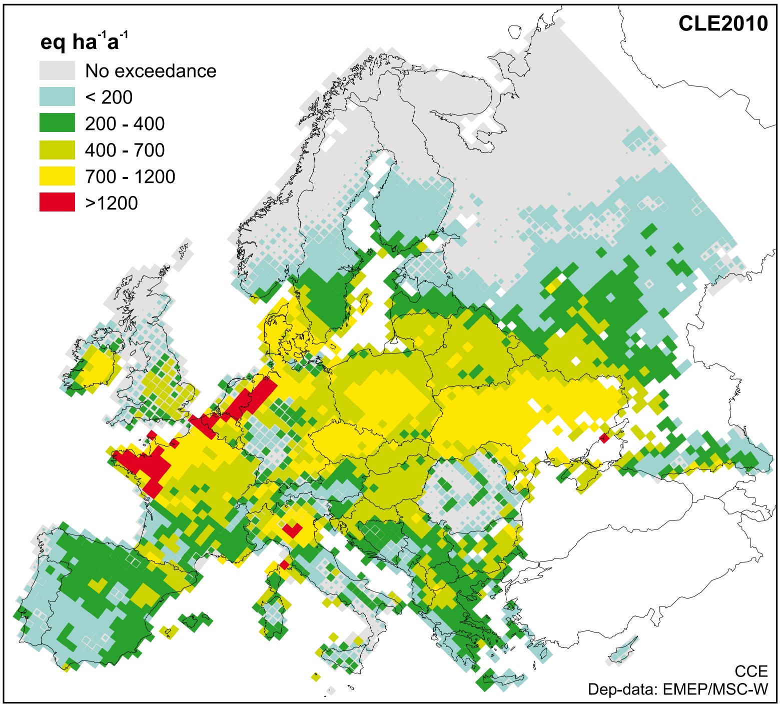

Figure 7.1a: Patterns of exceedance of the nutrient nitrogen critical load at different spatial scales: estimated exceedance across Europe in 2010 at 50 km resolution in response to total ammonia and nitrogen oxides emissions (Hettelingh *et al.*, CCE, 2008);

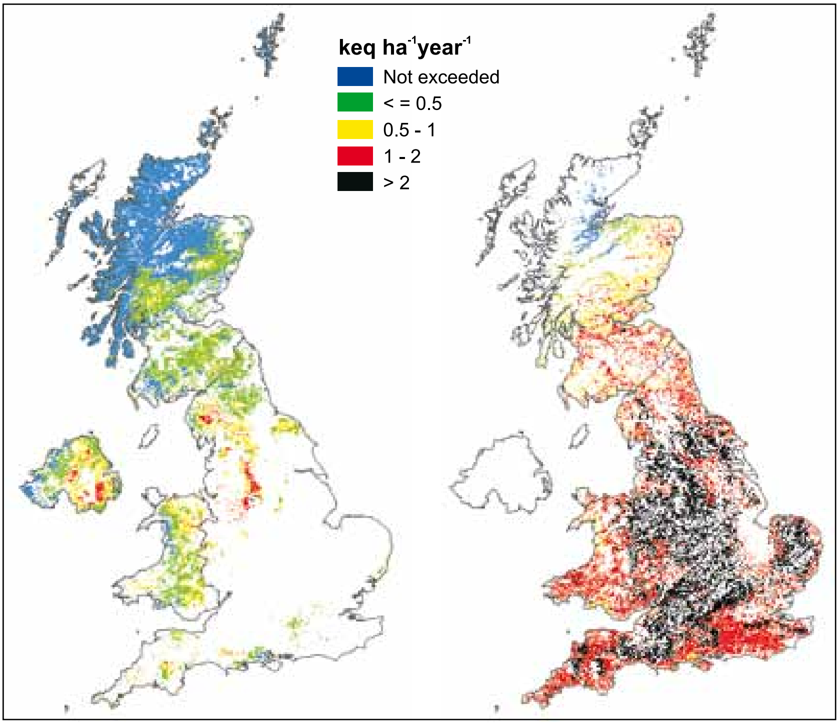

Figure 7.1b: Patterns of exceedance of the nutrient nitrogen critical load at different spatial scales: estimated exceedance across the UK at 1 km - 5 km resolution for two contrasting habitats: dwarf shrub heath (left) and managed broadleaf woodland (right) (for 2002-2004) (J. Hall, CEH);

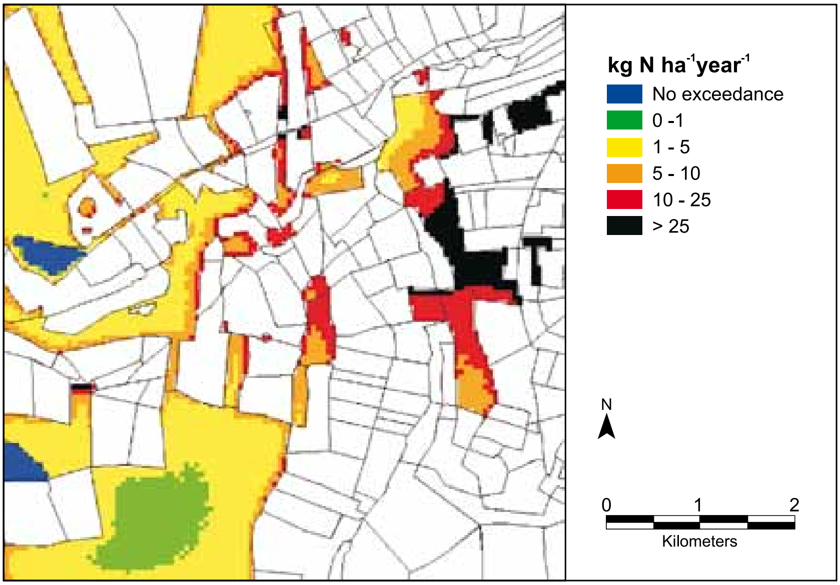

Figure 7.1c: Patterns of exceedance of the nutrient nitrogen critical load at different spatial scales: estimated exceedance across a landscape in central England at 50 m resolution in response to only dry deposition of ammonia (agricultural fields are shown in white; Dragosits *et al.*, 2002).

loss of nitrogen sensitive species communities, coupled with invasion by nitrogen loving species of lower conservation value. Examples of such changes include the loss of sensitive shrubs and wild flowers from heathlands and woodlands and their replacement by grasses (e.g., Pitcairn *et al*., 2002), loss of sensitive forbs from grasslands (Stevens *et al*., 2004) or the loss of sensitive lichens growing on trees trunks and their replacement by a few nitrogen loving species (van Herk, 1999; Wolseley *et al*., 2006; Sutton *et al*., 2009b).

Lichens are particularly sensitive to air pollution, and major changes can occur at low concentrations of ammonia. An extreme example of change appears in the paper on Moninea Bog (see Figure 3.7, this volume). These photos compares the trunk of a birch tree under clean conditions (0.4 $\mu g\ m^{-3}$ NH_3, Whim Bog, southern Scotland), with another tree growing on an SAC about 60 m downwind of a small poultry farm (15 $\mu g\ m^{-3}$ NH_3, Moninea Bog, Northern Ireland). In the latter case, the typical lichen community has been completely replaced by a thick green slime of free living algae. Such changes in species composition are replicated for many different plant groups, and can be accompanied by subsequent changes in associated animal communities.

The contrast between the high degree of protection afforded to Natura 2000 sites and the actual degree of critical load exceedances and current impacts might be considered as rather surprising. Over a decade after its adoption, it seems that the commitment to protect the Natura 2000 network has still to be met. There are a number of reasons for why nitrogen deposition is still a significant threat to Natura 2000 sites, and these apply on both on local and regional scales. For example:

- Article 6 (3) of the Habitats Directive can only meet its purpose where an appropriate assessment of a plan or project is carried out. However, in practice it requires other regulatory requirements to trigger such assessments when these are not located on a Natura 2000 site. Polluting activities that do not require any formal assessment therefore potentially constitute a loop-hole for protection of the Natura 2000 network (cf. Frost, 2004), i.e. plans and projects which are unregulated.
- Although required by the Directive, it is often difficult to consider all polluting activities in combination. Even when the polluting emissions in an area are known, it can be a major modelling challenge to consider all together. In addition, it is a point of debate whether the requirement is to consider a particular regulated source in combination with all other sources, or only to all other ***regulated*** sources.
- Nitrogen deposition results from both local and long-range sources. For example, deposition to remote tundra ecosystems is the result of long-range transport from Europe-wide nitrogen emissions. Such transboundary fluxes can only be reduced by international agreement, such as the NECD and the Gothenburg Protocol.

Presently, the goal of avoiding critical load exceedance over the whole Natura 2000 network therefore remains a long-term aspiration, even if the Habitats Directive implies an existing indirect legal commitment to reduce nitrogen deposition to the sustainable levels that would be necessary to achieve favourable conservation status.

In this context, there is an obvious need to investigate the future policy options that could strengthen the protection of the Natura 2000 network from nitrogen deposition. In the next section we first review the role of existing policies in supporting the implementation of the Habitats Directive as regards the threat of nitrogen deposition. In the subsequent sections we then explore several future options that could be developed, making the distinction between policies designed to protect from long-range transported air pollution and from those designed to protect from nearby air pollution sources. In practice, both elements are needed, with the priority depending on the location of individual Natura 2000 sites.

7.1.3 The role of existing legislation in protecting Natura 2000 sites from the impacts of atmospheric nitrogen deposition.

There are a large number of policy instruments that potentially interact with Natura 2000. In order to keep the focus, we here restrict the discussion to the main linkages. We consider the current status of each of the measures, and the potential for further development of each. The status of ongoing revisions is mentioned as far as it is known to the authors.

National Emissions Ceilings Directive (NECD, 2001/81/EC) and the UNECE Gothenburg Protocol.

The NECD provides for the EU implementation of the Gothenburg Protocol, with the focus on reducing transboundary impacts of air pollution. These instruments provide for national emissions ceilings of NO_x and NH_3 to reduce both acidification and eutrophication in sensitive ecosystems at the European scale. As the Gothenburg Protocol covers the UNECE, which has a much larger area than the EU, it has the advantage of also reducing reactive nitrogen import into the EU (and exports from the EU), as well as the transboundary fluxes between the EU Member States.

In addition to the national emissions ceilings, annexes in these instruments specify technologies that should be used to reduce both NO_x and NH_3 emissions, including various combustion and engine standards for NO_x, and a selection of mandatory measures to reduce ammonia emissions from agriculture. It should be noted that these texts represent the first time that Europe has set limits on ammonia emissions, and as such the ammonia ceilings are easily achievable for most countries. Both the Gothenburg Protocol and the NECD are being considered for future revision and the possible adoption of more ambitious targets (i.e., national ceilings) and requirements to adopt low emission technologies.

Although it is recognized in both instruments that the prime focus is on reducing transboundary transport and deposition, in practice it is difficult to separate deposition of local and transboundary origin. In general, a country reducing its emissions will be one of the largest beneficiaries of this action. On the other hand, the NECD and Gothenburg Protocol are not specifically designed to target the ***local*** reduction of emissions and environmental impacts. Thus, in meeting a national emission ceiling, it is still possible that source activities continue immediately adjacent to, and cause large local impacts on Natura 2000 sites.

Integrated Pollution Prevention and Control (IPPC, 96/61/EC and 2008/1/EC)

The EU Directive on Integrated Pollution Prevention and Control (IPPC) provides a contrasting emphasis to the NECD and Gothenburg Protocol. Rather, IPPC outlines a regulatory regime for an extensive list of specified industrial activities. Individual sources, described as ‘installations’ must obtain a permit to operate, based on the operation of Best Available Techniques (BAT) to reduce emissions.

The Directive is integrated to the extent that a wide range of emitted pollutants are specified, as well as noise, odour and losses to water. Many industrial activities are specified, which provides a means to reduce NO_x emissions. The main challenge in relation to nitrogen emissions has been the inclusion of agricultural emissions into such an ‘industrial’ regulatory regime for the first time. For this purpose, pig and poultry farms over certain size thresholds must operate according to BAT, which have been defined in extensive BAT Reference documentation (BREF, 2003). Currently, the thresholds are set at installations with more than 40,000 bird places for poultry, more than 2,000 fattening pigs or more than 750 sows.

As part of recent review of the IPPC directive, discussions have focused on possible lowering of these thresholds and inclusion of large cattle farms in the directive. For example, the body-mass and nitrogen excretion rates between poultry types are very different, and it could be justified to have a more diverse set of thresholds, e.g. with lower thresholds for large birds like turkeys and higher thresholds for small birds like pullets. These differences are illustrated in Figure 7.3, which shows the estimated annual total nitrogen excretion for farm installations according to different animal numbers, as well as estimated rates of total ammonia emission. In this graph, bars are also shown for farm level values of N excretion and ammonia emission for cattle farms according to different size classes. For all three of the farm size thresholds indicated, overall N and ammonia emission is at least as large as the amounts for the existing IPPC thresholds. It may be noted that the ammonia values for cattle in Figure 7.3 are relatively smaller than those for overall nitrogen. This is because this graph is calculated for UK conditions, where it is assumed that cattle spend roughly half of the year outdoors, where ammonia emissions are much smaller than for housed livestock (which contribute to emissions through housing, manure storage and manure spreading).

For the livestock sector, a particularly strong emphasis was given to the consideration of ammonia emissions in the definition of BAT (BREF, 2003). In addition to requiring practices in animal houses, which have been clearly specified, BAT was also defined for the land spreading of pig and poultry slurries and solid manures. For example, the Technical Working Group (TWG) agreed that default use of a ‘splash plate’ spreader system (the reference method) did not constitute BAT (BREF, 2003). However, the TWG was unable to reach consensus on fully defining what BAT would be for these systems. For example, low emissions spreading techniques listed as Category 1 (well suited methods) by the UNECE (2001), such as band spreading and slurry injection, were not specified as being BAT, possibly because at that time (discussions up to 2002) countries had limited experience of these methods. Most focus was placed on discussion about the maximum time before applied manure should be incorporated for arable land.

In addition, the debate continues on the extent to which manures generated by IPPC regulated farms are considered in different Member States as regulated through their entire life cycle. It seems that the potential remains for manures generated on IPPC regulated farms to be passed to other landowners, where BAT measures would not be required. For example, this could include uncontrolled manure spreading to land (and the associated peak ammonia emissions) immediately adjacent to sensitive SAC habitats.

The debate on whether to extend IPPC to cattle appears to have focused on agreeing an acceptable number of permits across Europe, from which a farm size limit could be defined. This process led to a rather large farm size threshold for discussion (e.g., ~600 cattle). The result was that this would only address a small percentage of the cattle farms in Europe, and it has therefore been argued that such an approach would not be worth the benefits. Discussions are ongoing and there are further points that should be considered. Firstly, cattle are the main source of ammonia emissions in Europe. Thus, even if only 10 per cent of the European cattle herd were included in IPPC, the emissions regulated would be of the same order as that from pigs or poultry. Secondly, the IPPC regime introduces a regulatory framework, requiring review and assessment in relation to other environmental issues. This means that where there is an application for an IPPC permit for a farm located near to an SAC or SPA, it must be assessed in relation to the provisions of the Habitats Directive (Article 6.3). IPPC thus provides an important mechanism to ensure that the objectives of the Habitats Directive are met. At present, it seems that cattle farms often operate without a requirement for environmental impact assessment. Inclusion of the largest cattle farms would therefore ensure that such assessment could be made, supporting the Habitats Directive.

Environmental Impact Assessment Directive (97/11/EC)

The Environmental Impact Assessment Directive specifies conditions where environmental assessments of new plans and projects should be made, linking to planning policies in different

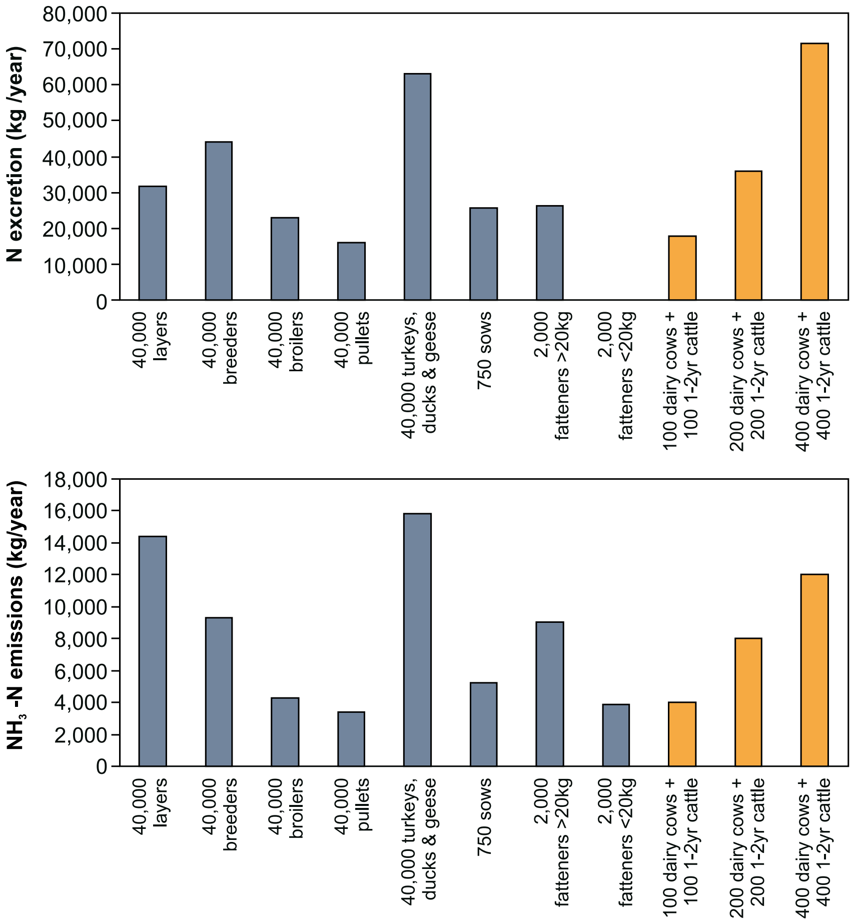

Figure 7.3: Comparison of overall nitrogen excretion rates and ammonia emissions for farm installations of different sizes according to numbers of different animals. The blue bars indicate current thresholds under IPPC, while the green bars indicate notional thresholds for cattle farms.

Member States. The EIA Directive includes a list of project categories that are subject to assessment (specified in the Directive Annex I), including oil refineries, power stations, motorways or express roads, widening of dual carriage ways of more than 10 km continuous length, waste disposal installations and quarries, open cast mining and peat extraction of over 150 hectares. It can be seen that many of these are relevant to ensure the assessment of NO_x emissions from combustion sources. The directive also includes thresholds for agriculture, 85,000 places for broilers, 60,000 places for hens, 3,000 places for production pigs (over 30 kg) and 900 places for sows. It is curious that the categories for animals broadly follow the IPPC directive, but with higher thresholds. Since assessment would already be required for IPPC installations, the intention of these higher thresholds is not clear.

The Directive also specifies a second list of activities (Annex II), for which assessments are required on a case-by-case basis according to thresholds to be set by Member States under the guidance of listed selection criteria (Annex III). The list includes many other small industries relevant for NO_x emissions. For ammonia, the list includes waste treatment plants, sludge deposition sites, projects for the restructuring of rural land holdings and intensive livestock installations (where not included in Annex I). The selection criteria for Member States to identify projects requiring assessment (Annex III) includes the characteristics of the project in regard to pollution, cumulative effect with other projects and the environmental sensitivity of areas likely to be affected, including areas classified as protected under Member States' legislation (including the Habitats Directive; SPAs are specifically mentioned).

In principle, therefore, provisions are available in the EIA Directive requiring the assessment of effects of most projects causing NO_x and NH_3 emissions on SACs and SPAs. However, work is needed to evaluate the interpretation given to Annex II categories by Member States. In practice, it appears that many agricultural activities are not assessed in regard of their impact on Natura 2000 sites. In the UK this links to the idea that agricultural activities are in general not classed as 'development'. A more-clear enforcement of the requirement to conduct environmental impact assessments for Annex II listed agricultural activities could provide a lighter touch approach than the extension of the detailed regulatory regime of IPPC to include more farms. However, as Annex II allows Member States to set their own criteria, there remains the danger that many activities impacting on Natura 2000 sites would continue to operate without assessment.

Strategic Environmental Assessment (SEA) Directive (2001/42/EC)

The focus on the SEA Directive is the specification of environmental assessment for large scale plans and programmes. A list of conditions apply that require an EIA under this directive, including the requirement to inform other Member States of possible transboundary impacts of proposed plans or programmes.

Most importantly, the SEA Directive specifies that assessment should be made in relation to regional plans. Under Article 3, paragraph 2 is written:

> *"Subject to paragraph 3, an environmental assessment shall be carried out for all plans and programmes, (a) which are prepared for agriculture, forestry, fisheries, energy, industry, transport, waste management, water management, telecommunications, tourism, town and country planning or land use and which set the framework for future development consent of projects listed in Annexes I and II to Directive 85/337/EEC, ..."*

Here it should be noted that the Annexes to Directive 85/337/EEC specify an extremely long list of categories including (under Annex II): "1. Agriculture (a) Projects for the restructuring of rural land holdings,… (e) Poultry-rearing installations (f) Pig-rearing installations." Cattle and arable farming activities are not specified, and no size thresholds are stated.

This directive therefore has the potential to review the impacts of nitrogen emissions more widely, including both NO_x emissions from roads and NH_3 emissions from agriculture. For example, where a regional plan specifies an area as being targeted for agricultural activities rather than urban or other development, then it could be argued that this choice should be assessed in relation to the protection of the Natura 2000 network. Such assessments are urgently needed, especially since the N deposition threat to many SACs and SPAs will result from the cumulative effect of many farms (inc. small farms) from the surrounding region.

