UK Status Report July 2011:
Update to empirical critical loads of nitrogen

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CONTENTS

EXECUTIVE SUMMARY

- Empirical critical loads of nutrient nitrogen were reviewed and updated at a workshop held under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) at Noordwijkerhout (NL) in June 2010. UK experts met in November 2010 to discuss the implications of the workshop results on the "mapping values" (ie, critical load values within the published ranges) for UK habitats. This report documents the changes made to the habitat distribution maps to which nitrogen critical loads are applied nationally, the critical load mapping values, and the impacts of these changes on critical load exceedances.
- As a result of this update empirical nitrogen critical loads are mapped nationally for 11 habitat types, compared to 8 habitats in 2003 (comprising 13 EUNIS habitat classes now compared to 11 EUNIS classes in 2003).
- Changes were made to the UK mapped distribution for dune grassland (previously represented under the "supralittoral sediment" broad habitat) to better reflect the habitat that nitrogen impacts data relate to.
- Habitat distribution maps were generated for new woodland types to enable empirical nitrogen critical loads to be mapped nationally for these habitats.
- Due to changes in the habitat distribution maps used for critical loads research the total area of sensitive habitats considered for eutrophication impacts in the UK has reduced by 1403 km^2 (1.9%).
- Empirical critical loads were applied to the UK distribution of saltmarsh for the first time.
- UK mapping values were lowered for five UK habitat types (comprising six EUNIS habitat classes) based on new UK evidence on the impacts of nitrogen.
- The area of UK habitats sensitive to eutrophication with exceedance of critical loads by current (2006-08) nitrogen deposition increased from 58.4% using the 2003 critical loads data to 71.2% using the updated (2010) critical loads.
- The magnitude of exceedance, expressed as Average Accumulated Exceedance (AAE) for all habitats, increased from 6.9 kg N ha^{-1} $year^{-1}$ using the 2003 critical loads data, to 7.9 kg N ha^{-1} $year^{-1}$ using the updated (2010) critical loads.

1 INTRODUCTION

Empirical critical loads of nutrient nitrogen were last updated for UK habitats in 2003 (Hall et al, 2003) following the CLRTAP workshop held in Berne in November 2002 (Achermann & Bobbink, 2003). In June 2010 a CLRTAP workshop took place in Noordwijkerhout (NL) to review and revise the ranges of empirical critical loads of nitrogen for natural and semi-natural ecosystems, on the basis of additional scientific information available for the period from late 2002 to 2010. A number of UK experts participated in this and the previous workshop. A short summary of the June 2010 workshop can be found in the report to CLRTAP (ECE/EB.AIR/WG.1/2010/14) and the proceedings of the workshop are published as an RIVM report (Bobbink & Hettelingh, 2011).

The critical loads from these workshops are presented as ranges rather than single values for each ecosystem. This range indicates the variation in sensitivity within a particular ecosystem, for example, because of differences in nutrient status or management etc. It is left to individual countries to decide where within these ranges the critical loads should be set for the purposes of national mapping; these values are referred to in this document for the UK as the “mapping values”. Environmental factors, for example, precipitation, base cation availability, or management, may influence where within a range the critical load should be set for some habitats. The decision of whether (and how) to apply these modifying factors is also left up to individual countries.

The Coordination Centre for Effects (CCE) in the Netherlands (www.rivm.nl/cce) is responsible for compiling European scale maps of critical loads and exceedances. These maps combine critical loads for countries that submit national data, with critical loads based on European background databases for countries that have not submitted national data. Where it is necessary to use the background databases for maps of nitrogen critical loads the CCE will apply the empirical values at the lower end of each habitat range, based on the precautionary principle, and will not apply any modifying factors. The UK submit national data, so all European maps of critical loads should be based on the UK data as agreed by UK experts and submitted by the UK National Focal Centre (NFC) at CEH Bangor (http://cldm.defra.gov.uk). Deposition data used in European-scale exceedance maps is derived from the EMEP model (www.emep.int).

The UK NFC circulated the summary report from the Noordwijkerhout workshop to nitrogen impacts experts in the UK and organised a small workshop of this group in November 2010 to look at the potential changes to the mapping values for UK habitats. At the November workshop the critical load ranges and available evidence for setting mapping values for each habitat type were discussed (See Appendix 1: notes from meeting).

In 2003 the following procedure was adopted in the UK for setting the mapping values (Hall et al, 2003):

- For those critical loads identified as expert judgement a mapping value was not recommended unless there was a specific evidence of relevance to the UK and referring to a significant UK plant community.
- When there was no specific UK evidence to suggest otherwise, the middle of the range from the Berne 2002 workshop was recommended for UK mapping.
- UK mapping values, which were not in the middle of the range were recommended where field or experimental evidence from the UK specifically suggested this was not appropriate.

- Values other than the mid-range were in some cases recommended where knowledge of UK ecosystems suggests they were more or less sensitive than the median for this ecosystem across Europe.

Although the Berne report (Achermann & Bobbink, 2003) included some information on the application of modifying factors, these were not applied in national mapping exercises in the UK in 2003. The only exception to this was the setting of the bog habitat critical load at the upper end of the range, based on the evidence at Berne suggesting that the impacts of N deposition would be lower in areas of high precipitation.

For this (2010/11) update the same general principles were adopted in setting the UK mapping values. Where no new evidence has become available for a particular habitat, the 2003 mapping value has been retained.

In addition to the UK and European evidence presented at the Noordwijkerhout workshop in June 2010, UK evidence collated under contract to JNCC and partners (Emmett et al, 2011; Stevens et al, 2011) has been used in reviewing the UK mapping values for four habitats: acid grassland, calcareous grassland, heathland and bogs. The JNCC Project had two objectives:

(i) Analysis of broad scale datasets to generate nitrogen response curves for species and summary response variables for habitat function indices, such as Ellenberg N.

(ii) Interpretation of (i) and other research (eg, summarised in RoTAP, 2011) in respect of the implications for "conservation policy commitments" and surveillance requirements.

Further background information on the JNCC Project is given in Appendix 2.

This report provides:

- the revised ranges of nitrogen critical loads as agreed at the Noordwijkerhout workshop;
- the agreed UK mapping values and the evidence to support them;
- UK habitat distribution maps used for nitrogen critical loads;
- a summary assessment of the impact of these changes on nitrogen critical loads exceedance for the UK.

This report also outlines a method proposed by the CCE for applying some of the modifying factors. However, UK experts agreed not to apply modifying factors in national-scale applications, with the exception of a precipitation modifier for the bog habitat, but noted the use of such modifiers for site-specific applications could be very important. Some site-specific applications may also use a different part of the critical load range to those given in this report for national mapping purposes, depending on the site and policy context. Assessment of site management practices is not possible in a national context.

2 RESULTS OF THE NOORDWIJKERHOUT WORKSHOP AND UK MAPPING VALUES

Critical loads of nitrogen were assigned at the Berne workshop (Achermann & Bobbink, 2003) and the Noordwijkerhout workshop to habitats of the European Nature Information System (EUNIS, http://eunis.eea.europa.eu/) habitat classification. This is a hierarchical classification that can be translated into other habitat classification systems, using tools such as the National Biodiversity Network (NBN) habitats dictionary (http://habitats.nbn.org.uk/), or for the UK, using a spreadsheet created by JNCC (based on the NBN dictionary) and downloadable from their website (http://www.jncc.gov.uk/default.aspx?page=1425).

The Noordwijkerhout workshop report (Bobbink & Hettelingh, 2011) provides ranges of nitrogen critical loads for 47 different EUNIS habitat classes. This report focuses on (a) the habitats mapped nationally for critical loads research in the UK, and (b) additional habitat types of conservation interest in the UK, but not mapped nationally due to a lack of appropriate data.

Table 2.1 presents the previous and updated critical load ranges for the habitats currently mapped nationally, plus additional habitats proposed for inclusion in this update.

Table 2.2 gives the critical load ranges for the additional habitats not mapped nationally but of high conservation value in the UK and for which critical loads are available.

The critical loads given in Tables 2.1 and 2.2 refer to natural and semi-natural ecosystems; critical loads for managed (productive) coniferous woodland and managed (productive) broadleaved woodland in the UK are still based on a simple mass balance equation (Hall et al, 2003).

Table 2.1. Critical loads of nitrogen for habitats currently (or planned to be) mapped nationally in the UK; values in bold type represent changes from the 2003 values.

Ecosystem type	EUNIS code	CLnutN range 2003 (kg N ha^{-1} $year^{-1}$)	CLnutN range 2010 (kg N ha^{-1} $year^{-1}$)	Indication of exceedance
Marine habitats				
Mid-upper saltmarshes	A2.53	30-40 (#)	**20-30 (#)**	Increase in dominance of graminoids.
Pioneer & low-mid saltmarshes	A2.54/55	30-40 (#)	**20-30 (#)**	Increase in late-successional species, increase in productivity.
Coastal habitats				
Shifting coastal dunes	B1.3	10-20 (#)	10-20 (#)	Biomass increase, increased N leaching.
Coastal stable dune grasslands (grey dunes)	B1.4[a]	10-20 #	**8-15 #**	Increase tall graminoids, decrease in prostrate plants, increased N leaching, soil acidification, loss of typical lichen species.
Mire, bog and fen habitats				
Raised & blanket bogs	D1[b]	5-10 ##	5-10 ##	Increase in vascular plants, altered growth and species composition of bryophytes, increased N in peat and peat water.
Grasslands and tall forb habitats				
Sub-atlantic semi-dry calcareous grassland	E1.26	15-25 ##	15-25 ##	Increase in tall grasses, decline in diversity, increased mineralization, N leaching; surface acidification.
Non-Mediterranean dry acid and neutral closed grassland	E1.7[c]	10-20 #	**10-15 ##**	Increase in graminoids, decline in typical species, decrease in total species richness.
Moist & wet oligotrophic grasslands:				
Heath (*Juncus*) meadows & humid (*Nardus Stricta*) swards	E3.52	10-20 #	10-20 #	Increase in tall graminoids, decreased diversity, decrease in bryophytes.
Moss & lichen dominated mountain summits	E4.2	5-10 #	5-10 #	Effects upon bryophytes and/or lichens.

Ecosystem type	EUNIS code	CLnutN range 2003 (kg N ha^{-1} $year^{-1}$)	CLnutN range 2010 (kg N ha^{-1} $year^{-1}$)	Indication of exceedance
Heathland, scrub & tundra				
Northern wet heaths				
• 'U' *Calluna*-dominated wet heath (upland moorland)	F4.11[b,d]	10-20 (#)	10-20 #	Decreased heather dominance, decline in lichens and mosses, increase N leaching.
• 'L' *Erica tetralix* dominated wet heath (lowland)	F4.11[b,d]	10-25 (#)	**10-20 (#)**	Transition from heather to grass dominance.
Dry heaths	F4.2[b,d]	10-20 ##	10-20 ##	Transition from heather to grass dominance, decline in lichens, changes in plant biochemistry, increased sensitivity to abiotic stress.
Forest habitats				
Fagus woodland	G1.6		**10-20 (#)**	Changes in ground vegetation and mycorrhiza, nutrient imbalance, changes in soil fauna
Acidophilous *Quercus*-dominated woodland	G1.8		**10-15 (#)**	Decrease in mycorrhiza, loss of epiphytic lichens and bryophytes, changes in ground vegetation
Pinus sylvestris woodland south of the Taiga	G3.4		**5-15 #**	Changes in ground vegetation and mycorrhiza, nutrient imbalances, increase d N_2O and NO emissions.
Forest habitats overall				
All forests: ground flora	G	10-15 #	see below	Changed species composition, increase of nitrophilous species, increased susceptibility to parasites.
Broadleaved woodland	G1		10-20 ##	Changes in soil processes, nutrient imbalance, altered composition of mycorrhiza and ground vegetation.
Coniferous woodland	G3		5-15 ##	Changes in soil processes, nutrient imbalance, altered composition of mycorrhiza and ground vegetation.

Reliability scores assigned at Berne in 2003 (Achermann & Bobbink, 2003) and Nordwijkerhout in 2010 (Bobbink & Hettelingh, 2011):
reliable: when a number of published papers of various studies showed comparable results.
quite reliable: when the results of some studies were comparable.
(#) expert judgement: when no empirical data were available for this type of ecosystem. For this, the nitrogen critical load was based upon expert judgement and knowledge of ecosystems which were likely to be comparable with this ecosystem.

Footnotes from the Noordwijkerhout workshop (Bobbink & Hettelingh, 2011):

(a) For acidic dunes, the 8-10 kg N ha^{-1} $year^{-1}$ range should be applied, for calcareous dunes this range is 10-15 kg N ha^{-1} $year^{-1}$.

(b) Apply the high end of the range to areas with high levels of precipitation and the low end of the range to those with low precipitation levels; apply the low end of the range to systems with a low water table, and the high end of the range to those with a high water table. Note that water tables can be modified by management.

(c) Apply the lower end of the range to habitats with a low base availability; and the higher end of the range to those with high base availability.

(d) Apply the high end of the range to areas where sod cutting has been practiced; apply the lower end of the range to areas with low-intensity management.

Table 2.2 Nitrogen critical loads for habitats of high conservation value which occur in the UK but are not included in national critical loads mapping from 2010. Values in bold type represent changes from 2003 values.

Ecosystem type	**EUNIS code**	**CLnutN range 2003 (kg N ha^{-1} year^{-1})**	**CLnutN range 2010 (kg N ha^{-1} year^{-1})**	**Indication of exceedance**
Coastal habitats				
Shifting coastal dunes	B1.3	10-20 (#)	10-20 (#)	Biomass increase, increased N leaching.
Coastal dune heaths	B1.5	10-20 (#)	10-20 (#)	Increase in plant production, increased N leaching, accelerated succession.
Moist to wet dune slacks	B1.8[c]	10-25 (#)	**10-20 (#)**	Increased biomass of tall graminoids.
Inland surface water habitats				
Softwater lakes (permanent oligotrophic waters)	C1.1[e]	5-10 ##	**3-10 ##**	Changes in the species composition of macrophyte communities, increased algal productivity and a shift in nutrient limitation of phytoplankton from N to P.
Permanent dystrophic lakes, ponds, pools	C1.4[f]	-	**3-10 (#)**	Increased algal productivity and a shift in nutrient limitation of phytoplankton from N to P.
Mire, bog & fen habitats				
Valley mires, poor fens & transition mires	D2[g]	10-20 #	**10-15 #**	Increase in sedges and vascular plants, negative effects on bryophytes.
Rich fens	D4.1	15-35 (#)	**15-30 (#)**	Increase in tall graminoids, decrease in bryophytes.
Montane rich fens	D4.2	15-25 (#)	15-25 (#)	Increase in vascular plants, decrease in bryophytes
Grasslands & tall forb habitats				
Inland dune pioneer grassland	E1.94[c]	10-20 (#)	**8-15 (#)**	Decrease in lichens, increase in biomass.
Inland dune siliceous grassland	E1.95[c]	10-20 (#)	**8-15 (#)**	Decrease in lichens, increase in biomass, increased succession.
Low & medium altitude hay meadows	E2.2	20-30 (#)	20-30 (#)	Increase in tall grasses, decrease in diversity.
Mountain hay meadows	E2.3	10-20 (#)	10-20 (#)	Increase in nitrophilous graminoids, changes in diversity

Ecosystem type	EUNIS code	CLnutN range 2003 (kg N ha^{-1} $year^{-1}$)	CLnutN range 2010 (kg N ha^{-1} $year^{-1}$)	Indication of exceedance
Grasslands & tall forb habitats				
Moist & wet oligotrophic grasslands:				
Molinia caerulea meadows	E3.51	15-25 (#)	15-25 (#)	Increase in tall graminoids, decreased diversity, decrease in bryophytes.
Alpine & subalpine acid grassland	E4.3	None	5-10 #	Changes in species composition; increase in plant production.
Alpine & subalpine calcareous grassland	E4.4	None	5-10 #	Changes in species composition; increase in plant production.
Heathland, scrub & tundra habitats				
Arctic, alpine & subalpine scrub habitats	F2	5-15 (#)	5-15 #	Decline in lichens, bryophytes and evergreen shrubs.
Forest habitats				
Meso- and eutrophic *Quercus* woodland	G1.A	-	**15-20 (#)**	Changes in ground vegetation.

Reliability scores assigned at Berne 2003 (Achermann & Bobbink, 2003) and Nordwijkerhout 2010 (Bobbink & Hettelingh, 2011):
reliable: when a number of published papers of various studies showed comparable results.
quite reliable: when the results of some studies were comparable.
(#) expert judgement: when no empirical data were available for this type of ecosystem. For this, the nitrogen critical load was based upon expert judgement and knowledge of ecosystems which were likely to be comparable with this ecosystem.

Footnotes from the Noordwijkerhout workshop (Bobbink & Hettelingh, 2011):
(a) For acidic dunes, the 8-10 kg N ha^{-1} $year^{-1}$ range should be applied, for calcareous dunes this range is 10-15 kg N ha^{-1} $year^{-1}$.
(b) Apply the high end of the range to areas with high levels of precipitation and the low end of the range to those with low precipitation levels; apply the low end of the range to systems with a low water table, and the high end of the range to those with a high water table. Note that water tables can be modified by management.
(c) Apply the lower end of the range to habitats with a low base availability; and the higher end of the range to those with high base availability.
(d) Apply the high end of the range to areas where sod cutting has been practiced; apply the lower end of the range to areas with low-intensity management.
(e) This critical load should only be applied to oligotrophic waters with low alkalinity with no significant agricultural or other human inputs. Apply the lower end of the range to boreal, sub-Arctic and alpine dystrophic lakes, and the higher end of the range to Atlantic soft waters.
(f) This critical load should only be applied to waters with low alkalinity with no significant agricultural or other direct human inputs. Apply the lower end of the range to boreal, sub-Arctic and alpine dystrophic lakes.
(g) For EUNIS category D2.1 (valley mires) use the lower end of the range (#).

