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Trends in critical load exceedances in the UK

Report to Defra, prepared under Contract AQ0826

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CONTENTS **PAGE**

Executive Summary

Critical loads define the amount of acid or nitrogen deposition below which significant harmful effects do not occur to sensitive habitats. An "exceedance" is the amount of excess acid or nitrogen deposition above the critical load. This report presents the trends in critical load exceedances for UK broad habitats, based on deposition data covering the period from 1995 to 2013. Summary statistics are published to monitor progress in the areas at risk from air pollution over time, and are used for:

- Defra: Environmental Statistics – Key Facts
  https://www.gov.uk/government/publications/environment-statistics-key-facts
- Welsh Government: Sustainable Development Indicators for Wales
  http://wales.gov.uk/topics/statistics/headlines/sustaindev/120829/?lang=en
- Scottish Government: Key Scottish Environment Statistics
  http://www.scotland.gov.uk/Topics/Statistics/Browse/Environment/
- UK Biodiversity Indicators in Your Pocket: JNCC; biodiversity indicator for assessing the pressures from air pollution
  http://jncc.defra.gov.uk/page-4233

For acidity, the area of sensitive habitats in the UK with exceedance of critical loads has fallen by 28.1% since 1995, from 73% based on 3-year mean deposition data for 1995-97, to 45% based on mean deposition data for 2011-13. Over the same time period the Average Accumulated Exceedance has more than halved, from 0.78 to 0.29 keq ha^{-1} $year^{-1}$.

For nutrient nitrogen, the reductions have been smaller with a 12.5% decrease in the area exceeding nitrogen critical loads, from 75% in 1995-97 to 63% using deposition data for 2011-13. The Average Accumulated Exceedance for nutrient nitrogen has declined by approximately one third, from 9.5 kg N ha^{-1} $year^{-1}$ to 6.2 kg N ha^{-1} $year^{-1}$ over the same time period.

1. Introduction

This report presents the trends in the areas of sensitive habitats at risk from the adverse impacts of excess acid and/or nitrogen deposition. The metrics are based on the exceedance of critical loads for acidification and eutrophication. This section provides a brief overview of UK critical loads and deposition data and the calculation of exceedances; further details can be found in Hall et al (2014). The trends in critical loads exceedances are presented and discussed in Section 2.

1.1 Overview of UK critical loads

Critical loads are thresholds for effects from atmospheric deposition and defined as "a quantitative estimate of the exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (Nilsson & Grennfelt, 1988).

The methods used to calculate and map UK critical loads are described in detail in Hall et al (2014). Critical loads are calculated and mapped for UK habitats sensitive to acidification and/or eutrophication (Table 1.1). Habitat distribution maps are based on the CEH Land Cover Map 2000 (LCM2000: Fuller et al, 2002(a)(b)) and additional data sets such as species distribution data and altitude. Habitat areas, used for assessing the areas of habitats at risk from acidification and or eutrophication, are based on the LCM2000 data. *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. This may also result in a difference in the total habitat areas mapped for acidity and for nutrient nitrogen critical loads.*

Published correspondence tables (available from: http://jncc.defra.gov.uk/page-1425) are used to relate broad habitats to the European Nature Information System (EUNIS: Davies & Moss, 2002) hierarchical habitat classification scheme, developed for pan-European applications.

Table 1.1: Habitat distributions mapped for acidity and for nutrient nitrogen critical loads (Y=yes, N=no).

Habitat	**EUNIS habitat class(es) assigned[1]**	**Mapped for acidity**	**Mapped for nutrient nitrogen**
Acid grassland (wet & dry)	E1.7 & E3.52	Y	Y
Calcareous grassland	E1.26	Y	Y
Dwarf shrub heath (wet & dry)	F4.11 & F4.2	Y	Y
Montane	E4.2	Y	Y
Bog	D1	Y	Y
Managed coniferous woodland	G3	Y	Y
Managed broadleaved woodland	G1	Y	Y
Beech woodland (unmanaged)	G1.6	Y (mapped together)	Y
Acidophilous oak woodland (unmanaged)	G1.8		Y
Scots Pine woodland (unmanaged)	G3.4		Y
Other unmanaged woodland	G4		Y
Freshwaters[2]	C1 & C2	Y	N
Dune grassland	B1.4	N	Y
Saltmarsh	A2.53/54/55	N	Y

[1]EUNIS class closest to broad habitat and critical loads habitat; class used for assigning empirical nutrient nitrogen critical loads and for classifying UK critical loads data for submission to the CCE.
[2]Critical loads are calculated for 1752 freshwater sites across the UK (see Section 1.1.1 below); habitat areas are based on the catchment areas of these sites.

1.1.1 Acidity critical loads

Two methods are used in the UK for calculating acidity critical loads for terrestrial habitats: the empirical approach is used to provide estimates for non-woodland habitats and a simple mass balance equation used for woodland habitats.

An empirical approach is used to define acidity critical loads for UK soils; critical loads are assigned to each 1km grid square of the UK based on the amount of acid deposition that could be neutralised by the base cations produced by mineral weathering of the dominant soil type in the grid square. This approach is applied to mineral and organo-mineral soils (Hornung et al, 1995) but is inappropriate for peat soils because of the absence of inputs of alkalinity from mineral weathering (Smith et al, 1992; Gammack et al, 1995). Critical loads of acidity for peat soils are set to the value corresponding to the amount of acid deposition that would give rise to an effective rain pH value of 4.4 (Calver, 2003; Calver et al, 2004; Skiba & Cresser, 1989); this pH reflects the buffering effects of organic acids upon peat drainage water pH. This method is applicable to upland and lowland acid peat soils, but not to peats in lowland arable fen areas that are less sensitive to acidification, where a higher critical load is set than would be applied to acid peats (Hall et al, 2014).

The acidity critical loads for soils as outlined above are used to set the acidity critical loads to protect the soils on which non-woodland habitats occur. In addition, they are used, with additional habitat-specific data, in deriving the acidity critical load input parameters for the "Critical Loads Function" (Section 2).