Other national legislation

It would be a large task to summarize all the other national legislation that exists which is relevant to support implementation of the Habitats Directive. Nevertheless, it would be useful to list examples during the workshop, in order to develop a fuller understanding of the variation between Member States.

In particular, as has been highlighted in the sections above, there appears to be a major loophole regarding the regulation and impact of ammonia emissions from agriculture on Natura 2000 sites. For example, under UK legislation, many agricultural activities are not considered part of ‘development’ legislation for the purposes of local planning policies. This may mean that a new animal house might be built or stocked without requiring planning permission, thereby avoiding assessment under the terms of the Habitats Directive.

Only in certain instances would such developments be assessed. For example, in the UK one public planning enquiry considered the siting of an agricultural dwelling in an area designated as ‘green belt’. In such an area, only ‘agricultural dwellings’ would be allowed (pending the requirement obtain planning permission). However, to be accepted as an agricultural dwelling, the applicant had to demonstrate a viable agricultural business (in this case a poultry farm). In fact, the farming activity itself required no permission (it was below the IPPC threshold), even though the site was immediately adjacent to a sensitive heathland SAC. The inspector noted that there might be a loophole in the legislation, i.e. were it possible to conduct the farm business without an associated dwelling. However, he concluded that such a possible loophole did not apply in this instance, since the dwelling and the farm needed to be considered together, and thereby tested in relation to Article 6(3) of the Habitats Directive. Considering, in particular, the short distance to the SAC (around 10 m), the proposal was refused (Frost, 2004). This example highlights that there will be many other instances of agricultural activities that go untested in relation to the Habitats Directive.

7.1.4 Future options for protection of Natura 2000 sites from long -range transported nitrogen deposition

Here we consider the potential for other approaches that could reduce the nitrogen deposition impacts to Natura 2000 sites, firstly from long-range transported N deposition and secondly (in the following section), from locally transported deposition in source regions. We give particular attention to the role of agricultural sources, as the issue of most concern.

Revision of the Gothenburg Protocol and NECD

Both instruments are currently undergoing development work in preparation for their potential revision. The establishment of new, more ambitious national ceilings would result in an overall reduction in nitrogen deposition from both nitrogen oxides and ammonia emissions. It is worth comparing the progress already made in reducing the emissions of pollutants regulated under the Gothenburg Protocol. Figure 7.4 distinguishes between countries in the EU and other Parties in the UN-ECE area. For the EU, the baseline reductions are largest for SO_2 (72 per cent reduction) and NO_x (53 per cent reduction), and smallest for ammonia (7 per cent reduction). The gap between Baseline and the Maximum Reduction specified by measures included in the RAINS model (MRR) is also largest for ammonia, highlighting that the current commitments for this pollutant are the lightest of the different pollutants considered.

Figure 7.4 shows that there is considerable potential for further reduction of ammonia emissions under revision of the Gothenburg Protocol, which would result a substantial decrease in the threat to sensitive Natura 2000 sites. At present the degree of ambition, both in terms of the national ceilings and in the technical requirements, remains a topic for future discussion among the Parties to the Convention.

In addition to the benefits for the Natura 2000 network and Europe’s natural environment as a whole, there would be substantial co-benefits from further reduction of nitrogen emissions under the Gothenburg Protocol. Both nitrogen oxides and ammonia contribute to particulate matter formation, which leads to significant life shortening across Europe, through respiratory and other illnesses. In the case of agriculture, nitrogen lost from the farming system as ammonia represents a waste of fertilizer N inputs. Given the high costs of fertilizer nitrogen, their sensitivity to oil price changes, and the energy consumed in nitrogen fertilizer production (2 per cent of world energy consumption), saving nitrogen in the system has the potential to save farmers money, make them less at risk to fertilizer price changes, and reduce energy consumption. Many other co-benefits can be expected. For low emission manure spreading this can include: increased agronomic flexibility, more accurate delivery of manure to crops, more accurate avoidance of spreading adjacent to surfaces to be avoided (near water courses, near SACs etc) and a reduction in odour emissions (see discussion by Webb *et al*., 2009).

Interactions between other community legislation and Natura 2000

The targets of the Gothenburg Protocol and the NECD are set using a modelling optimization approach that aims to minimize environmental effects, including those on ecosystems as specified using Europe-wide maps of critical loads, such as that illustrated in Figure 7.1. By contrast, the legislative commitments of these instruments are set as the combination of required technologies (e.g., Gothenburg Protocol annexes) and the national emissions ceilings. There is currently no legal commitment in these instruments that is directly related to an ecosystem protection target.

As a large scale 'plan', it might be argued that the even revision of the NECD should be assessed under the SEA Directive, meaning that the implications of revision must be assessed explicitly in relation to the possible threat to the Natura 2000 network. Potentially this could lead to a circular position where only a revision that was sufficiently ambitious to protect the Natura 2000 network fully could be adopted, but that this would be, at the same time, too ambitious to be acceptable by Member States.

More constructively, such interactions should be considered in relation to directives considering other objectives. For example, it is understood that new European animal welfare legislation will require a change in animal housing, leading to a phasing out of the traditional 'tied stalls' for housing of cattle. This will require a change to more open animal houses allowing free animal movement, which is its core objective. However, it is also expected that this change will increase ammonia emissions, leading to an exacerbated threat to the Natura 2000 network. Presumably, through the requirements of the SEA directive, the impact on Natura 2000 should to be assessed. Subject to the conclusions of any such review, it might therefore be expected that any move from tied stall to open barn would be accompanied by the requirement to adopt techniques to ensure that overall ammonia emissions from each farm did not increase.

Development of an effects oriented goal for nitrogen exposure to Natura 2000 sites

In order to better protect the Natura 2000 network, there is a need for the legal commitments to be set directly in relation to environmental goals. Thus the NECD achieves a general reduction in emissions, but it does not relate closely to the commitment to protect the Natura 2000 network. For this purpose, critical loads (as already used by SEBI, 2010) and critical levels could be used to set a ***nitrogen target for Natura 2000 protection*** across Europe and for each Member State. Such a target could be expressed as:

> *"A long term goal to ensure that 95 per cent of Natura 2000 designated sites do not exceed critical loads or levels for reactive nitrogen compounds by 2030".*

The details would need debate, including the 95 per cent number and the target year, but the principle should be clear. It may be noted that this goal is phrased as the per cent number of designated sites,

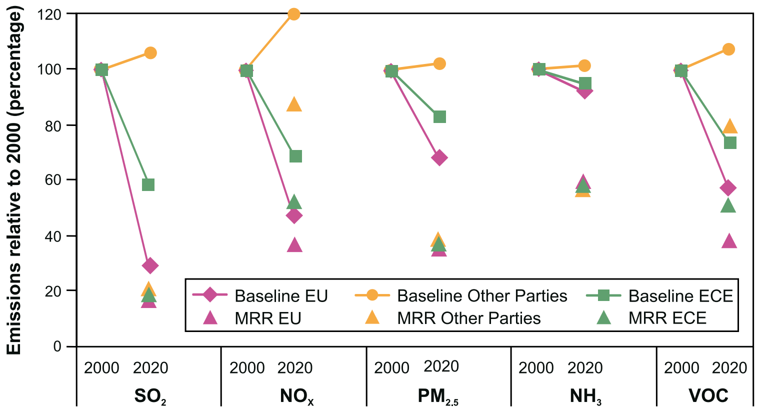

Figure 7.4: Comparison of baseline projections in emissions between 2000 and 2020 with the maximum rains reduction (MRR), which relates to full implementation of measures currently considered within the RAINS model. The distinction is made between countries of the EU (i.e. linked to NECD projections) and other parties to the UN-ECE Convention on Long Range Transboundary Air Pollution. The Gothenburg Protocol did not include explicit commitments for particulate matter ($PM_{2.5}$), but it is currently proposed to include this in the protocol revision (Amman, 2009, pers. comm..).

rather than the per cent area of the overall Natura 2000 network. This is important, since it could be argued that each SAC or SPA designation is of equal value to society. For example, a large SAC may occur in a very remote area, where there is no shortage of land, while a small SAC may occur as a priority for protection in a landscape under high human pressure. In an analysis for the UK presented by Hallsworth *et al*., (this volume; Hallsworth *et al*., 2011), it is shown that there is a tendency for small SACs to occur in the most polluted areas. Finally, loss of integrity over any part of an SAC may be considered as a threat to the integrity of the whole. For this reason, Hallsworth *et al*., (2009) calculated the per cent number of SACs where the critical level was exceeded over some part of the each SAC (Designation Weighted Index, DWI). They compared this with the total area of SACs exceeded in the country (Area Weighted Index, AWI). Using ammonia critical levels of one µg m^{-3} (ecosystems with relevant epiphytes) and two µg m^{-3} (precautionary value for higher plants on Natura 2000 sites), they concluded that 11 per cent and 1 per cent of the area of the UK Natura 2000 network (AWI) exceed the critical levels, respectively. By contrast, 59 per cent and 24 per cent of Natura 2000 sites (DWI) exceed the same critical levels (Hallsworth *et al*., 2009). The AWI approach did not provide an appropriately precautionary measure because of: a) the anti-correlation between NH_3 concentrations and area of each SAC and b) the failure to consider variation in NH_3 concentrations across SACs. These last points can be seen clearly in Figure 7.5.

Co-benefits of planting trees and other low-nitrogen biomass

A rather different regional scale approach to reduce impacts of reactive nitrogen deposition and concentrations on Natura 2000 sites is through the application of land use policies. For example, such policies are already discussed in relation to carbon sequestration under the Kyoto Protocol, i.e. allowing credit for increasing carbon sinks in planted forests (Article 3.3).

In the context of carbon sequestration, it has recently been discussed whether a certain amount of N deposition would be beneficial in increasing forest C uptake rates (Hogberg, 2007; Magnani *et al*., 2007, de Vries *et al*., 2008, Sutton *et al*., 2008). Of course it must be recognized that such potential benefits must be balanced against increases in nitrous oxide emissions and impacts on biodiversity, water quality etc. (De Schrijver *et al*., 2008).

In the present discussion, however, the point of interest is that increasing forest area will lead to a decrease in atmospheric nitrogen concentrations and deposition to other receptor ecosystems. The reason for this is that forest land (and other unfertilized tall biomass crops) scavenges nitrogen compounds (especially ammonia, nitric acid and particulate matter) through dry deposition more effectively than short, fertilized agricultural land. A larger area of woodland therefore results in faster removal of these compounds from the atmosphere to these surfaces, resulting in less being available for deposition elsewhere. Policies of extending forest area based on this principle therefore have the potential for substantial co-benefit between carbon and nitrogen impacts. The idea of urban forest plantations has also been considered in relation to its benefits for human health, through reducing particulate matter concentrations (McDonald *et al*., 2007).

Theobald *et al*., (2004) examined scenarios of forest planting in the UK, showing that these had potential to give significant reductions in ammonia deposition to existing forests and to other semi natural land, such as heathlands. However, they pointed out that the location of the forest plantings is important in this context, as these should be made in the areas with highest nitrogen emissions and deposition. Planting a forest in a remote area with very low nitrogen deposition would lead to little benefit. Such policies should also be considered in relation to their local implications, for example in the establishment of buffer-zones (Section 5.2).

It should be examined whether this link between carbon and nitrogen policies could be made at a European scale. For example, it should be considered whether the benefits of Article 3.3. forests under the Kyoto protocol could also be considered as 'nitrogen emission credits' under the terms of a revised NECD.

Patterns of societal behaviour

It should briefly be noted that the directives discussed focus mainly on technical changes, whereas the overall burden of nitrogen emissions is a result of a much wider set of societal choices. For example, the choices of individual European citizens determine their energy consumption (emissions through electricity generation), their annual vehicle mileage and (emissions from transport) and their consumption of animal products (NH_3 emissions from livestock agriculture). A great deal of effort is currently placed on educating the public in their energy and transport choices, particularly to reduce carbon footprints. In parallel, much more thinking needs to be done to consider how to optimize European dietary choices for both human health and the environmental consequences. Such societal chances have a huge potential to influence European scale emissions of reactive nitrogen, thereby affecting the transboundary transport and deposition of nitrogen to Natura 2000 sites.

7.1.5 Future options for protection of Natura 2000 sites from short-range transported nitrogen concentrations and deposition

While the above policy interactions have the potential to affect transboundary fluxes, they do not directly address the problems of short range transport to Natura 2000 sites in source areas, with these often being the sites under the most extreme threat. Options for further development include strengthening the links with cross-compliance in agriculture, spatial planning including buffer zones and the application of air concentration objectives and local air quality management for ecosystems.

Strengthening the cross-compliance links for Natura 2000

One of the principles of European agricultural financial support (i.e., the single farm payment system) is that the payments are made to farmers under the principle of cross compliance. This includes two requirements:

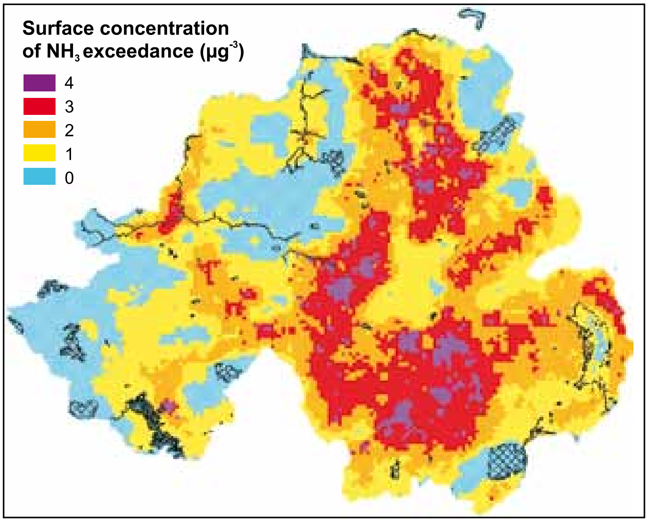

Figure 7.5: Spatial pattern of NH_3 concentration and the location of Special Areas of Conservation (SACs) in Northern Ireland (1 km resolution FRAME model estimates calibrated against UK measurement network). Although many of the largest SACs do not exceed the lowest critical level (1 μg m^{-3}), substantial exceedance is seen for the smaller sites. 22 per cent and 5 per cent of the area of SACs in Northern Ireland exceed the 1 and 2 μg m^{-3} critical levels, respectively (Area Weighted Index, AWI), however, 74 per cent and 42 per cent of the SACs exceed the same critical levels over part of their domain (at 1 km^2 resolution, Designation Weighted Index, DWI). The DWI is considered the legally correct approach under the terms of the Habitats Directive (Hallsworth *et al.*, 2009a,b). Moninea Bog is located ~2 km from the SW border (1-2 μg m^{-3}, area ~1 km^2).

- ***statutory management regime***: that farmers are in full compliance with existing legislation relating to their farm and the environment. For example, farmers need to comply with the Nitrate Directive, the Habitats Directive and any other relevant legislation. This requirement applies equally across the European Union.
- that farmers maintain land in ***good agricultural and environmental condition***, primarily relating to the condition of the farmland itself, but also with implications for off-site losses, e.g. avoidance of manure spreading adjacent to water courses. This requirement is delegated for each Member State to define.

The implication of cross-compliance is that, in principle, any farmer in receipt of a single farm payment should already have demonstrated that they have no adverse impact on Natura 2000 sites. In practice, it should be asked to what extent such links are currently made between different Member States. The impression is that, at present, this link is not adequately treated and that further guidance needs to be developed on: a) general rules for avoiding impacts on Natura 2000 sites through N concentrations and deposition, b) specification of suitable impact assessment approaches, including cost-effective methods applicable for small farms.

It is worth noting that, even under the previous system of agricultural area support payments, the principle of cross-compliance already applied. However, in practice the linkages seem to have been rarely enforced. This highlights the challenges involved in developing these linkages for the future.

Spatial planning, including buffer zones

Spatial planning has a significant role to play in reducing the impacts of nitrogen deposition and concentrations on the Natura 2000 network. In landscapes with large N emissions (source areas), the amount of N deposited to a sensitive site is very closely linked to the distance from major nearby emissions. This is for example, clearly shown for Northern Ireland (Figure 7.5), where the patterns of ammonia concentration (modelled at one km resolution) closely match to the mapped ammonia emissions.

In the Netherlands, policies were already established some years ago whereby manure from areas with high ammonia emissions was transported to areas with low emissions. Naturally, this resulted in an increase in ammonia concentrations in the cleaner areas, which caused some debate as to the benefits of the policy (see, Bleeker and Erisman, 1998). However, if the priority is to protect those areas most under threat and the other areas were established as a) less under threat and b) of lower priority for nature conservation, then the policy remains logical. If such policies should be considered more widely, a clear agreement on the relative priorities would need to be established from the outset. This poses a challenge for the wider objectives of the Habitats Directive, which seeks to maintain conservation status of habitats and species across Europe as a whole, including sites not designated as Natura 2000.

Local spatial planning policies, including the use of buffer zones have the potential to be much less controversial, and are already established for other effects, such as the use of buffer zones adjacent to water courses. In the case of nitrogen emissions to air, such buffer zones could be appropriate both for nitrogen oxides emissions from roads and for ammonia emissions from agriculture. Three aspects to such buffer zones should be considered:

- increasing the distance from the source, allowing greater dispersion before the air reaches the sensitive area, such as an SAC,
- increasing the dispersion between source and receptor, such as by planting tall rough vegetation, further diluting the pollutant before it reaches the sensitive area,
- encouraging deposition between the source and receptor, such as provided by planting tall vegetation as a buffer zone.

In practice, the first two benefits are expected to be most important for narrow buffer zones of a few 10s of metres. For the third benefit, planting a single row of trees would have a trivial effect in removing ammonia from the atmosphere, for which purpose wide tree belts of >100 m would be required (see Theobald *et al*., 2004, Loubet *et al*., 2009). As dry deposition rates for NO_x are very small, only the first two benefits would apply for this pollutant. Enhanced nitrogen deposition adjacent to major roads is due to both NO_x and NH_3 (Cape *et al*., 2004), due to catalytic converters increasing NH_3 emissions compared with cars without converters. Hence broad woodland plantings adjacent to roads could achieve all three benefits.

Dragosits *et al*., (2006) considered the potential for tree plantings to reduce nitrogen deposition to a landscape in the UK. For example, they showed how tree plantings both adjacent to farm sources and to the nature reserve sinks could lead to significant reductions in deposition (Figure 7.6). They also investigated the potential of other buffer zones, for example, the avoidance of manure spreading and urea application up to 100 m, 300 m and 500 m from the nature reserves. These scenarios led to smaller benefits, mainly because in their model scenario, overall emissions were dominated by farm point sources (including a large poultry farm). Such buffer zones would, however, have significantly reduced peak ammonia concentrations on the nature reserves immediately after manure spreading.

The same authors addressed the effect of location of the major point source. The scenarios shown in Figure 7.7 indicate that there are significant benefits, even if the farm is located one km further away from the reserve, to the west in this example. At a distance of three km, the farm makes a relatively minor contribution to deposition at this the nature reserve site, as shown by comparison of the scenario with the farm removed.

The use of buffer zones therefore has a high potential for further policy development to protect Natura 2000 sites from nitrogen deposition in source areas. In particular, the approach has the advantage that rather simple distance rules could be set for the avoidance of different sources, e.g., farm buildings or of manure spreading activities. For example, rules might be established that up to 300 m from a sensitive SAC (effectively at least one field distance), slurry and urea were not spread to agricultural land (or not unless a high abatement efficiency technique was applied, such as immediate ploughing in).

Air concentrations objectives and local air quality management for ecosystems.

Under the Air Quality Directive (AQD) (2008/50/EC), ambient air standards have been set for NO_x (expressed as NO_2), SO_2, O_3 and particulate matter, with the prime focus on protecting human health from air pollutant exposure in the urban and industrial environments. However, the directive also includes critical levels for SO_2, NO_x and O_3 set for the protection of vegetation.

A major tool that was widely used in previous air quality directives, and has been continued in the AQD is the establishment of objective concentrations linked to local Air Quality Plans, or local air quality management (LAQM). There is a requirement for local authorities to regularly review and assess air quality in their area against the standards and objectives prescribed in regulations.

When these objectives are not being achieved, or are not likely to be achieved within the relevant period an Air Quality Management Area (AQMA) must be designated. Once this area has been designated the local authority must develop a remedial Action Plan to improve air quality in that area. The local authority should define the boundaries of the AQMA, communicate the implications to the local community and statutory consultees and coordinate with neighbouring authorities regarding possible adjacent AQMAs.

Given the existing commitment under the Habitats Directive, such an approach would be applicable for the protection against ecological effects on Natura 2000 sites. For this purpose, existing critical levels for NO_x (ICP Modelling & Mapping, 2004) and NH_3 (UNECE, 2007; Sutton *et al.*, 2009) could be used as the starting point for defining objective concentrations.

The actual values set for this purpose would presumably depend on the balance of ecological risk versus costs, as negotiated between the Member States. For the purpose of ecosystem protection, the main focus could be in relation to annual mean concentrations, based on monthly sampling (also ensuring that certain peak monthly concentrations are not exceeded). Since daily fluctuations in NO_2 and NH_3 are not considered important from an ecosystem perspective, this would reduce the costs of the measurements required, because passive sampling methods could be used (where shown to be reliable).The following approach might be taken:

- Establish NO_x and NH_3 concentration objectives that apply in air over the surface of Natura 2000 sites (e.g., measured at 1-2 m above ground). The main focus should be on annual values, but monthly averaged maxima should also apply.
- National modelling is used to assess whether the NO_2 or NH_3 objectives are exceeded over all or part of the domain of a Natura 2000 site.