3 MODIFYING FACTORS

The footnotes to Tables 2.1 and 2.2 include the proposed modifying factors for certain habitats. These modifiers are designed to help take into account habitat sensitivity to nitrogen under different abiotic conditions. A method has been proposed by the CCE (Slootweg et al, 2008, modified & extended) for applying two of these modifying factors at the national and/or European scale. The method is outlined in 3.1 below. However, this approach was rejected at the UK experts workshop in November 2010 as it was considered that it implied greater knowledge of the spatial variability in habitat sensitivity than exists. This does not mean that the modifying factors should not be applied (they may be very important for site-specific applications), but alternative methods of applying them may be needed, such as defining thresholds for high/low precipitation or base availability. An alternative, simpler approach has been applied to mapping critical loads for bog habitats in the UK; the rationale for adopting the use of the modifier ***for this habitat alone*** is given in Section 3.2 below.

It should be noted that it could also be important to apply the different modifying factors relating to management, base availability, precipitation or water tables in site-specific applications where local knowledge is available.

3.1 An approach proposed by the CCE for applying modifying factors

Precipitation modifier

Bog and heathland habitats are considered to be less sensitive to nitrogen in wetter areas than drier areas (Bobbink & Hettelingh, 2011). Therefore it is suggested that in areas of low precipitation the lower end of the critical load ranges should be applied, and in areas of high precipitation the upper end of the ranges should be used for these habitat types. “High” and “low” precipitation should reflect the variation in precipitation across the entire geographic range of each habitat across Europe (or the EMEP grid region). To assist with this, cumulative distribution functions (CDFs) are available from the CCE of rainfall vs the percentage habitat area across the European region; these provide 1-percentiles of the percentage habitat area vs rainfall that can be applied to national scale rainfall to determine the critical load:

$$CLempN = CL_{lo} + fmod * (CL_{up} – CL_{lo})$$

Where:
CLlo = critical load at the lower end of the range
CLup = critical load at the upper end of the range
Fmod = modifying factor (value between 0 and 1) from the CDF

For example, Figure 3.1 below shows the CDF from the CCE for rainfall vs the area of heathland (F4) across Europe. Table 3.1 shows selected percentiles from the full list of 1-percentile values provided by the CCE, and the corresponding fmod values. The full list of 1-percentile values is used as a look-up table to generate fmod values for each 1x1km habitat square for the UK based on UK rainfall data (annual average 1961-90).

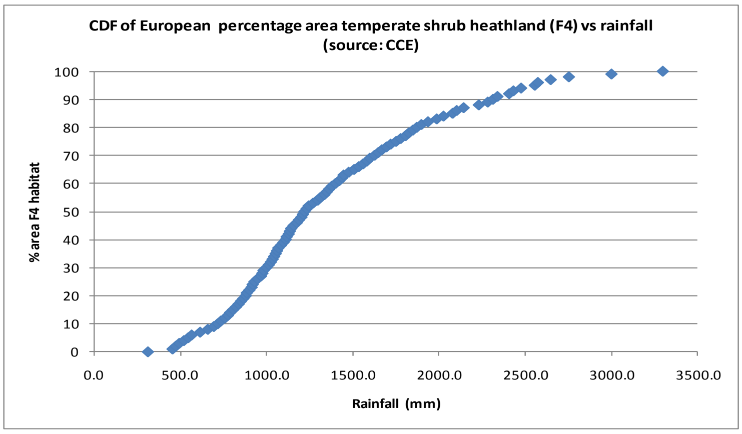

Figure 3.1: CDF of European percentage area of heathland vs rainfall

Table 3.1 Look-up table of selected percentiles from full data used to generate CDF in Figure 1.

Rainfall (mm) for heathland habitat across Europe	**Percentiles of percentage heathland across Europe**	**fmod**
314.4	0	0
457.2	1	0.01
476	2	0.02
495.5	3	0.03
523	4	0.04
547.7	5	0.05
567.8	6	0.06
617.05	7	0.07
661.6	8	0.08
696.3	9	0.09
719.4	10	0.10

So, all 1km habitat squares of the UK with rainfall <= 314.4 mm are assigned an fmod value of zero; squares with rainfall > 314.4 and <= 457.2 mm are assigned an fmod value of 0.01, and so on for all 100 x 1 percentiles. These fmod values can then be used to calculate the critical loads using the equation above.

Base availability modifier

The dry acid grassland habitat (E1.7) is considered to be more sensitive to nitrogen in areas where base cation availability is low (Bobbink & Hettelingh, 2011). Therefore it is recommended that in areas of low base availability the low end of the critical load range is used for this habitat, and in areas of high base availability the higher end of the range is used. Base availability can be represented by the sum of base cation weathering plus base cation deposition. The CCE can provide a CDF of base cation availability vs the percentage area of dry acid grassland across its European range. These data can be used to determine fmod values for the UK if applied to UK data on base availability, and then critical loads calculated using the same equation as above.

3.2 Applying a precipitation modifier for setting the mapping values for UK bogs

The mapping values applied in the UK are based on scientific evidence of nitrogen impacts available in 2003 (Hall et al, 2003), or updated based on new evidence (see Section 5). In the case of bog, no new evidence was available to support lowering the mapping value from 10 kg N ha^{-1} year^{-1}. However, at the November 2010 UK experts meeting, concern was raised that this value would not protect bogs in drier parts of the country. Examining long-term average rainfall data across the geographic range of UK bogs (as determined by the bog distribution map used for critical loads; see Section 4) showed their occurrence from the east of England with average rainfall of ~550mm per annum to those in the north-west with average rainfall above 3000mm per annum. The presence of bogs in drier parts of the country were overlooked in setting the mapping value in 2003, when this was set at the top of the range on the basis that lower values were inappropriate for habitats in areas of high rainfall, such as the UK (Hall et al, 2003). ***Therefore, for this update, it was agreed that the precipitation modifier should be applied to this habitat (only) and that scientific evidence of the impacts of nitrogen on bogs in drier regions of the UK should still be sought to underpin this decision.***

The CCE provided a CDF and percentiles of annual average rainfall for 1961-90 for areas of bog across the whole of Europe (Figure 3.2a). From this information values of fmod for bog were derived as described for heath in Section 3.1 above. The fmod values were then applied to each 1x1km square (containing bog habitat) according to UK data on annual average rainfall for 1961-90 (SAAR 1961-90) and used to calculate nitrogen critical loads using the equation in Section 3.1 above. Critical loads derived in this way are highly variable spatially and may infer a greater knowledge of the spatial variability of response of bog habitats to nitrogen deposition than actually exists. However, the data collated were valuable for informing a simpler approach for applying rainfall thresholds for setting the mapping values for bogs; the data are summarised in figure 3.2 as follows:

- Figure 3.2b shows the CDF of the UK average annual rainfall data vs UK bog habitat area; this shows that UK bogs receive average annual rainfall in the range 548 – 3792mm per annum.
- Figure 3.2c shows a histogram of the number of UK bog habitat squares by rainfall category; this shows that the majority of bog habitat squares receive an average of 1000 - 1500mm rainfall per annum.
- Figure 3.2d shows a histogram of the number of UK bog habitat squares by nitrogen critical load category based on the spatial values calculated as described above; this shows that the calculated critical load for the majority of bog habitat squares would be above 8.5 kg N ha^{-1} year^{-1}. The median critical load for all bog habitat squares using this approach is 9.5 kg N ha^{-1} year^{-1}.

Using the available data it was decided to calculate the rainfall ranges that would give specified median nitrogen critical load values as shown in Table 3.2, and use this information to apply these mapping values to bog habitats across the UK. For bog squares with rainfall above 1286mm per annum, a mapping value of 10kg N ha^{-1} year^{-1} is used. Figure 3.3 shows the results of applying this approach to setting the mapping values for bog.

Table 3.2 Rainfall ranges used to determine median nitrogen critical loads for bog

Rainfall range (mm)	**Median CLnutN (kg N ha^{-1} year^{-1})**
548 - 758	8
759 – 1285	9
>1285	10

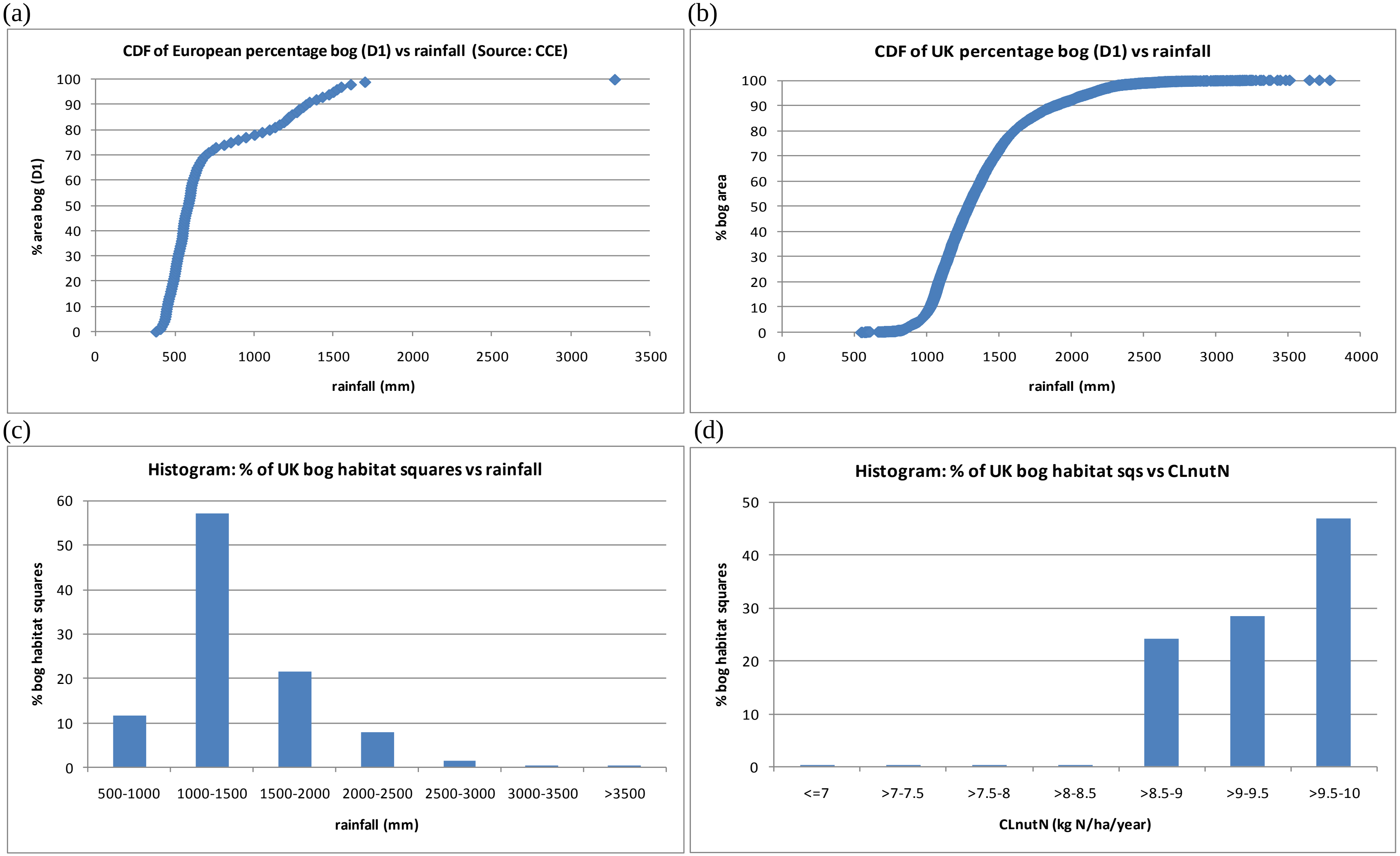

Figure 3.2. (a) CDF of percentage of bog (D1) vs annual average rainfall 1961-90 across the European region; (b) CDF of percentage of bog in UK vs UK annual average rainfall 1961-90; (c) Histogram of the number of bog 1x1km squares vs annual average rainfall (1961-90) categories; (d) Histogram of the number of bog 1x1 km squares vs nitrogen critical load calculated by using (a) to derive fmod values applied to the data in (b).

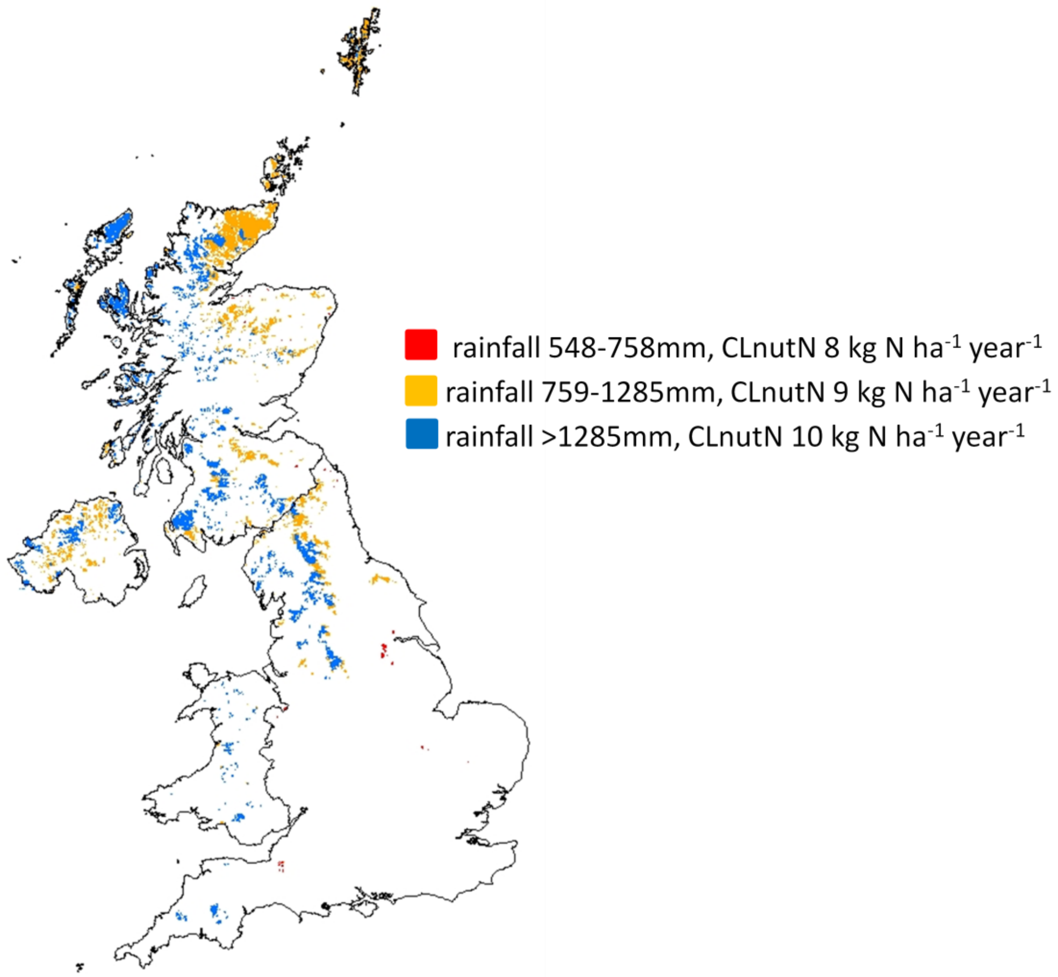

Figure 3.3. Three categories of rainfall and empirical nitrogen mapping values for the UK bog habitat

4 NATIONAL HABITAT MAPS

The derivation of the national habitat distribution maps, used for critical loads (acidity and nitrogen) mapping, are described in detail in Hall et al, 2003 and 2004. For this update, changes have been made to the distribution of dune grassland (previously mapped as the "supralittoral sediment" habitat), and to the distribution of unmanaged woodland to allow this habitat to be sub-divided into different woodland types. In addition, the distribution of saltmarsh is included for the first time. The derivation of the habitat distribution maps for saltmarsh, dune grassland and unmanaged woodlands are described below.

For national critical load and exceedance assessments the areas of habitats at risk are required. The habitat areas are also required by the CCE so they can be incorporated in exceedance calculations and assessments at the European scale (eg, Hettelingh et al, 2009). To achieve this, the CEH Land Cover Map 2000 (LCM2000: Fuller et al, 2002a&b) is used as the base map from which the area of habitat in each 1x1 km grid square is obtained. The habitat distributions as defined by LCM2000 have been further refined using ancillary data sets (eg, species abundance data derived by Preston et al, 2002; 2003) to generate the habitat maps for use in UK critical loads research (Hall et al, 2003). For this update, additional individual species distributions on a 10x10 km grid were downloaded from the NBN Gateway (http://data.nbn.org.uk/). The National Vegetation Classification (NVC: Rodwell 1991) data used in the creation of the distribution maps for the new woodland habitats were downloaded from the JNCC website (http://www.jncc.gov.uk/page-4267).