For woodland habitats a simple mass balance (SMB) equation, based on balancing the acidic inputs to and outputs from the ecosystem, is used to derive a critical load that ensures a specified critical chemical limit is not exceeded (Sverdrup et al, 1990; Sverdrup & De Vries, 1994). In the UK the SMB equation is parameterised using different chemical criteria for woodlands on mineral or organo-mineral soils, and woodlands on peat soils (Hall et al, 2014). Critical loads are calculated for both managed (productive) and unmanaged woodlands in order to protect the long-term ecosystem function of the woodland habitats; this also aims to protect the land under managed conifer forest for possible future non-forest use and reversion to semi-natural land uses. These critical loads are also used with additional habitat-specific data to derive the acidity critical load input parameters for the "Critical Loads Function" (Section 2) for woodland habitats.

Acidity critical loads for freshwaters are calculated using the catchment-based First-Order Acidity Balance (FAB: Henriksen & Posch, 2001) model. FAB is currently applied to 1752 sites across the UK, comprising a mixture of mainly upland, lakes, reservoirs and first-order streams (ie, streams that feed into other larger streams, but do not have any other streams draining into them). The critical load calculations are based on the most recent, best available estimate of annual mean water chemistry data.

1.1.2 Nutrient nitrogen critical loads

Empirical and mass balance methods also exist for calculating critical loads for eutrophication (ie, an excess of nitrogen as a nutrient). The empirical critical loads are based on experimental or field evidence of thresholds for changes in species composition, plant vitality or soil processes. The empirical approach is suited to semi-natural communities for which the long-term protection of biodiversity and/or ecosystem function is the key concern. In the UK the empirical approach is applied to natural and semi-natural habitats, including unmanaged (non-productive) woodland, based on critical load values agreed at international workshops (Bobbink & Hettelingh, 2011; Hall et al, 2014).

In the mass balance approach the long-term inputs and outputs of nitrogen from the ecosystem are calculated, with the critical load being exceeded when any excess nitrogen input is calculated to lead to an exceedance of a specified critical rate o nitrogen leaching. This approach is suited to managed ecosystems of low biodiversity, in which the inputs and outputs can be quantified with some confidence and in which the key concern is nitrate leaching. In the UK, this approach is applied to managed (productive) woodlands to ensure that long-term ecosystem function (eg, soils, soil biological resources, trees, linked aquatic systems) is protected.

1.2 Overview of UK deposition data

The sulphur, nitrogen and base cation deposition data used in the UK calculations of critical loads and their exceedances are based on the “Concentration Based Estimated Deposition” (CBED) methodology (RoTAP, 2012). Site based measurements of air concentrations of sulphur and nitrogen gases are interpolated to generate 5km maps of concentrations for the UK. Ion concentrations in precipitation (from the UK Eutrophying and Acidifying Pollutants (UKEAP) network) are combined with the Met Office annual precipitation map to generate maps of wet deposition. The wet deposition values include (a) direct deposition of cloud droplets to vegetation (known as “occult” deposition); (b) an orographic enhancement to take account of the “seeder-feeder” effect in upland regions (Fowler et al, 1988). Gas and particulate concentration maps are combined with spatially distributed estimates of vegetation-specific deposition velocities (Smith et al, 2000) to generate dry deposition. Combining these data sets produces 5km maps of total (wet + cloud + dry) deposition of sulphur (non-marine), oxidised nitrogen and reduced nitrogen; two different sets of deposition values are used in critical load and exceedance applications: (i) assumes grassland or moorland vegetation everywhere; (ii) assumes forest everywhere, based on the different deposition velocities to different land cover types.

Significant inter-annual variations in deposition can occur due to the natural variability in annual precipitation (which influences wet deposition) as well as the general circulation of air which can increase or decrease the amount of polluted air imported from the European continent. The CBED deposition data used to calculate critical load exceedances is therefore averaged over a three-year period; this has been demonstrated to be a suitable time period to smooth out inter-annual variations in deposition.

As critical loads for terrestrial habitats are mapped on a 1km grid, for exceedance calculations deposition is assumed to be constant for all 1 km squares within each 5km grid square. For freshwater exceedance calculations catchment-weighted mean sulphur and nitrogen deposition values are calculated by overlaying the catchment boundary and land cover information (moorland vs forest) onto the 5km deposition maps.

1.3 Overview of the calculation of critical load exceedances

Critical load exceedances are the amount of excess deposition above the critical load; for nutrient nitrogen the calculation is simply total nitrogen deposition (derived from nitrogen oxides and ammonia) minus the critical load. For acidification, deposition of both sulphur and nitrogen compounds can contribute to the exceedance of critical loads. The Critical Load Function, developed under the UNECE CLRTAP (Posch *et al.*, 1999; Posch & Hettelingh, 1997; Posch *et al.*, 1995; Hettelingh *et al.*, 1995), defines combinations of sulphur and nitrogen deposition that will not cause harmful effects. In its simplest form, an acidity critical load can be defined graphically by a 45 degree diagonal line on a sulphur-nitrogen deposition plot (Figure 1.1a). The line intercepts the x-axis (representing nitrogen deposition) and y-axis (representing sulphur deposition) at chemically equivalent points, each representing the nitrogen or sulphur deposition equal to the critical load for acidity. Each point along the diagonal line represents the critical load in terms of some combination of sulphur and nitrogen deposition.

To allow for the long-term nitrogen removal processes by the soil and through harvesting of vegetation, the simple diagonal line is shifted along the nitrogen axis to increase the nitrogen values across the entire CLF (Figure 1.1b). More nitrogen can then be deposited before the acidity critical load is exceeded. There are no similar removal processes that need to be considered for sulphur.

The intercepts of the CLF on the sulphur and nitrogen axes (Figure 1.1c) define the following terms:

- The “maximum critical load of sulphur” (CLmaxS): the critical load for acidity expressed in terms of sulphur only, ie, when nitrogen deposition is zero.
- The “maximum critical load of nitrogen” (CLmaxN): the critical load for acidity expressed in terms of nitrogen only (when sulphur deposition is zero).
- The “minimum critical load of nitrogen” (CLminN): the long-term nitrogen removal processes in the soil (eg, nitrogen uptake and immobilisation) and harvesting of vegetation.

These critical loads are calculated from the acidity critical loads described in Section 1.1 and additional soil-specific or habitat-specific data.