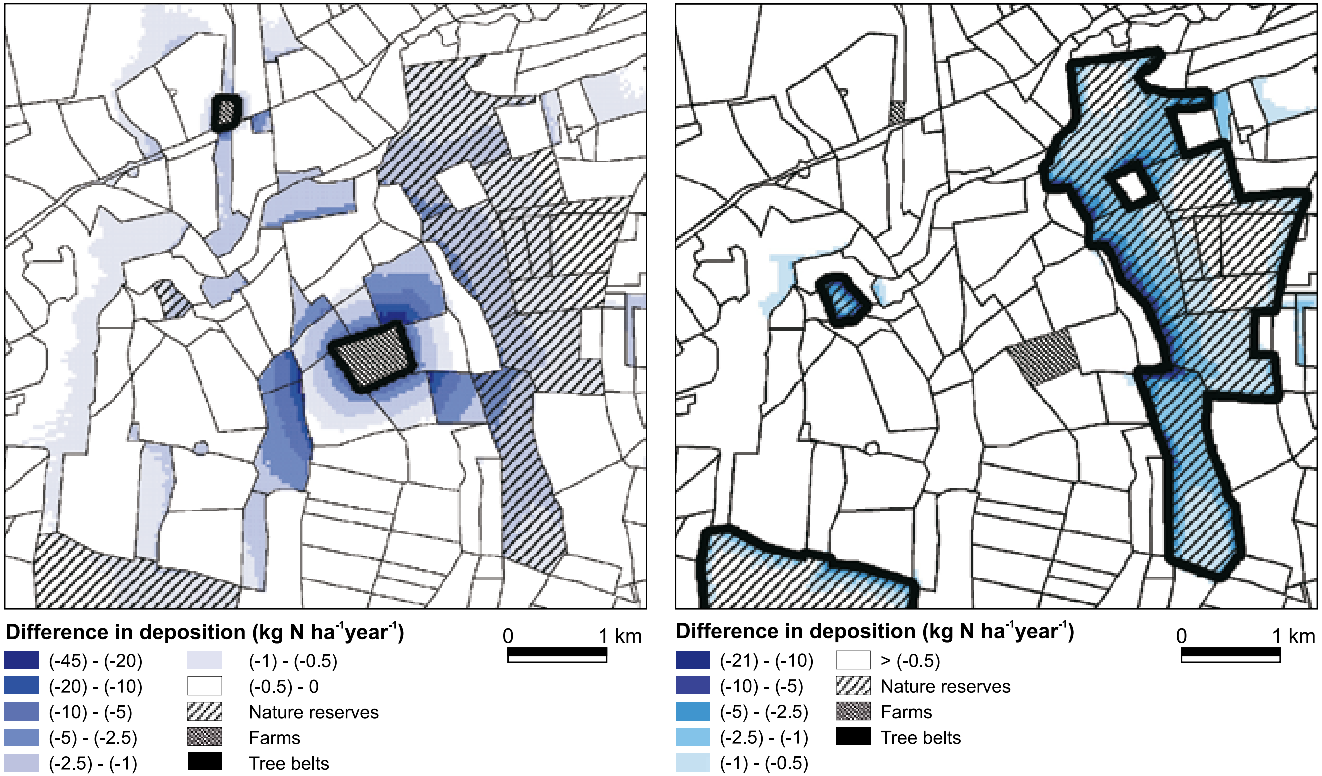

Figure 7.6: Landscape-level scenarios illustrating the effect of woodland buffer zones on atmospheric nitrogen deposition to three nature reserve areas. On the left, the scenario consisted of adding a 50 m wide buffer of trees planted around two farms (a small beef farm, and a large poultry farm). On the right, the scenario represented the adding of a 50 m wide buffer of trees around each of the nature areas. The maps show the reduction in N deposition compared with the base run. Both scenarios demonstrate significant benefits (Dragosits *et al.*, 2006).

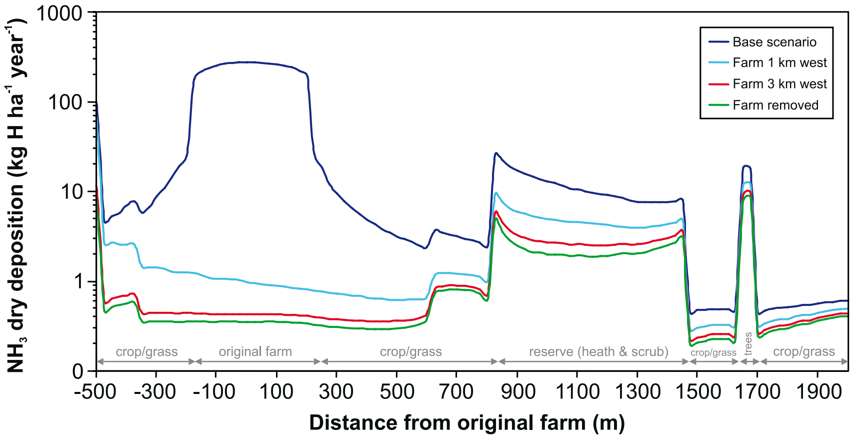

Figure 7.7: Modelled transect of atmospheric nitrogen deposition due to ammonia assuming a base situation and three scenarios related to the location of a major point-source livestock farm (Dragosits *et al.*, 2006). The reserve area could be considered as an SAC or SPA.

- Local screening models are applied to identify the locations on the Natura 2000 site that are most at risk of exceeding the NO_2 or NH_3 objectives.
- Atmospheric monitoring is conducted at the locations identified in c) for at least one year (using monthly sampling with robust passive sampling methods).
- If the objective concentrations are not exceeded, no action needs to be taken. If the objectives are exceeded, then a local management plan should be established that specifies a course of action by which they would be reduced.

Such an approach would necessarily need to be backed up by a clear set of legislative and voluntary tools to achieve the concentration objective values, and thereby reduce the impacts to Natura 2000 sites. The potential to link this to the existing Articles 6.1 and 6.2 of the Habitats directive should also be considered.

7.1.6 Conclusions

This review has identified that atmospheric nitrogen deposition and the associated concentrations of reactive nitrogen represent a significant threat to the Natura 2000 network. The evidence is that the application of existing policies is not currently adequate to protect these flagship sites for the protection of Europe's biodiversity. Many sites exceed critical levels and loads, with consequent adverse ecological effects.

It is concluded that the nature of the nitrogen deposition problem for biodiversity can be distinguished into: a) reducing long-range transboundary air pollution and b) reducing short-range pollution impacts in source areas. While policies addressing the first, e.g. NECD, will have some benefits for the second, they are not specifically targeted for this purpose, with the result that many local impacts can still be expected. To reduce the impacts on Natura 2000 sites in source areas requires a specific set of policies designed for this purpose.

In comparing NO_x and NH_3 emissions, it is clear that there is a much greater regulatory control over the NO_x emissions. This is reflected in a significant reduction in baseline estimates of European NO_x emissions over 2000-2020. By contrast, there has been hardly any reduction in NH_3 emissions, which mainly arise from agriculture. This difference is reflected in the current degree of attention to reducing NH_3 emissions in existing policies. Although requirements are included in both the

NECD and IPPC Directives, these represent the first such agreements, and consequently the current ambition levels are rather modest.

In regard of the impacts on Natura 2000 sites, the existing commitments of the Habitats Directive should afford a high level of protection. In practice, this intended degree of protection is not achieved, in particular, because many sources of NH_3 continue with little regulation.

At the regional scale, there is potential for more effective protection of the Natura 2000 network through revision of the NECD and the IPPC Directives. In addition, there is substantial scope for revision or more rigorous enforcement of the Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) Directives. For example, extending the provisions of the EIA Directive to include other farms could provide a light touch approach for these farms that would avoid the full regulatory regime of IPPC. Secondly, under the SEA Directive, the implications of regional plans on ammonia emissions need to be tested in relation to the terms of the Habitats Directive. Similarly, the effect of other proposed legislation (e.g., animal welfare legislation causing increased NH_3 emissions) needs to be tested in relation to the Habitats Directive.

New approaches that should be investigated include an effects-oriented goal for N effects on Natura 2000, the linking of carbon sequestration and nitrogen deposition benefits in forest planting policies (linking Kyoto Article 3.3 and NECD revision) and approaches that help foster reduced nitrogen consumption by European citizens. Approaches that include the assessment of ecosystems services, such as carbon sequestration, could highlight important positive and negative effects of nitrogen deposition on Natura 2000 sites that could provide an added incentive for actions to protect sites.

Much more effort needs to be given to managing the local impacts of nitrogen deposition and concentrations on Natura 2000 sites in source areas. This could include strengthening the enforcement of existing cross-compliance links between single-farm payments and impacts on Natura 2000 sites, coupled with the development local spatial planning measures, including guidance on buffer zones for atmospheric N deposition. Finally, substantial focus has been given to developing local air quality management under the EU Air Quality Directive, linked to human health protection. Currently, no such system is in place for ecosystem protection. A combination of establishing objective concentrations for NO_x and NH_3, together with a system of local air quality management for ecosystem protection would provide a suitable approach. By integrating ecosystem-level air quality management with some of the options mentioned above, a more rigorous approach could be developed that matches to the existing commitments under the Habitats Directive.

7.1.7 Key questions for discussion

- Have Natura 2000 sites been assessed for the risk of N deposition in your country?
- Are sufficient policies in place to protect Natura 2000 sites, and if so are they being adequately implemented and enforced?
- Do you see a need for further policy development in this area?
- To what extent do you agree that the procedures needed to protect from NO_x emissions are largely in place?
- Do you agree that the challenges to protect Natura 2000 sites from nitrogen deposition and concentrations are greatest for the impacts of agricultural ammonia emissions?
- To what extent do you think that existing legislation could be enforced more effectively to protect the Natura 2000 network?
- How important do you rate the usefulness of high level goals, e.g., "***A long term goal to ensure that 95 per cent of Natura 2000 designated sites do not exceed critical loads or levels for reactive nitrogen compounds by 2030***", as compared with the application local level policies?

- What are the other possible approaches that have not been discussed in this document?
- If you were to develop a package of measures to protect Natura 2000 sites from nitrogen deposition, what would you consider to be the most suitable elements?
- How might such a package be expected to differ when viewed from different viewpoints (scientific, administrative, policy, political, industry, conservation etc.)?
- How should such a package be considered in relation to wider objectives of the Habitats Directive to maintain Europe wide conservation status, including areas outside the territory designated as Natura 2000 sites?
- Would an assessment of ecosystem services provided by Natura 2000 sites be a help or a hindrance to policy development for their protection?

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7.2 Working group report

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7.2.1 Conclusions and recommendations of group discussions

Overview of current situation with regard to nitrogen deposition impacts to Natura 2000 sites

Regarding the current policies and their adequacy for the protection of Natura 2000 sites from the threat of nitrogen deposition, the workshop concluded that:

- The Natura 2000 network remains under threat from atmospheric nitrogen deposition despite the Habitats Directive affording it a high level of protection.
- Atmospheric nitrogen deposition is a Europe-wide problem but with very high spatial variability in severity of impacts and a high variability in national policy responses.
- Natura 2000 sites are not routinely assessed for the risk of nitrogen deposition effects and present policies and /or their enforcement are not sufficient.
- A lack of awareness of the nitrogen threat is the main problem in many Member States.
- Ammonia emissions present the greatest policy challenge in Europe.
- There is currently insufficient linkage between biodiversity and air pollution policy development.
- Economic and conservation priorities clash particularly in countries with significant levels of nitrogen deposition.

Recommendations for policy development

The role of existing legislation
It was recommended by the working group that:

- Those Member States that have advanced policies integrating several legislative instruments could provide practical advice for other Member States.
- International agreements (NEC Directive and Gothenburg Protocol) should have a higher level of environmental ambition (especially for ammonia), in particular to improve protection at local scale.
- Exceedance of critical loads (including in Natura 2000 sites) should be more explicitly considered in optimization of abatement measures.
- Ammonia should be included in the Air Quality Directive (2008/50/EC) and there is potential for setting standards for annual mean concentrations of ammonia to protect ecosystems.
- The potential for 'cross compliance' of different legislative measures to address nitrogen deposition issues should be more actively promoted.
- All existing projects should be captured by Article 6.3 of the Habitat Directive.

Future options for protection of Natura 2000 sites
The working group discussions captured the following suggestions and recommendations:

- Legislation at both regional and local scales is needed, including measures to deal with within-country atmospheric transport.
- Policies and procedures should be considered that distinguish between the management of nitrogen oxides and ammonia, and to address the role of organic nitrogen compounds emitted to the atmosphere.
- It is recommended that new approaches are explored in future policy development to complement existing approaches to managing the nitrogen deposition threat in relation to Natura 2000 and the wider objectives of the Habitats Directive, including:

    – Multi-media regional reactive nitrogen ceilings, limited by the most sensitive N_r species and effect, should be explored as a basis for further policy development. This approach could enable the optimization of all nitrogen emissions of a region in relation to the adverse impacts;
    – Nitrogen reduction plans could include a long-term plan to attain critical loads on a regional level in countries with high levels of exceedance;
    – Spatial Planning (operated at local and regional levels) can optimize the location of existing pollution sources to minimize the overall threats, exploiting where possible landscape structures to buffer impacts (including buffer zones and tree belts);
    – Nitrogen impact assessment techniques should be further developed to take into account the objectives of the Habitats Directive more specifically;
    – The Ecosystem Services concept may provide a holistic framework for examining the links between air pollution effects on ecosystems and human well-being.

- The following specific measures were recommended for further consideration:

    – Improve ammonia coverage in the Intergovernmental Panel on Climate Change (IPCC), i.e. include manure spreading, consider the current farm size thresholds and inclusion of cattle;
    – Set strict emission limits and management obligations to encourage abatement technology development;

- Strategic Environmental Assessment (SEA) has a role to play at high level planning for pollution abatement;
- Develop and encourage non-technical measures (societal behaviour);
- Consider establishing a high-level goal as part of a package of actions, for example to ensure that 95 per cent of Natura 2000 designated sites do not exceed critical loads or levels for reactive nitrogen compounds by 2030.

7.2.2 Introduction to the structure of discussions

The working group started its discussions by considering the key questions presented in Sutton *et al.,* (this volume). To facilitate structured discussions the working group decided to order key questions with similar themes into the following groups:

- Are sufficient policies in place? (Questions: 1, 2, 3 and 6 from Sutton *et al*, this volume)
- Do existing policies adequately cover oxidized and reduced nitrogen? (Questions: 4 and 5)
- Local versus regional policy, and the usefulness of an overall goal (Question: 7)
- New approaches (Question: 8)
- Most suitable approaches (Questions: 9, 10 and 11)
- Ecosystem services (Question: 12)

Working group members and members from other groups were invited to share their experience of nitrogen deposition and Natura 2000 network issues in their country of residence. These presentations are presented as supporting papers in Sections 7.3 to 7.7.

7.2.3 Highlights of discussion and views expressed

Are sufficient policies in place? (Questions: 1, 2, 3 and 6)

The working group agreed that there is various legislation and policy in place that can address nitrogen emissions and impacts across Europe but that it is not consistently applied in all Member States.

It was agreed that the most pronounced nitrogen deposition problems for Natura 2000 sites are in NW Europe. However, nitrogen deposition also affects biodiversity in other areas, and it is crucial that improvements to policy implementation are made in all areas with significant nitrogen deposition. “Significant” could be defined as “above the critical load”.

Many EU Member States are active in implementing measures to protect Special Areas of Conservation (SAC) sites, designated under the EC Habitats Directive, and Special Protection Areas (SPAs), classified in accordance with the EC Directive on the Conservation of Wild Birds. The consensus view was that more ambition needs to be realised in respect of nitrogen deposition. Several ways of doing this were explored by the group:

- International agreements could have a higher level of environmental ambition to help reach local targets, and decision makers and polluters could be made more aware of the benefits. In this respect the National Emission Ceilings Directive (NECD) and the Gothenburg Protocol to the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) are very important as countries are unlikely to be more ambitious than what is needed to fulfil the Directive/Protocol emission reduction obligations at national levels. The consensus was that National Emission Ceilings should be much more closely tied to the conservation status in the Member / Signatory States (Sections 7.1; Sutton *et al*., this volume).
- The policy process at regional level could be optimized by an ***ex post*** analysis to see how scenarios fulfil effects targets. This is being done within the CLRTAP in the Gothenburg

Protocol revision process. The European Union should consider using and extending these methodologies to focus specifically on Natura 2000 sites (Sutton *et al*., this volume).

- The Integrated Pollution and Control (IPPC) Directive could be expanded, e.g. to include cattle and manure spreading, although this route may not be the most suitable for small farmers[1]. It was also suggested that the Environmental Impact Assessment (EIA) Directive could cover this without the full burden of IPPC approach. The IPPC Directive is a good tool for nitrogen management as it can introduce more efficient nitrogen use through Best Available Techniques (BAT) (see Section 3 of Sutton *et al*., this volume).
- Under the Air Quality Directive there is potential for setting standards for annual mean concentrations of NO_x and NH_3 to protect ecosystems (Sutton *et al*., this volume).
- The EU Environmental Liability Directive (2004/35/EC) that aims to 'establish a common framework for the prevention and remedying of environmental damage at a reasonable cost to society…' covers air pollution and could potentially be linked to the protection of Natura 2000 sites from N deposition.
- Existing projects are not always included in site assessments; both existing and future developments need to be assessed together.

As well as the value of individual measures the importance of cross-compliance was highlighted, with an emphasis on assessing the willingness to apply existing or new measures and the potential for enforcement. For instance, the advantages of farms taking an integrated approach to applying legislative requirements is clear but the mechanisms needed to do this efficiently are currently lacking. This situation could be improved by more integration of directives under DG Environment (e.g. Habitats Directive and NECD) such as integrated policy to lower background nitrogen deposition.

Oxidized versus reduced nitrogen (Questions: 4 and 5)

The working group recommended that increased emphasis be given to considering policies and procedures that distinguish the management of nitrogen oxides and ammonia:

- The procedures needed to protect sites from NO_x emissions are largely in place in many Member States. While this can be considered a success, it does not mean there is no need for further reduction in NO_x emissions;
- The challenges concerning agricultural ammonia emissions, which are under-regulated across most Member States, are much larger. In most cases, agricultural ammonia emissions are not assessed in relation to their impacts on the Natura 2000 sites;
- Agricultural activities are also thought to emit various organic nitrogen compounds to the atmosphere. These have seldom been assessed and represent a potentially significant additional threat to Natura 2000 sites that requires further quantification.

Local versus regional policy and the usefulness of an overall goal? (Question: 7)

This question was articulated as 'how important do you rate the usefulness of high level goals, e.g., "***A long term goal to ensure that 95 per cent of Natura 2000 designated sites do not exceed critical loads or levels for reactive nitrogen compounds by 2030***", as compared with the application of local level policies?'

There was consensus that this type of target would be a very useful high level policy goal (equivalent to the preamble of Gothenburg Protocol or NECD). It was also proposed, as discussed

1 Note: the IPPC Directive has meanwhile been recast as the Industrial Emission Directive. It includes neither cattle nor manure spreading, but it calls for a review by the European Commission by 31 December 2012 on the need for emission controls on these sources.

in the background document on N policies (Section 4.3 Sutton *et al.*), that any target should be defined as the per cent number of designated sites, rather than the per cent area of the overall Natura 2000 network (see Hallsworth *et al.*, this volume). This is important, because each site contributes to conservation status of habitats and species listed under the directive.

New approaches (Question: 8)

The working group recommended that several new approaches are explored in future policy development to complement existing approaches to managing the nitrogen deposition threat in relation to Natura 2000 and the wider objectives of the Habitats Directive:

- Multi-media regional reactive nitrogen (N_r) ceilings, limited by the most sensitive nitrogen species and effect, should be explored as a basis for further policy development. This approach could enable the optimization of all nitrogen emissions of a region in relation to the adverse impacts.
- As already proposed a few years ago (see e.g. http://asta.ivl.se/Saltsjobaden3.htm, Conclusions of Group 5), N_r produced in an area enters the soil, water or air and it is therefore theoretically possible to set critical loads / limits based on the sensitivity of ecosystems affected by these fluxes. The use of thresholds gives the opportunity to spatially integrate the effects using modelling approaches potentially including fluxes of reduced and oxidized nitrogen to air, soils and water. Spatial scaling could be attempted linked to the thresholds but a major challenge would be to balance the sources and avoid double counting etc. The aim would be to operate the model at regional scale or even European scale but there needs to be a demonstration of whether the idea is implementable in the near future or long-term (and a road map defined).
- Nitrogen reduction plans: this could include a long-term plan to attain critical loads at a regional level including: (i) regional legislation; (ii) abatement techniques (BAT); (iii) autonomous development; (iv) trading permits (as considered already in the Netherlands). It should be noted that any trading permits should consider the spatial aspects of the ecological impacts.
- Spatial Planning: this may be operated at landscape and regional levels. The approach optimizes the location of existing pollution sources to minimize the overall threats, exploiting where possible landscape structures to buffer impacts.
  - The use of tree belts, and other buffering options, around habitats and sources were discussed. The group agreed that local spatial planning policies, including buffer zones, are a practical and usually uncontroversial way to tackle more local effects.
  - In addition, the group discussed how the Nitrates Directive could have important co-benefits for ammonia emission control in combination with spatial planning.
- Further development of nitrogen indicators: a number of indicators are available, but the policy message depends on their implementation. For example, it was shown that for ammonia critical level exceedance in the Natura 2000 network, the Area Weighted Index (AWI), underestimates the scale of threat compared with a Designation Weighted Index (DWI) (see Sutton *et al.*, this volume).
- Ecosystem Services concept: This may provide a holistic framework for examining the links between air pollution effects on ecosystems and human well-being (see below and Hicks *et al.*, this volume).