Table 4.1 gives the UK habitat names used in 2003 and in 2010 and the corresponding EUNIS habitat classes they aim to represent nationally. Figures 4.1-4.3 show the distribution maps for all habitats that empirical nitrogen critical loads are applied to in the UK, including those that remain unchanged from 2003. Although the maps are presented on a 1x1 km grid, the area of each habitat in a grid square may vary from less than 1ha to 100 ha (ie, 1km^2). The total area of sensitive habitats mapped for eutrophication (including managed woodlands to which mass balance critical loads are applied) represents 30% of the UK land area (assuming a UK area of 244020 km^2, source: The Times Atlas of the World, Eighth Edition 1991, Times Books, London). The habitat areas for the UK and its constituent countries, derived from these maps and used in critical load exceedance assessments, are given in the tables in Section 7.

It should be noted that the habitat distribution maps and areas used for UK critical loads (acidity, nitrogen) research (a) only include areas where data exist for the calculation or derivation of critical loads; (b) may differ from other national habitat distribution maps or estimates of habitat areas.

Table 4.1 UK habitat names used in 2003 with the EUNIS classes each habitat aimed to represent nationally, and corresponding habitat names used in 2010 and the EUNIS classes associated with each for the purposes of assigning empirical nitrogen critical loads and for the submission of UK data to the Coordination Centre for Effects (NL) for use in work under the Convention on Long-Range Transboundary Air Pollution. NB. Empirical critical loads not used for managed woodland habitats.

UK habitat name 2003	EUNIS classes 2003	UK habitat name 2010	EUNIS classes 2010
Acid grassland (wet & dry)	E1.7 & E3.52	Acid grassland (wet & dry)	E1.7 & E3.52
Calcareous grassland	E1.26	Calcareous grassland	E1.26
Dwarf shrub heath (wet & dry)	F4.11 & F4.2	Dwarf shrub heath (wet & dry)	F4.11 & F4.2
Bog	D1	Bog	D1
Montane	E4.2	Montane	E4.2
Managed coniferous woodland	G3	Managed coniferous woodland	G3
Managed broadleaved woodland	G1	Managed broadleaved woodland	G1
Unmanaged conifer/broadleaf woodland[a]	G4	Unmanaged conifer/broadleaf woodland[a]	G4
Atlantic oak woodland	(G4 but mapped separately from the rest of the unmanaged woodland)	Acidophilous oak woodland	G1.8
		Beech (Fagus) woodland	G1.6
		Scots Pine woodland	G3.4
Supralittoral sediment	B1.3 & B1.4	Dune grassland	B1.4
Not mapped		Saltmarsh	A2.5 (A2.53, A2.54, A2.55)

Notes:

(a) In 2003 there were four categories of woodland mapped for nutrient nitrogen critical loads: (i) managed coniferous woodland (G3); (ii) managed broadleaved woodland (G1); (iii) unmanaged coniferous and/or broadleaved woodland with the critical load set to protect ground flora (G4); (iv) atlantic oak woods with the critical load set to protect epiphytic lichens (G4). In 2010 the unmanaged woodland category has been sub-divided into four new categories: (i) acidophilous oak woodland including Atlantic oak woods (G1.8); (ii) Fagus woodland (G1.6); (iii) Scots Pine woodland (G3.4); (iv) the remaining area of unmanaged (conifer and/or broadleaf) woodland not falling into the first three categories (G4). The habitat data available only allow these sub-divisions to be made for the unmanaged woodland in GB and not for NI.

(b) The “Supralittoral sediment” habitat in 2003 was represented by two EUNIS classes (B1.3 and B1.4); this habitat has now been renamed to “Dune grassland” (representing EUNIS class B1.4 only) to better reflect the habitat to which the nitrogen impacts data relate.

(c) For mapped habitat areas by country see tables in Section 7.

4.1 Saltmarsh (A2.53, A2.54, A2.55) distribution map

This habitat had not been previously mapped for critical loads in the UK. LCM2000 includes a saltmarsh class (LC5), but as for other habitats it was decided to refine and confirm the habitat distribution using ancillary data, in this case species distribution data for *Puccinellia maritima* (common saltmarsh grass) and *Juncus maritimus* (sea rush). The saltmarsh distribution map was defined by selecting the 1x1km squares of LC5 within the mapped 10x10km squares of the species distribution data. This combination of data identifies all the key areas of saltmarsh in the UK (Figure 4.1a).

4.2 Dune grassland (B1.4) distribution map

In 2003 the distribution of the dune grasslands was represented by two LCM2000 classes (LC4: Littoral sediment; LC7: Supra-littoral sediment) and the presence of between one and five key dune grassland species, based on 10x10km species abundance data (Hall et al, 2003). In reviewing this habitat distribution to better reflect the habitat for which nitrogen impacts data are available, it was decided to use LC7 and a 2km buffer around the coast to remove any anomalous data points away from the coastal zone. Species distribution data for *Ammophila arenaria* were then used to further refine the habitat distribution. Finally areas where *Corynephorus canescens* has also been recorded were used to identify the distribution of acid dunes. Whilst the resulting distribution identified most areas of dune grassland in England, Wales and Northern Ireland, areas in Scotland were under-represented. After examining possible options for improving the distribution across Scotland, it was agreed to include areas of LC18 (calcareous grassland) that fell within the 2km coastal buffer and within the species distribution for Scotland. Only LC18 squares that were not already captured within the calcareous grassland habitat map for critical loads were included in the final Dune grassland map (Figure 4.1b).

4.3 Woodland distribution maps (G1.6, G1.8, G3.4, G4)

In 2003 a combination of LCM2000, Forest Research data and NVC data were used to derive woodland distribution maps for the following woodland types:

- Managed (productive) coniferous woodland
- Managed (productive) broadleaved woodland
- Unmanaged conifer and broadleaf woodland
- Atlantic oak woodland

The managed woodland is assumed to be primarily managed as productive forest where harvesting and removal of trees takes place. The unmanaged woodland consisted of ancient and semi-natural woodland, yew and Scots Pine, “managed” for biodiversity or amenity, but not timber production (Hall et al, 2003). The nitrogen mass balance equation is used to calculate the critical loads for the managed woodlands and the distributions of these classes remains unchanged from 2004 (Hall et al, 2004). Empirical critical loads were previously assigned to the unmanaged woodland (for the protection of ground flora) and to Atlantic oak woodlands (to protect epiphytic lichens).

The Noordwijkerhout workshop defined ranges of empirical critical loads for a larger number of different EUNIS woodland classes and mapping values have been assigned to four of relevance to the UK (see section 5.6); these are:

- G1.6 Beech (*Fagus*) woodland: not previously mapped separately for critical loads in the UK (Figure 4.3a).
- G1.8 Acidophilous oak (*Quercus*) dominated woodland: this includes the areas of Atlantic oak woodland mapped in 2003 (Hall et al, 2003) but is extended to incorporate other acidophilous oak-dominated woodland (Figure 4.3b).
- G3.4 Scots pine (*Pinus sylvestris*) woodland: not previously mapped separately for critical loads in the UK (Figure 4.3c).
- G4 mixed woodland: this includes all remaining areas of unmanaged (conifer and/or broadleaf) woodland from the 2003 distribution that do not fall within the above three categories and maps (Figure 4.3d).

In generating these four new woodland distribution maps, the 2003 map of unmanaged woodland was used as the base map. This 2003 map was derived from a combination of LCM2000 data and Forest Research data (Hall et al, 2003) and provides an estimate of the area of unmanaged (conifer and broadleaf) woodland in each 1x1 km grid square for the UK. As this map does not distinguish between different types of woodland, 10x10km spatial data sets of the relevant National Vegetation Classification (NVC) woodland communities (Rodwell, 1991) were also used. Table 4.2 lists the NVC classes used for the different woodland types; this is based upon correspondence tables relating the NVC classes to the EUNIS classes and available from the JNCC web site (http://www.jncc.gov.uk/page-1425) and derived from the National Biodiversity Network Habitats Dictionary (http://www.nbn.org.uk/Useful-things/Dictionaries/Habitat-Dictionary.aspx). The distributions for G1.6, G1.8 and G3.4 were generated by extracting the 1x1km unmanaged woodland squares from within the 10x10km squares of the relevant NVC classes (Table 4.2). All remaining 1x1km squares of unmanaged woodland that did not fall within the NVC squares for the new woodland types, were mapped in a separate fourth category of "G4: unmanaged mixed woodland" and treated the same as the unmanaged woodland habitat in 2003, with a critical load set to protect ground flora.

As mentioned above the areas of woodland habitat within each 1x1km square were taken from the 2003 unmanaged woodland map. However, in some instances the 10x10km squares of the NVC classes for G1.6 overlapped with the 10x10km squares of the NVC classes for G1.8. In order to provide an estimated area for both G1.6 and G1.8, the area of unmanaged woodland in each 1x1km square was divided equally between the two woodland classes.

Table 4.2. List of NVC classes used in the creation of woodland distribution maps for G1.6, G1.8 and G3.4.

Habitat	**EUNIS class**	**NVC class(es)**
Beech (Fagus) woodland	G1.6	W12 *Fagus sylvatica-Mercuralis perennis* W14 *Fagus sylvatica-Rubus fruticosus* W15 *Fagus sylvatica-Deschampsia flexuosa*
Acidophilous oak (Quercus) dominated woodland	G1.8	W11 *Quercus petraea-Betula pubescens-Oxalis acetosella* W16 *Quercus spp.-Betula spp. – Deschampsia flexuousa* W17 *Quercus petraea-Betula pubescens-Dicranum majus*
Scots Pine (Pinus sylvestris)	G3.4	W18 *Pinus sylvestris-Hylocomium splendens*

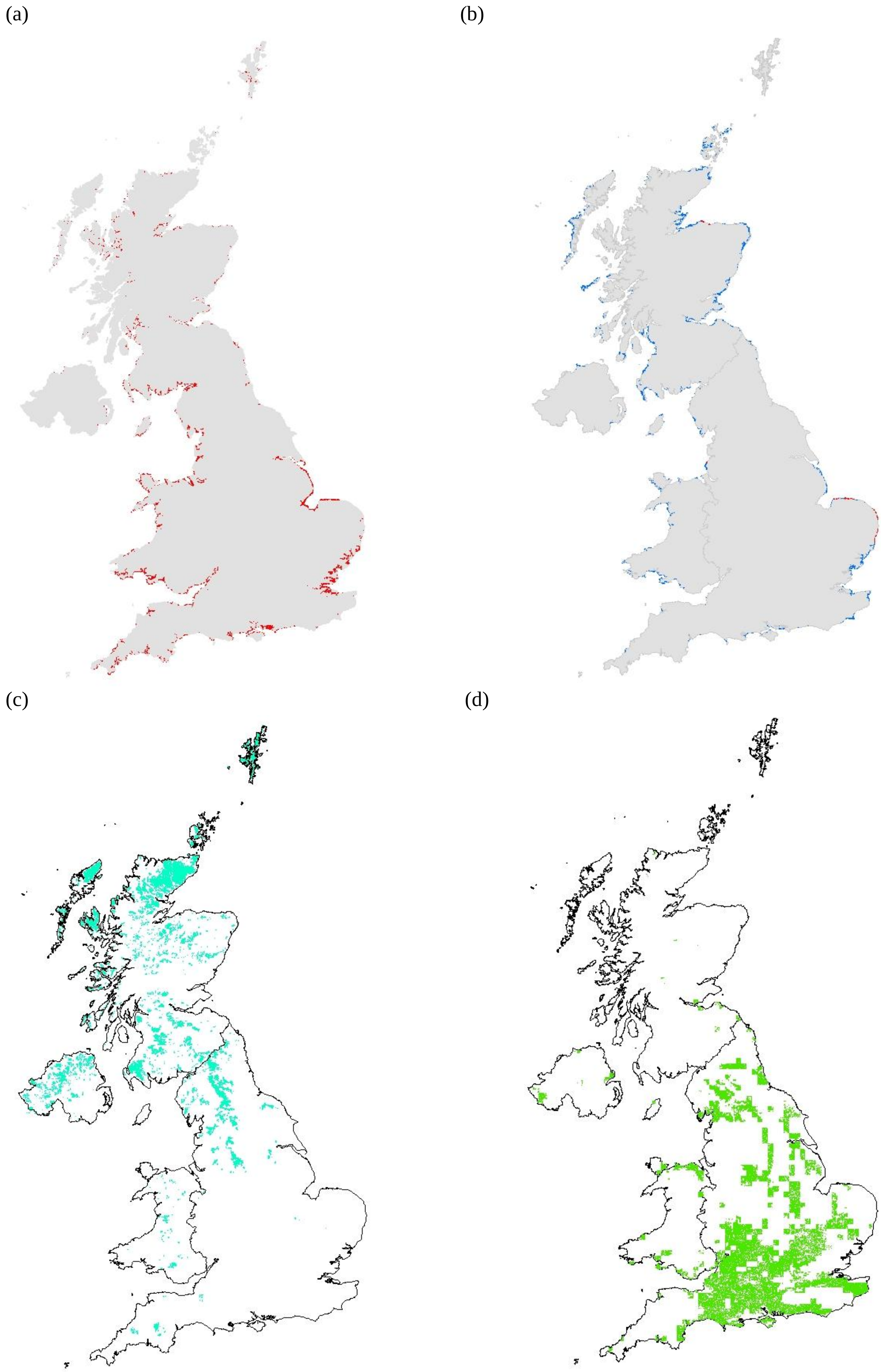

Figure 4.1. Habitat distribution maps for (a) A2.5 saltmarsh; (b) B1.4 acid dune grassland (red) and calcareous dune grassland (blue); (c) D1 bog; (d) E1.26 calcareous grassland

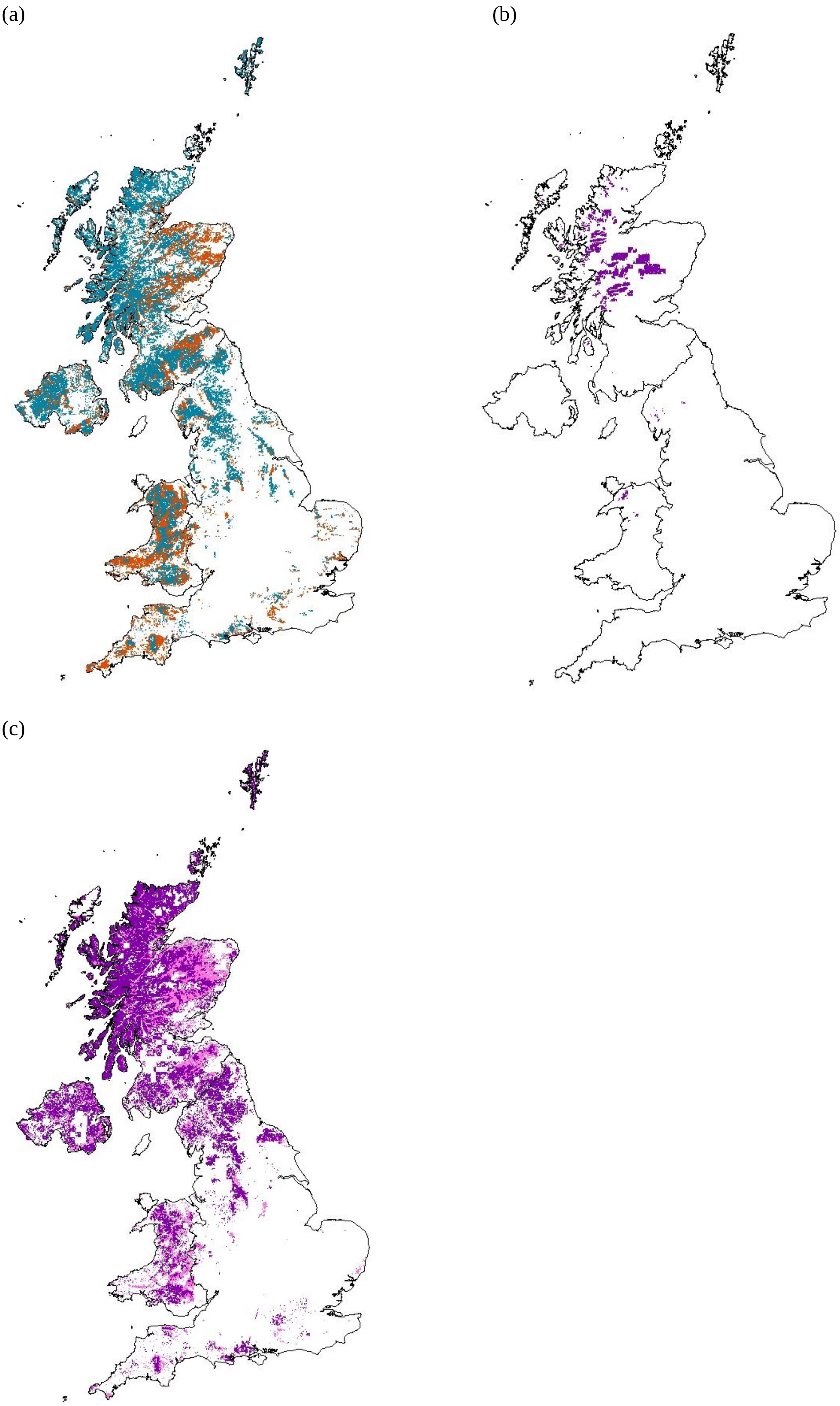

Figure 4.2. Habitat distribution maps for (a) E1.7 dry acid grassland (orange) and E3.52 wet acid grassland (blue); (b) E4.2 montane; (c) F4.11 wet dwarf shrub heath (purple) and F4.2 dry dwarf shrub heath (pink).