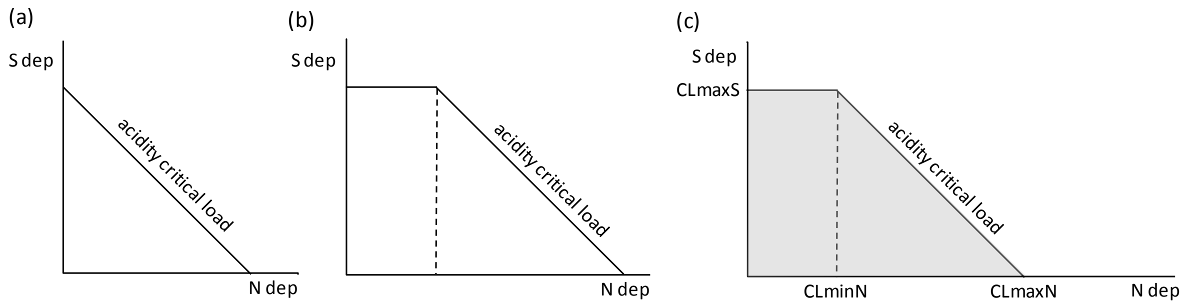

Figure 1.1: Development of the CLF: (a) acidity critical load defined by equal amounts of sulphur and nitrogen deposition; (b) shifting the acidity critical load diagonal line to allow for nitrogen removal processes; (c) the 3 nodes of the CLF: CLmaxS, CLminN, CLmaxN. The area shown in grey represents the combinations of sulphur and nitrogen deposition that are below the critical load (ie, critical load is not exceeded).

Exceedances are calculated by comparing the values of CLmaxS, CLminN and CLmaxN to the values of sulphur and nitrogen (oxidised + reduced) deposition. The actual calculation depends on where the deposition falls in relation to these critical load values; the CLF is divided into five different regions for this purpose (Figure 1.2). The exceedance is defined by the sum of sulphur and nitrogen deposition as shown by the red arrows in Figure 1.2 (ie, not the length of the diagonal line); this is referred to as the "shortest distance" exceedance. Further details on the calculations are given in Hall et al (2014).

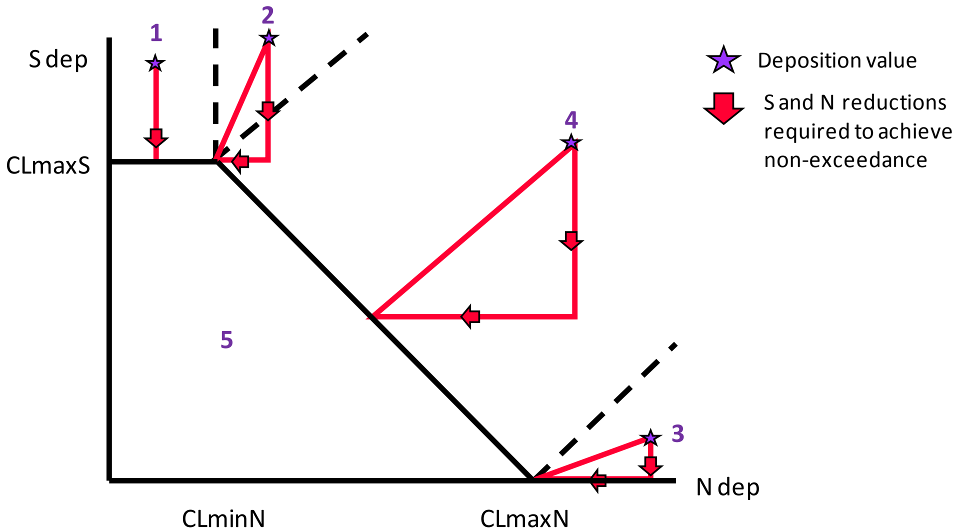

Figure 1.2: Example of S and N deposition reductions required depending on the region of the CLF. Deposition that falls in region 5 is below the critical load (ie, critical loads not exceeded).

1.3.1 Critical load exceedance metrics

Critical load exceedances are calculated for each 1km square of the distributions of each terrestrial habitat, and for each catchment for freshwaters. The results are then summarised by habitat and country using the following exceedance metrics:

(i) Area of habitat exceeded

For terrestrial habitats the area values are based on the LCM2000 data; if the critical load for any individual habitat is exceeded, the exceeded area is set to the habitat area within the 1km square for that particular habitat. For freshwater habitats, if the FAB critical load is exceeded, the whole catchment is assumed to be exceeded and the exceeded area set to the catchment area. The total exceeded areas for individual habitats are summarised by country.

(ii) Percentage area of habitat exceeded

This is calculated from the exceeded areas derived in (i) and the total area of each habitat mapped in each country (Section 1.1). While this is a useful metric, it has its limitations, for example, when comparing exceedance results from one year to another (or one deposition scenario to another), there may very small (or no) changes in the percentage area of habitat exceeded. This is because the magnitude of the exceedance may have reduced, but the area exceeding the critical load remains the same; the area exceeded will only reduce when the critical load is no longer exceeded.

(iii) Accumulated Exceedance (AE)

AE takes account of both the magnitude of exceedance and the habitat area exceeded:

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

AE is calculated for each 1km square for each habitat and then summarised by habitat and country. AE is set to zero where critical loads are not exceeded. This metric can be useful for comparing results for different years or scenarios, but because the results are expressed in keq year^{-1} they tend to be very large numbers and not intuitive to understand. It should also be noted that the same AE can arise from a large exceedance and small exceeded area, or a small exceedance and a large area.

(iv) Average Accumulated Exceedance (AAE)

AAE averages the AE across the entire sensitive habitat area:

AAE (keq ha^{-1} year^{-1}) = AE (keq year^{-1}) / total habitat area (ha)

This metric provides an exceedance value averaged across the whole habitat area. In the summary statistics presented (Section 2) it is based on the AE for the habitat (by country) divided by the total habitat area (by country). AAE is set to zero where critical loads are not exceeded. This metric provides a more intuitive value for comparing the exceedance results for different years or scenarios, and gives an indication of the reduction in the magnitude of exceedance even if there is no change in the percentage area of habitat exceeded.

1.3.2 Critical load exceedance maps for all habitats combined

Critical load exceedances are calculated by habitat; exceedance maps can be generated for individual habitats or for all terrestrial habitats combined. The exceedance data for freshwaters are not incorporated into these combination maps because the data are catchment-based rather than for 1km squares and as such may overlap with other habitat data. This section focuses on maps of AAE for all terrestrial habitats combined (Figure 1.3); other maps are presented and discussed in Hall et al (2014). Maps of AAE provide a good representation of the summary critical load exceedance statistics since they are based on all the critical load values for all habitats and habitat-specific deposition. The AAE for each 1km square is calculated as:

$$AAE = \sum(\text{AE for all habitats})/\sum(\text{area for all habitats})$$

AE (and AAE) is set to zero where the critical loads are not exceeded.