Most suitable approaches (Questions: 9, 10 and 11)

The discussions underlined the importance of flexible and integrated approaches, building on existing legislation such as the Air Quality, NEC, Nitrates, Water Framework, IPPC, EIA, SEA and Environmental Liability Directives. Denmark for instance has combined different legislation (see Dinesen and Bjerregaard, this volume). It was stressed that future options need to address nitrogen import and export, as well as within-country transport. The role that non-technical measures (societal behaviour) could play was also highlighted.

An immediate step that could be taken was improving the ammonia coverage of the IPPC Directive by including manure spreading in IPPC, e.g. consider the current farm size thresholds and inclusion of cattle. The potential for the Environmental Impact Assessment (EIA) directive and other approaches to attain ammonia emission reductions without the full burden of the IPPC obligations was also noted. Attention was drawn to the current proposals for revision of the mandatory measures in the Gothenburg Protocol (Technical Annex IX), for which options are being provided by the CLRTAP Task Force on Reactive Nitrogen.

The SEA Directive could also have a role to play in high level planning for pollution abatement but that a permitting system may be required. Also regional plans should be tested in relation to Article 6.3 of the Habitats Directive.

In addition to these messages, the following specific measures were recommended for further consideration:

- Negotiate more ambitious ammonia ceilings under NECD and Gothenburg Protocol.
- Include ammonia in the Air Quality Directive (2008/50/EC).
- Set strict limits encourages abatement technology development.
- Include non-technical measures (societal behaviour).
- Consider establishing a high level goal as part of a package of actions to ensure that 95 per cent of Natura 2000 designated sites do not exceed critical loads or levels for reactive nitrogen compounds by 2030.

Ecosystem services (Question: 12)

The suitability of a using assessment approaches based on the concept of ecosystem services to provide a holistic assessment of nitrogen impacts in the environment was discussed (Hicks *et al.*, this volume). The potential for ecosystem services such as carbon sequestration and greenhouse gases fluxes (N_2O) to be valued using carbon equivalent pricing approaches was also discussed. It was clear that data availability is not sufficient to allow for quantification and economic valuation of the whole range of effects that nitrogen deposition can have on ecosystems. But there is potential for qualitative assessments to offer a framework for policy development where benefits and trade-offs of different policies can be compared. However, the scale and temporal aspects that need to be addressed are seen as key challenges.

7.2.4 Country presentations

A series of informal presentations were given to the working group on the approaches to protecting Natura 2000 sites from nitrogen deposition in different countries. The main issues discussed are described below and fuller descriptions are provided in Section 7.3 to 7.7.

The key issues raised were:

- A lack of awareness of the nitrogen threat is the main problem in some Member States. Many Member States have not assessed the risk to Natura 2000 or conservation status from nitrogen deposition, yet European critical loads exceedance maps show widespread exceedance.
- Some Member States see other more significant threats to their Natura 2000 sites which are a higher priority than nitrogen deposition, such as land-use change, fragmentation or fires.
- Some Member States are actively pursuing integrated approaches to nitrogen management;

- For other Member States, nitrogen emissions are thought to be very closely coupled with the economy and there are difficulties with limiting emissions despite many sensitive sites with critical loads already being exceeded and not fully recovered.
- For some of the more nitrogen polluted of the Member States, where critical loads are already exceeded, the focus may need to be on maintaining the status quo with a requirement to guarantee that existing and new sources do not lead to increases in nitrogen deposition to vulnerable ecosystems.
- Air pollution experts in Member States are often not linked effectively to conservation practitioners.
- Some Member States are limited in their capacity to reduce nitrogen deposition as over 50 per cent of their deposition can be imported, therefore international agreements, e.g. NECD and Gothenburg Protocol, are important.

7.3 Nitrogen deposition and Natura 2000 sites in Austria

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7.3.1 Introduction

Austria is a landlocked country in Central Europe covering an area of c. 84000 km^2. The eastern Alps cover two-thirds of Austria, making it the country with the largest share of the entire Alps. In the eastern part continental pannonian flatlands are typical. Accordingly, FFH habitats and species from the alpine and the continental biogeographic region can be found. The article 17 reporting in the year 2007 includes 66 habitats and 172 species listed in the annexes of the FFH directive (http://eea.eionet.europa.eu/Public/irc/eionet-circle/habitats-art17report).

Similar to many European countries, nitrogen deposition exceeds the critical loads at the majority of the area and particularly in forests (Umweltbundesamt, 2008). Effects of nitrogen deposition in natural and semi-natural ecosystems were found in the early nineties (Zukrigl *et al*., 1993) and later on (Hülber *et al*., 2008, Zechmeister *et al*., 2007, Dirnböck & Mirtl, 2009) but most studies focussed on forests. Very few knowledge exists regarding alpine habitats and other natural and semi-natural grasslands. Neither the current status of nitrogen deposition and related effects in the Natura 2000 network were assessed nor will the future monitoring of the conservation status include a "nitrogen component".

7.3.2 Trends of nitrogen deposition

Emission of nitrogen oxides decreased by 10.8 per cent, ammonia by 4.4 per cent between 1990 and 2008 (Umweltbundesamt, 2010). Whereas emission targets for ammonia (according to the NEC directive) were achieved, the emission of NO_x is still far above. Totally 46 per cent of the Austrian area is covered by forests and almost the entire forested area is exposed to a critical load exceedance regarding nitrogen. A preliminary assessment shows that the risk for adverse effects in non-forest habitats is also very high (Umweltbundesamt, 2008).

7.3.3 Agriculture and Natura 2000

The Natura 2000 network in Austria includes 220 single areas and 14 per cent of the total designated area is used for agriculture. Apart from this direct impact of agricultural practices on the conservation status, emissions of nitrogen may pose indirect negative effects in neighbouring Natura 2000 areas through short-range transport. This is particularly important in a country where small scale farming is dominating in a very heterogeneous environment. As a result, conservation areas are almost always embedded in agricultural land.

Land management in Austria is mainly cattle farming, whereas crop farming is less important. Totally 187034 agricultural and forestry enterprises were managed in Austria in 2007. Since the year 1999, a reduction by 14 per cent was observed. The average size of farms is 18.9 hectares of arable land. Mountain farms are even smaller. In 2009 the Austrian cattle population amounted to about two million, pig population to three million, the sheep population to 350000.

In 2009 the number of subsidized organic farms rose to 20870, which is 15 per cent of all holdings. The share of organic farming area in the arable land is 18.5 per cent. Totally 73 per cent of all farms or 89 per cent of the total arable land participated in the Agri-environmental Programme (ÖPUL) in 2009. For the ÖPUL and the "Compensatory allowance for less-favoured areas" (2nd CAP pillar), 73 per cent of all subsidies (agriculture and forestry) were used (Lindner *et al*., 2010).

This increasing share of organic farming is most likely one of the major triggers towards decreasing ammonia emissions in Austria. Between 1990 and 2008 ammonia emissions decreased by 4.4 per cent (Umweltbundesamt, 2010).

The opening of the agricultural market after 2013 will likely reduce cattle numbers in Austria and strengthen the current ongoing loss of farmland to forestry. Further decrease of ammonia emissions from agriculture is thus likely.

7.3.3 Implications for Natura 2000 sites

Although the risk of adverse effects of excess N deposition in designated conservation areas and for endangered species is obvious, the problem is not currently recognized as a top priority issue in Austria. Firstly, air pollution experts in Austria are not linked effectively to conservation practitioners. Secondly, knowledge about the effects of N deposition in some important habitats is very rare. There are very few studies in alpine areas, especially in calcareous grasslands, and none in Austria. In particular, studies on short range impacts near farms are missing. As a result, and though Article 17 reporting included air pollution as a frequent pressure, the Article 11 monitoring scheme does not address the issue. There is a general need for a broader monitoring system that is effect related because currently effect-monitoring is restricted to forests.

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7.4 Nitrogen deposition and Natura 2000 in Denmark

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7.4.1 Introduction

Status and trends

From 1989 to 2008 nitrogen deposition on land surfaces and marine waters in Denmark has decreased about 30 per cent and 28 per cent respectively (Ellermann *et al*., 2010). It has been a gradual decline with some variation between years due to changing weather conditions, and it is explained by a reduction in European as well as Danish emissions. Results from the National Monitoring Programme (NOVANA) of terrestrial habitats indicate a resulting significant decline in the nitrogen content of lichens on heaths and dunes, which receive all nitrogen from the air, although the level is still considered being too high (Bruus, 2010). A corresponding decline in the nitrogen content in shoots of dwarf shrubs is not seen which is interpreted as the nitrogen content in the soil still being high due to accumulation of deposited nitrogen from earlier years (Bruus, 2010).

The Danish emissions of ammonia peaked in the mid 1980s at about 114,000 tons and were reduced by about 30 per cent about twenty years later. About 98 per cent of these ammonia emissions come from agriculture especially livestock production. In Jutland the average nitrogen deposition in 2005 from agriculture was 61 per cent and on Zeeland 49 per cent and the contribution from Danish farms were about 41 per cent and 24 per cent respectively (Ellermann *et al*., 2007).

The nitrogen deposition in 2008 was via modelling based on pilot stations estimated by the National Environmental Research Institute (NERI) to be about 14 kg N $ha^{-1}yr^{-1}$ on land surfaces and 6.7 kg N $ha^{-1}yr^{-1}$ in marine areas (Ellermann *et al*., 2010).

Airborne nitrogen deposition plays a major role regarding impact on Natura 2000 habitat types and the Danish National Monitoring Programme (NOVANA) includes monitoring the annual deposition.

For marine waters the overall Danish contribution in 2008 range from about nine per cent to the North Sea to about 27 per cent to the Lillebaelt and up to 44 per cent to Limfjorden (Ellermann, 2010). For land surfaces the average deposition deriving from Danish sources is estimated to be about 36 per cent and this generally larger proportion is caused by livestock production locally and differences in surface characteristics. The regional variation is quite large with livestock production being responsible for 41-45 per cent of total deposition in mid and northern Jutland but only 21 per cent in the capital region.

Natura 2000 and favourable conservation status

Nutrients, especially nitrogen, are a threat to vulnerable habitat types in Denmark, and large amounts are emitted from livestock, industry, energy production and transport. Some nitrogen is deposited close to the source but wind can transport nitrogen some distances. Ammonia is usually transported 60-120 km and NO_x 400 km dependent on the weather, however, more than 1,000 km is also possible under dry conditions without rainfall (Ellermann *et al*., 2007). In connection with rain nitrogen will be washed down quite quickly. When nitrogen is deposited to natural habitats on land or water it leads to eutrofication of plant communities and habitats may eventually disappear due to changes in species composition. Increased levels of nitrogen deposition through many years have led to overloading of Danish ecosystems (Normander *et al*., 2009). Airborne deposition consists of wet deposition deposited by rain or dry deposition deposited by wind.

The aim of the Natura 2000 network is to maintain or restore favourable conservation status of the habitat types and species the areas have been designated for. A number of Annex I habitat types are sensitive to nitrogen deposition and the critical load for some of the habitats has been exceeded.

The most sensitive habitats such as raised bog and oligotrophic waters (which are very poor in nurients) have critical loads of 5-10 kg N $ha^{-1}yr^{-1}$ and other sensitive habitats such as certain heath and dunes habitats have critical loads of 10-20 kg N $ha^{-1}yr^{-1}$ (Ellermann *et al*., 2010). Hence the critical load for some habitats has been exceeded for a long period in Denmark as average airborne deposition of nitrogen exceeded five kg N $ha^{-1}yr^{-1}$ about 1910 and 10 kg N $ha^{-1}yr^{-1}$ about 1945 (Ellermann, 2007).

Government objectives

The overall aim for the government is to reduce nitrogen deposition and thereby protect sensitive nature and the biological diversity (Regeringen, 2009). Denmark has undertaken to reduce atmospheric nitrogen emissions by 2010 by 55 per cent in comparison to 1990. The government's Green Growth agreement of 2009 sets more stringent requirements with regard to the emission of ammonia in order to protect especially sensitive habitats from nitrogen (see discussion).

7.4.2 Nature conservation legislation and measures

Natura 2000 planning

As part of the Danish implementation of the Habitat and Bird Directives, Denmark has chosen to develop a management plan for each of her Natura 2000 sites as part of implementing article 4.4 of the Habitat Directive. The basic objective for the mangement plans is to provide for the maintenance or restoration of favourable conservations status as set out in article 6.1 and 6.2 of the directive. Thus 246 draft plans have in 2010 been submitted to a technical hearing with relevant municipalities. The plans cover 3,591 km^2 on land equivalent to about 8.4 per cent of the Danish land area and in total about 13,047 km^2 are covered by the Danish Natura 2000 network. The plans are legally binding and come with funding. The management plan is a framework plan and relevant municipalities, possibly in collaboration with state agency landowners were relevant, will design action plans to implement the overall plan.

In the long run the plans aim to ensure the integrity of a site and a favourable conservation status for the habitat types and species for which the Natura 2000 sites have been designated. The plans generally regard nitrogen deposition as one of the major threats to e.g. dunes, oligotrophic waters, heath and scrub, dry grassland and meadows, raised bogs, mires and fens and decidious forests. Apart from opportunities in the action plans for implementing management activities such as removal of nitrogen by removal of plant material, sod cutting etc. regulation of nitrogen deposition is handled by the Environmental Approval Act for Livestock Production and follows a separate track in the Green Growth agreement.

Nature Conservation Act

The Nature Conservation Act provides the main legislative framework for nature conservation in Denmark. It includes general protection of habitats and specific regulatory powers for the protection of nature. Thus lakes over 100 m^2, water courses that have been designated as protected areas, heaths, bogs, moors, salt marshes, swamps, coastal meadows, grasslands of more than 2,500 m^2 are protected - so-called § 3 areas in the Conservation Act. Dispensation from the act is necessary if activities including e.g. a nitrogen source are considered established or extended and which may result in changing the § 3 areas. Moreover, it may be possible to prevent harmful activities if they constitute a threat to Natura 2000 habitats following § 19 f.

Agricultural policies and measures
In 2008 about 63 per cent of the total area of Denmark i.e. 27,330 km^2 was used for agriculture. This proportion is decreasing slightly. The primary agricultural sector produced 1.5 per cent of GDP in 2005, and has been in a steady decline since the 1960's. The adoption of intensive farming increased the average size of holdings from 16 ha in 1965 to about 55 ha in 2005, while the number of holdings decreased from about 200,000 to 46,000 during the same period. There was also an increase in the number of livestock (less cattle but more pigs), though the number of livestock units has been almost the same through these years (BLST, 2010).

According to the arable land Denmark has a regulation which set obligatory and fixed standards (a nitrogen quota) for the application of nitrogen from both livestock manure and chemical fertilizers. The nitrogen quota is set 10 per cent below the economical optimum. All farmers have to submit a fertilizer status account to the authorities every year. In order to control the information the regulation also impose any company, who trade with fertilizers, to submit information on the annually delivery of nitrogen fertiliser to each farmer. To control the livestock production the authorities have a legal access to information from slaughterhouses and dairies about deliveries from each farm. In order to control the exchange between farmers, the farmers also are imposed to submit information about every exchange of nitrogen in fertilizer or manure between farmers.

Denmark also has legislation with fixed environmental standards regarding odour emission, ammonia emission, and surplus of phosphorus and leaching of nitrate, which should be met in connection with the approvals. Local authorities often set further demands with reference to the Habitat Directive or the Water Frame Directive, which in some cases have given long casework.

Impact assessment
Under the Planning Act the Danish Government has issued two orders, which implement the EU directives on EIA and SEA. All projects, plans and programmes that may have a significant effect on national and environmental values of national interest are subject to such assessments. Moreover, plans and projects in Natura 2000 areas are subject to an assessment regarding the habitats and species for which the areas are designated according to the rules for administration of the Natura 2000 sites and regarding deterioration or destruction of breeding sites or resting places of annex IV species set up in Executive Order No. 477, as amended (Ministry of Environment, 2004).

In addition to the general rules livestock production units have since 2001 been subject to special legislation requiring impact assessment of nitrogen deposition to habitats. From 2001 to 2006 the impact assessment was carried out as part of the EIA screening (c. The EIA Directive). Since 2007 livestock production units with more than 15 animal units have been required to attain an environmental approval, whenever there are plans to establish, change or extend their production.

In addition to the impact assessment in relation to Natura 2000 the Danish legislation includes means to achieve a general reduction of nitrogen emission as part of the implementation of the IPPC and EIA directives. Beside that the environmental approvals of livestock production units are required to include the use of approved eco-efficient technologies (BAT). A more detailed description of the Danish impact assessment and regulation of livestock holdings is provided in Bjerregaard (in press.).

Discussion

In 2007 a new Environmental Approval Act for livestock farms was endorsed. With this act a set of criteria was established for securing that establishing, changing or extension of livestock holdings did not result in negative environmental impacts following the Habitat Directive and the act on Environmental Impact Assessment. As indicated earlier it is the expectation that most livestock holdings will be involved in this regulation in a 10 to 20 years time period because of the rapid development in the sector. This act contains both specific regulation in buffer zones around selected habitats as well as general reduction demands and BAT requirements. Moreover the municipalities have to carry out additional Natura 2000 impact assessment in cases were this is relevant.

The Green Growth agreement

The Danish government signed an agreement on Green Growth in 2009. The purpose of the agreement is to ensure that a high level of environmental, nature and climate protection goes hand in hand with modern and competitive agriculture and food industries. This is along-term plan defining environment and nature policies and the agriculture industry's growth condition. A total of DKK 13.5 billion is to be invested until 2015, which is about a 50 per cent increase in investments compared to previous initiatives. The agreement sets up new targets for general nitrogen depostion as well as regulation in relation to Natura 2000 habitats. In relation to sensitive Natura 2000 habitats the resulting target is a maximum total nitrogen contribution from each livestock unit of 0.2 to 0.7 kg N $ha^{-1}yr^{-1}$ depending on the number of livestock holdings in the particular area (Regeringen, 2009).

The wider countryside

The government intends to strengthen regulation of nitrogen deposition in the wider countryside, hence according to the Green Growth agreement the general regulations would be enhanced as well.

Thus BAT standard criteria for all holdings over 250 animal units and special BAT criteria for holdings of more than 500 animal units are being developed. For certain valuable and nitrogen sensitive nature areas outside Natura 2000 a permitted load from holdings would be up to a total load of one kg N $ha^{-1}yr^{-1}$ and for other nature the permitted load would be up to one additional kg N/ha. Moreover, Denmark has set up ceilings for emissions as obliged to by the Gothenburg protocol from 1999 and the NEC Directive (National Emission Ceilings).

Management

Studies have shown that large amounts of nitrogen accumulated in the soil on heath can be removed by sod cutting and other results show that hay mowing may remove as much as 40 to 180 kg N $ha^{-1}yr^{-1}$ (Damgaard *et al*., 2007). Removal is only applicable however on relatively level soils without stones, swampy patches, scattered woody plants and characteristic structures like tufts, tussocks, ant hills etc. For habitats such as raised bogs or decidious forests it is not an option. Such management interventions would probably be seen as a restoration approach or an additional effort in situations where reducing nitrogen deposition needs to be catalysed.

Challenges ahead

The Green Growth agreement is expected to limit the number of specific Natura 2000 impact assessments thus reducing the administrative burden on the part of the farmer as well as the municipality as well as being better at securing the sensitive Natura 2000 habitats. At the same time a strong structural development is going on and e.g. the number of farms is expected to be reduced with 50 per cent in the next 10 years. Thus because of the regulation there will be a tendency that the remaining farms will be located away from neighbours and vulnerable nature. As part of the air quality programme under the National Monitoring Programme (NOVANA) nitrogen deposition is monitored at local scale at various Natura 2000 habitat types around the country with specific reference to the Habitat Directive. The calculations include both wet and dry deposition in the 400 x 400 m grids i.e. the deposition on the targeted habitat types, which included heath, fens, meadows, dunes, raised bogs, deciduous forest and a few other habitat types to get information at as high a resolution as possible.

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7.5 Nitrogen deposition and Natura 2000 in Greece

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7.5.1 Introduction

The responsibility of the European countries towards the global community for the conservation of biodiversity is high and they have agreed to join efforts to conserve threatened species and habitats within their territories. In order to further promote their conservation, the Bern Convention on the conservation of European wildlife and natural habitats, the Birds Directive (79/409/EEC) and the Directive 92/43/EEC, commonly referred to as the “Habitats Directive”, are the main tools at a European level.

Greece has a wide range of climate types, ranging from the semi-desert to the cold humid continental climate. The topography of the country is also complex. More than two third of the land is mountainous, there is a relatively high number of islands (Figure 7.8) and a lengthy shore line of about 15,000 km. These unique environmental features are reflected in the high number of plant and animal species, considerable number of which are endemic. Approximately 6,000 plant species have been identified and according to Legakis (2004), 23,130 land and freshwater animal species have been recorded in a variety of terrestrial and aquatic ecosystems. This diversity of ecosystems is crowded into a relatively small space (132,000 km^2).

Unfortunately this national heritage has not been adequately studied, evaluated and managed to date. The Habitats Directive aims at contributing to the preservation of biodiversity through the conservation and hopefully the restoration of the various types of natural habitats and species.

The identification of the Natura 2000 network in Greece has started in June 1994, with the execution of a project entitled "Inventory, Identification, Evaluation and Mapping of the Habitat types and Flora and Fauna species in Greece" (Dafis *et al.*1996).