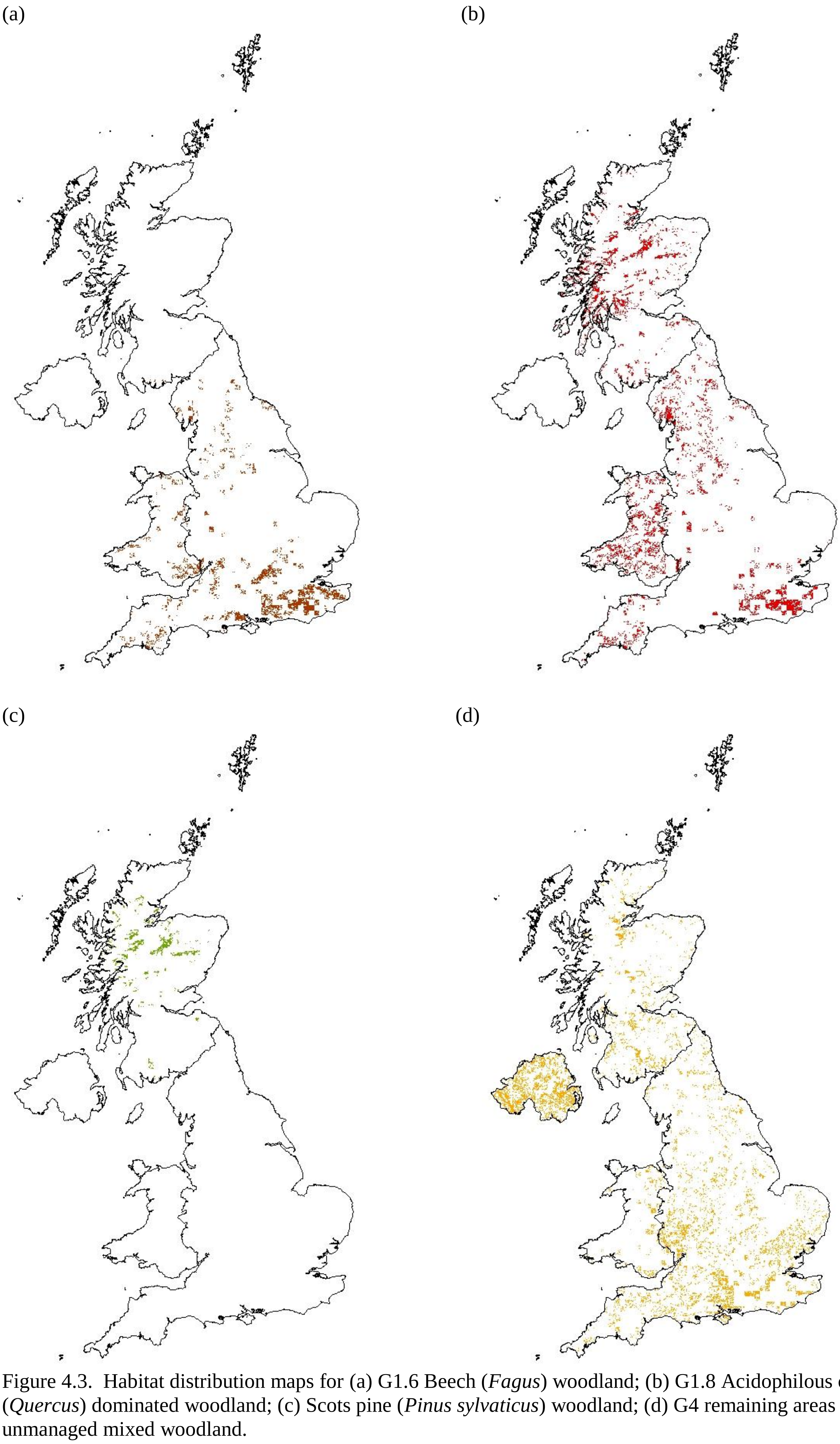

Figure 4.3. Habitat distribution maps for (a) G1.6 Beech (*Fagus*) woodland; (b) G1.8 Acidophilous oak (*Quercus*) dominated woodland; (c) Scots pine (*Pinus sylvaticus*) woodland; (d) G4 remaining areas of unmanaged mixed woodland.

5 EVIDENCE TO SUPPORT UK CRITICAL LOADS OF NITROGEN

This section of the report provides the rationale and evidence to support the UK mapping values for empirical nitrogen critical loads for each habitat type mapped nationally. The headings within the sections below include the EUNIS classes (in parentheses) these habitat types aim to represent nationally.

For four of the habitats (acid grassland, calcareous grassland, bog, heath) evidence collated by Emmett et al (2011) was used to help inform where within the critical load range the UK mapping values should be set. The decisions were based on there being several strands of evidence available, for example, a change in a single species plus functional indices, or changes in several species.

5.1 Marine habitats

Critical loads for marine habitats have not previously been mapped for the UK. In this update it is proposed that the saltmarsh habitat is included in the national data sets.

Saltmarshes (A2.53, A2.54, A2.55)

Critical loads for saltmarshes have not previously been mapped for the UK, despite there being a critical load range, and mapping of the habitat possible. Part of the reason for this was that the critical load range was so high (30-40 kg N ha^{-1} $year^{-1}$) that there would be very limited, if any, exceedance around the UK. Another reason was the lack of UK studies to corroborate continental research.

However, in the 2010 revisions at Noordwijkerhout (Bobbink & Hettelingh, 2011), it was proposed to reduce the critical load range to 20-30 kg N ha^{-1} $year^{-1}$, based on the following evidence. It is generally accepted that saltmarsh vegetation is primarily N limited (Mitsch and Gosselink 2000) and N limitation has been demonstrated in European saltmarshes at the island of Schiermonnikoog in the Netherlands (Kiehl et al. 1997) and in Norfolk, UK (Jefferies and Perkins 1977). A previous experiment in the Netherlands used high deposition rates (50 and 100 kg N ha^{-1} $year^{-1}$), but saw effects of increased biomass in the first growing season, repeated each year for the three years of the experiment, on the young saltmarsh (Van Wijnen & Bakker, 1999), and accelerated succession of the plant communities towards older stages. More recently, repeat vegetation survey analysis showed significant correlations with N deposition and vegetation change (de Vries unpublished data) in a barrier island saltmarsh in the Netherlands. By extrapolation to these continental systems, it can be assumed that UK saltmarshes will behave in a similar manner, although field experiments are still needed in the UK at lower N deposition rates to verify this proposed range. Therefore it is proposed that UK saltmarshes are assigned a mapping value of the mid-point of the range: 25 kg N ha^{-1} $year^{-1}$.

5.2 Coastal habitats

Dune grassland habitats were mapped in 2003 (Hall et al, 2003) as a combination of EUNIS classes B1.3 (shifting coastal dunes) and B1.4 (stable dune grasslands) and the same mapping value applied to both. The extent of B1.3 around the UK is fairly small and due to a lack of sufficient national data to enable this habitat to be adequately mapped, this habitat is no longer included in the UK national maps. In reviewing the critical loads for coastal habitats the habitat distribution map for B1.4 was updated to better reflect the habitat for which nitrogen impacts data were available (Section 4.2). At Noordwijkerhout (Bobbink & Hettelingh, 2011), critical loads were also assigned to two other coastal habitats (B1.5 coastal dune heaths; B1.8 moist/wet dune slacks) but these habitats are not included in the national mapping of critical loads.

Dune grasslands (B1.4)

Updated critical loads for dune grasslands were applied based on the recommendations from the Noordwijkerhout meeting (Bobbink & Hettelingh, 2011) and the evidence below.

Research by Remke et al. (2009a) in Baltic dunes showed changes in *Cladonia portentosa* tissue N content, soil acidification, and greater mineralisation rates in acidic dune systems above 5 kg N ha^{-1} $year^{-1}$ wet deposition. These changes were associated with greater cover of *Carex arenaria* in acidic dunes, but no clear changes in soil properties or species composition in calcareous dunes in the same deposition range (Remke et al. 2009b). As dry deposition in the Baltic is relatively low this probably relates to ~ 8 kg N ha^{-1} $year^{-1}$ total N deposition. This was proposed to be the new lower end of the critical load range at Noordwijkerhout.

UK research by Plassmann et al. (2009) in an N manipulation experiment on fixed dune grassland at Newborough Warren in N. Wales showed significantly increased N pools in moss in the low N treatment of 7.5 kg N ha^{-1} $year^{-1}$ on top of a background of 10 – 12 kg N ha^{-1} $year^{-1}$. These changes occurred despite P co-limitation and heavy grazing, both previously considered as factors likely to minimise adverse effects of N. However, no effects on species composition were observed. More recent work in the UK on the same experiment has shown roughly linear increases in leaching fluxes with N additions above the background (Laurence Jones, CEH, unpublished data, Fig 5.2.1 below). Therefore adverse effects on N leaching and N storage have been observed somewhere within the deposition range 12 - 19 kg N ha^{-1} $year^{-1}$.

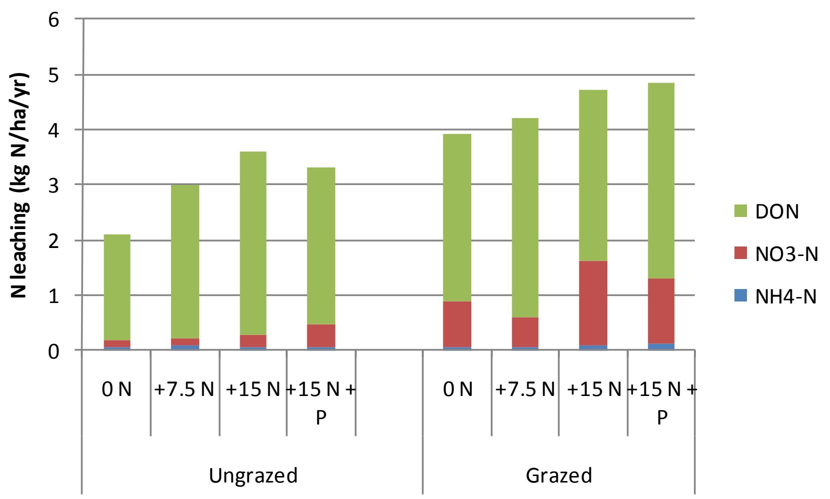

Figure 5.2.1. Increased leaching of inorganic and organic N with N additions (kg N ha^{-1} $year^{-1}$) above a background of 10-12 kg N ha^{-1} $year^{-1}$ under two grazing regimes on a partially de-calcified calcareous fixed dune grassland at Newborough Warren, N. Wales. (DON = dissolved organic nitrogen)

A recent survey in the UK and four other European countries on de-calcified dune grasslands showed adverse effects on plant species richness occurring somewhere between 5 and 10 kg N ha^{-1} $year^{-1}$ (unpublished data, Fig 5.2.2 below). However, there is insufficient evidence to define precisely the minimum load at which damage might occur and hence for the UK situation we have applied values at the mid-point of the ranges for acidic and calcareous grassland.

Together this evidence supports the recommendations from Noordwijkerhout for the critical load range of 8 – 15 kg N ha^{-1} $year^{-1}$; and that acidic dunes are more sensitive than calcareous dunes and the range 8 – 10 kg N ha^{-1} $year^{-1}$ be applied to acidic dunes, and 10 – 15 kg N ha^{-1} $year^{-1}$ to calcareous dunes. Applying the mid-point of each range for national mapping purposes gives 9 kg N ha^{-1} $year^{-1}$ for acidic and 12 kg N ha^{-1} $year^{-1}$ for calcareous dune grassland.

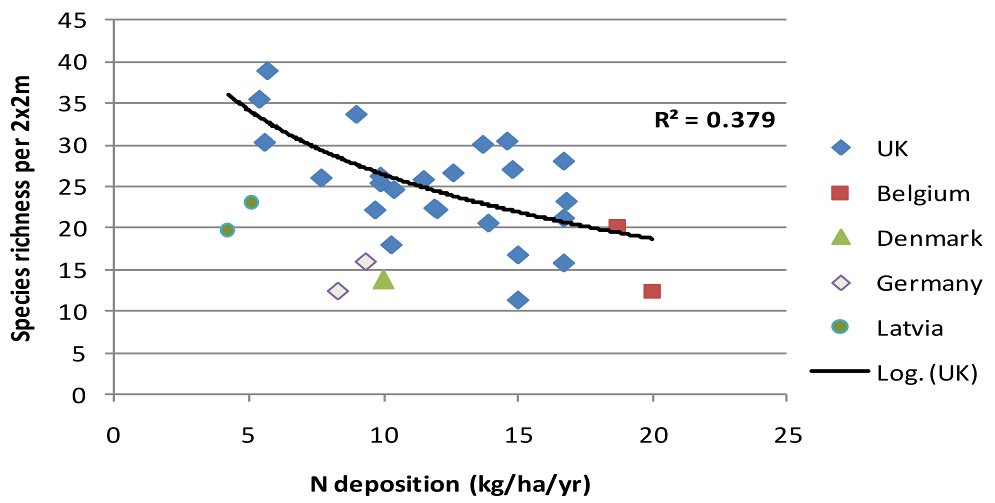

Figure 5.2.2. Species richness in de-calcified dune grasslands (NVC SD12), showing greatest species loss occurring somewhere between 5 and 10 kg N ha^{-1} $year^{-1}$.

5.3 Mire, bog and fen habitats

The only habitat in this category mapped nationally is bog.

Raised and blanket bogs (D1)

The critical load range for this habitat remains unchanged at 5-10 kg N ha^{-1} $year^{-1}$. The Noordwijkerhout workshop (Bobbink & Hettelingh, 2011) proposed that the critical load should be set at the high end of the range in areas of high precipitation and at the low end of the range in areas of low precipitation. This is based upon expert judgement from observations that responses to nitrogen are smaller in wetter areas where bogs receive higher effective precipitation than those in drier areas (eg, Sweden: Gunnarson 2002).

In 2003 the UK mapping value was set at the upper end of this range (ie, 10 kg N ha^{-1} $year^{-1}$) to take into account the higher precipitation in the UK (Hall et al, 2003) compared to other regions of Europe where much of the evidence for the critical load range originates. Concern was raised at the November 2010 workshop that this value may not adequately protect bogs in drier regions of the UK, which could require a lower critical load. Stevens et al (2011) and Emmett et al (2011) examination of bog habitat data (Table 5.3.1 below) did not provide sufficient new UK evidence to recommend lowering the critical load for the bog below the current value of 10 kg N ha^{-1} year^{-1}. Section 3.2 of this report shows the range of annual average precipitation to bogs in the UK and identifies areas of bog that occur in drier regions of the country. It was concluded that the impacts of nitrogen to drier areas could have been considered when setting the mapping value for bogs in 2003, and despite the lack of UK-specific evidence of higher sensitivity of drier bogs to nitrogen, it was agreed that a precipitation modifier should be used in setting the mapping value for bogs in this update. Further details of the rationale and method used are given in Section 3.2. Scientific evidence from UK studies should be sought to underpin this decision.

It should be noted that the use of a rainfall or water table modifier could be important for setting a mapping value for bog habitats in site-specific applications where site-specific knowledge is available. For practical reasons, water table could not be taken into account for national mapping.

Table 5.3.1 Extract of Table 2.5 from Emmett et al (2011) showing impacts of N deposition on bog species, ecosystem function and processes. (This extract only shows the results for N deposition covering the critical load range for this habitat).

N deposition range (kg N ha^{-1} year^{-1})	**Species distribution inhibited[#] by N deposition as determined by Stevens et al (2011)**	**Species distribution strongly inhibited[##] by N deposition as determined by Stevens et al (2011)**	**Evidence of change including impacts on ecosystem functions and soil processes**
0-5			No evidence of impact on indices of ecological function below 10 kg N ha^{-1} year^{-1} identified in new analyses (Stevens et al, 2011).
5-10	*Odontoschisma denudatum* *Anastrophyllum minutum*		

[#] species distribution inhibited = species occurrence fell by 20% relative to occurrence at the lowest N deposition levels
[##] species distribution strongly inhibited = species occurrence fell by 50% relative to occurrence at the lowest N deposition levels

5.4 Grasslands and tall forb habitats

There are four habitats in this category that are mapped nationally: calcareous grassland (E1.26), wet and dry acid grassland (E3.52 and E1.7 respectively) and montane (E4.2).

Calcareous grassland (E1.26)

The critical load range agreed at Noordwijkerhout (Bobbink & Hettelingh, 2011) for this habitat remains unchanged at 15-25 kg N ha^{-1} year^{-1}; the UK mapping value agreed in 2003 was 20 kg N ha^{-1} year^{-1} (Hall et al, 2003).

New UK evidence is available to enable the mapping value for this habitat to be reviewed. Van den Berg et al (2010) analysed permanent quadrat data from 106 plots (56 sites) on calcareous grassland in nature reserves across the UK, surveyed between 1990 and 1993, and compared these with a re-survey between 2006 and 2009 of 48 of these plots (35 sites). Their results provided evidence of a decrease in species diversity and evenness, a decline in the frequency of characteristic species, and a lower number of rare and scarce species, when nitrogen deposition exceeds the critical load range (15-25 kg N ha^{-1} year^{-1}).