The latest AAE maps for acidity and nutrient nitrogen (Figure 1.3) clearly show the lower exceedances in Scotland compared to other regions of the UK. High exceedances of acidity critical loads are focussed in upland areas of central and north western England, as well as smaller areas in eastern England and the far south-west, as well as parts of Wales and southern Scotland and Northern Ireland. High exceedances of nutrient nitrogen critical loads are widespread across England, Wales and Northern Ireland and parts of southern and eastern Scotland, with many areas having exceedances above 14 kg N ha^{-1} year^{-1} (1 keq ha^{-1} year^{-1}).

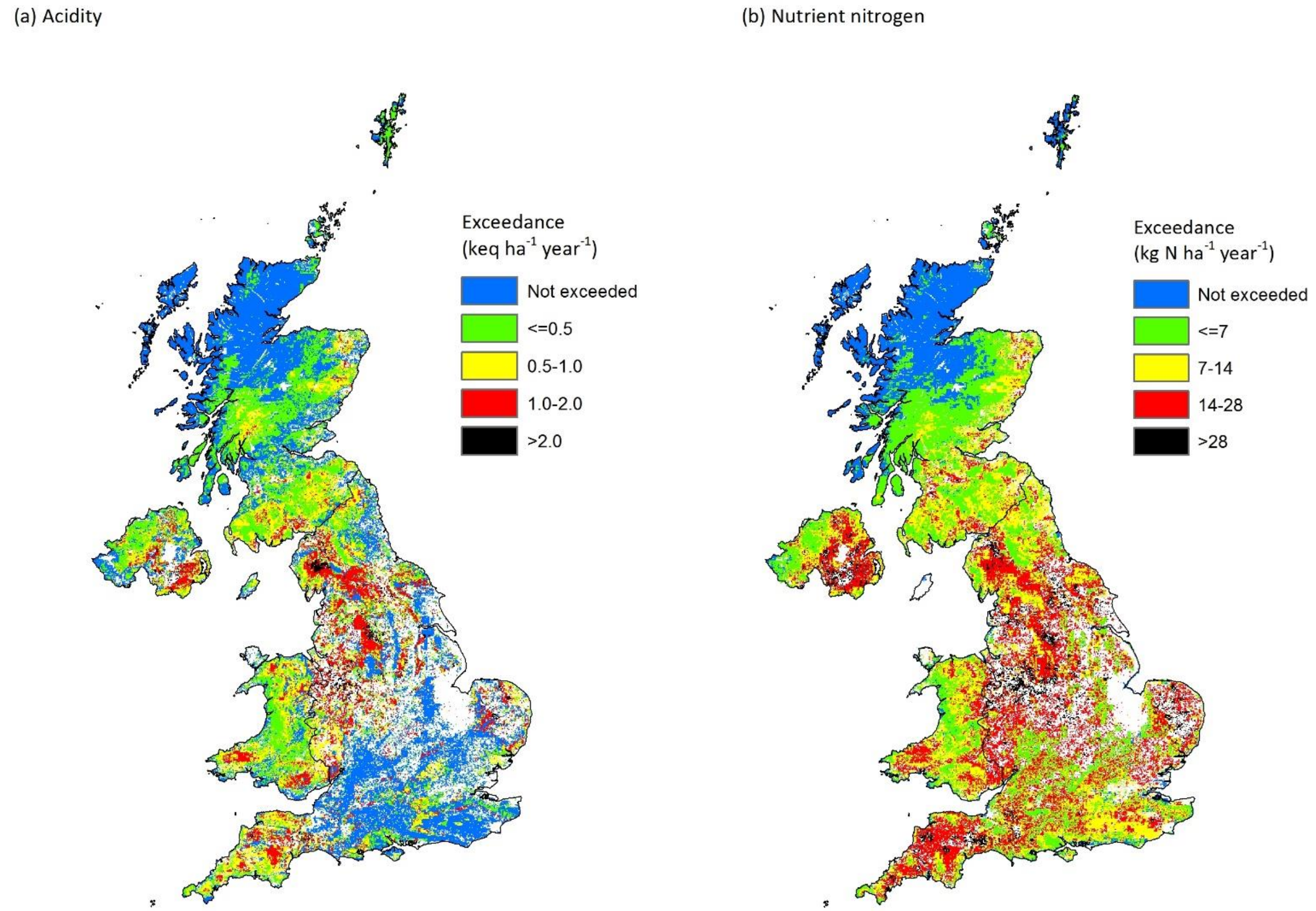

Figure 1.3: Average Accumulated Exceedance (AAE) of critical loads by CBED deposition for 2011-13. Although the legends for the two maps are given in different units the class intervals are equivalent (ie, 7 kg N ha^{-1} $year^{-1}$ is equivalent to 0.5 keq ha^{-1} $year^{-1}$).

2. Trends in critical loads exceedance by habitat and country

Acidity and nutrient nitrogen exceedances by habitat and country are updated annually using the latest 3-year rolling mean CBED deposition data. The summary statistics as described in Section 1.3.1 are made available to Defra and the Devolved Administrations and JNCC; from these they have used the trends in the percentage area of habitats exceeded for the following:

- Defra: Environmental Statistics – Key Facts
  https://www.gov.uk/government/publications/environment-statistics-key-facts
- Welsh Government: Sustainable Development Indicators for Wales
  http://wales.gov.uk/topics/statistics/headlines/sustaindev/120829/?lang=en
- Scottish Government: Key Scottish Environment Statistics
  http://www.scotland.gov.uk/Topics/Statistics/Browse/Environment/
- JNCC: biodiversity inidicator for assessing the pressures from air pollution
  http://jncc.defra.gov.uk/page-4233

The data used for the trends analysis are summarised in Box 1; there are a few inconsistencies between years due to changes in methods used to derive deposition estimates, and some minor alterations to the acidity critical loads. This information should be taken into account when interpreting the trends results.