7.5.2 Legal framework of protected areas and Natura 2000 Sites in Greece

A number of laws offer a direct or indirect protection of the Natura 2000 Sites. Legislation is complex and covers a number of designated categories of protected areas in Greece. Most important legal framework arises from the forest legislation, the law for the environment and the Ramsar convention. According to forest legislation (L.D. 996/1971), a number of sites (or parts of them) have the status of 1) National Forest Parks, 2) Aesthetic Forests and 3) Natural Monuments. Designation categories defined in law for the environment (L. 1650/86) are: 1) Strict nature Reserves, 2) Nature Reserves, 3) National Parks, 4) Protected Natural Formations - Protected Landscapes, 5) Ecodevelopment Areas. Ten wetlands of international importance are designated under the Ramsar convention. The vast majority of the above areas are included in the Natura 2000 network. With regard to the Natura 2000 network, in Greece this is composed of 239 Sites of Community Importance (SCIs) and 163 Special Protection Areas (SPAs) according to the Birds Directive. Their surface area (excluding overlaps) comes to around 34.000 km^2 covering around 21 per cent of the land area of the country. The breakdown of the sites' areas, as presented in the EC Natura 2000 barometer, is shown in Table 7.1. These sites are of community interest and require the designation and proper management of special areas of conservation. Responsible for managing protected areas are management bodies (L. 2742/99).

7.5.3 Threats to Natura 2000 Sites and nitrogen deposition in Greece

Various human activities might have adverse effects on valuable habitats and species. Human activity in Greece has resulted in three quarters of the wetlands having been destroyed in the past. Today, it is widely accepted that the main threats to Natura 2000 sites are: Forest fires, drainage and pollution of wetlands (eutrophication), road construction through sensitive ecosystems, overgrazing, illegal hunting and fishing, industrial pollution (water and air pollution), intensive agricultural practices and not regulated tourism. These threats have not been studied systematically and in relation to Natura 2000 sites in Greece. More specifically the nitrogen effects on these sites are largely unknown, although nitrogen deposition is a threat to biodiversity across large areas of Europe (CCE, 2008).

Research on nitrogen deposition by rain (Tables 7.2 and 7.3) has been conducted in urban areas of Greece (Figure 7.8).

Table 7.1: Sites of Community Importance and Special Protection Areas in Greece [European Commission Natura 2000 barometer, Natura 2000 newsletter no 26 (2

	Number of sites	Total sites area (km^2)	Terrestrial area (per cent)	Number of marine sites	Marine area (km^2)
SCIs	239	27,641	16.4	102	5,998
SPAs	163	16,755	12.3	16	567

Nitrate nitrogen deposition by rain was 1.2 to 5.9 kg $ha^{-1}yr^{-1}$, while the ammonia nitrogen was 1.5 to 11 kg $ha^{-1}yr^{-1}$. In recent years the highest deposition was measured in the area of Ptolemais city, because of the local lignite-burning plants operation. This N-deposition contributes to the fertilization of various terrestrial and aquatic ecosystems with unknown effects on species composition of the Natura 2000 sites in Greece. It has been reported that species composition of Greek grasslands was considerably affected by fertilizer application. N favours grasses and depresses legumes unless it is combined with P when a more balanced species composition is secured (Papanastasis and Koukoulakis, 1988). Addition of N increased community productivity and changed also species composition, especially in years when soil moisture was adequate (Mamolos *et al*., 1995). In a competition experiment the nitrophilous species Bromus sterilis was able to increase growth at increasing N-fertilizer level, at the expense of other species (Tsiouris and Marshall, 1998).

The wetlands in Greece are also threatened by various human activities taking place either in the water bodies or on their watersheds. Various agricultural activities e.g. application of agrochemicals, ploughing, burning plant residues etc., which take place on the watersheds are considered as one reason for non point pollution of the wetlands. The NO_3-N concentrations of the runoff water from experiment sites in the watersheds of two Ramsar wetlands (Prespa and Koronia) were higher than the NO_3-N concentrations in rain and stream water samples taken from the same watersheds (Tsiouris *et al*., 2002a and Tsiouris *et al*., 2002b).

7.5.4 Management tools

As stated in the 2nd national report on the implementation of the Habitats Directive (article 17 report), there are management plans and management bodies for some of the Natura 2000 sites. One comprehensive management plan has been adopted for the National Park of Shinias, but several others are in preparation. More particularly, according to the above report, there are 95 sites for which comprehensive management plans are in preparation and in 48 Natura 2000 sites management bodies have been established. In 203 sites there is not a comprehensive management plan, but nature conservation objectives have been included in the relevant territorial planning instruments as for example, designation for wildlife refugee, forest management plan, management of grazing etc.

In 72 sites nature conservation objectives are not defined in a territorial planning instrument (nor in a comprehensive management plan), but other management instruments have been put in place as for example, application of agrienvironmental measures, management project through operational project “Environment”, application of Life-Nature project etc.

7.5.5 Conservation measures

As stated in the 2nd national report on the implementation of the Habitats Directive (article 17 report), in Greece, the main statutory measure for the conservation of the Natura 2000 sites is their designation according to the existing national legislation. The core areas of National Forest Parks and the Natural Monuments are considered strictly protected and various activities like excavation, industrial activities, tree felling and destruction of plants, grazing and every construction in general

Figure 7.8: Five cities of Greece, where nitrogen deposition by rain was studied.

Table 7.2: Rain Nitrogen (kgN $ha^{-1}yr^{-1}$) in two sites of Thessaloniki (East and West).
(Mourkides et al., 1981).

Site	Form	1977	1978	1979	1980
East	NO_3-N	1.24	1.65	2.69	2.12
West[1]	NO_3-N	1.38	4.16	3.14	2.34
East	NH_4-N	1.97	4.56	5.00	-
West	NH_4-N	4.81	11.13	5.67	-

1 West is industrial site.

Table 7.3: Nitrogen deposition (kgN $ha^{-1}yr^{-1}$) by rain in five cities of Greece.
(Tsikritsis, 2006).

Cities	Period	mm	NO_3-N	NH_4-N
Athens	1987-8	377	1.51	1.47
Patras	2000-1	678	1.83	1.56
Larissa	2001-2	424	1.91	1.99
Thessanloniki	1993-4	458	1.74	3.71
Ptolemais	1986-7	493	5.87	3.25

except for those favouring nature conservation are prohibited. In the peripheral zones of National Forest Parks and in Aesthetic Forests, activities are regulated by the competent Forest Services, aiming to nature conservation. Wildlife Refugees (L. 2367/98), aim to the protection of the areas for feeding, wintering, breeding and rescuing of the species of wild fauna and flora. Within Wildlife Refugees, hunting, caption of species for reasons other than research, destruction of vegetated areas, sand removal, drainage of marshes, pollution and inclusion of the area in town planning is prohibited. According to the Law 1650/86 for the protection of the environment, for the designation of protected areas, a Specific Environmental Study (SES) is required. After its completion, the SES is approved and then, together with the draft legislation text for the designation of the area, it is opened to the public. Comments are incorporated and the legislative text is signed by the competent Ministers. If the draft legal text is a Presidential Decree, then it has to be checked by the High Court and then signed by the President of Democracy.

Under the designation act of each area, a number of restrictions for works and activities are determined; among them, restrictions and prohibitions in land use, in building and cutting of land into smaller pieces, in constructions, in implementation of agricultural, fishing, stock raising activities etc.

In general, in Strict Nature Reserves all activities are prohibited, except research and works for nature conservation. In Nature Reserves only research and some traditional activities are allowed.

Protection and management of the natural environment lies within a number of public services with overlapping responsibilities. Protected areas designated according to L. 1650/86 can be managed by various management schemes. The scheme applied till now regards the establishment of Management Bodies (L. 2742/99) consisted by a Managing Board of representatives of central ministries, regional, prefectural and local authorities, local stakeholders, NGOs and scientists. Managing Boards must be supported by scientific, technical and administrational personnel. The existent 27 management bodies have not yet in all cases engaged all the personnel needed for their proper operation.

Through spatial planning (Regional Spatial Plans, Specific Spatial Plan for the Renewable Sources of Energy), specific provisions have also been issued for the sites of the Natura 2000 network.

Management measures have also been applied by beneficiaries through projects supported at EC and at national level. Most important of them are Life-Nature projects.

Applied agro-environmental measures concern mainly organic farming, organic livestock farming, protection of nitrate vulnerable zones, protection of wetlands, extensive livestock farming, protection of traditional orchards, maintenance of local endangered breeds, maintenance of plant resources under threat of genetic erosion, promotion of farm practices for the protection of wild life, long-term set-aside, conversion of arable land to extensive pastures and preservation of hedgerows and terraces.

At cultivated areas, Codes of Good Agricultural Practice were implemented in all agro-environmental schemes, whereas Cross Compliance Requirements and additional measures, in accordance with the regulation 1782/03, are applied. In the freshwater environment, L. 1740/87 provides for the issuing of Presidential Decrees for the regulation of fisheries in inland waters. In general, regulations and restrictions are valid for the protection not only of fish but also of lobsters, shrimps, mussels, molluscs, shells etc. Coralligenous are protected through regulation of exploitation whereas fishing with trawlers is prohibited above posidonia meadows of Natura 2000. Midwater otter trawls and pelagic pair trawl are not allowed in Greece, whereas fishing with beach seines and trawlers is regulated (several prohibitions exist at local level as regards the distance from the coast and the period of fishing). Drift nets are prohibited since 1993 according to P.D. 40/93. Through L. 3409/05, recreational diving is regulated. Enforcing of legislation is monitored by the competent services of the Ministry of Merchant Marine.

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7.6 Nitrogen deposition and Natura 2000 in Portugal

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Abstract

- The aim of this paper is to provide a general perspective on the current status of nitrogen related issues in Portugal. The focus is on the current science and practice in mainland Portugal.
- It is concluded that for the Natura 2000 network and Mediterranean type ecosystems, the current monitoring of atmospheric ammonia in Portugal is clearly insufficient for a suitable protection of Natura 2000 biodiversity.
- Three different integrative ecological indicators are considered for the assessment of the impact of N deposition on biodiversity: functional lichen diversity for evaluating the impact of atmospheric NH_3 in sensitive ecosystems, N in lichens as a first level for regional risk of N deposition impact and N in litter as the second level for assessing ecosystem functional response of N deposition.
- Considering the insufficient number of national monitoring stations, the Mediterranean landscape's peculiarities together with the N trade-offs, we recommend the use of ecological integrative indicators as innovative tools for risk analysis of N deposition, as well as assessment of biodiversity shifts at ecosystem level.

7.6.1 Introduction

The spatial resolution of NO_x and NH_3 measurements in Portugal

In Portugal there are two main institutions that may deal with nitrogen (N) emissions and deposition compliances and their effects on biodiversity that are, respectively: the Environmental Portuguese Agency-APA (www.apambiente.pt) and the Institute for Nature and Biodiversity Conservation-ICNB (www.icnb.pt).

APA is the national entity responsible for the overall coordination of the Portuguese inventory of air pollutants emissions. Air emission inventories in Portugal were initiated in 1989/1990 and first estimates of NO_x were made at this time. Only in 1992, under the CORINAIR90 and UNECE/EMEP report was NH_3 first included in the inventory. At present, emission factors for NO_x and NH_3 are determined from the available set of algorithms reported in EMEP/CORINAIR handbook (EMEP, 2002).

In Portugal there are approximately 70 air quality monitoring stations measuring NO_x permanently (http://www.qualar.org), located in urban, suburban and rural areas. Concerning this pollutant both in space and time the level of information is quite detailed.

The Convention on Long-Range Transboundary Air Pollution (LRTAP), requires NH_3 emissions to be reported in a spatial pattern following a 50km x 50km grid. However, at present, APA present the data according to the council level, which is more detailed. Despite this effort, the level of information at spatial dimension is still not adequate to characterise deposition at local scale, most effects occurring at less than 500 m from the source (Pinho *et al*., 2009). Moreover, there are no NH_3 monitoring stations at the national level and there are only two NH_4+ monitoring stations in the country, one in the north and other in the south (http://www.meteo.pt/pt/ambiente/atmosfera/). Thus, the information concerning the air quality and the deposition of NH_3 is only based on statistical information and air deposition models not validated with NH_3 measurement. As we can see in Figure 7.9 most part of the NH_3 emissions are related to agricultural activities (41.5 per cent) or livestock production (39.3 per cent). Knowing that most of Portugal's 2000 Natura Network is located in rural areas with high agriculture and livestock activities, the assessment of the impact of NH_3 on biodiversity and ecosystem function is of high importance for Portugal. Moreover, the Global Strategy for Plant Conservation, that Portugal has also signed, emphasizes the need for capacity-building in order to enable the implementation of the targets for 2010 using a flexible framework within which national and regional actions are developed. Thus, there is a need to take the targets into consideration for monitoring and assessing progress of N deposition particularly on Natura 2000 sites.

7.6.2 Aims and objectives

- The aim of this paper is to evaluate the situation of Portugal in terms of monitoring assessments of N deposition particularly on Natura 2000 areas.
- Consideration of the use of integrative ecological indicators that reflect the NH_3 atmospheric deposition and the ecosystem response to N increase.
- Specifically scientifically based strategic and practical tools, to assess the potential for shifts in biodiversity in response to N deposition are considered to fulfill Target 3 of the Global Strategy of Plant Conservation within the Natura 2000 sites.

7.6.3 Results and discussion

The Portuguese climate and biogeography

Portugal is on the edge between Mediterranean and Atlantic-eurosiberian biogeographic regions. It presents a high patchiness of natural habitats, and it is unique in the Mediterranean context because of the Atlantic influence that produces higher levels of precipitation, and therefore the climate varies between humid and arid Mediterranean within a small area. This climate is associated with poor or very poor nutrient soils (Cruz *et al*., 2008; Cruz *et al*., 2003) some of them with low water retention. These environmental conditions have a great effect on vegetation dynamics and landscapes (Figure 7.10). In Portugal, natural conditions together with the long history of land use has produced a landscape dominated by thin, acid or slightly acid and oligotrophic soils, normally with an extensive woodland for wood production and agriculture use. This combination of ecological factors and of anthropogenic perturbation patterns led to a heterogeneous landscape..

The Portuguese Mediterranean type ecosystems

Most of Mediterranean Portuguese ecosystems are part of a mosaic-type landscape, shaped by diverse geomorphologic, climatic and human-induced factors (Blondel and Aronson, 1999; Palahi *et al*., 2008). In fact human influence shaped most of the Mediterranean ecosystems over centuries of traditional land-use practices. For example, Montado, the dominant landscape in the south is a unique agro-silvopastoral system found only in the Iberian Peninsula dominated by evergreen tree-species (cork Quercus suber and holm Q. rotundifolia oaks). This multi-use forest system combines, in a single space, forest harvesting, extensive livestock husbandry and intermittent cereal cultivation, together with the provision of mushrooms, aromatic plants, game and bees. This long history of human-nature interactions in a region identified as one of the 25 world hotspots of biodiversity (Mediterranean basin; see Myers *et al*., 2000) allowed species, many of which endemic and therefore of high conservation value, to co-evolve under traditional management practices. In modern times however this system faces degradation due to different type of threats, namely, intensive and extensive agriculture, agriculture abandonment, fires,

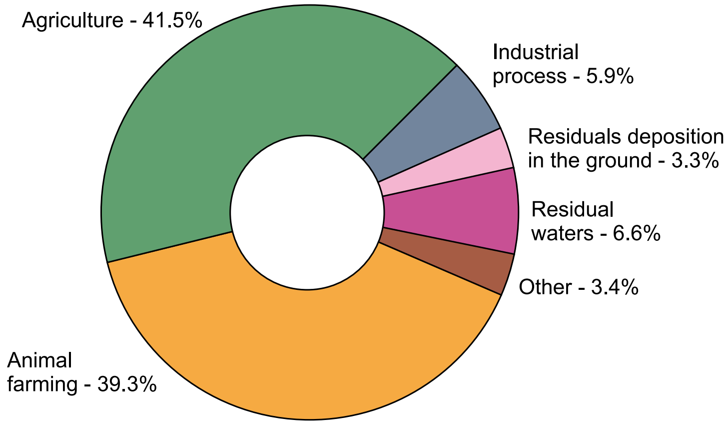

Figure 7.9: Relative proportion (per cent) of NH_3 emissions in 2005 following each activity sector (source APA, 2008).

different types of forest production, invasive species. All these have, in the short- and long-term a negative influence on biodiversity, threatening the extinction of many species and habitats.

Several authors (e.g.Sutherland *et al*., 2006) identified a large number of ecological questions with policy relevance related to nature conservation in humanized landscapes. These include the impact of farming, urban development, pollution, and conservation strategies. An enrichment in N of vegetation tissues (Pocewicz *et al*., 2007) and a change towards more nitrophytic flora (Willi *et al*., 2005) resulting from an increase in nitrogen deposition, mainly from ammonia emitted by farming activities (EPER, 2004; Galloway *et al*., 2003), is related to biodiversity loss (Bobbink *et al*., 2010; Phoenix *et al*., 2006; Suding *et al*., 2005). In fact, nitrogen deposition is considered not only a major threat to global biodiversity but also one of those threats that are expected to increase worldwide (SCBD, 2006).

Nevertheless, the impact of nitrogen on biodiversity is not a priority subject for our conservation biology governmental authority, ICNB (www.icnb.pt). Thus, N deposition is never considered as a threat/pressure in habitats status reporting, or as a factor for conservation management. Nevertheless, some protected Natura 2000 sites are located in areas where the NH_3 deposition is between one and 1.6 ton/km^2 (Figure 7.11). Despite the weak spatial resolution of the NH_3 emissions that this level of information can provide, it is important to notice that the Natura 2000 sites that are located in areas with high NH_3 deposition should be assessed as a priority for the impact on the biodiversity. Of those, the most problematic are the ones located near large urban areas or in the west central part of the country, where intensive agriculture practices take place (Figure 7.11). It is also interesting that low intensive agriculture practices and/or extensive livestock production, associated with Montado ecosystems, that occur in the south part of the country, lead to medium levels of NH_3 emissions.

Use of lichens to determine critical areas for monitoring N impact N ecosystems

Because the available information on NH_3 emission is clearly at an insufficient spatial resolution to allow its use for assessing the impact of N in biodiversity, another approach must be considered. In order to assess the range of effects of NH_3 in natural ecosystems, that can be used for effective NH_3 mitigation policies (Dragosits *et al*., 2006) one can rely on two distinct approaches: (i) direct measurements of atmospheric NH_3 concentrations, which provide an estimate of dry

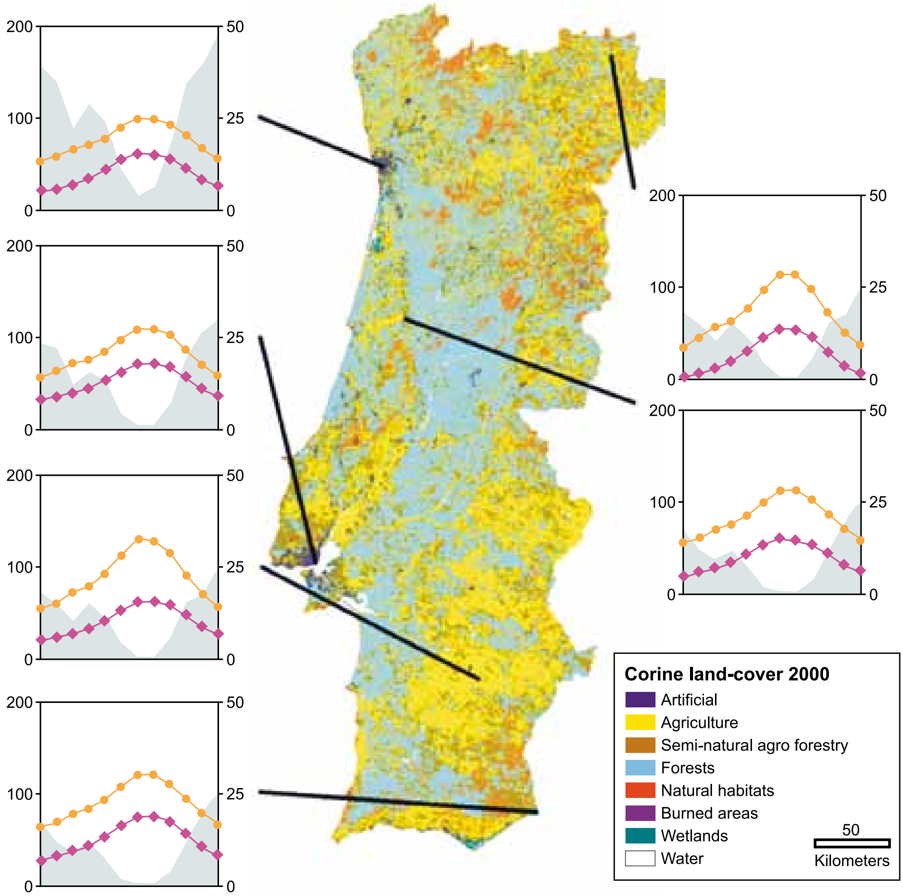

Figure 7.10: Map of the distribution of land-cover types in Portugal, adapted from Corine Land-Cover 2000. Note that the class "forest" includes Pinus and Eucalyptus plantations, oak forest as well as cork and holm-oak woodlands. Climatograms are shown for different areas in continental Portugal. Lower axis are months (from January do December), left axis monthly total precipitation (mm) represented by the filled shape, right axis monthly temperature (ºC) using averages of the maximums (triangles) and minimums (circles). Values are averages from 1971 to 2000, source IM (2009).