An extract of Table 2.3 from Emmett et al (2011) is given in Table 5.4.1 below. This shows the species inhibited by N deposition and evidence of other impacts on ecosystem functions and soil processes. The extract only shows the results for N deposition covering the critical load range for this habitat.

Based on the evidence for impacts on species, on mean Ellenberg N scores and on canopy height (including impacts at N deposition levels below the minima of the critical load range), Emmett et al (2011) propose a new UK mapping value at the lower end of the range for calcareous grassland (15 kg N ha^{-1} $year^{-1}$).

Table 5.4.1 Extract of Table 2.3 from Emmett et al (2011) showing impacts of N deposition on calcareous grassland species, ecosystem function and processes.

N deposition range (kg N ha^{-1} $year^{-1}$)	**Species distribution inhibited[#] by N deposition as determined by Stevens et al (2011)**	**Species distribution strongly inhibited[##] by N deposition as determined by Stevens et al (2011)**	**Evidence of change including impacts on ecosystem functions and soil processes**
0-5			
5-10	*Spiranthes spiralis* *Bromopsis erecta* *Allium vineale* *Geranium columbinum* *Centaurea scabiosa* *Daucus carota*	*Spiranthes spiralis* *Bromopsis erecta* *Centaurea scabiosa*	Reduced presence of *Bromopsis erecta* below 2003 critical load mapping value (20 kg N ha^{-1} $year^{-1}$) identified in Stevens et al (2011) may have important implications as it is usually a dominant species when present. Changes in productivity and nutrient cycling may then follow.
10-15	Species above plus: *Carex spicata* *Ononis repens* *Carlina vulgaris*	Species above plus: *Daucus carota* *Ononis repens* *Carex spicata*	A 20% increase in Ellenberg N at 10-15 kg N ha^{-1} $year^{-1}$ identified in new analyses (Stevens et al, 2011). Canopy height increases by 20% at 5-10 kg N ha^{-1} $year^{-1}$ and 50% at 15-20 kg N ha^{-1} $year^{-1}$ identified in new analysis of one dataset (Stevens et al, 2011).
15-20	Species above plus: *Echium vulgare* *Rosa micrantha* *Cynoglossum officinale* *Cladonia foliacea* *Melica nutans*	Species above plus: *Allium vineale* *Geranium columbinum*	
20-25	Species above plus: *Campanula glomerata*	Species above plus: *Carlina vulgaris* *Echium vulgare* *Rosa micrantha* *Cynoglossum officinale* *Cladonia foliacea* *Melica nutans*	Altered species composition previously reported both in Stevens et al (2011) and RoTAP (2011). Increase in competitive species and plant productivity as indicated by increased canopy height and specific leaf area by Stevens et al (2011). Increased Ellenberg N value with N deposition indicating shift to more nutrient-loving species in Stevens et al (2011). A 20% change at 10-15 kg N ha^{-1} $year^{-1}$ and a 50% change at 35-40 kg N ha^{-1} $year^{-1}$ in one dataset. Evidence of further increases in nitrate leaching, loss of forb species and overall plant species richness (RoTAP, 2011).

[#] species distribution inhibited = species occurrence fell by 20% relative to occurrence at the lowest N deposition levels

[##] species distribution strongly inhibited = species occurrence fell by 50% relative to occurrence at the lowest N deposition levels

Wet and dry acid grassland (E3.52 & E1.7)

The critical load range for wet acid grassland (E3.52) agreed at Noordwijkerhout (Bobbink & Hettelingh, 2011) remains unchanged at 10-20 kg N ha^{-1} $year^{-1}$. The critical load range for dry acid grassland (E1.7) was reduced from 10-20 kg N ha^{-1} $year^{-1}$ to 10 to 15 kg N ha^{-1} $year^{-1}$. The UK mapping value in 2003 was 15 kg N ha^{-1} $year^{-1}$ for both wet and dry acid grassland.

Base cation availability may affect the sensitivity of dry acid grassland to nitrogen and the Noordwijkerhout workshop (Bobbink & Hettelingh, 2011) recommended the use of the lower end of the range in areas of low base availability and the higher end of the range in areas of high base availability. However, it was agreed at the UK experts meeting in November 2010 (Appendix 1) not to apply a base availability modifier (using the CDF of base availability vs habitat area: Section 3) in national scale applications, on the basis of: (a) it implies a greater knowledge of the habitat response spatially than exists; (b) the guidance only applies to dry acid grassland.

New evidence for lowering the UK mapping value for dry acid grassland is provided by Hicks & Ashmore (2010) who used UK field survey data to examine (a) the relationship between nitrogen deposition and species richness ratio, and (b) the relationship between critical load exceedance and species richness ratio, using critical loads at the minimum (10kg N ha^{-1} $year^{-1}$) and former maximum (20kg N ha^{-1} $year^{-1}$) of the range for E1.7. Regression equations showed a worse fit to the exceedance data based on the maximum critical load, and a reduction in the number of species between the minimum and maximum of the critical load range. The regression (Figure 5.4.1) showed there is a significant effect on the species richness ratio when the minimum critical load (10kg N ha^{-1} $year^{-1}$) is exceeded by 20% (ie 2kg N ha^{-1} $year^{-1}$). Hicks & Ashmore (2010) concluded that the threshold for site integrity should therefore be based on the minimum of the critical load range (10 kg N ha^{-1} $year^{-1}$).

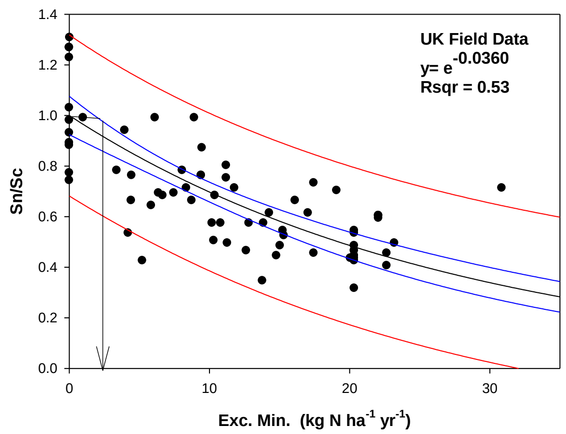

Figure 5.4.1 (from Hicks & Ashmore 2010): Relationship between the species richness ratio (Sn/Sc) and N exceedance calculated using modelled N deposition values minus the minimum critical load (10kg N ha^{-1} $year^{-1}$) for unfertilized plots of dry acid grassland at 68 sites across the UK. Sn/Sc = species richness ratio where Sn = number of species in a treatment and Sc = number of species in the control.

Emmett et al (2011) indicate the acid grassland species likely to be inhibited at different N deposition levels and the impacts on ecosystem function and soil processes. The evidence is summarised in the extract of Table 2.2 of Emmett et al (2011) in Table 5.4.2 below, which presents the information for N deposition levels encompassing the critical load range. Based on the evidence for the impacts on species and on changes in Ellenberg N (including changes at N deposition levels below the minima of the critical load range), Emmett et al (2011) support setting the mapping value for **dry** acid grassland (E1.7) to the lower end of the range at 10 kg N ha^{-1} $year^{-1}$. However, it was felt there was insufficient evidence to support a change to the mapping value for wet acid grassland (E3.5) and that the previous mapping value of 15 kg N ha^{-1} $year^{-1}$ should be retained for this habitat.

Table 5.4.2 Extract of Table 2.2 from Emmett et al (2011) showing impacts of N deposition on acid grassland species, ecosystem function and processes.

<table>
<tr><th>N deposition range (kg N ha⁻¹ year⁻¹)</th><th>Species distribution inhibited[#] by N deposition as determined by Stevens et al (2011)</th><th>Species distribution strongly inhibited[##] by N deposition as determined by Stevens et al (2011)</th><th>Evidence of change including impacts on ecosystem functions and soil processes</th></tr>
<tr><td>0-5</td><td></td><td></td><td></td></tr>
<tr><td>5-10</td><td>Cerastium arvense
Vicia lathyroides
Trifolium arvense
Peltigera didactyla
Cetraria aculeate
Cerastium semidecandrum</td><td></td><td rowspan="2">20% increase in Ellenberg N at 5-10 kg N ha⁻¹ year⁻¹ and 50% increase at 10-15 kg N ha⁻¹ year⁻¹ in analysis of one dataset suggests a major change in N availability and nutrient cycling rates (Stevens et al, 2011).

Plant canopy height found to be positively related to N deposition in one dataset at 5-10 kg N ha⁻¹ year⁻¹ and negatively in another in new analyses. Suggests sensitivity of habitat to change with direction of change dependent on site factors (Stevens et al, 2011).

Decline of Cerastium arvense identified in new analyses (Stevens et al, 2011) unlikely to have major functional implications but together with evidence from Stevens et al (2004) indicates species change starts to occur below 2003 mapping value in dry acidic grasslands (15 kg N ha⁻¹ year⁻¹).</td></tr>
<tr><td>10-15</td><td>Species above plus:
Viola canina
Scapania gracilis
Racomitrium lanuginosum</td><td>Cerastium arvense
Vicia lathyroides
Trifolium arvense
Cetraria aculeate
Cerastium semidecandrum</td></tr>
<tr><td>15-20</td><td>Species above plus:
Frullania tamarisci</td><td>Species above plus:
Peltigera didactyla
Viola canina
Scapania gracilis</td><td>Reduced retention of deposited N in soils with increased nitrate leaching to freshwaters (RoTAP, 2011).

Altered species composition both in Stevens et al (2011) and RoTAP (2011).

Risk of increased fungal pathogen damage to sensitive species such as Vaccinium myrtillus (Strengbom et al, 2002).

Increased Ellenberg N value with N deposition indicating shift to more nutrient-loving species in Stevens et al (2011) but no change in Ellenberg R (acidity) value.

Evidence that species are differentially sensitive to forms of N deposited (UKREATE, 2010).</td></tr>
</table>

[#] species distribution inhibited = species occurrence fell by 20% relative to occurrence at the lowest N deposition levels
[##] species distribution strongly inhibited = species occurrence fell by 50% relative to occurrence at the lowest N deposition levels

Montane: moss & lichen dominated mountain summits (E4.2)
The critical load range agreed at Noordwijkerhout (Bobbink & Hettelingh, 2011) for this habitat remains unchanged at 5-10 kg N ha^{-1} $year^{-1}$. Since 2003 the UK mapping value has been 7 kg N ha^{-1} $year^{-1}$. Montane experts in the UK have studied the available evidence and concluded that although chemical changes may occur below 7 kg N ha^{-1} $year^{-1}$, habitat degradation is not seen below this threshold, and therefore the mapping value should also remain unchanged. This decision is supported by evidence from Armitage (2010) that was presented and discussed at the Noordwijkerhout workshop.

The study by Armitage (2010) surveyed *Racomitrium lanuginosum – Carex bigelowii* (“alpine moss heath”) on the mountain summits at 38 sites in the UK, plus additional sites in Norway, the Faroes and Iceland. Moss tissue N increases with N deposition (CBED 2004-06: CEH Edinburgh) (Fig 5.4.3), as does shoot growth. Despite the increased shoot growth however, the depth of the moss layer decreases with increased N deposition, and this is due to increased shoot turnover (ie higher ratio of decomposition at the bottom of the shoot to growth at the top). Sites with a high rate of moss shoot turnover have lower moss cover. There is no clear threshold of effect, but shoot turnover begins to increase at tissue N of c. 0.5 %, which corresponds to total N deposition of 7 kg ha^{-1} $year^{-1}$, supporting the use of 7 kg N ha^{-1} $year^{-1}$ as the mapping value for this habitat in the UK. It should be noted that the interpretation of these data is not completely straightforward as the N gradient corresponds with a climatic gradient. Nevertheless N deposition accounts for more of the patterns than the climate variables.

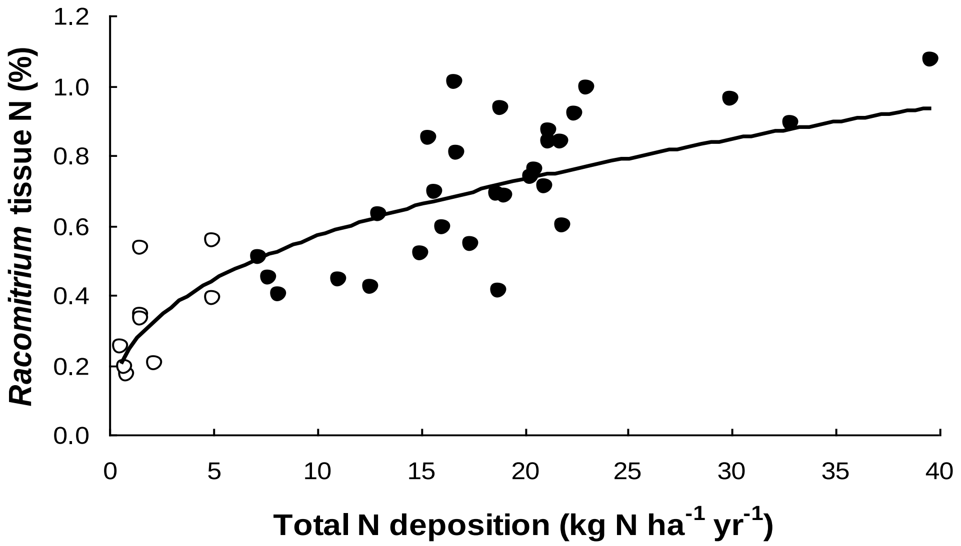

Fig. 5.4.3. Relationship between mean *R. lanuginosum* tissue N content (%) at 38 sites (filled circles – UK, open circles - Europe) and total N deposition, R^2 = 73%; $P < 0.001$; $\log y = 0.364(\log x) - 0.61$. Each point is the mean of 8 samples.

5.5 Heathland, scrub and tundra habitats
There are two heathland habitats mapped nationally in this category: dry heaths (F4.2) and wet upland and wet lowland heaths (F4.11 U and F4.11 L). The Noordwijkerhout workshop (Bobbink & Hettelingh, 2011) recommended applying the high end of the critical load ranges for heathland in areas with high precipitation or for systems with a high water table, and the low end of the range in areas of low precipitation or for systems with a low water table. The low end of the range should also be used where management intensity is low. The

application of these modifying factors was discussed at the UK experts meeting in November 2010 where it was agreed not to apply them in national-scale applications, but noted it could be important to apply these for site-specific applications where local knowledge on management practice, water table height etc is available.

Upland and lowland wet heath (F4.11)
In 2003 the critical load range for lowland wet heath was 10-25 kg N ha^{-1} $year^{-1}$; at the Noordwijkerhout workshop (Bobbink & Hettelingh, 2011) the upper end of this range was reduced to 20 kg N ha^{-1} $year^{-1}$. This results in the same overall range (10-20 kg N ha^{-1} $year^{-1}$) being applicable to both upland and lowland wet heaths. Since 2003 the UK mapping value for both has been set at 15 kg N ha^{-1} $year^{-1}$ (Hall et al, 2003).

Dry heaths (F4.2)
The critical load range agreed at Noordwijkerhout (Bobbink & Hettelingh, 2011) for this habitat remains unchanged at 10-20 kg N ha^{-1} $year^{-1}$. In 2003 the UK mapping value for this habitat was set to 12 kg N ha^{-1} $year^{-1}$ (Hall et al, 2003).

New mapping value for wet heaths (F4.11) and dry heaths (F4.2)
No new evidence was available at the November 2010 UK experts meeting to suggest altering the UK mapping values for wet or dry heaths. However, Stevens et al (2011) and Emmett et al (2011) do provide new evidence of impacts of N deposition to heathlands in the UK. Table 5.5.1 below presents an extract of Table 2.4 of Emmett et al (2011) showing the impacts of N deposition on heathland species and ecosystem function at N deposition levels encompassing the critical load range. Note that the evidence does not distinguish between wet and dry heathland habitats. Based on the evidence of impacts on species and the increase in Ellenberg N (including impacts at N deposition values below the minima of the critical load range), Emmett et al (2011) support the use of a new mapping value at the lower end of the range (10 kg N ha^{-1} $year^{-1}$) for both wet (F4.11) and dry (F4.2) heathland.

Table 5.5.1 Extract of Table 2.4 from Emmett et al (2011) showing impacts of N deposition on heathland species, ecosystem function and processes.

N deposition range (kg N ha^{-1} year^{-1})	**Species distribution inhibited# by N deposition as determined by Stevens et al (2011)**	**Species distribution strongly inhibited## by N deposition as determined by Stevens et al (2011)**	**Evidence of change including impacts on ecosystem functions and soil processes**
0-5			
5-10	*Fossombronia wondraczekii* *Cladoia cervicornis verticillata* *Cladonia strepsilis* *Arctostaphylos uva-ursi* *Anastrophyllum minutum* *Lepidozia pearsonii* *Cetraria aculeate* *Cetraria uncialis biuncialis* *Lichenomphalia umbellifera* *Microlejeunea ulicina* *Cladonia cervicornis cervicornis* *Cladonia subulata* *Leucobryum glaucum*	*Fossombronia wondraczekii* *Cladonia strepsilis* *Arctostaphylos uva-ursi*	A 20% increase in Ellenberg N at 5-10 kg N ha^{-1} year^{-1} relative to lowest levels of N deposition according to one dataset (BSBI LCS) (Stevens et al, 2011).
10-15	Species above plus: *Cladonia portentosa* *Vaccinium vitis-idaea*	Species above plus: *Cladonia cervicornis verticillata* *Anastrophyllum minutum* *Lepidozia pearsonii* *Cetraria aculeate* *Cetraria muricata* *Cladonia uncialis biuncialis* *Microlejeunea ulicina*	
15-20	Species above plus: *Viola canina* *Dibaeis baeomyces* *Cladonia glauca*	Species above plus: *Lichenomphalia umbellifera* *Cladonia cervicornis cervicornis* *Cladonia subulata* *Leucobryum glaucum* *Cladonia portentosa* *Vaccinium vitis-idaea* *Viola canina*	Altered species composition both in Stevens et al (2011) and RoTAP (2011). A 20% increase in Ellenberg N value at 5-20 kg N ha^{-1} year^{-1} relative to lowest levels of N deposition for both upland and lowland heathland indicating shift to more nutrient-loving species in Stevens et al (2011). A 20% reduction in Ellenberg R value at 15-20 kg N ha^{-1} year^{-1} relative to lowest levels of N deposition (Stevens et al, 2011). Conflicting evidence of change in canopy height with both positive and negative relationships described. Suggests sensitivity of habitat to change with direction of change dependent on site factors (Stevens et al, 2011).