Box 1:
Data used for critical loads trends analysis

Critical loads data
Acidity: data as summarised in Section 1.1.1 of this report were used for all years except results prior to 2004-2006 where: (a) the acidity critical loads for the bog habitat were based on the dominant soil in each 1x1km grid square; later results use critical loads data that assume all areas of bog habitat occur on peat soils; (b) freshwater exceedances were based on catchment-weighted grid-average deposition; the later results are based on catchment-weighted ecosystem-specific deposition. Note that the freshwater results are based on critical loads for 1752 lake or stream sites across the UK, and therefore do not represent all waters in the UK.
Nutrient nitrogen: data as summarised in Section 1.1.2 of this report.

Deposition data
All results based on 5x5 km resolution "concentration based estimated deposition" (CBED) values averaged over a three year period. All data are based on a consistent methodology except:
(a) Deposition data prior to 2001-2003 exclude nitric acid as the monitoring network for this pollutant was not in operation prior to this time.
(b) Deposition data prior to 2002-2004 excludes aerosol deposition of NH_4, NO_3, SO_4.
(c) Data for 2004-06 onwards updated in February 2015 to correct for over-estimate of nitric acid deposition.
CBED moorland values are applied to non-woodland terrestrial habitats, and CBED woodland values are applied to woodland habitats.

Habitat area data
These are based on the habitat distribution maps generated for UK critical loads research (see Section 1.1 of this report). There was a small reduction in the area mapped for acidity for the bog habitat as a result of the change to the critical loads in 2008; results using the updated habitat area apply to all results from 2005-2007 onwards.

The trends results are shown as both tables and simple plots; it is worth noting that while the percentage area exceeded for some habitats may not alter from one year to another, the AE values fluctuate reflecting changes in the national deposition data.

2.1 Trends by country

Table 2.1 shows the total land area by country and the area of habitats sensitive to acidification and eutrophication to which critical loads have been applied; 32% of the UK land area has habitats mapped for acidity critical loads, and 29.9% for nutrient nitrogen. *Note: throughout this report the summary exceedance statistics of the percentage area exceeded are percentages of the habitat areas mapped as sensitive to acidification/eutrophication (ie, not % land area).*

Table 2.1: Total land area and habitat areas mapped for critical loads by country

Country	Land area (km^2)[#]	Habitat areas mapped for acidity (km^2)	Area mapped for acidity as % of country	Habitat areas mapped for nutrient nitrogen (km^2)	Area mapped for nutrient nitrogen as % of country
England	130360	18635	14.3	19522	15.0
Wales	20760	7798	37.6	6837	32.9
Scotland	78750	48083	61.1	43200	54.9
NI	14150	3541	25.0	3467	24.5
UK	224020	78051	32.0	73027	29.9

2.1.1 Acidity results

The results for acidity (Table 2.2, Figure 2.1) show that the total area of habitats exceeding critical loads in the UK has declined from 72.6% in 1995-97 to 44.5% in 2011-13. However, the area exceeded varies between countries (Table 2.2, Figure 2.2), due to (a) geographic location of different sensitive habitats across the country (see Section 2.2); (b) the range in critical load values across the country – lower critical loads are mainly found in the uplands in the north and west in the UK; (c) higher wet deposition (and therefore higher total deposition) in the uplands or wetter regions of the country. The percentage area of habitats exceeded is lowest in Scotland in all years; however as shown in Table 2.1 61.1% of Scotland has habitats mapped for acidity critical loads, and that means the actual areas exceeded are larger than in the other countries (eg, 14894 km^2 exceeded by 2011-13 deposition). Although only 14.3% of England has habitats mapped for acidity critical loads, 62.1% of their area is exceeded for 2011-13, equivalent to 11581 km^2. The magnitude of exceedance across the UK, expressed as AAE (Table 2.3, Figure 2.1), has more than halved from 0.78 keq ha^{-1} $year^{-1}$ in 1995-97 to 0.29 keq ha^{-1} $year^{-1}$ in 2011-13. The data show the largest reductions in the exceedances were in the late 1990s; changes since then have been smaller and fluctuated from one year to another, but continuing the general downward trend. Note that the acidity critical loads for calcareous grassland are not exceeded in any year (Table 2.3).

Table 2.2: Acidity: Percentage area of habitats by country and deposition dataset year where acidity critical loads are exceeded

Year	Percentage habitat area exceeded by country:				
	England	Wales	Scotland	NI	UK
1995-1997	75.8	90.0	68.2	76.8	72.6
1998-2000	71.6	83.1	52.6	67.2	60.8
1999-2001	71.9	83.0	51.6	66.8	60.3
2001-2003	72.3	82.4	43.0	67.4	55.0
2002-2004	72.3	82.3	44.8	69.2	56.2
2003-2005	71.8	83.2	44.5	67.1	55.9
2004-2006	66.8	81.2	48.0	68.1	56.7
2005-2007	66.1	81.0	46.1	68.5	55.4
2006-2008	64.3	79.2	40.7	68.6	51.4
2007-2009	63.6	77.4	32.9	69.4	46.3
2008-2010	63.2	74.9	31.5	69.6	45.2
2009-2011	63.8	74.5	33.9	71.0	46.8
2010-2012	62.8	74.2	32.2	67.8	45.3
2011-2013	62.1	74.4	31	69.4	44.5
Reduction in % area exceeded 1995-2013	13.7	15.6	37.2	7.4	28.1

Table 2.3: Acidity: Average Accumulated Exceedance (AAE in keq ha^{-1} $year^{-1}$) by country and deposition dataset year

Year	AAE (keq ha^{-1} $year^{-1}$) by country:				
	England	Wales	Scotland	NI	UK
1995-1997	1.33	1.36	0.47	0.80	0.78
1998-2000	1.00	0.84	0.28	0.46	0.51
1999-2001	0.98	0.82	0.27	0.46	0.50
2001-2003	1.04	0.82	0.23	0.51	0.50
2002-2004	0.94	0.79	0.24	0.46	0.48
2003-2005	0.93	0.84	0.24	0.42	0.47
2004-2006	0.77	0.74	0.24	0.42	0.43
2005-2007	0.74	0.73	0.21	0.45	0.40
2006-2008	0.68	0.61	0.17	0.44	0.35
2007-2009	0.62	0.54	0.12	0.45	0.3
2008-2010	0.59	0.49	0.12	0.47	0.29
2009-2011	0.62	0.48	0.15	0.53	0.31
2010-2012	0.6	0.47	0.14	0.46	0.3
2011-2013	0.59	0.47	0.13	0.46	0.29
Reduction in AAE 1995-2013	0.74	0.89	0.34	0.34	0.49