NH_3-N deposition, but require intensive and costly operations; (ii) monitoring of effects on the biotic component. The latter approach should be carried out using groups of biota that are more sensitive to the pollutant of interest. Lichens have been reported as the most sensitive group to NH_3 emissions (van Herk, 1999; Wolseley *et al.*, 2006). Lichens are symbiotic organisms widely used as biomonitors of environmental changes (Pinho *et al.*, 2004; Pinho *et al.*, 2008a; Pinho *et al.*, 2008b). In fact, the information obtained from lichens compliments the information collected from chemical sampling, because lichens provide a biological perspective, integrated in the long-term on the effects of N. By examining changes in lichen communities, specifically by using lichen indicators based on nitrogen-tolerance, an estimate of atmospheric NH_3 critical levels was made for Portugal in the Montado ecosystem under Mediterranean climate (Pinho *et al.*, 2009). The critical level found was between one and two µg/m^3, much lower than previous

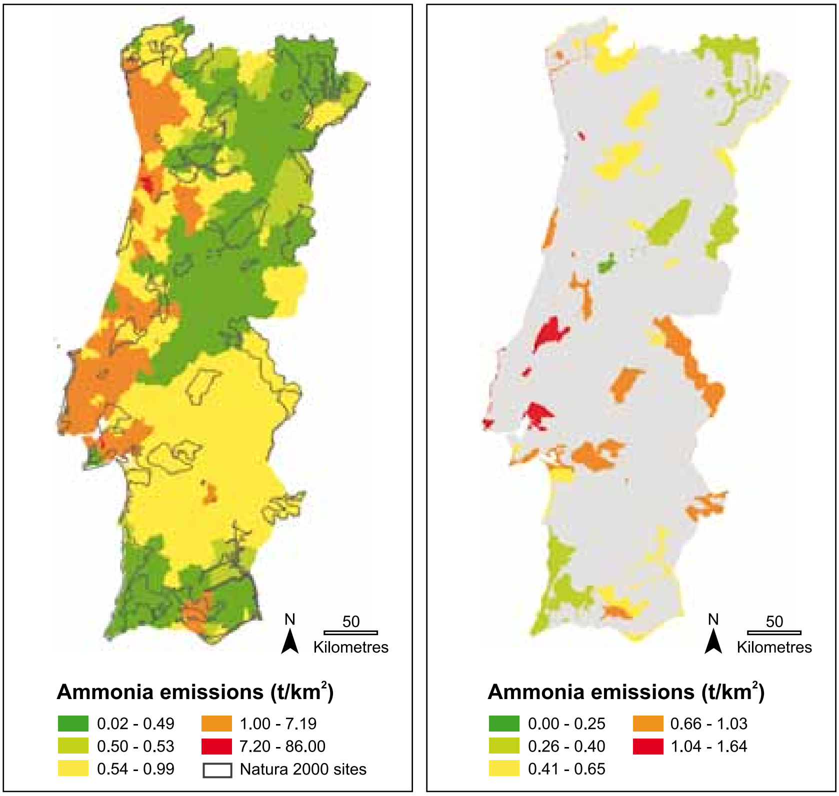

Figure 7.11: Left - Map of the level of ammonia emissions by council (source APA, 2008) superimposed to the limits of the protected areas in Portugal, Natura 2000 sites in black line. Right – Average value of the NH_3 emissions for the Natura 2000 network in Portugal based on NH_3 emissions information at the council level

limits (eight µg/m^3) but in accordance with the concentrations found in other works using lichens (Cape *et al*., 2009; Wolseley *et al*., 2006).

However, although lichen diversity is a suitable tool for determining if ecosystems are affected by N pollution, its use at a landscape scale, e.g. within Natura 2000 areas, may be hampered by the fact that lichen diversity may respond to other environmental factors (Pinho *et al*., 2008b). Therefore, how to select critical areas for monitoring N polluted areas? Pinho *et al*., (this book) provided a practical method for selecting critical areas for monitoring the impact of NH_3 in plant biodiversity within Natura 2000 sites. There, it was shown that the concentration of N in lichens was very significantly related to agriculture land-use and not to industrial and urban areas thus showing that N concentration in lichens is most probably reflecting the NH_3 emissions. In this way the authors proposed to apply the N concentration in lichens as a detailed ecological indicator for fulfilling the objective of selecting critical areas for the impact of NH_3 on biodiversity. The authors applied this indicator to two Portuguese Natura 2000 sites by mapping N concentration in lichens. By doing so, they select the critical areas for the assessment of the impact of atmospheric NH_3 deposition on plant diversity in Mediterranean Natura 2000 sites.

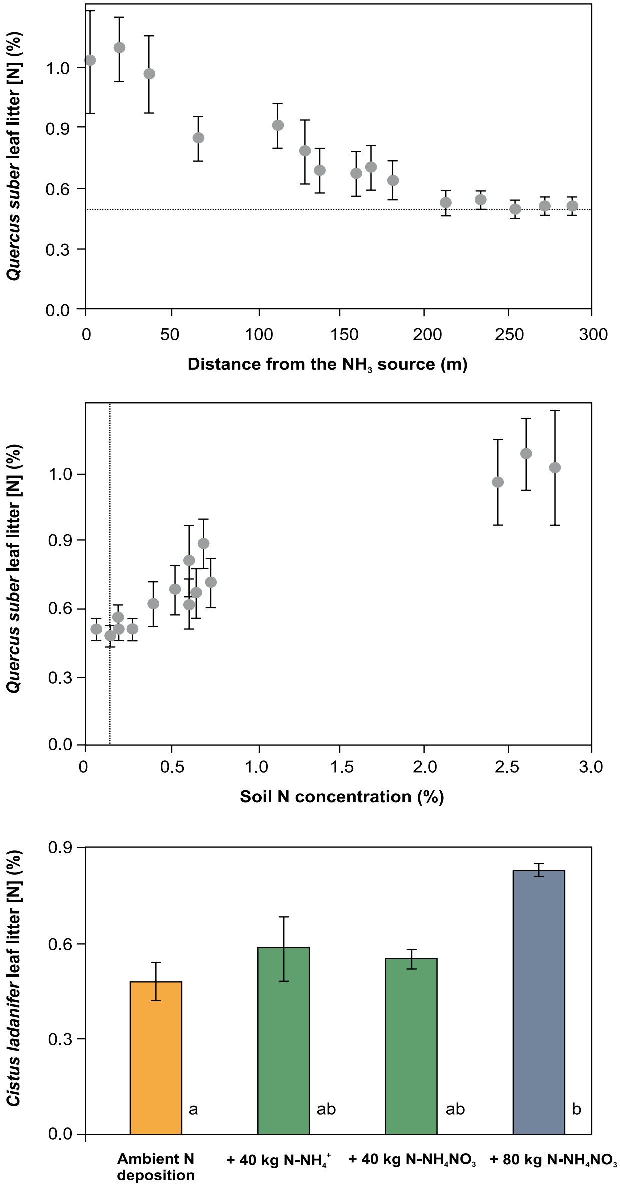

Figure 7.12a,b,c: Changes in leaf litter N concentration in response to increased N availability in two Natura 2000 sites in Portugal that correspond to different Mediterranean-type ecosystems: a) relation between leaf litter N (mainly Quercus suber leaves – collected in the four seasons in 2008) concentration and distance to a source point of ammonia (barn with 200 cows, Pinho *et al.*, 2009) in a cork oak system (values represent mean ± sd; n= 4 sampling points); b) relation between leaf litter N concentration (collected in summer 2008), and soil N concentration in the same cork oak system as in a); c) relation between leaf litter N concentration from Cistus ladanifer and N additions beginning in 2007 in a semi-natural Mediterranean Maquis (bars represent mean values ± se; N = 3 experimental plots per treatment).

How can we monitor increased N availability in ecosystems

Mediterranean-type ecosystems are expected to be very responsive to increased N availability as increased N deposition constitutes a significant increase in the availability of a nutrient that limits the productivity of these systems (Cruz *et al*., 2003). .

Dias *et al*., (this book) provided evidence that Mediterranean-type ecosystems are highly N responsive, and that changes can be seen after one year of N additions. Increasing N availability leads to increased below and aboveground diversity (richness and evenness) and creates new and distinct seasonal patterns of soil N availability, which translates into changes in the nitrogen recycling in the ecosystem. Higher nitrogen availabilities change the chemical composition of plant and microbial biomass, affecting the remobilization processes in the plant. Therefore the litter produced under high nitrogen availability is enriched in N. Two parallel studies that are being conducted in distinct Natura 2000 habitats showed that N concentration of litter from the dominant plant species could be a good indicator of the N status of the site (Figure 7.12). One site is a cork oak field with a source point of ammonia (Pinho *et al*., 2009). Litter mainly corresponds to cork oak (Quercus suber) leaves. Litter N concentration decreased inversely with distance to the ammonia source, which was an important nitrogen input to the system (Figure 7.12a), and increased with increasing soil N concentrations (Figure 7.12b). The other site (PTCON0010 Arrábida/Espichel) is a Mediterranean Maquis dominated by Cistus ladanifer and has been submitted to N-manipulation since 2007 (Dias *et al*., this book). Litter N concentration's dependence on the added N dose was evident (Figure 7.12c). Adding 40 Kg N $ha^{-1}yr^{-1}$ did not significantly affect the nitrogen concentration of the litter (relatively to the control), but the adding 80 Kg N $ha^{-1}yr^{-1}$ had a significant effect.

In Mediterranean ecosystems the high N use efficiency is related with a great nutrient remobilization capacity from old to new leaves. This decreases dramatically the nitrogen content of the litter and constrains decomposition, consequently altering the structure and activity of the microbial community. An alleviation of the nitrogen limitation to plant growth allows plants to increase their N content and to afford a decrease in internal N turnover. This changes litter quality, as well its decomposition rate and, consequently, the structure and activity of the microbial community. These small adjustments at individual and community level take place in different time scales. Internal resources and plant-microbe interactions may be some of the adjustments that induce changes in species composition in a larger time scale. Therefore, monitoring changes in litter N concentration may function as an integrative ecological parameter of the Mediterranean-type ecosystem's responses to high N inputs. For these systems N concentration in litter can thus be considered a more integrative indicator that foliar N concentration, acting as a tool for evaluating N-induced biodiversity shifts.

7.6.4 Conclusions

- In the framework of Natura 2000 network and Mediterranean type ecosystems, we conclude that the current monitoring of atmospheric ammonia in Portugal is clearly insufficient for a suitable protection of biodiversity on Natura 2000 sites.
- Here we make use of an integrated framework for assessing Mediterranean Ecosystems responses to N availability: (i) nitrogen concentration in lichens was shown to be related to agriculture areas, and could therefore be used to map the areas at greater risk from N-deposition; (ii) in risk areas, lichen functional-diversity can be used to establish the ecosystem critical level for ammonia and (iii) by measuring N concentration on litter we could integrate the balance between the two compartments of the ecosystem, the below- and aboveground.
- Considering the insufficient number of national monitoring stations, the Mediterranean landscape's peculiarities together with the N trade-offs, we recommend the use of

ecological integrative indicators as innovative tools for risk analysis of N deposition, as well as assessment of biodiversity shifts at ecosystem level.

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7.7 Challenges to reducing the threat of nitrogen deposition to the Natura 2000 network across the UK and Europe

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SUMMARY

- While emissions of nitrogen compounds (oxides of nitrogen and ammonia) have decreased in the UK, there is evidence of only a small reduction in total nitrogen deposition over the last 20 years.

- Even with projected emission reductions factored in, critical loads for nitrogen deposition will still be exceeded at almost half of the UK's sensitive habitats in 2020. This clearly demonstrates the need for significant additional reduction in the emission of nitrogen compounds.

- The Habitats Directive requires a very high level of protection for habitats across Europe. However, it is widely accepted that presently nitrogen deposition impacts are not addressed consistently in relation to the requirements and objectives of the Directive.

- A number of countries have used critical load assessments to inform their reporting on the conservation status of habitats listed under the Directive. However, it is also recognised that there needs to be a much more robust and consistent approach taken to reporting nitrogen deposition impacts, linking critical loads and levels approaches to the protection of biodiversity.

- Where nitrogen deposition is a “pressure” or “threat” to the conservation status of habitats it should be identified in reporting by Member States under Article 17 of the

Habitats Directive. The use of critical loads and levels should form an integral part of this assessment, to inform the determination of threat.

- While at EU level there is a high level objective to achieve no exceedance of critical loads, there is no timetable or trajectory in place to help deliver this. It is therefore vital that a number of high level and local air pollution initiatives are coordinated in a targeted manner to help achieve this.

- The UK has rigorously applied the requirements of Article 6.3 of the Habitats Directive in relation to nitrogen deposition. However, ambiguity in interpreting and defining an "adverse affect" remains an issue.

- There is a great deal of legislation at an EU level intended to offer a high level of environmental protection. This could be much better integrated at a UK level to deliver outcomes to significantly reduce the impacts of nitrogen deposition on habitats and species.

- The UK Air Quality Strategy (UK AQS) needs to be strengthened in order to deliver the requisite provision for the protection of sensitive habitats. At present ammonia is not covered by the UK AQS and should be incorporated and supported by a Nitrogen or Ammonia Strategy.

Background

This paper focuses on the issues relating to atmospheric nitrogen pollution and its threat to biodiversity. The main emphasis concerns impacts on Natura 2000 sites relating to the situation within the UK, but set in a European perspective.

A brief introduction to current and future air pollution threat is provided. Details of how nitrogen pollution is being addressed in relation to the protection of Natura 2000 sites are then discussed. Examination of how two regulated sectors (power stations and intensive livestock) provide reflections of how we tackled this in the UK and the issues still remaining. Finally, consideration is given to the various policy drivers that exist within the EU and UK to tackle nitrogen pollution. Suggestions are made on how existing measures could be better integrated and used to provide greater protection. The chapter does not intend to provide a comprehensive summary of the entire process, but draws upon the approach we adopted, with observations provided on the strengths and weaknesses encountered. The views expressed are therefore those of the author rather than the organisations detailed.

7.7.1 Introduction: Global and European context

Over the past 40 years the world population has more than doubled from approximately three billion to over six billion currently with projections for a global world population of over nine billion by 2050 (UNFPA, 2008). As a result of emissions arising from food production and combustion activities, global levels of nitrogen pollution will continue to rise. For the first time, man made emissions of nitrogen compounds are now on a level comparable to, or exceeding, the releases from natural sources. This means the global pool of "available" nitrogen has doubled in less than a century (Galloway *et al.*, 2008). Emissions of nitrogen can have local impacts (e.g. close to conurbations or intensive livestock production), and can also be carried long distances and contribute to transboundary impacts away from the point of origin. The result is that many sensitive ecosystems are exposed to rates of nitrogen deposition much larger than sustainable limits.

Emissions of nitrogen pollution are considered to pose a significant threat to sensitive habitats across Europe. An assessment method using "critical loads" is well established and has allowed us to report risk in an agreed and consistent manner. Critical loads are used to inform EU air pollution policy development, for example under the National Emissions Ceiling Directive (NECD, 2001), as well as the UNECE Convention on Long Range Transboundary Air pollution (LRTAP), incorporating the Gothenburg Protocol. A substantial area of semi-natural habitat in the UK exceeds its critical load for nitrogen and will continue to do so in 2020 (Hall *et al.*, 2006). The critical loads approach provides a very useful tool to support air pollution policy options. However, it tells us little about the areas on the ground, or the ecological interest of these areas, where this impact is predicted to occur.

More recently attempts have been made to use the critical loads approach in a more targeted manner to better understand the environmental outcomes of predicted exceedances. For example "Nitrogen Deposition" has been listed as a global threat to biodiversity and an indicator by the Convention on Biological Diversity (CBD). More recently, critical load Exceedance for nitrogen being agreed as the indicator as part of the Streamlining European 2010 Biodiversity Indicators (SEBI, 2010) programme (EEA, 2007).The critical loads approach allows the cross-over of an air pollution indicator, *per se* (i.e. a pressure) into the potential effects on biodiversity (i.e. and impact). This provides an opportunity to better understand the impacts of nitrogen deposition on biodiversity and to respond to emission reduction considerations in a much more informed manner. Although critical loads originated in Europe they are now more widely used, for example in the United States and parts of Asia.

7.7.2 UK air pollution trends and forecasts in the European context

By 2020 emissions of sulphur dioxide across Europe are predicted to have been reduced by approximately 90 per cent from 1980 levels. Emission of will have fallen by about 70 per cent from their peak around 1990. However, reductions in ammonia (NH_3) emission are predicted to be much more modest with only an estimated fall in European emissions of 40 per cent, by 2020 from 1990 levels predicted, unless further NH_3 emission control is implemented (ROTAP, 2011).

In the UK sulphur emissions have fallen by over 90 per cent from their peak in the 1970s. This is predominately down to a decline in heavy industry, sulphur reduction in vehicle fuel and the use of sulphur abatement on some power stations. There has also been a significant increase in gas fired power generation and a consequent reduction in coal use overall (despite increasing use of coal in the last few years).

The fall in NO_x emissions are much less pronounced, in comparison to SO_2, with a reduction of only 50 per cent since 1970. There are two main reasons for this. Firstly, the largest emission sector is transport. The EU has been tightening emission standards on new vehicles through various phased Euro standards. However, the "lab based" theoretical improvements have not translated into the real world situation in the UK. Higher vehicles number on the UK roads and the level of congestion means that the cars are performing worse in terms of national emissions than had been calculated.

The second reason for the lower fall in emissions in the UK relates to a lack of control on the power sector, the second largest source of emission. There has been a repeated failure to retrofit existing power plant with reduction technology (such as Selective Catalytic Reduction –SCR) used elsewhere in Europe) and apply this technology to all new power stations. This means that the relative contribution of power station , as a percentage of the total emission budget, has increased from about 19 per cent in 1999 to about 28 per cent today (NAEI, 2009). As a result of the UK is only likely to narrowly achieve its 2010 NEC Directive ceiling for NO_x.

Ammonia (NH_3) emissions have fallen even less than NO_x with only a 20% decrease since 1990 (the earliest date from which reliable NH_3 inventories exist in the UK). The main reason for this reduction is a gradual decline in animal numbers and in total use of mineral fertilizers. Although the Directive on Integrated Pollution Prevention and Control (IPPC, 96/61/EC) has applied to large pig and poultry farms, in the UK, since 2007, this is estimated to have had little impact on overall UK NH_3 emissions. The reason is that IPPC only applies to a relatively small fraction of the UK NH_3 source (cattle, fertilizers, small farms, other sources etc are not included). Until now, there has been little explicit action to implement the discretionary requirements of the Gothenburg Protocol (as listed in the Gothenburg Protocol Annex IX) to use low NH_3 emission methods in the cattle or fertilizer sectors.

Concentrations of sulphur dioxide in ambient air have fallen to levels where they no longer pose a threat to ecosystems. Generally this is also true for concentrations of NO_x, although there are some notable exceptions, for example close to major roads (Defra, 2007) and developments such as airports.

Despite the 50 per cent reduction in NO_x emissions, measurement of total nitrogen deposition (both oxidised and reduced) has not reduced significantly over the past 20 years, remaining at approximately 400kT pa throughout (ROTAP, 2011). Over the UK concentrations of NH_3 have changed little over the past 10 years, with the exception of localised variability. Over the past 20 years the proportion of NH_3 to total nitrogen deposition has increased from 45-55 per cent (ROTAP, 2011).

At present, in the UK, approximately 60 per cent of all sensitive habitat area exceeds their critical load for nutrient nitrogen deposition (ROTAP, 2011). This figure will only decrease to approximately 50 per cent by 2020 unless further and substantial cuts are made in the emissions of NH_3 and NO_x.

7.7.3 The Habitats Directive in relation to nitrogen deposition

The Habitats Directive (92/43/EEC) provides a cornerstone for European nature conservation policy. It promotes the maintenance of biodiversity and requires Member States to maintain or restore the threatened natural habitats and wild species listed in the Directive at "favourable conservation status", introducing robust protection for those habitats and species of European importance.

Habitats Directive- Article 17.

Every six years, Member States must report on the implementation of the Directive. Article 17 requires Member States to make an assessment of the conservation status of all relevant habitats and species listed in the annexes of the Directive. The 2006 reports include a list of "pressures" to the structure and functions of habitats or "threats" to future prospects. However, at present there is no category specifically for nitrogen deposition as there is under the overarching Convention on Biological Diversity or the SEBI 2010. So while nitrogen deposition is a well known and accepted pressure and threat, Member States were unable to report it explicitly during the 2007 Article 17 reporting round. This shortfall has been recognised and should be addressed by the next reporting round. Examination of how Member States dealt with reporting under Article 17 was a key consideration of the COST 729 workshop and is reported elsewhere in this publication (Whitfield *et al*., this volume).

A number of Member States have annotated their reports with explicit reference to nitrogen deposition and used critical load exceedance as a method to assess air pollution or eutrophication as "current pressure" or "future threat". However, it is clear from the workshop that some countries such as Portugal and Austria have yet to recognise N deposition as a national issue, despite concerns of their scientists and the critical load maps showing exceedance (e.g. see Martins-Loução et al., and Dirnböck, this volume). This contrasts sharply with the position in the UK, where air pollution (including nitrogen deposition) was listed as a pressure to "the current structures and functions" or a "threat to future prospects" for 53 out of 87 Annex I habitats. Quite clearly there is a need to identify nitrogen deposition as a pressure or threat in reporting for all Member States under Article 17. It is recommended that critical loads and levels should form an integral part of this assessment (Whitfield *et al.*, this volume). This should recognise the need to better understand the consequences of critical load exceedance on those habitats involved.

As well as improving the reporting of nitrogen deposition impacts on conservation status for the Habitats Directive, there is obviously the need to minimise the nitrogen risk, in the most efficient and targeted manner at EU, national and local levels. Because of the risk that nitrogen deposition poses across Europe air pollution policy should be targeted to ensure that EU Member States can meet the Habitats Directive objectives.

Habitats Directive – Article 6.3

The Habitats Directive provides for a very high level of protection for the Natura 2000 network. It does this by requiring a considered and precautionary approach to allowing or authorising "plans or projects" that may have a significant effect on a site. Article 6.3 of the Directive provides a requirement under which plans or projects may only be permitted if it can be demonstrated that they will have no adverse affect on the integrity of a Natura 2000 site.

We have already recognised that nitrogen deposition is a significant threat to many Natura 2000 sites across the EU. Indeed from 2010, it is estimated that N deposition threatens the long term viability of about 70 per cent of the EU 27 natural area (CCE, 2008). Therefore, at the workshop it was very interesting to see how Article 6.3 was being applied across the EU (Bealey *et al*., this volume) to see if the required precautionary approach was being applied in a robust and consistent manner. It became apparent that there are major issues on how Member States interpret the provisions of Article 6.3, which affect the degree of protection afforded to the Natura 2000 sites.