[#] species distribution inhibited = species occurrence fell by 20% relative to occurrence at the lowest N deposition levels

[##] species distribution strongly inhibited = species occurrence fell by 50% relative to occurrence at the lowest N deposition levels

5.6 Forest habitats

In 2003 empirical critical loads of nitrogen were only applied to two woodland habitat types in the UK:

(i) Unmanaged coniferous and broadleaf woodland with a mapping value of 12 kg N ha^{-1} year^{-1} to protect the woodland ground flora.

(ii) Atlantic oak woodlands with a mapping value of 10 kg N ha^{-1} year^{-1} to protect epiphytic lichens.

At the Noordwijkerhout workshop ranges of critical loads were set for larger number of woodland types (Bobbink & Hettelingh, 2011), those relevant to the UK are listed in Table 2.1. The sections below provide the evidence for setting the UK mapping values for each of four unmanaged (ie, non-productive) woodland classes.

Beech (Fagus) woodland (G1.6)

The critical load range set for this habitat at Noordwijkerhout (Bobbink & Hettelingh, 2011) was 10-20 kg N ha^{-1} year^{-1}. Within that range a UK mapping value of 15 kg N ha^{-1} year^{-1} has been agreed based on evidence available from: (a) a long term nitrogen gradient experiment on a small scale (Thetford gradient study) and (b) a regional scale comparison from high (Thetford: 15-35 kg N ha^{-1} year^{-1}) and low (Alice Holt: 8-12 kg N ha^{-1} year^{-1}) N deposition beech forests (Vanguelova and Pitman, 2009). At Thetford impacts have been observed (at N deposition >15 kg N ha^{-1} year^{-1}) on soil NO_3 availability, foliar N and K, beech flowering patterns and seed and litterfall production (e.g. double leaf biomass at high N) (Vanguelova and Pitman, 2009). Increased soil nitrification rates and reduced soil microbial diversity seen at Thetford were not observed at Alice Holt (Emma Thorpe, PhD study, http://www.forestry.gov.uk/fr/INFD-8DPG55).

Acidophilous oak (Quercus) dominated woodland (G1.8)

The critical load range set for this habitat at Noordwijkerhout (Bobbink & Hettelingh, 2011) was 10-15 kg N ha^{-1} year^{-1} and within that range the agreed UK mapping value is 10 kg N ha^{-1} year^{-1}. This mapping value is supported by evidence from a typical acidophilous (Atlantic) Oak (*Quercus petraea*) woodland at Grizedale, part of the Level II Forest Intensive Monitoring network. The range of N deposition at this site for the last 15 years has been between 9 and 20 kg N ha^{-1} year^{-1}. Increasing N leaching, in the form of NO_3 and DON, has been measured at this site for the last 15 years, in addition to soil acidification (Vanguelova et al, 2010). Oak crown condition has also deteriorated with time (Vanguelova et al., 2007) with increased susceptibility to insect attacks. An insect infestation during 2004 to 2005 added an extra 4-5 kg N ha^{-1} y^{-1} to the N deposition at Grizedale (Pitman et al., 2010). Soil NO_3-N leaching significantly increased and ground vegetation composition response was subsequently observed at the site together with a significant increase in Ellenberg scores at N deposition exceeding 10 kg ha^{-1} year^{-1} (Figure 5.6.2). The lag effect between N input and plant response is between one to two years which is illustrated in Figure 5.6.2. The mapping value for this habitat is the same as the mapping value used for Atlantic oak woodlands since 2003 (Hall et al, 2003), to protect epiphytic lichens within this woodland type.

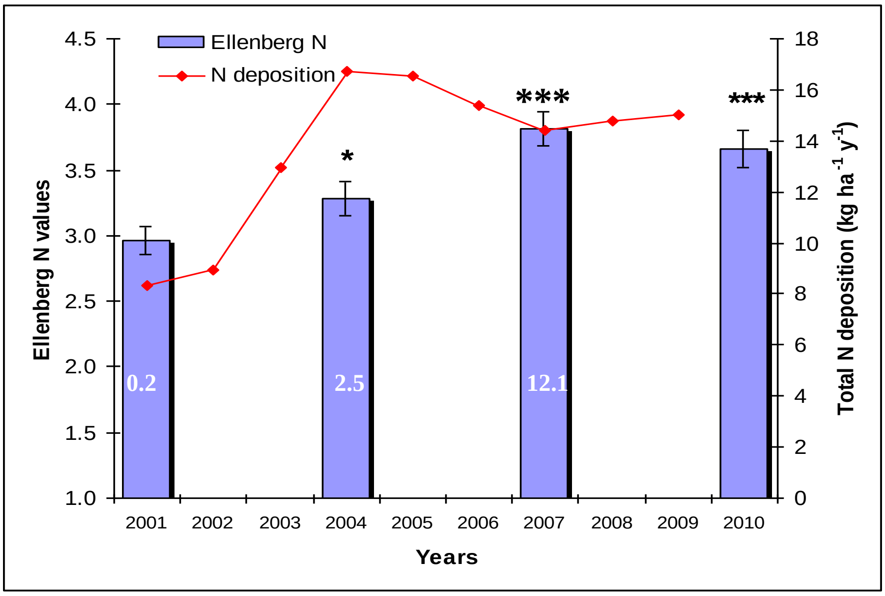

Figure 5.6.2.Change in Ellenberg N scores derived from repeated ground flora surveys at Grizedale acidophilous *Quercus* dominated forest with measured temporal total N deposition to the site and NO_3 leaching fluxes from deep soil from 2001 to 2010. Blue bars are mean Ellenberg values from 10 replicates, vertical bars are *se* of the mean and stars indicate significant difference of Ellenberg score away from 2001 baseline at $p<0.05$ (*) and $p<0.001$ (***). Red line is the total annual N deposition and white values within bars are the deep soil NO_3 leaching flux in kg ha^{-1} year^{-1}.

***Pinus sylvestris* woodland G3.4**

The critical load range set for this habitat at Noordwijkerhout (Bobbink & Hettelingh, 2011) was 5-15 kg N ha^{-1} year^{-1} and within that range the agreed UK mapping value is 12 kg N ha^{-1} year^{-1}. This mapping value is based on evidence from large scale UK Level I forest monitoring which suggests that Scots pine needle N concentrations go above the critical threshold of 1.7% (Taylor, 1991, Gundersen, 1999) when N deposition is higher than 12 kg ha^{-1} year^{-1} (Figure 5.6.3., Kennedy, 2003). This is further supported by evidence of N recovery at the Level II Scots pine Intensive Forest Monitoring plot at Thetford, where N deposition values of 17-19 kg N ha^{-1} year^{-1} in 1995 have fallen to an average of 10-12 kg N ha^{-1} year^{-1} in recent years. This decrease in N deposition has been accompanied by a significant decrease in soil NO_3 leaching in winter drainage (Vanguelova et al, 2010) and a temporal response of ground flora to N deposition and soil NO_3 changes have been observed using Ellenberg scores.

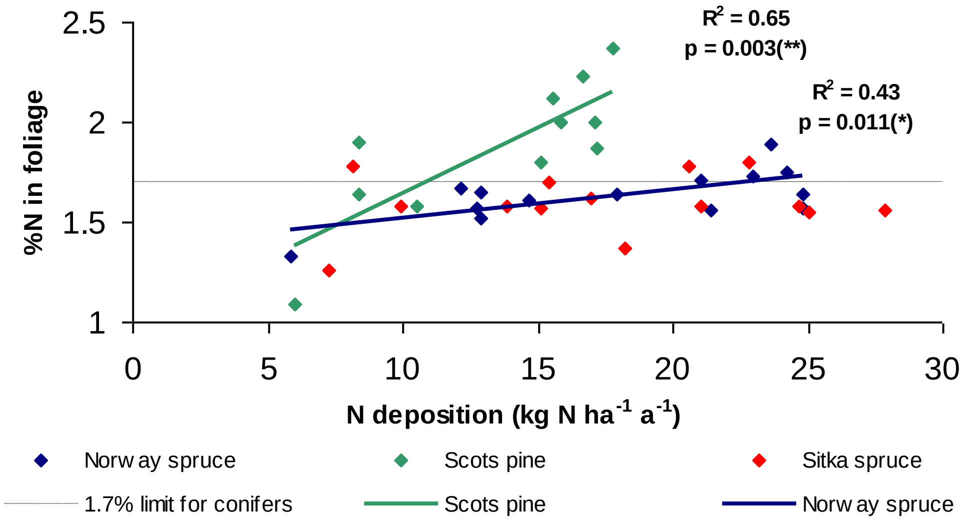

Figure 5.6.3. Relationship between nitrogen deposition and foliar nitrogen in three conifer species in Great Britain (Kennedy, 2003).

Remaining unmanaged coniferous and broadleaved woodland (G4)

The Noordwijkerhout workshop (Bobbink & Hettelingh, 2011) gave ranges of critical loads for broadleaved woodland (G1: 10-20 kg N ha^{-1} year^{-1}) and for coniferous woodland (G3: 5-15 kg N ha^{-1} year^{-1}) for application at broad geographical scales. The data the UK hold on the distribution of managed and unmanaged woodland does not allow for the differentiation between unmanaged conifer and unmanaged broadleaf woodland. In 2003 all UK unmanaged coniferous and broadleaved woodland (except Atlantic oak woodland) was assigned a mapping value of 12 kg N ha^{-1} year^{-1} to protect the woodland ground flora, based on the range for all forests of 10-15 kg N ha^{-1} year^{-1} (Achermann & Bobbink, 2003). Without additional evidence available it was agreed that the mapping value for all remaining areas of unmanaged woodland (see Figure 4.3d), that are not included within the distributions for the above three categories (G1.6, G1.8, G3.4), should be kept at 12 kg N ha^{-1} year^{-1}; this value falls within the new ranges for G1 and G3.

6 RECOMMENDED UK MAPPING VALUES

The introduction (Section 1) outlines the process used in the UK for setting UK "mapping values"; these are the value(s) within each critical load range for each habitat that are used in UK critical load maps and in the calculation of critical load exceedances. Section 5 provides the scientific evidence and rationale underpinning the selection of these mapping values. Table 6.1 below gives the ranges of critical load values from the 2003 Berne (Achermann & Bobbink, 2003) and 2010 Noordwijkerhout (Bobbink & Hettelingh, 2011) workshops and the UK mapping values used in 2003 and the updated 2010 values applied in UK maps from March 2011.

Table 6.1. Critical loads of nitrogen for habitats mapped nationally in the UK; values in bold type represent changes from the 2003 values.

Ecosystem type	**EUNIS code**	**CLnutN range 2003 (kg N ha^{-1} $year^{-1}$)**	**CLnutN mapping value 2003 (kg N ha^{-1} $year^{-1}$)**	**CLnutN range 2010 (kg N ha^{-1} $year^{-1}$)**	**CLnutN mapping value 2010 (kg N ha^{-1} $year^{-1}$)**	**Indication of exceedance**
Marine habitats						
Mid-upper saltmarshes	A2.53	30-40 (#)	Not mapped	**20-30 (#)**	**25**	Increase in dominance of graminoids.
Pioneer & low-mid saltmarshes	A2.54/55	30-40 (#)	Not mapped	**20-30 (#)**	**25**	Increase in late-successional species, increase in productivity.
Coastal habitats						
Shifting coastal dunes	B1.3	10-20 (#)	15	10-20 (#)	**Not mapped**	Biomass increase, increased N leaching.
Coastal stable dune grasslands (grey dunes)	B1.4[a]	10-20 #	15	**8-15 #**	**9 acid dunes 12 non-acid dunes**	Increase tall graminoids, decrease in prostrate plants, increased N leaching, soil acidification, loss of typical lichen species.
Mire, bog and fen habitats						
Raised & blanket bogs	D1[b]	5-10 ##	10	5-10 ##	**8, 9, 10 depending on rainfall**	Increase in vascular plants, altered growth and species composition of bryophytes, increased N in peat and peat water.
Grasslands and tall forb habitats						
Sub-atlantic semi-dry calcareous grassland	E1.26	15-25 ##	20	15-25 ##	**15**	Increase in tall grasses, decline in diversity, increased mineralization, N leaching; surface acidification.
Non-Mediterranean dry acid and neutral closed grassland	E1.7[c]	10-20 #	15	**10-15 ##**	**10**	Increase in graminoids, decline in typical species, decrease in total species richness.
Moist & wet oligotrophic grasslands:						
Heath (*Juncus*) meadows & humid (*Nardus Stricta*) swards	E3.52	10-20 #	15	10-20 #	15	Increase in tall graminoids, decreased diversity, decrease in bryophytes.
Moss & lichen dominated mountain summits	E4.2	5-10 #	7	5-10 #	7	Effects upon bryophytes and/or lichens.

Ecosystem type	**EUNIS code**	**CLnutN range 2003 (kg N ha^{-1} year^{-1})**	**CLnutN mapping value 2003 (kg N ha^{-1} year^{-1})**	**CLnutN range 2010 (kg N ha^{-1} year^{-1})**	**CLnutN mapping value 2010 (kg N ha^{-1} year^{-1})**	**Indication of exceedance**
Heathland, scrub & tundra *Northern wet heaths*						
• 'U' *Calluna*-dominated wet heath (upland moorland)	F4.11[b,d]	10-20 (#)	15	10-20 #	**10**	Decreased heather dominance, decline in lichens and mosses, increase N leaching.
• 'L' *Erica tetralix* dominated wet heath (lowland)	F4.11[b,d]	10-25 (#)	15	**10-20 (#)**	**10**	Transition from heather to grass dominance.
Dry heaths	F4.2[b,d]	10-20 ##	12	10-20 ##	**10**	Transition from heather to grass dominance, decline in lichens, changes in plant biochemistry, increased sensitivity to abiotic stress.
Forest habitats overall All forests: ground flora	G	10-15 #	12	see below		Changed species composition, increase of nitrophilous species, increased susceptibility to parasites.
Broadleaved woodland	G1			10-20 ##	see below	Changes in soil processes, nutrient imbalance, altered composition of mycorrhiza and ground vegetation.
Coniferous woodland	G3			5-15 ##	see below	Changes in soil processes, nutrient imbalance, altered composition of mycorrhiza and ground vegetation.
Mixed woodland	G4				12	This is the mapping value used in 2003 for all unmanaged woodland (see G). This is within the ranges for G1 and G3 and will be applied to all unmanaged woodland not included in G1.6, G1.8 or G3.4.

Ecosystem type	**EUNIS code**	**CLnutN range 2003 (kg N ha^{-1} year^{-1})**	**CLnutN mapping value 2003 (kg N ha^{-1} year^{-1})**	**CLnutN range 2010 (kg N ha^{-1} year^{-1})**	**CLnutN mapping value 2010 (kg N ha^{-1} year^{-1})**	**Indication of exceedance**
Forest habitats						
Fagus woodland		G1.6		**10-20 (#)**	**15**	Changes in ground vegetation and mycorrhiza, nutrient imbalance, changes in soil fauna
Acidophilous *Quercus*-dominated woodland		G1.8	10 (epiphytic lichens in Atlantic oak)	**10-15 (#)**	**10**	Decrease in mycorrhiza, loss of epiphytic lichens and bryophytes, changes in ground vegetation.
Pinus sylvestris woodland south of the taiga		G3.4		**5-15 #**	**12**	Changes in ground vegetation and mycorrhiza, nutrient imbalances, increased N_2O and NO emissions.

Reliability scores assigned at Berne in 2003 (Achermann & Bobbink, 2003) and Nordwijkerhout in 2010 (Bobbink & Hettelingh, 2011):
reliable: when a number of published papers of various studies showed comparable results.
quite reliable: when the results of some studies were comparable.
(#) expert judgement: when no empirical data were available for this type of ecosystem. For this, the nitrogen critical load was based upon expert judgement and knowledge of ecosystems which were likely to be comparable with this ecosystem.

Footnotes from the Noordwijkerhout workshop (Bobbink & Hettelingh, 2011):
(e) For acidic dunes, the 8-10 kg N ha^{-1} year^{-1} range should be applied, for calcareous dunes this range is 10-15 kg N ha^{-1} year^{-1}.
(f) Apply the high end of the range to areas with high levels of precipitation and the low end of the range to those with low precipitation levels; apply the low end of the range to systems with a low water table, and the high end of the range to those with a high water table. Note that water tables can be modified by management.
(g) Apply the lower end of the range to habitats with a low base availability; and the higher end of the range to those with high base availability.
Apply the high end of the range to areas where sod cutting has been practiced; apply the lower end of the range to areas with low-intensity management.