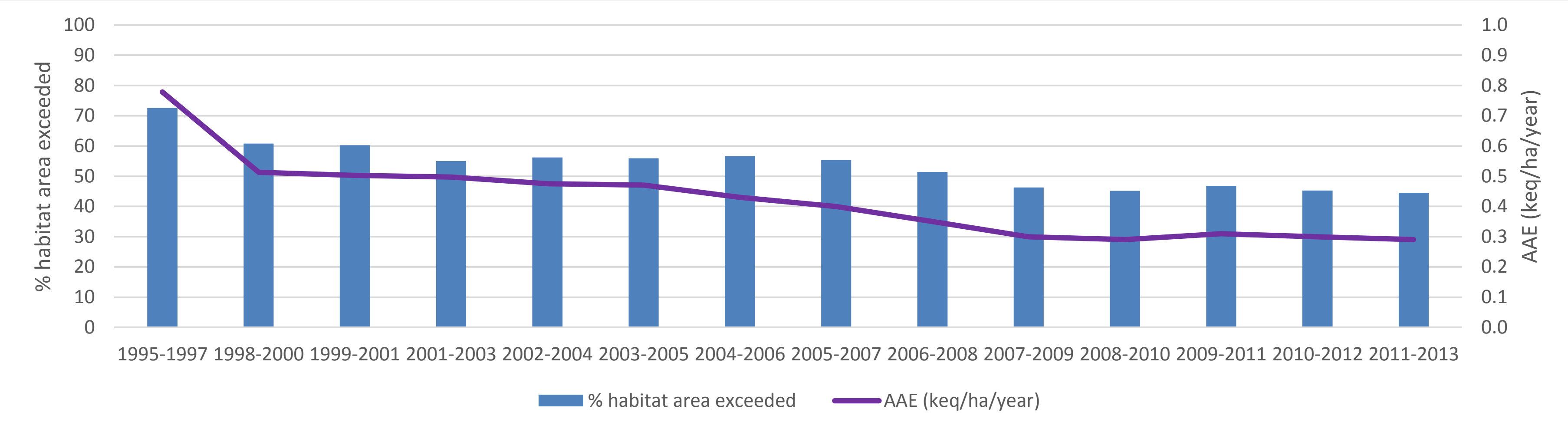

Figure 2.1: Acidity: Percentage area of acid-sensitive habitats with exceedance of acidity critical loads in the UK by year, and AAE in keq ha^{-1} $year^{-1}$.

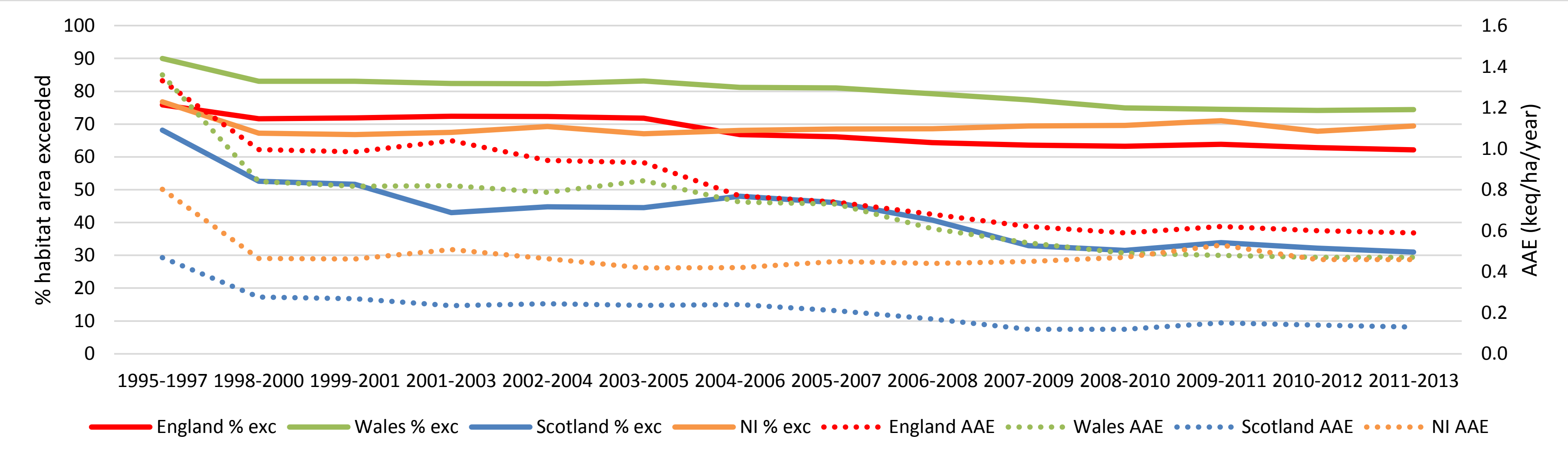

Figure 2.2: Acidity: Percentage area of acid-sensitive habitats with exceedance of acidity critical loads, by country and year, and AAE in keq ha^{-1} $year^{-1}$.

2.1.2 Nutrient nitrogen results

The results for nutrient nitrogen (Table 2.4 and Figure 2.3) show a decline in the percentage area of habitats exceeded in the UK, from 75% in 1995-97 to 62.5% in 2011-13. The results for England and Wales remained above, or close to, 90% exceeded over the same time period (Table 2.4, Figure 2.4). Scotland shows the smallest percentage habitat area exceeded of all countries, but the area exceeded (17574 km^2 for 2011-13) is similar to the area exceeded in England (18748 km^2 in 2011-13). The results reflect the smaller reductions in nitrogen deposition over the last two decades compared to the reductions in sulphur deposition (which helped reduce the exceedances of acidity critical loads). However, the magnitude of the exceedance (expressed as AAE) across the UK has reduced by about one-third, from 9.5 kg N ha^{-1} $year^{-1}$ in 1995-97 to 6.2 kg N ha^{-1} $year^{-1}$ in 2011-13 (Table 2.5, Figure 2.3). The AAE varies from one region to another with the lowest values in Scotland and the highest in England (Table 2.5, Figure 2.4).