In light of the workshop findings, it is worth exploring the wording of Article 6.3, to see the key areas where the environmental outcome may be influenced by interpretation of the text (as highlighted in bold below):

> *Article 6.3 – Any plan or project not directly connected with or necessary to the management of the site but* ***likely to have a significant effect*** *thereon, either individually or in combination with other plans or projects, shall be* ***subject to appropriate assessment*** *of its implications for the site in view of the site's conservation objectives. In the light of the conclusions of the assessment of the implications for the site and subject to the provisions of paragraph 4, the competent national authorities shall agree to the plan or project only after having ascertained that it* ***will not adversely affect the integrity of the site*** *concerned and, if appropriate, after having obtained the opinion of the general public.*

According to current practice, each Member State is left to define what they view to be a ***"significant effect"***. In the UK the term significant has caused some confusion and has been adopted to mean a 'process contribution' (of a plan or project) that is clearly identifiable at a site level (rather than the emission itself causing a significant effect). Pre-existing criteria, already used in UK pollution legislation, were adopted and once a plan or project was screened as being identifiable (significant) a further examination is required to gauge its impact (degree of significance) via an "***appropriate assessment***". This assessment was undertaken "in view of that site's conservation objectives". As we have seen, not all Member States have identified nitrogen deposition as a major threat and of those that have, (e.g. the U.K.) nitrogen deposition is not detailed systematically in the conservation objectives. Therefore, even where critical loads have been used in assessments under Article 6.3, it is still up to individual countries to define an assessment that is appropriate, because no common methodology exists to consider the impacts of nitrogen deposition.

Assuming an assessment has been carried out in a robust manner, there is still the final hurdle of defining what represents an acceptable level of critical load contribution from a plan or project. In other words, there is a difficulty in agreeing the threshold emission/deposition contribution that "***will not adversely affect the integrity of the site".*** It appears that, of all Member States, only Denmark and Germany have set out clear parameters of acceptable additional process contributions relating to additional nitrogen emissions from intensive livestock units that would not adversely affect an SAC or SPA (See e.g., Bealey *et al*.,this volume).

From this we can clearly see that Article 6.3 is open to interpretation as to the degree of precaution that individual Member States apply. This applies to their interpretation for each of significant, appropriate assessment and adverse affect.

Site-specific consideration will always be a key factor in assessing a plan or project in the light of the conservation objectives for a site. This allows some latitude in defining significance and the scope of the appropriate assessment. However, unless some generic guidance is provided (as already happens in Denmark and Germany), it is open to interpretation and possible abuse as to what level of process contribution will or will not cause an adverse effect. It is quite clear that linking a defined threshold or additional process contribution in terms of allowable critical level or critical load contribution for nitrogen is required to determine if the plan or project is acceptable as proposed.

In the UK, these issues of interpretation have vexed the application of Article 6.3 as applied through national regulations transposing the Directive. So although agreed frameworks have been established between competent authorities and the nature conservation agencies in terms of "significant effect" and what constitutes an "appropriate assessment", the process has struggled to agree a generic threshold for an "adverse affect". This is highlighted below in two examples: a) relating to the power station sector and the introduction of the IPPC Directive and, b) consideration between the UK environment agencies and the country conservation agencies of pig and poultry units, regulated under the IPPC Directive.

7.7.4 Assessment of key nitrogen source sectors

Assessment of UK Power Stations

During the 1970's and 1980's, pollution from UK power stations transformed the air chemistry of the UK and resulted in high levels of acid deposition across much of Northern Europe. The failure to tackle pollution from the power station sector led to Britain being termed the "dirty man" of Europe and brought the term acid rain into common parlance in the UK. Since that time, the decline in coal burn and EU legislation has led to significant reductions in emissions of sulphur dioxide from the power station sector. In 2006, the major UK coal and oil fired power stations were reviewed under the 'Habitats Regulations' with assessments based on critical loads exceedance.

The UK Department for Environment Food and Rural Affairs (Defra) (Defra, 2007) predict that, by 2020, acid deposition will still be exceeded at almost 40 per cent of sensitive UK habitats with almost 50 per cent exceeding their critical load for nitrogen deposition. Overall, the largest regulated source of acid and nitrogen deposition to UK ecosystems is the Electricity Supply Industry (ESI), mainly through emissions from power stations. The critical load modelling studies concluded that the power stations were responsible for significant deposition at a number of Natura 2000 sites (Environment Agency, 2006). However, the UK environment agencies concluded that while significant, all the emissions from the ESI were not having an adverse impact on the integrity of sites. In Wales, the statutory conservation agency (the Countryside Council for Wales) rejected this conclusion and formally adopted an "agree to disagree" position with the Environment Agency.

Because there is no agreed threshold for defining 'adverse affect' in terms of critical load exceedance it is hard to argue definitively against the environment agencies' position. However, as the critical loads approach is being used as a risk based criteria for an appropriate assessment it can equally be argued that it should be incumbent on the 'competent authority' (i.e. the relevant environment agency) to define an acceptable process contribution on the basis of critical load. In identifying a risk it is essential to quantify at what point that risk is acceptable or unacceptable.

Another issue about using the critical loads as the risk based criteria for the assessment results is in the time taken to reduce deposition to reach critical load. It is planned that the ESI will be making significant emission cuts by 2016 under the provisions of the Large Combustion Plant Directive (LCPD) (LCPD, 2001). It is hard to quantify the risks involved in delaying emission cuts until 2016. The same issue remains at the highest level in terms of EU and UK air policy. For both, there is a high-level policy commitment to achieve no exceedance of critical loads or levels. However, without a timetable for this commitment, it is hard to set high-level emission reductions, for example within the National Emissions Ceilings (NEC) Directive (NECD, 2001), or to provide clear targets for the ESI which are needed to help deliver these commitments

Assessment of the Intensive livestock Industry in the UK

Under the provisions of the IPPC Directive, large pig and poultry units are currently being authorised in the UK. Where these units are sited near to Natura 2000 sites and are judged to have a significant effect, they require an 'appropriate assessment' under the provisions of the Habitats Directive.

A number of studies from the early 1990's have demonstrated that ammonia emissions from these units can be many times the critical level and critical load for the receiving habitat (Sutton *et al*, 2009). Studies have shown that these emissions can cause substantial changes in vegetation structure and composition with the loss of sensitive lichens and forb species at the expense of nitrogen tolerant species such as grasses (Pitcairn *et al*., 2009). In part, the results of these studies supported the need to regulate large NH_3 sources under the IPPC Directive.

The site-level environmental assessments have closely followed the requirements of Article 6.3, with screening criteria being agreed along with the scope of the appropriate assessment. However, as with the power stations in the UK, the major issue under consideration is defining an acceptable process contribution, i.e. a contribution of the plan or project (in terms of critical load or critical level contribution) below which it can be concluded that the emission will not have an adverse impact on the integrity of the site.

The situation for the UK contrasts with the situation in Denmark where allowable additional emissions are defined in terms of kgN $ha^{-1}yr^{-1}$ and in Germany where any process contributing more than 10 per cent is deemed unacceptable (Bealey *et al*., this volume). It is agreed that control of pig and poultry units under IPPC will make only a modest reduction in overall UK ammonia emissions. However, locally control could have a profound effect by making significant reductions in critical load and critical level contribution to specified sensitive habitats.

These two examples demonstrate that while the UK has expended great effort and detail in transposing the Habitats Directive, there has been little air pollution environmental improvement beyond that which would have occurred as a result of other drivers, such as the Large Combustion Plant Directive. Yet in terms of environmental outcome, the Habitats Directive arguably provides a stronger requirement for protection than any other piece of legislation. Therefore, despite the UK's intention to rigorous application of the Directive, there has been little significant environmental gain in terms of additional measures to tackle air pollution impacts. This is largely a result of the difficulty faced by the relevant authorities to agree a process contribution that will not cause an adverse impact. Furthermore, regulated sources, while significant are often only a part of a wider diffuse nitrogen issue (see section 5.2)

7.7.5 Legislative and Policy framework to protect Natura 2000

European Union context

While it can be concluded that the Habitats Directive provides a requirement for robust protection, the elements that could deliver that protection are open to interpretation and therefore fragment its effectiveness. A cornerstone of both EU and UK legislation is to provide a high level of protection to man and the environment as a whole (IPPC Directive, 1996). However, in reality legislation is often narrowly scoped with limited environmental focus targeted at very specific outcomes.

A notable exception to this is the transposition of the Water Framework Directive (2000/60/EC) with its objective end point in the attainment of "good ecological status" of water bodies. Integrated action for the protection of water is thus much more advanced than that to protect terrestrial environments from air pollution. Such thinking has been used to protect shared resources through initiatives on rivers such as the Rhine and Danube through to regional measures to protect shared coastal resources (e.g. the Barcelona Convention (1976) and Oslo and Paris Commission (OSPAR) (1992)).

Nevertheless, there are cases where a more effective integration would be justified. For example, the 1991 Nitrates Directive (91/676/EEC) makes provision for the protection of water from nitrate pollution. However, the way it has been interpreted in the UK and several other European countries means that the primary focus has been on the protection of human health by targeting nitrate levels in groundwater used for potable extraction. This is despite the Directive also referring to the protection of nature conservation interests.

The closest we get to an integrated initiative to control air pollution is the Clean Air For Europe-CAFÉ) Directive (2008/50/EC). However, again the main thrust of CAFÉ, so far, has been the protection of human health. Nevertheless, in recent years there have been positive moves to link air pollution drivers with biodiversity outcomes. Within the UN-ECE Convention on Long-range Transboundary Air Pollution (CLRTAP), the critical loads scientific community are committed to establishing appropriate critical loads aimed at protecting biodiversity more specifically (CCE, 2008). Although this may be some way off, it will hopefully help influence meaningful emission control strategies focused on biodiversity outcomes. This offers the opportunity to link ecological outcomes of a Directive directly to the emission reductions required for various Member States.

In December 2007, the European Environment Agency published a list of 26 indicators that will be used to monitor progress toward the objective of halting biodiversity loss by 2010 (EEA, 2007) under the Convention on Biological Diversity. The Streamlining European Biodiversity Indicators (SEBI, 2010) endorsed the use of critical load Exceedance (CLE) for Nitrogen as the indicator against which to mark progress toward the 2010 target.

The use of CLE within a convention to protect nature conservation interests represents a major cross-over between two key policy arenas. While this represents a significant development in using critical loads, it is recognised that much work will be required to develop biodiversity relevant critical loads.

With the critical loads and levels approach providing a suitable framework, there is now the need to develop more specific high-level goals of suitable ambition. Such goals should be broad in scope and combine a quantifiable target with a suitable time frame.

Transposition into UK regulations and practice

European legislation is transposed in the UK through a series of Acts and Regulations. Additional strategies provide mechanisms to deliver national objectives, for example the National Air Quality Strategy (Defra, 2007). At a European level there would appear to be sufficient drivers to deliver a high level of environmental protection. Some of the major EU policy instruments offer a range of opportunities to deliver this, for example the Habitats Directive, the Environmental liability Directive (2004/35/EC), the Environmental Impact Assessment Directive (85/337/EEC) Strategic Environmental Assessment (SEA) Directive (2001/42/EC) the Water Framework Directive (2000/60/EC) and the Thematic Strategy for soil protection and proposals for an EU Soil Framework Directive (Soil Framework Directive, 2006).

Individual Member States have some flexibility when transposing EU Directives into domestic legislation. While we have highlighted examples where interpretation has caused problems (e.g. in defining adverse affect), there are opportunities to use the directives to target domestic programmes to deliver a high level of environmental protection. For example, while cattle are not covered by the IPPC Directive, their emissions can have a significant impact on habitats. In Denmark the introduction of the EIA Directive has provided a lever to enact domestic measure to address ammonia emissions from cattle close to Natura 2000 sites (H. Bjerregaard, this volume). It is quite clear that before Member States go seeking new legislation, to protect wildlife, reinterpretation and better use of the provisions incumbent in the existing rafts of legislation is essential.

Within the UK, the main framework for delivering Air Quality outcomes is through the UK Air Quality Strategy (Defra, 2007). The target of the Strategy is to ensure compliance with EU air quality legislation, as well as setting national objectives. However, its main focus is on the protection of human health, where a number of air quality thresholds are mandatory. The few thresholds that are listed for ecosystems are much less prescriptive being termed "national objectives" relating to concentrations for SO_2 and that in large part are already met. As previously detailed, the UK is committed to the long term objective of non-exceedance of critical loads, but a targeted trajectory to support this is not currently covered in the AQS, or elsewhere. The absence of ammonia as a named air pollutant in the strategy is notable.

As a result the level of public awareness about potential impacts of ammonia to nature conservation is significantly lowered. So while large organisations like the UK environment agencies are aware of ammonia as an issue, other competent authorities such as local planning authorities may be poorly informed of the potential impact. This has come to light on a number of occasions when livestock units are developed, such as for cattle or for pigs and poultry but below the IPPC threshold. Such plans or projects often proceed without assessment, "off-the-radar", in relation to the terms of the Habitats Directive, while others may occasionally be identified if planning permission is for some other reason required (Frost, 2004). It is thus of concern that Natura 2000 sites may be more severely impacted by proximal livestock units not covered by the IPPC thresholds than other sites further from livestock units that are regulated under IPPC. While other legislative measures may need to be adopted to prevent this happening in future, there is a great urgency to raise the issue of ammonia in future development of the Air Quality Strategy.

As discussed, control of ammonia is a key priority in protecting sensitive habitats. For a number of years there have been indications from Defra (and its predecessors) that a separate strategy is required for ammonia. Both Joint Nature Conservation Committee and the Environment Agency have called for an ammonia strategy. However, given the current recognition of the wider issue of nitrogen impacts, it is probably now more intuitive to have a 'nitrogen strategy', within which NH_3 control would form a central component. This could ensure that all environmental media were consider in a holistic manner in order to prevent control of one sector leading to pollution swapping to a different environmental receptor. While control of nitrogen pollution from individual sources can be extended and strengthened, a major source of this pollution will come from a range of diffuse agricultural sources. Joined up approaches to tackle point-source and diffuse pollutants have been proposed before in the UK in relation to the water environment. For example, the environment agency 'Aquatic eutrophication strategy' in England and Wales (Environment Agency, 1999). A similar integrated approach considering impacts from all sources across all environmental media is urgently needed.

Over recent years a number of studies across the globe and northern Europe have examined a range of ammonia emission options from buffer areas to consideration of diet formulation to reduce ammonia emission (Sutton *et al*., this volume). NH_3 abatement techniques have also been trialled and applied in countries such as the Netherlands where frameworks exist in which these measures alongside other controls can be delivered within a common framework.

There are therefore an extensive range of options available to address the ammonia issue. An overarching national strategy is, however, needed as a basis to ensure that appropriate measures are put in place to ensure the protection of sensitive habitat sites.

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7.8 Quantifying the threat of atmospheric ammonia to UK Natura 2000 sites

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Abstract
High levels of atmospheric ammonia can damage sensitive ecosystems.

We derive spatially detailed atmospheric-ammonia surface concentrations using a high resolution atmospheric transport model.

We apply two types of indicator to quantify the threat of atmospheric ammonia to UK Natura 2000 sites, the flagship for biodiversity protection in the European Union.

7.8.1 Introduction
High levels of atmospheric ammonia (NH_3) may cause adverse effects on the environment through a range of processes, including eutrophication effects on biodiversity, acidification

of soils and particulate matter effects on human health (Erisman and Sutton, 2008). The magnitude of the ecological effects can be assessed by thresholds of atmospheric NH_3 concentrations, referred to as critical levels (Achermann and Bobbink, 2003; Sutton *et al.*, 2009c). New critical levels (CLE) for assessing the effects of atmospheric ammonia on sensitive ecosystems (shown in Table 7.4) have recently been adopted by the United Nations Economic Commission for Europe for different habitats (UNECE 2007, Sutton *et al.*, 2009b).

The FRAME atmospheric dispersion and deposition model (e.g., Fournier *et al.*, 2005) was used to estimate surface air concentrations of ammonia at a spatial resolution of 1 km by 1 km (Figure 7.13a). By overlaying the air concentration data with the boundaries of the UK Natura 2000 sites (Figure 7.13b) in a Geographical Information System, a map of Critical level exceedance was derived (Figure 7.13c).

7.8.2 Aims and objectives

The new CLE estimates are particularly relevant for assessing ecological conditions under the terms of the Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora), and the associated Birds Directive (Council Directive 79/409/EEC on the conservation of wild birds). These seek to protect Europe's natural resources, especially the most seriously threatened habitats and species across Europe. The 'Natura 2000' network, to be implemented by all EU Member States, represents a flagship for biodiversity protection in the European Union. In this study, we have sought to investigate how the recently established CLEs could be used to develop indicators to assess the ammonia threat to the Natura 2000 network in the UK.

Two main types of indicator were investigated, to assess the threat of atmospheric ammonia concentrations on Natura 2000 sites in the UK:

- Percentage area of Natura 2000 sites where the critical level is exceeded (Area Weighted Indicator AWI)
- Number of Natura 2000 sites where the Critical level is exceeded (Designation Weighted Indicator DWI)

7.8.3 Results and discussion

Over the UK as a whole, the three critical levels of one, two and three $\mu g\ NH_3\ m^{-3}$ are exceeded over 69 per cent, 42 per cent and 19 per cent of the land area, respectively (Table 7.5). The choice of indicator (AWI or DWI) used to estimate the stock-at-risk at UK 'Natura 2000' sites has a large impact on the outcome (as does the spatial resolution). Using the AWI we estimate that 11 per cent and one per cent area of the UK Natura network exceeds the CLE values of one and two $\mu g\ NH_3\ m^{-3}$, respectively. By contrast, using the DWI, the equivalent exceedances are 59 per cent and 24 per cent. The highest regional exceedance (DWI, CLE one $\mu g\ NH_3\ m^{-3}$) was calculated for England (92 per cent exceeded), and the lowest for Scotland (24 per cent exceeded). This is shown in Tables 7.6 and 7.7 and Figure 7.14. The Designation Weighted Indicator is more precautionary than the Area Weighted Indicator. It may be argued that the DWI is the most appropriate indicator since exceedance over any part of a Natura 2000 site represents a threat to the integrity of the whole site (Frost, 2004).

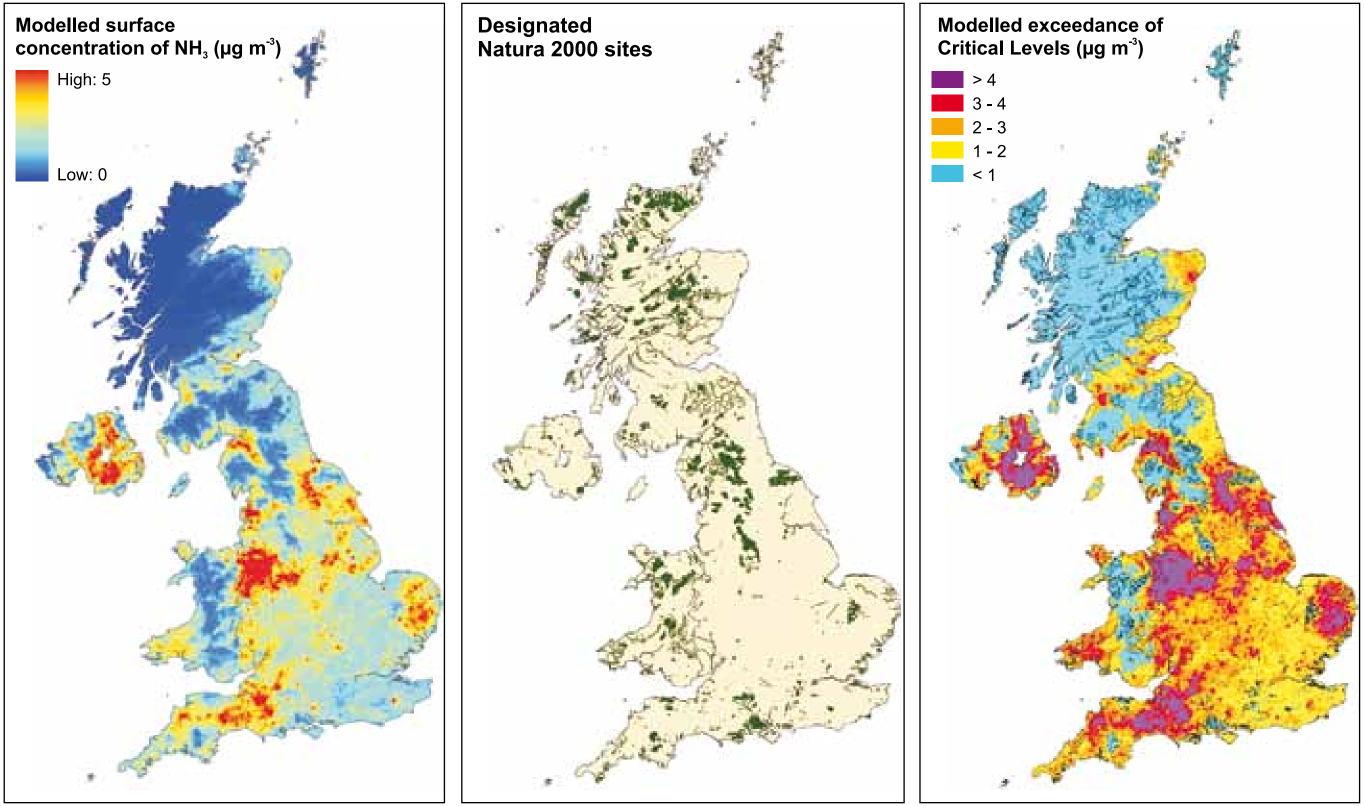

Figure 7.13: a) Modelled UK NH_3 concentrations at surface level (average height of air column 0-1 m above ground), b) Designated Natura 2000 sites in the UK, c) Modelled exceedance of critical levels for the UK.