7 IMPACTS ON CRITICAL LOAD EXCEEDANCES

This section assesses the impact of changes to the habitat distributions and the UK critical load mapping values on the exceedances of critical loads. The UK mapping value(s) for each habitat (Table 6.1) are applied to each 1x1 km square that contains an area of that habitat as defined by the distribution maps in Section 4. The mapping values are compared with values of nitrogen deposition (NO_x + NH_x) from national 5x5 km maps, to calculate the amount of excess deposition above the critical load (ie, the exceedance). Deposition values for "moorland" are applied to all non-woodland habitats, and deposition values for "woodland" are applied to all woodland habitats. The results presented here are based on Concentration Based Estimated Deposition (CBED; RoTAP 2011) for 2006-08 and include all UK habitats for which exceedances are calculated nationally, including managed woodland habitats to which mass balance critical loads are applied (Hall et al, 2003). The summary tables (Tables 7.1-7.5) give the following results by habitat and country based on the 2003 and the 2010 UK mapping values:

- the area of habitat exceeded;
- the percentage area of habitat exceeded;
- the accumulated exceedance (AE)

AE is a way of summarising the magnitude of exceedance over a large area and is calculated as:

$$\text{AE (keq year}^{-1}) = \text{exceedance (keq ha}^{-1}\text{ year}^{-1}) * \text{exceeded area (ha)}$$

However, some care is needed in the interpretation of AE since a small exceedance and large exceeded area may give the same result as a high exceedance and a small area. To give an estimate of the average accumulated exceedance (AAE in keq ha^{-1} year^{-1}), AE can be divided by the total habitat area (note: not just the exceeded area).

The tables (7.1-7.5) also give the area of each habitat type by country based on the habitat distribution maps (Section 4). There are small changes in the area of the bog habitat mapped for Scotland and NI in 2010 compared to 2003; this is due to the spatial coverage of the available rainfall data used to define the different mapping values for bogs in wet and dry areas of the country. There are also minor changes to the habitat (acid grassland, unmanaged woodland) areas in Northern Ireland due to the conversion of habitat data from the Irish Grid to the British National Grid carried out in 2007. Due to these changes and changes in the habitat distribution for dune grassland (Section 4.2) the total area of sensitive habitats considered for eutrophication impacts in the UK has reduced by 1403 km^2 (1.9%). However, for the UK the area of sensitive habitats exceeding critical loads increased from 58.4% using the 2003 critical load mapping values, to 71.2% using the updated critical load mapping values and the AAE increased from 6.8 kg N ha^{-1} year^{-1} to 7.9 kg N ha^{-1} year^{-1}. The largest change in the area exceeded is seen in Scotland where an additional 15.7% (6637 km^2) of the habitat area is exceeded using the updated critical loads. The largest increases in the magnitude of exceedance (expressed as AAE) are seen in England and in Wales where AAE increases by 2 kg N ha^{-1} year^{-1}.

To compare the results spatially, an updated map of the 5th-percentile critical loads of nutrient nitrogen has been generated. This is the critical load that will protect 95% of the total sensitive habitat area in each 1x1km grid square and combines the critical loads data for all habitats, including the mass balance critical loads of nitrogen for the managed conifer and managed broadleaf habitats. Exceedance of the 5th-percentile critical loads are calculated using CBED "grid-average" deposition (ie, average values for all habitat types) because different habitats determine the 5th-percentile critical load value in different 1x1 km squares.

This means that for some squares exceedance may be overestimated and for others exceedance may be underestimated, but this approach enables a simple comparison of two maps at the national scale, rather than comparing exceedance maps for individual habitats based on ecosystem-specific deposition. The exceedance maps based on the 2003 5^{th}-percentile critical load map and the updated 5^{th}-percentile map are shown in Figure 7.1; the maps show similar spatial patterns and magnitude of exceedance

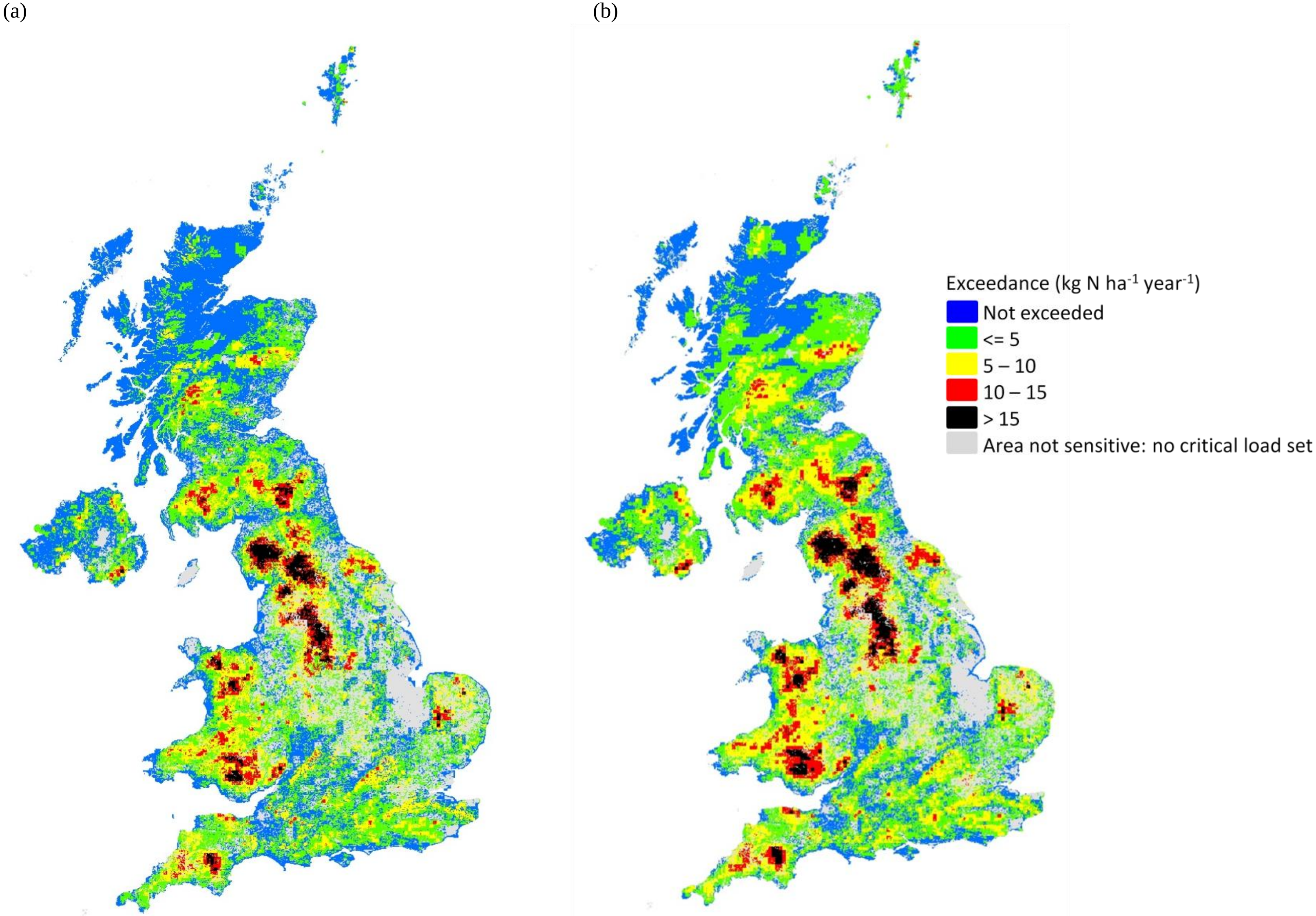

Figure 7.1. Exceedance of the 5th-percentile critical loads of nutrient nitrogen by CBED nitrogen (NOx + NHx) deposition for 2006-08: (a) based on 2003 5th-percentile critical loads; (b) based on updated 5th-percentile critical loads of nutrient nitrogen.

Table 7.1 Nitrogen exceedance results for England

(a) Based on 2003 mapping values

Broad Habitat	EUNIS class(es)	Habitat Area (km^2)	Exceeded Area (km^2)	Percentage Area Exceeded	Accumulated Exceedance (keq/year)	AAE (keq/ha/year)	AAE (kg N/ha/year)
Acid grassland	E1.7 & E3.52	2620	2523	96.3	166821	0.64	8.9
Calcareous grassland	E1.26	3312	1750	52.8	65251	0.20	2.8
Dwarf shrub heath	F4.11 & F4.2	2466	2313	93.8	138715	0.56	7.9
Bog	D1	1007	1007	100.0	102197	1.01	14.2
Montane	E4.2	2	2	100.0	259	1.30	18.1
Coniferous woodland (managed)	G3	1719	1719	100.0	287843	1.67	23.4
Broadleaved woodland (managed)	G1	5588	5588	100.0	999473	1.79	25.0
Unmanaged woods (ground flora)	G4	2252	2252	100.0	382419	1.70	23.8
Atlantic oak (epiphytic lichens)	G4	150	150	100.0	29381	1.96	27.4
Supralittoral sediment	B1.3 & B1.4	1183	235	19.9	4465	0.04	0.5
All habitats		20299	17539	86.4	2176824	1.07	15.0

(b) Based on updated (2010/11) mapping values

Broad Habitat	EUNIS class(es)	Habitat Area (km^2)	Exceeded Area (km^2)	Percentage Area Exceeded	Accumulated Exceedance (keq/year)	AAE (keq/ha/year)	AAE (kg N/ha/year)
Acid grassland	E1.7 & E3.52	2620	2572	98.1	193280	0.74	10.3
Calcareous grassland	E1.26	3312	3142	94.9	158509	0.48	6.7
Dwarf shrub heath	F4.11 & F4.2	2466	2464	99.9	216928	0.88	12.3
Bog	D1	1007	1007	100.0	104938	1.04	14.6
Montane	E4.2	2	2	100.0	259	1.30	18.1
Coniferous woodland (managed)	G3	1719	1719	100.0	287843	1.67	23.4
Broadleaved woodland (managed)	G1	5588	5588	100.0	999473	1.79	25.0
Fagus woodland (unmanaged)	G1.6	650	650	100.0	88712	1.36	19.1
Acidophilous oak (unmanaged)	G1.8	601	601	100.0	111826	1.86	26.0
Scots Pine (unmanaged)	G3.4	0	0	0.0	0	0	0
Other unmanaged woodland	G4	1152	1152	100.0	203808	1.77	24.8
Dune grassland	B1.4	93	69	74.3	1129	0.12	1.7
Saltmarsh	A2.5	312	4	1.1	139	0.00	0.1
All habitats		19522	18970	97.2	2366844	1.21	17.0

Table 7.2 Nitrogen exceedance statistics for Wales

(a) Based on 2003 mapping values

Broad Habitat	EUNIS class(es)	Habitat Area (km^2)	Exceeded Area (km^2)	Percentage Area Exceeded	Accumulated Exceedance (keq/year)	AAE (keq/ha/year)	AAE (kg N/ha/year)
Acid grassland	E1.7 & E3.52	3146	2717	86.4	104500	0.33	4.7
Calcareous grassland	E1.26	171	41	23.7	424	0.02	0.3
Dwarf shrub heath	F4.11 & F4.2	1094	1021	93.3	51380	0.47	6.6
Bog	D1	56	54	96.0	3651	0.65	9.1
Montane	E4.2	18	18	100.0	1955	1.09	15.2
Coniferous woodland (managed)	G3	1052	1052	100.0	155532	1.48	20.7
Broadleaved woodland (managed)	G1	798	798	100.0	109699	1.37	19.2
Unmanaged woods (ground flora)	G4	226	226	100.0	33988	1.50	21.1
Atlantic oak (epiphytic lichens)	G4	171	171	100.0	25562	1.49	20.9
Supralittoral sediment	B1.3 & B1.4	369	42	11.4	671	0.02	0.3
All habitats		7101	6140	86.5	487362	0.69	9.6

(b) Based on updated (2010/11) mapping values

Broad Habitat	EUNIS class(es)	Habitat Area (km^2)	Exceeded Area (km^2)	Percentage Area Exceeded	Accumulated Exceedance (keq/year)	AAE (keq/ha/year)	AAE (kg N/ha/year)
Acid grassland	E1.7 & E3.52	3146	2888	91.8	152484	0.48	6.8
Calcareous grassland	E1.26	171	124	72.5	3745	0.22	3.1
Dwarf shrub heath	F4.11 & F4.2	1094	1090	99.6	82325	0.75	10.5
Bog	D1	56	54	96.0	3691	0.66	9.2
Montane	E4.2	18	18	100.0	1955	1.09	15.2
Coniferous woodland (managed)	G3	1052	1052	100.0	155532	1.48	20.7
Broadleaved woodland (managed)	G1	798	798	100.0	109699	1.37	19.2
Fagus woodland (unmanaged)	G1.6	65	65	100.0	8469	1.30	18.2
Acidophilous oak (unmanaged)	G1.8	251	251	100.0	39263	1.56	21.9
Scots Pine (unmanaged)	G3.4	0	0	0.0	0	0	0
Other unmanaged woodland	G4	81	81	100.0	11566	1.43	20.0
Dune grassland	B1.4	37	9	25.6	107	0.03	0.4
Saltmarsh	A2.5	68	0	0.1	1	0.00	0.0
All habitats		6837	6430	94.0	568837	0.83	11.6

Table 7.3 Nitrogen exceedance statistics for Scotland

(a) Based on 2003 mapping values

Broad Habitat	EUNIS class(es)	Habitat Area (km^2)	Exceeded Area (km^2)	Percentage Area Exceeded	Accumulated Exceedance (keq/year)	AAE (keq/ha/year)	AAE (kg N/ha/year)
Acid grassland	E1.7 & E3.52	8283	2686	32.4	53255	0.06	0.9
Calcareous grassland	E1.26	24	0	0.0	0	0.00	0.0
Dwarf shrub heath	F4.11 & F4.2	20284	3314	16.3	64563	0.03	0.4
Bog	D1	4005	1343	33.5	34619	0.09	1.2
Montane	E4.2	3109	3026	97.3	109448	0.35	4.9
Coniferous woodland (managed)	G3	5111	4619	90.4	343203	0.67	9.4
Broadleaved woodland (managed)	G1	1096	937	85.5	76645	0.70	9.8
Unmanaged woods (ground flora)	G4	570	446	78.2	32900	0.58	8.1
Atlantic oak (epiphytic lichens)	G4	501	472	94.2	16835	0.34	4.7
Supralittoral sediment	B1.3 & B1.4	547	25	4.6	385	0.01	0.1
All habitats		43530	16868	38.8	731853	0.17	2.4

(b) Based on updated (2010/11) mapping values

Broad Habitat	EUNIS class(es)	Habitat Area (km^2)	Exceeded Area (km^2)	Percentage Area Exceeded	Accumulated Exceedance (keq/year)	AAE (keq ha/year)	AAE (kg N/ha/year)
Acid grassland	E1.7 & E3.52	8283	3303	39.9	93535	0.11	1.6
Calcareous grassland	E1.26	24	10	41.0	113	0.05	0.7
Dwarf shrub heath	F4.11 & F4.2	20284	8903	43.9	233872	0.12	1.6
Bog	D1	3993	1749	43.8	40655	0.10	1.4
Montane	E4.2	3109	3026	97.3	109448	0.35	4.9
Coniferous woodland (managed)	G3	5111	4619	90.4	343203	0.67	9.4
Broadleaved woodland (managed)	G1	1096	937	85.5	76645	0.70	9.8
Fagus woodland (unmanaged)	G1.6	4	4	100.0	306	0.77	10.7
Acidophilous oak (unmanaged)	G1.8	581	559	96.1	28038	0.48	6.8
Scots Pine (unmanaged)	G3.4	204	125	61.6	4221	0.21	2.9
Other unmanaged woodland	G4	282	214	75.8	18425	0.65	9.1
Dune grassland	B1.4	184	56	30.2	905	0.05	0.7
Saltmarsh	A2.5	45	0	0.0	0	0.00	0.0
All habitats		43200	23505	54.4	949366	0.22	3.1

Table7.4 Nitrogen exceedance statistics for Northern Ireland

(a) Based on 2003 mapping values

Broad Habitat	EUNIS class(es)	Habitat Area (km^2)	Exceeded Area (km^2)	Percentage Area Exceeded	Accumulated Exceedance (keq/year)	AAE (keq ha/year)	AAE (kg N/ha/year)
Acid grassland	E1.7 & E3.52	1198	901	75.2	35521	0.30	4.2
Calcareous grassland	E1.26	70	8	11.2	394	0.06	0.8
Dwarf shrub heath	F4.11 & F4.2	983	787	80.1	36174	0.37	5.2
Bog	D1	469	453	96.6	23126	0.49	6.9
Montane	E4.2	0	0	0.0	0	0	0
Coniferous woodland (managed)	G3	502	496	98.9	59780	1.19	16.7
Broadleaved woodland (managed)	G1	0	0	0.0	0	0	0
Unmanaged woods (ground flora)	G4	248	246	99.1	40480	1.63	22.9
Atlantic oak (epiphytic lichens)	G4	0	0	0.0	0	0	0
Supralittoral sediment	B1.3 & B1.4	30	15	50.1	768	0.26	3.6
All habitats		3500	2906	83.0	196243	0.56	7.8