Table 2.4: Nutrient nitrogen: Percentage area of habitats by country and deposition dataset year where nutrient nitrogen critical loads are exceeded

Year	Percentage habitat area exceeded by country:				
	England	Wales	Scotland	NI	UK
1995-1997	98.3	98.0	59.4	92.6	75.0
1998-2000	97.6	92.5	48.9	80.0	67.5
1999-2001	97.7	91.1	50.9	82.5	68.7
2001-2003	97.8	93.5	47.7	85.4	67.1
2002-2004	97.6	93.3	50.2	86.3	68.6
2003-2005	97.5	94.1	50.6	83.8	68.8
2004-2006	96.7	93.2	52.9	84.8	69.9
2005-2007	96.5	93.6	53.6	86.4	70.4
2006-2008	96.1	92.9	49.0	86.8	67.5
2007-2009	96.4	91.7	41.8	88.7	63.3
2008-2010	96.5	89.7	40.7	89.7	62.6
2009-2011	97.0	89.8	44.5	91.4	65.0
2010-2012	96.5	89.6	41.4	88.5	62.9
2011-2013	96.0	90.3	40.7	89.9	62.5
Reduction in % area exceeded 1995-2013	2.3	7.7	18.7	2.7	12.5

Table 2.5: Nutrient nitrogen: Average Accumulated Exceedance (AAE in kg N ha^{-1} $year^{-1}$) by country and deposition dataset year

Year	AAE (kg N ha^{-1} $year^{-1}$) by country:				
	England	Wales	Scotland	NI	UK
1995-1997	19.0	15.8	4.1	10.6	9.5
1998-2000	16.8	10.3	2.7	6.5	7.4
1999-2001	17.4	10.6	2.9	6.8	7.7
2001-2003	19.7	12.2	3.1	8.9	8.7
2002-2004	18.0	12.2	3.3	8.7	8.3
2003-2005	18.2	13.2	3.3	8.3	8.4
2004-2006	14.9	11.4	3.1	7.9	7.2
2005-2007	14.9	11.4	2.9	8.8	7.2
2006-2008	14.1	9.9	2.5	8.8	6.6
2007-2009	13.8	9.5	2.1	9.4	6.3
2008-2010	13.9	9.2	2.2	9.8	6.3
2009-2011	14.6	9.2	2.6	10.9	6.8
2010-2012	13.8	8.8	2.4	9.6	6.4
2011-2013	13.3	8.9	2.3	9.5	6.2
Reduction in AAE 1995-2013	5.7	6.9	1.8	1.1	3.3

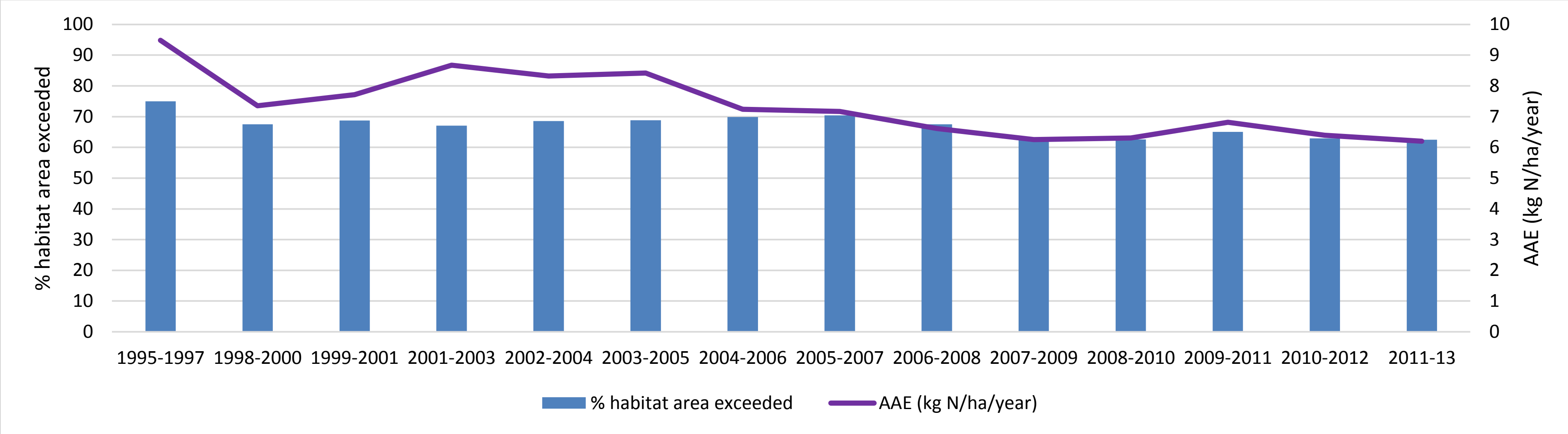

Figure 2.3: Nutrient nitrogen: Percentage area of nitrogen-sensitive habitats with exceedance of nitrogen critical loads in the UK by year, and AAE in kg N ha^{-1} year^{-1}.

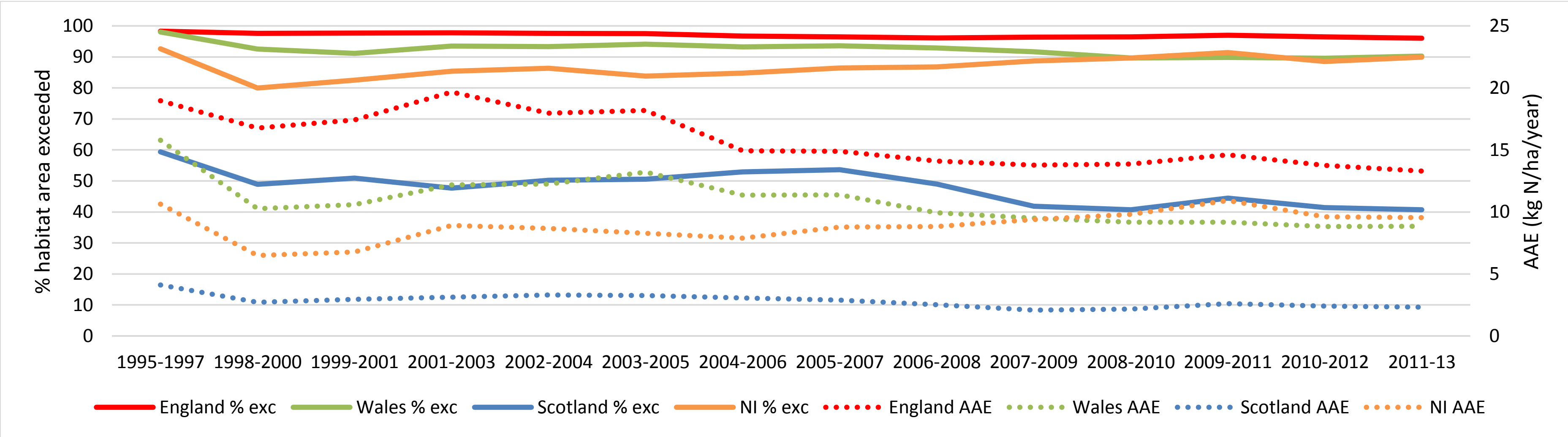

Figure 2.4: Nutrient nitrogen: Percentage area of nitrogen-sensitive habitats with exceedance of nitrogen critical loads, by country and year, and AAE in kg N ha^{-1} year^{-1}.