Table 7.4: New critical levels (CLE) for effects of atmospheric ammonia on sensitive ecosystems adopted by UNECE (2007):

Receptor	Critical level (μg NH_3 m^{-3})
Lichens and bryophytes	1
Higher plants	3 (uncertainty range 2-4)

Table 7.5: Whole country area (in per cent) where critical levels of 1, 2 and 3 μg NH_3 m^{-3} are exceeded.

Critical level	England	Wales	Scotland	N. Ireland	UK
1 mg m^{-3}	93 per cent	68 per cent	26 per cent	85 per cent	69 per cent
2 mg m^{-3}	61 per cent	38 per cent	9 per cent	65 per cent	42 per cent
3 mg m^{-3}	27 per cent	14 per cent	2 per cent	43 per cent	19 per cent

Table 7.6: Number of UK Natura 2000 sites (DWI, in per cent) where critical levels of 1, 2 and 3 μg NH_3 m^{-3} are exceeded.

Critical level	England	Wales	Scotland	N. Ireland	UK
1 mg m^{-3}	98 per cent	92 per cent	34 per cent	85 per cent	68 per cent
2 mg m^{-3}	69 per cent	56 per cent	13 per cent	63 per cent	42 per cent
3 mg m^{-3}	32 per cent	26 per cent	6 per cent	34 per cent	19 per cent

Table 7.7: Area of UK Natura 2000 sites (AWI, in per cent) where critical levels of 1, 2 and 3 μg NH_3 m^{-3} are exceeded.

Critical level	England	Wales	Scotland	N. Ireland	UK
1 mg m^{-3}	44 per cent	16 per cent	3 per cent	39 per cent	22 per cent
2 mg m^{-3}	7 per cent	4 per cent	0.4 per cent	17 per cent	4 per cent
3 mg m^{-3}	2 per cent	1 per cent	0 per cent	4 per cent	1 per cent

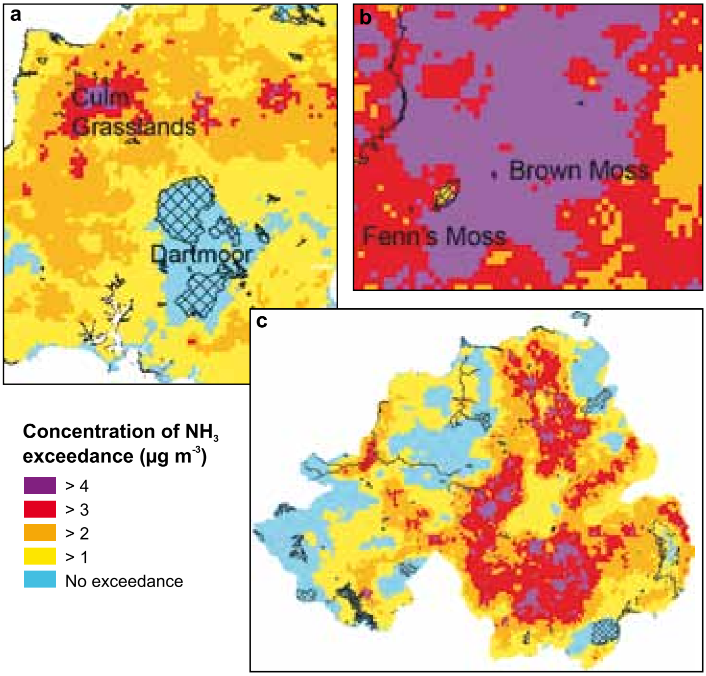

Figure 7.14: Spatial pattern of estimated critical level exceedance and the location of Natura 2000 sites. a) SW England: With the exception of small areas at the boundaries, most of Dartmoor is below the 1µg m-3 critical level. By contrast, the Culm Grasslands mostly exceed a critical level of 2 µg m-3. 2b) W England: small SACs in agricultural regions, such as Fenn's Moss and Brown Moss (NW England) exceed the critical levels. 2c) Northern Ireland: Although many of the largest sites do not exceed the lowest critical level, substantial exceedance is seen for the smaller sites.

7.8.4 Conclusions

The choice of indicator used to estimate the stock-at-risk at UK Natura 2000 sites has a large impact on the outcome.

The Designation Weighted Indicator is more precautionary than the Area Weighted Indicator, as it may be argued that exceedance over any part of a Natura 2000 site represents a threat to the integrity of the whole site.

Small sites are often more at risk than larger sites, as they tend to occur in source areas with larger atmospheric NH_3 concentrations and dry deposition of N. They are also more likely to be overlooked when meeting policy targets with an Area Weighted Indicator, since their small area will not contribute significantly to the overall statistics.

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7.9 Beyond Nitrogen critical loads – is there a Role for Ecosystem Services?

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Abstract
This paper considers the extent to which indicators of critical load exceedance capture the potential impacts of changes in nitrogen deposition on ecosystem services. It shows that there are significant links between nitrogen deposition and a large range of ecosystem services. There is potential for indicators to be adapted to provide more specific qualitative information for Natura 2000 sites of the implications of critical load exceedance for ecosystem services.

For ecosystem goods, water quality, and erosion regulation, it is likely that quite specific information can be provided on the effects of nitrogen deposition. For others, such as pollination and cultural services, the implications for ecosystem services are likely to depend on the specific changes in species composition that are found in specific habitats and sites. The issue of climate regulation has been identified as a critical ecosystem service, but this effect is not currently considered explicitly in setting critical loads, and given the complexity of the potential effects of nitrogen deposition on different greenhouse gas fluxes, it seems impractical to include this in any simple assessment of effects of critical load exceedance.

There are ecosystem services where exceedance of the established empirical critical load for nitrogen input can be a positive outcome, for example, increases in more nitrophilous species increasing productivity in certain grassland types and increased grass growth stabilising coastal dunes, and hence enhancing erosion regulation. An ecosystems approach would therefore have value in informing the prioritization of conservation management practices in areas with high nitrogen deposition, depending on the ecosystem service that is most valued at any particular site. However, given that the cause and effect relationships underlying important ecosystem services are

often complex and not sufficiently understood, more data and research is needed to provide specific guidance on potential conservation priorities.

7.9.1 Introduction

The ecosystem service approach based on the work of the Millennium Ecosystem Assessment (MEA, 2005) and the Convention for Biological Diversity (CBD, 2004) is currently being considered across Europe as a potential means of more effective management of the environment. By comparison with the existing focus on critical thresholds, an ecosystems approach may offer important advantages for air quality management, such as:-

- a holistic assessment that considers the whole range of ecosystem services affected as a starting point;
- inclusion of regulating services, such as ecosystem controls on fluxes of pollutants in land-water-air systems, which are currently under-represented in European policy;
- identification of negative externalities, ancillary benefits and trade-offs of policy measures;
- insight into the full costs and benefits of policy measures

Currently, evaluation of the benefits of measures to reduce nitrogen (N) deposition across Europe is based on critical loads, which are set to prevent 'significant harmful effects on specified elements of the environment'. These provide policy makers with values of ecological thresholds above which adverse and potentially irreversible environment effects may occur. Critical loads for nitrogen are either calculated using a steady-state mass balance approach to determine, at steady state, the rate of deposition at which a critical chemical threshold for effects is exceeded or an empirical critical load has been set based on observed effects in the field and in long-term field experiments. Alongside these empirical critical loads, typical biological or chemical indicators of exceedance are provided for different habitats (Bobbink *et al.*, 2010). However, there is no explicit consideration of ecosystems services in setting critical loads and in identifying the implications of critical load exceedance. Therefore, a key question for the application of the ecosystem service approach is if and how this approach could be better integrated with the assessment and application of critical loads for sensitive habitats and sites.

This short paper addresses this question by considering the extent to which indicators of critical load exceedance provided for the users of this information capture the potential impacts of changes in N deposition on ecosystem services. Our analysis is based on a study on the feasibility of embedding an ecosystem services framework into air quality policy (Hicks *et al.*, 2008) and an assessment of economic quantification of changes in ecosystem services caused by control of ammonia emissions by Smart *et al.*, (2011), to which the reader is referred for more detail.

7.9.2 Results

The results of an initial scoping study by Hicks *et al.*, (2008) to identify the presence of any significant links between ecosystem services and nitrogen deposition are summarized in Table 7.8. The results show significant potential links between N deposition and a large range of ecosystem services. The most important, and relatively well understood, positive (beneficial) changes to ecosystem services that could result from decreasing N deposition were related to air and water quality, species composition and climate regulation (i.e., decrease in greenhouse gas (GHG) emissions from soils). Important negative changes as a result of decreasing nitrogen deposition occurred where the fertilizing effect of nitrogen deposition had previously had a beneficial effect on harvested goods and carbon sequestration by vegetation and with specific agricultural management changes (e.g., changes in methods of slurry storage and application may lead to decreased ammonia emission, potentially at the expense of increased nitrate leaching from soils unless certain precautions are taken).

Table 7.8: Preliminary assessment of effects of nitrogen emissions on ecosystem services (after Hicks *et al*., 2008)

Ecosystem Service	Effect of nitrogen emissions
1. Provisioning Services	
Ecosystem goods	Production of goods (e.g. food, fuel, fibre) can be increased and decreased.
Water quality	Acidification and eutrophication of surface waters can be caused by direct deposition or by leaching from terrestrial ecosystems.
Biochemical/genetics	Abundance of species can be reduced (or increased in certain circumstances) and community composition can be changed in both terrestrial and aquatic ecosystems.
2. Regulating services	
Air-quality regulation	The growth of trees and tall vegetation can be affected, altering their ability to remove air pollution, while NH_3 emissions contribute to formation of secondary particulates
Climate regulation	Carbon sequestration, methane fluxes and nitrous oxide production are all affected
Water regulation	Effects on peat creation and forest growth can affect water storage and interception.
Water purification	The capacity of wetlands to remove nutrients from water may be reduced by excess atmospheric inputs.
Natural hazard regulation	No significant direct effects
Pest regulation	No significant direct effects
Disease regulation	No significant direct effects
Pollination	Both vegetation composition and flowering intensity can be affected.
Erosion regulation	Increases and decreases in vegetation cover can be caused, leading to changes in rates of erosion
3. Supporting services*	
Soil formation	Detrimental effects can occur on peat formation, but successional change and soil formation can be enhanced in other soils
Primary production	Increase of biomass in N limited terrestrial and aquatic habitats
Nutrient cycling	Rates of soil mineralization can be increased and production of greenhouse gases and nitrate leaching can be enhanced Increased soil N accumulation can occur and may be associated with increased C sequestration
4. Cultural services	
Recreation and tourism	Large changes in terrestrial and aquatic species composition may affect field sports and ecotourism
Aesthetic	Significant if it is assumed that changes from the status quo (e.g. changes in species composition) are negative.
Educational	Reduction in species rich habitats as sites for study
Cultural heritage	Loss of iconic species

Note: Including Supporting Services can lead to double counting

Table 7.9 provides a more detailed analysis of the effects of regional-scale N deposition on a selected range of the most important ecosystem services listed in Table 1. This study integrates data from two sources. Hicks *et al.*, (2008) conducted a qualitative assessment, based on expert judgement, of the impacts of nitrogen deposition on different UK broad habitat types, of which a selection (chosen to represent the Natura 2000 network) are shown in Table 7.9. Table 7.9 also shows the relevant EUNIS category for each UK Biodiversity Action Plan (BAP) broad habitat type, and lists the indicators of exceedance of the empirical critical load (Bobbink *et al*., 2010). On the basis of these indicators, we provide a qualitative assessment based on our own judgement, for each ecosystem service and habitat, as to whether any effect on ecosystem services could be deduced based on the indicators of exceedance for critical loads.

The results in Table 7.9 are considered briefly below for each ecosystem service in turn.

Provisioning Service: Ecosystem goods

Nitrogen deposition to nitrogen-limited ecosystems can cause a plant fertilisation effect leading to an increase in harvestable material, e.g. of crops (arable land), timber (woodlands), hay (grasslands). Some of the indicators of empirical critical load exceedance imply this effect (e.g., through an increase in tall grasses) but do not state it specifically. It is also important to note that N deposition at rates both above and below the critical load may be beneficial for ecosystem goods. It should be noted that, in the case of oxidized N deposition from industrial and traffic emissions of NO_x, these simply represent additional N sources. By contrast, in the case of reduced N deposition, any productivity gains need to be weighed up against the reduction of agricultural productivity due to NH_3 losses from crop and livestock systems.

Provisioning Service: Water quality

Water quality can be directly and indirectly impacted by N deposition through both acidification and eutrophication. Nitrogen leaching, which is linked to acidification, is a common indicator of exceedance of critical loads in Table 7.9, but is not indicated in some cases (e.g., for acid grasslands) for which effects might be expected.

Regulating services: Climate regulation

None of the indicators of critical load exceedance specifically relates to climate regulation. This is likely to reflect the complex responses of habitats to N deposition and the need to consider several greenhouse gases. In addition to any effect on above-ground or below-ground carbon sequestration, increased N deposition generally causes higher rates of N_2O emission, an effect that becomes more pronounced as deposition rates increase (Skiba *et al.,* 1998). This effect will occur to some extent in all terrestrial habitats, but it is particularly important in arable and improved grassland areas, which are subject to direct fertilisation. Furthermore, nitrogen fertilisation effects are also known to suppress CH_4-oxidation in grasslands, forests and arable systems potentially causing increased concentrations of this potent greenhouse gas (Hutsch *et al*., 1993).

Hence, identifying the net effect of additional N on the greenhouse gas balance and hence climate regulation represents a major current research challenge (e.g. Sutton *et al*., 2008; Smart *et al*., 2011), and it is difficult to quantify the trade-offs between changes in CO_2, N_2O and CH_4 fluxes for different habitats. These trades-offs become even more complex when the interactions between nitrogen emissions and secondary aerosol and ozone formation are considered. Hence, it is not realistic to consider this effect within the critical load exceedance context. Butterbach-Bahl *et al*., (2011) have made a first estimate of the net effect of nitrogen emissions on European radiative

Table 7.9: Impacts of nitrogen deposition on selected ecosystem services in UK Biodiovbersity Action Plan (BAP) Broad Habitat Types and typical indicators of empirical critical load exceedance for relevant EUNIS (European Nature Information System) habitat types (after Bobbink et al., 2010).

UK BAP Broad habitat type (Empirical critical load category in parenthesis)	Supra littoral sediment (Coastal Habitat (EUNIS B))	Broad-leaved, Mixed and Yew Woodland (Forest habitats (EUNIS G))	Acid Grassland (Grasslands and tall forb habitats (EUNIS E))	Calcareous Grassland (Grasslands and tall forb habitats (EUNIS E))	Dwarf Shrub Heath Heathland, scrub and tundra habitats (EUNIS F)	Bogs (Mire, bog and fen habitats (EUNIS D))
Typical indicators of empirical critical load exceedance (Relate to broad habitat type within EUNIS class.)	Increase tall graminoids, decrease prostrate plants, increased N leaching, soil acidification, loss of typical lichen species, accelerated succession	Changes in soil processes, nutrient imbalance, altered composition mycorrhiza and ground vegetation	Increase in gramin-oids, decline of typical species, decrease in total species richness	Increase in tall grasses, decline in diversity, increased mineral-ization, N leaching; surface acidification	Transition from heather to grass dominance, decline in lichens and mosses, changes in plant biochemistry, increased sensitivity to abiotic stress, increase in N leaching	Increase in vascular plants, altered growth and species compos-ition of bryophytes, increased N in peat and peat water
Provisioning Services Ecosystem goods (e.g. food, fibre, fuel)	+/+	+/0	+/+	+/+	+/0	?/+
Water quality	-/-	-/0	-/0	-/0	?/-	-/-
Regulating services Climate regulation	0/0	-/0	-/0	-/0	-/0	-/0
Pollination	0/?	-/0	-/?	-/?	?/?	0/+
Erosion Regulation	+/+	0/0	+/0	+/0	-/0	?/?
Cultural services Recreation and tourism	-/-	-/0	-/-	-/-	-/-	-/?
Cultural heritage	-/-	-/?	-/-	-/-	-/-	-/?

Scores are indicated as follows.
1. The symbol before the / indicates the evaluation of effects on ecosystem services based on Hicks et al., (2008) as follows : '+' potential positive or beneficial effect; '0'negligible effect; '-'potential negative or adverse effect; ?' gaps in evidence.
2. The symbol after the / indicates the possible effects on ecosystem services based on the indicators of critical load exceedance (Bobbink et al., 2010) as follows: + potential positive or beneficial effect can be inferred; - potential negative or adverse effect can be inferred; 0 no inferences can be drawn about effects on ecosystem service; ? some effect can be inferred but the direction is uncertain.

balance, highlighing the importance of addressing this interaction from the broadest possible perspective.

Regulating services: Pollination
Pollinators require islands of alternative flowers to provide food at specific times. N deposition can reduce patchiness of vegetation and change species composition, which may result in the loss of flowering species that may be crucial to particular pollinator species. When species composition remains unchanged, empirical data show both increases in flowering (e.g. in dwarf shrub heath) and decreases in flowering (e.g. in acid and calcareous grasslands) (RoTAP, 2011). Pollination ecosystem services are likely to be affected by critical load exceedance, but it is not possible to deduce the direction of change without further information on the specific changes in species composition. Furthermore, some effects (e.g., changes in and amount and timing of flowering) are not currently captured in critical loads.

Regulating services: Erosion regulation
Erosion is controlled by the presence or absence of vegetation and N deposition may change their abundance and occurrence. In early successional communities (e.g. sand dune systems (supra-littoral sediment)), nitrogen inputs may increase the growth of "sand holding" grass and sedge species and so reduce coastal erosion. Hence, in this case, critical load exceedance may be associated with a benefit for the ecosystem service. However, this effect is only clearly inferred by the indicators of exceedance in the supra littoral sediment habitat. In bogs and montane habitats, N inputs may decrease moss, and lead to increased erosion, but the indicators of exceedance only refer to 'altered growth and species composition' of bryophytes, hence not clearly identified the potential benefits for erosion.

Cultural services (Recreational, Aesthetic, Educational, and Cultural)
The impact of N deposition on cultural services is highly subjective and difficult to define. For the purposes of Table 7.9, we assumed that all changes from currently defined BAP habitat types are negative, and this is the case where loss of typical species is included in the indicators of critical load exceedance. However, the impact of N on cultural heritage is likely to be particularly important where individual iconic species are under threat (e.g. insectivorous plants such as sundew; fruit bearing plants such as bilberries). However, the critical load indicators only refer to broad functional groups which cannot be used to infer effects on individual species.

7.9.3 Discussion

The results show that there is potential for the consideration of positive and negative nitrogen impacts on ecosystem services provided by Natura 2000, and other sites of conservation interest, to guide policy development for their protection. However, the cause and effect relationships underlying important ecosystem services are often complex and not sufficiently understood. The implication of our study is that factors that may have a likely significant effect on a site protected under the Habitats Directive may not always be sufficiently described by the current indicators of exceedance of critical loads. Table 7.9 is very preliminary, and can certainly be improved upon, but does illustrate the range of ecosystem services affected and that the link to indicators of exceedance of empirical critical loads is stronger for some ecosystem services than for others.

For empirical critical loads to prevent eutrophication, a range of adverse effects have been identified as potentially occurring when the critical load is exceeded (Bobbink *et al*.,2003 and 2010; see Table 7.9). While there is considerable variation between habitats, these effects can generally be characterised as one of three major classes of impacts:-

- Invasion of competitive, fast growing species
- Decreased plant species diversity or loss of characteristic species of the habitat,
- Increased nitrate leaching once the system reaches nitrogen saturation.

Each of these has a broad link to specific ecosystem services. However, the critical load approach does not consider the implications of loss of characteristic species or nitrate leaching in terms of specific ecosystem services – rather it is simply set to prevent these adverse effects. Furthermore, changes in primary production are treated quite differently under the ecosystems approach than under the critical load approach. Whereas the former sees this an increase in provisioning services, the latter sees this as an adverse effect because it is normally associated with increased cover of fast-growing species which will out-compete other valued species for the particular habitat. The balance between these two effects is habitat specific – for most woodlands and grasslands, for example, primary production is a central ecosystem service, but for mires or sand dunes it is not. An ecosystems approach would therefore have implications for the prioritization of conservation management practices depending on the ecosystem service most valued at any particular site.

Nevertheless, it could be argued that the indicators of critical load exceedance could be readily adapted and clarified to provide more specific, albeit qualitative, information for Natura 2000 sites of the implications of critical load exceedance for ecosystem services. Actual quantification of these effects is another challenge, and is outside the scope of this brief paper. For ecosystem goods, water quality, and erosion regulation, it is likely that quite specific information can be provided. For others, such as pollination and cultural services, the implications for ecosystem services are likely to depend on the specific changes in species composition that are found in specific habitats, and hence the rather general language of the indicators of exceedance would need to be made more specific if effects on ecosystem services were to be evaluated.

Finally, the issue of climate regulation is particularly challenging, although it has been identified as a critical ecosystem service. This effect is not considered explicitly in setting critical loads, and given the complexity of the potential effects on different greenhouse gas fluxes and nitrogen aerosol affects on radiative balance (Butterbach Bahl *et al*., 2011), it seems impractical to include this in any simple assessment of effects of critical load exceedance. This is especially because any positive or negative effects of N deposition on ecosystem radiative balance need to be weighed against the potential existence of an opposing effect elsewhere, such as that related to an accompanying loss of N from agriculture. The extent of such interactions points to the need to complement the development of the ecosystems approach with studies that integrate the multiple consequences of human activities.

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