(b) Based on updated (2010/11) mapping values

Broad Habitat	EUNIS class(es)	Habitat Area (km^2)	Exceeded Area (km^2)	Percentage Area Exceeded	Accumulated Exceedance (keq/year)	AAE (keq ha/year)	AAE (kg N/ha/year)
Acid grassland	E1.7 & E3.52	1186	926	78.1	43002	0.36	5.1
Calcareous grassland	E1.26	70	17	24.0	903	0.13	1.8
Dwarf shrub heath	F4.11 & F4.2	983	933	94.9	64907	0.66	9.2
Bog	D1	470	454	96.5	24380	0.52	7.3
Montane	E4.2	0	0	0.0	0	0	0
Coniferous woodland (managed)	G3	502	496	98.9	59780	1.19	16.7
Broadleaved woodland (managed)	G1	0	0	0.0	0	0	0
Fagus woodland (unmanaged)	G1.6	0	0	0.0	0	0	0
Acidophilous oak (unmanaged)	G1.8	0	0	0.0	0	0	0
Scots Pine (unmanaged)	G3.4	0	0	0.0	0	0	0
Other unmanaged woodland	G4	246	244	99.1	40197	1.63	22.9
Dune grassland	B1.4	9	5	49.7	267	0.30	4.2
Saltmarsh	A2.5	1	0	11.1	3	0.03	0.4
All habitats		3467	3075	88.7	233439	0.67	9.4

Table 7.5 Nitrogen exceedance statistics for the UK

(a) Based on 2003 mapping values

Broad Habitat	EUNIS class(es)	Habitat Area (km^2)	Exceeded Area (km^2)	Percentage Area Exceeded	Accumulated Exceedance (keq/year)	AAE (keq ha/year)	AAE (kg N/ha/year)
Acid grassland	E1.7 & E3.52	15247	8826	57.9	360097	0.24	3.3
Calcareous grassland	E1.26	3578	1798	50.3	66069	0.18	2.6
Dwarf shrub heath	F4.11 & F4.2	24826	7435	29.9	290832	0.12	1.6
Bog	D1	5537	2857	51.6	163593	0.30	4.1
Montane	E4.2	3129	3046	97.3	111662	0.36	5.0
Coniferous woodland (managed)	G3	8383	7886	94.1	846356	1.01	14.1
Broadleaved woodland (managed)	G1	7482	7323	97.9	1185816	1.58	22.2
Unmanaged woods (ground flora)	G4	3297	3170	96.2	489787	1.49	20.8
Atlantic oak (epiphytic lichens)	G4	822	793	96.5	71778	0.87	12.2
Supralittoral sediment	B1.3 & B1.4	2129	317	14.9	6290	0.03	0.4
All habitats		74430	43451	58.4	3592280	0.48	6.8

(b) Based on updated (2010/11) mapping values

Broad Habitat	EUNIS class(es)	Habitat Area (km^2)	Exceeded Area (km^2)	Percentage Area Exceeded	Accumulated Exceedance (keq/year)	AAE (keq ha/year)	AAE (kg N/ha/year)
Acid grassland	E1.7 & E3.52	15235	9689	63.6	482301	0.32	4.4
Calcareous grassland	E1.26	3578	3293	92.0	163270	0.46	6.4
Dwarf shrub heath	F4.11 & F4.2	24826	13390	53.9	598032	0.24	3.4
Bog	D1	5526	3263	59.0	173664	0.31	4.4
Montane	E4.2	3129	3046	97.3	111662	0.36	5.0
Coniferous woodland (managed)	G3	8383	7886	94.1	846356	1.01	14.1
Broadleaved woodland (managed)	G1	7482	7323	97.9	1185816	1.58	22.2
Fagus woodland (unmanaged)	G1.6	719	719	100.0	97486	1.36	19.0
Acidophilous oak (unmanaged)	G1.8	1434	1411	98.4	179127	1.25	17.5
Scots Pine (unmanaged)	G3.4	204	125	61.6	4221	0.21	2.9
Other unmanaged woodland	G4	1761	1690	96.0	273995	1.56	21.8
Dune grassland	B1.4	323	139	42.9	2408	0.07	1.0
Saltmarsh	A2.5	427	4	0.9	143	0.00	0.0
All habitats		73027	51978	71.2	4118481	0.56	7.9

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APPENDIX 1:
Notes from UK Nitrogen Critical Loads mapping. 16th November 2010.
Bangor Management Centre, 16 Nov 2010

Attendees
In person: Jane Hall (CEH), Peter Coleman (Defra), Will Cook (Defra), Simon Bareham (JNCC), Laurence Jones (CEH), Lucy Sheppard (CEH), Simon Caporn (MMU), Andrea Britton (MLURI, first 20 mins), Bridget Emmett (CEH)
By phone: Clare Whitfield (JNCC), Zoe Russell (NE), Mike Ashmore (Uni. York)

Aim: Discussion of whether to revise UK mapping values based on revisions to nutrient nitrogen CL ranges agreed in Nordwijkerhout, June 2010.
(http://www.unece.org/env/documents/2010/eb/wge/ece.eb.air.wg.1.2010.14.e.pdf.)

Brief discussion on implications of UNECE guidance (see above link, paragraph 15) to use low end of CL range: for clarification this refers to the use of the low end of the CL range (and no modifying factors) where countries have not submitted national CL data to the CCE; this approach will be used for European-scale studies to compare different abatement scenarios.
-Conclusion that this has little relevance to UK decisions on mapping values. At the national scale countries are free to decide where to set the CL within each range, whether or not to apply the modifying factors and how they do so.

Our documentation needs to clarify that the default mapping value applied to UK habitats is the mid-point, unless there is UK specific evidence to warrant a different value, for which evidence must be presented.

Applying modifying factors to UK mapping of CL for bogs (rainfall modifier), dwarf shrub heath (rainfall modifier), dry acid grassland (base cation availability) was **rejected** based on discussion on bogs. Principle reasons: using the method proposed by Max Posch (CCE) using CDFs of rainfall or base availability vs habitat area, extends the mapping values across the whole CL range and the resulting level of spatial differentiation suggests a level of detailed information on adverse effects and their spatial location that we just don't have. However, a simpler application of the modifying factors has not been completely ruled out; for example, see text on bogs and on acid grassland below.

Documentation required to justify decisions for each habitat:
Changes to the current mapping values need to be transparent with robust scientific evidence and consensus. For each habitat, one paragraph of text, with 1-2 graphs/figures providing evidence, with citations need to be sent to Jane Hall, for circulation and discussion/agreement by (this) panel of experts. Actions required are given under each habitat heading below.

Montane (EUNIS class E4.2 Moss & lichen dominated mountain summits):
Suggestion to use low end of CL range (5) based on evidence from Heather Armitage PhD thesis.
ACTION: Andrea Britton to provide evidence required for lower CL.

Calcareous grassland (EUNIS class E1.26:
No evidence to change from mid-point. But, forthcoming JNCC report may provide new evidence.

ACTION: Delay final decision until January when JNCC report published.

Dwarf Shrub Heath (EUNIS classes F4.11 upland & lowland wet heath, F4.2 dry heath):
Retain current mapping values of 12 for dry heaths and 15 for wet lowland and upland heaths, unless new evidence available.
ACTIONS:
- Sally Power: to check if any new evidence for dry heaths.
- Possible further information may be available in JNCC report to be published in January: any evidence of damage at locations where new CL range lower (ie, lowland wet heath)?
- Delay final decision until January when JNCC report published.

Bogs (EUNIS class D1):
Currently at high end of CL range (10). JNCC report should provide evidence to support lowering mapping value to mid or even low end of range. Concern raised that high end doesn't adequately protect drier bogs in England. May re-visit idea of applying a rainfall modifier if CL not altered by JNCC evidence.
ACTIONS:
- All: please send any evidence of effects on bogs in drier parts of the UK to Jane Hall.
- Delay final decision until January when JNCC report published.

Acid grassland (EUNIS classes E1.7 dry acid grassland; E3.52 wet acid grassland (Juncus/Nardus)):
Suggest to use low end of CL range (10) for dry acid grassland (=NVC U4) based on extensive new UK evidence. Retain mid-point for wet acid grassland (=NVC U6, Juncus …) as no new evidence available. Base cation availability may determine sensitivity to N in dry acid grassland BUT we decided not to use modifiers (see above). Comment received from Clare Whitfield after meeting regarding working group report for grasslands at Noordwijkerhout workshop:
"E3.51 and E3.52. The group agreed with the recommendation in the background document for no change to the critical load. No new data were identified by the group. Base status was identified as a significant modifying factor; systems with low base status are likely to be more sensitive. Fluctuations in the water table will make E3.52 less sensitive. Updated information is also available from a study in Wales with 10 kg/ha/yr added to a background of 20 kg/ha/yr for 15 years. There was evidence of interactions with grazing from the experiment, but this was not adequate to recommend a modifying factor. Information from this study should be added to the background document." At present the final workshop report chapter on grasslands is not available so we cannot see if this information has been added to the document.
ACTIONS:
- Mike Ashmore: to provide evidence required for dry acid grassland (EUNIS E1.7).
- All: we rejected the use of the base availability modifier (using the CDF of base availability vs habitat area) on the basis of:
  (a) it suggesting more detailed information on habitat response than we have spatially;
  (b) the guidance only applying to dry acid grassland;
  Do we want to re-consider applying a base availability modifier (in a simpler way: maybe based on base-poor vs base-rich soils?) given the update provided by Clare? Views please.

Dune grassland (EUNIS classes B1.3 shifting coast dunes, B1.4 stable dune grassland):
At present B1.3 and B1.4 have not been mapped separately for the UK and the same CL (15 kg N/ha/yr) applied to both.
The CL range for shifting dunes (B1.3) remains the same as before and it was agreed the mapping value should be left at 15 kg N/ha/yr.
The CL range for stable dune grasslands (B1.4) has been changed from 10-20 kg N/ha/yr to 8-15 kg N/ha/yr. It was agreed to adopt the distinction between acid and calcareous stable dune grasslands suggested at Noordwijkerhout, provided we can map these separately, and to use the mid-points of each category for mapping (ie, 9kg N/ha/yr for acid and 12 kg N/ha/yr for calcareous). At the national scale, if it's not possible to separately map acid and calcareous stable dunes, then set the CL to both to 10 kg N/ha/yr.
<u>ACTIONS:</u>

- Laurence Jones: (i) to provide evidence supporting lower CL for acid dunes; (ii) to advise on the appropriate CL and evidence if B1.3 and B1.4 cannot be mapped separately.
- Jane Hall: to explore the possibility of separately mapping B1.3 and B1.4 as well as dividing B1.4 into acid and calcareous sub-habitats.

Woodland (EUNIS classes G1, G3 and selected sub-classes):
Elena Vanguelova and Rona Pitman were unable to attend the meeting but provided suggestions on how to proceed with the different woodland categories; the meeting agreed with their suggestions. Ask MLURI to provide evidence to support choice of CL for Caledonian Pinewoods (7 or 10).
We need clarification on the evidence base used at Noordwijkerhout since the previous report explicitly included woodland categories to protect groundflora and to protect epiphytic lichens. We need to check if the evidence base and range of impacts described this time are broader than in the past.
<u>ACTIONS:</u>

- Elena Vanguelova: to provide evidence supporting mapping values for G1, G3, G1.6, G1.8, G1.A and G3.4.
- Alison Hester: to provide evidence supporting mapping value for Caledonian Pine (G3.4).
- All: to check the final report from the Noordwijkerhout workshop to confirm the evidence base used for the different woodland categories.
- Jane Hall: to further explore national mapping of different woodland habitats in collaboration with Elena.

Site-based CL application for habitats not mapped nationally.
Critical loads are also used to assess the risks to designated site feature habitats from acidification and eutrophication. There are a number of habitat types (EUNIS classes) that are important features of designated sites but not assessed in the national critical load maps (often it's not possible to map the habitat at the national scale). Evidence is rarely available to support using any value other than the mid-range CL for these assessments. However, the local application of modifying factors, including management, should be considered.
<u>ACTION:</u>
All: If any evidence is available to support the use of a particular part of the CL range for any of these additional habitats in the UK (Table 1 below), please provide the details to Jane Hall.

Table 1: Designated site features not mapped nationally in the UK

EUNIS class	Name	Berne 2003 CL range (kg N/ha/yr)	Noordwijkerhout 2010 CL range (kg N/ha/yr)	Proposed modifiers 2010
A2.54/5	Pioneer & low-mid saltmarshes	30-40 (#)	20-30 (#)	
B1.5	Coastal dune heaths	10-20 (#)	10-20 (#)	
B1.8	Moist to wet dune slacks	10-25 (#)	10-20 (#)	Base availability
C1.1	Softwater lakes	5-10 ##	3-10 ##	CL by water type
D2	Poor fens (D2.2 in 2003)	10-20 #	10-15 #	Use lower CL for D2.1
D4.1	Rich fens	15-35 (#)	15-30 (#)	latitude
D4.2	Montane rich fens	15-25 (#)	15-25 (#)	latitude
E1.94	Inland dune pioneer grassland	10-20 (#)	8-15 (#)	Base availability
E1.95	Inland dune siliceous grassland	10-20 (#)	8-15 (#)	Base availability
E2.2	Low & medium altitude hay meadows	20-30 (#)	20-30 (#)	
E2.3	Mountain hay meadows	10-20 (#)	10-20 (#)	
E3.51	Molinia caerulea meadows	15-25 (#)	15-25 (#)	
E4.3	Alpine & subalpine acid grassland	10-15 (#)	5-10 #	
E4.4	Alpine & subalpine calcareous grassland	10-15 (#)	5-10 #	
F2	Arctic, alpine & subalpine scrub habitats	5-15 (#)	5-15 #	

For further details please refer to material circulated prior to meeting on 16th November 2010.

APPENDIX 2:
Background information on the JNCC project

The JNCC Project had two objectives:

(i) Analysis of broad scale datasets to generate nitrogen response curves for species and summary response variables for habitat function indices, such as Ellenberg
(ii) Interpretation of and other research (eg, summarised in RoTAP, 2011) in respect of the implications for "conservation policy commitments" and surveillance requirements.

It investigated the relationships with nitrogen deposition in eight different large-scale vegetation surveillance datasets:

- Vascular Plant Database: records the presence of all vascular plant species growing in the wild within 10x10km grid squares for the whole of the UK.
- British Bryological Society Database: records the presence of all bryophyte species growing within 10x10km squares for the whole of the UK.
- Botanical Society of the British Isles (BSBI) Local Change Survey: records all vascular plant species growing in the wild in 822 2x2 km squares in a regular grid across Great Britain.
- British Lichen Society (BLS) Database: records the presence of all lichen species growing within 10x10km squares across the UK.
- Plantlife Common Plant Survey: looks at the presence and percentage cover of 65 common species in two plots: a 5x5 m "centre" plot and a 1 x 20 m linear plot taken on a linear feature. Data are held for a total of 3863 plots.
- Countryside Council for Wales grassland survey: data for Welsh lowland grassland sites, with a varying number of 2x2 m quadrats per site. Contains data from 397 calcareous and 940 acid grassland quadrats.
- Scottish Natural Heritage National Vegetation Classification (NVC) survey: NVC data from selected sites across Scotland, comprising 2775 bog locations, 1100 heathland locations, 275 calcareous grassland locations and 1189 acid grassland locations.
- Natural England Grassland database: data for English grasslands, with a varying number of 2x2 m quadrats per site. Contains data for 5332 calcareous grasslands and 149 acid grasslands.

For the data sets that record species presence at a large spatial scale Stevens et al (2011) investigated the relationships between nitrogen deposition and individual species response, Ellenberg N and R scores, specific leaf area and plant canopy height. Where quadrat data were available the following were also examined: species richness and species diversity. The data analysis took into consideration other potential drivers, including climate, land use and sulphur deposition. Further information on the data sets and analysis can be found in Stevens et al (2011).

Emmett et al (2011) focused on objective (ii) above and collated the evidence of nitrogen impacts in relation to nitrogen deposition loads and evaluated the consequences for species prevalence and indices of habitat structure and function at different nitrogen deposition loads. This potentially provides useful evidence to inform the setting of critical load mapping values for the four habitats considered. These mapping values were based on there being several strands of evidence available which suggest the current mapping value is too high (eg, a change in a single species plus functional indices, or changes in several species). The evidence is given in the following categories:

(a) Impacts on species:

- Species prevalence inhibited by nitrogen deposition when its occurrence fell by 20% relative to the prevalence found at the lowest levels of N deposition.
- Species prevalence strongly inhibited by nitrogen deposition when its occurrence fell by 50% relative to the prevalence found at the lowest levels of N deposition.

(b) Impacts on indices of ecosystem structure and function based on typical values for individual species:

- An increase in Ellenberg N score.   indicating a shift in species composition consistent with greater nitrogen availability due to nitrogen deposition.
- An increase in canopy height. Habitats with greater numbers of more competitive species typical of nutrient rich situations would be expected to have higher canopy height (assuming management remains constant). Nitrogen deposition would be expected to increase competitive species and thus increase the mean habitat canopy height.
- An increase in specific leaf area (SLA). More competitive species typical of nutrient rich situations would be expected to have a higher SLA. Nitrogen deposition would therefore be expected to increase the mean SLA for a habitat.

For these functional indices, a 20% change in the variable at the lowest deposition was identified as “functional change” and a 50% change as “major functional change”.

Further information can be found in Stevens et al (2011) and Emmett et al (2011).