2.2 Trends by habitat

Exceedances are summarised by habitat and country. This section focuses on the results by habitat for the UK; habitat results for individual countries are supplied to Defra and the devolved administrations.

2.2.1 Acidity results

As mentioned in Section 2.1 there is no exceedance of the acidity critical loads for calcareous grassland and this habitat is therefore excluded from Tables 2.6 and 2.7 and Figures 2.5 and 2.6. The habitats with the highest percentage area exceeded are acid grassland, montane, bog and managed woodlands (Table 2.6, Figure 2.5); these habitats also have the highest AAE values (Table 2.7, Figure 2.6). Of the habitats mapped for acidity, dwarf shrub heath is the habitat with the largest cover across the UK (10.1%); the largest decrease (41.8%) in the area exceeded is also seen for this habitat from 70.3% in 1995-97 to 28.5% in 2011-13. The largest reductions in AAE over the same timescale are for woodland, acid grassland and montane habitats (Table 2.7).

2.2.2 Nutrient nitrogen results

There are six habitats with more than 80% of their area exceeded for nitrogen in all years (Table 2.8, Figure 2.7): calcareous grasslands and woodlands (beech, oak, managed conifer and broadleaf and other unmanaged woodland). The largest reduction (41.4%) in the area exceeded is for dune grassland from 70.6% in 1995-97 to 29.2% in 2011-13. Another coastal habitat, saltmarsh, has virtually no exceedance in any year, due to a combination of its high critical load and the lower deposition in coastal areas**.** AAE is generally highest for the woodland habitats (Table 2.9, Figure 2.8), with the exception of Scots Pine, which is only found in Scotland where the magnitude of exceedance is generally lower due to the lower deposition in this region. The beech woodland is virtually 100% exceeded in all years, but the AAE has decreased from 22.7 kg N ha^{-1} $year^{-1}$ in 1995-97 to 13.3 kg N ha^{-1} $year^{-1}$ in 2011-13.

Table 2.6: Acidity: Percentage area of habitats where acidity critical loads are exceeded in the UK by deposition dataset year.

Year	Percentage habitat area with exceedance of acidity critical loads:								
	Acid grassland	Dwarf shrub heath	Bog	Montane	Coniferous woodland (managed)	Broadleaved woodland (managed)	Unmanaged woodland	Freshwaters	All habitats
1995-1997	92.0	70.3	88.0	95.8	79.4	75.8	69.5	29.9	72.6
1998-2000	84.9	49.5	78.8	91.3	69.9	68.4	57.2	24.2	60.8
1999-2001	84.7	47.9	76.1	93.4	70.2	69.1	58.2	23.9	60.3
2001-2003	79.5	40.7	61.6	82.5	66.5	69.6	58.5	21.9	55.0
2002-2004	80.3	42.3	60.1	89.4	68.4	70.8	60.1	21.3	56.2
2003-2005	80.4	41.5	59.3	92.9	68.2	70.1	59.1	21.7	55.9
2004-2006	82.5	45.1	71.7	96.3	64.2	61.5	48.3	21.7	56.7
2005-2007	81.9	41.5	76.4	94.4	63.6	60.5	46.7	21.3	55.4
2006-2008	78.9	35.4	73.3	85.6	60.5	57.2	43.4	20.6	51.4
2007-2009	73.9	28.5	63.7	71.4	57.1	55.9	42.1	19.0	46.3
2008-2010	72.2	28.1	57.9	70.1	55.6	55.6	42.0	18.5	45.2
2009-2011	74.8	30.6	54.9	71.6	58.0	57.0	43.3	18.9	46.8
2010-2012	73.0	29.3	54.4	65.3	56.7	55.0	41.5	19.0	45.3
2011-2013	73.4	28.5	50.1	62.3	56.2	53.5	40.5	18.8	44.5
Reduction in % area exceeded 1995-2013	18.6	41.8	37.9	33.5	23.2	22.2	29.1	11.1	28.1

Table 2.7: Acidity: AAE (in keq ha^{-1} $year^{-1}$) by habitat for the UK by deposition dataset year.

Year	AAE (keq ha^{-1} $year^{-1}$) by habitat:								
	Acid grassland	Dwarf shrub heath	Bog	Montane	Coniferous woodland (managed)	Broadleaved woodland (managed)	Unmanaged woodland	Freshwaters	All habitats
1995-1997	1.15	0.47	0.76	0.81	1.13	1.20	0.87	0.36	0.78
1998-2000	0.80	0.28	0.53	0.57	0.68	0.88	0.58	0.23	0.51
1999-2001	0.77	0.26	0.50	0.59	0.68	0.90	0.61	0.21	0.50
2001-2003	0.70	0.24	0.46	0.60	0.72	1.01	0.68	0.18	0.50
2002-2004	0.67	0.22	0.41	0.64	0.74	0.94	0.65	0.17	0.48
2003-2005	0.68	0.21	0.39	0.62	0.73	0.94	0.65	0.17	0.47
2004-2006	0.68	0.22	0.44	0.66	0.58	0.66	0.44	0.17	0.43
2005-2007	0.64	0.19	0.45	0.53	0.56	0.65	0.43	0.16	0.40
2006-2008	0.57	0.16	0.42	0.39	0.49	0.56	0.36	0.13	0.35
2007-2009	0.49	0.12	0.34	0.28	0.43	0.53	0.34	0.12	0.30
2008-2010	0.47	0.12	0.33	0.28	0.42	0.52	0.34	0.11	0.29
2009-2011	0.51	0.14	0.35	0.31	0.46	0.56	0.36	0.12	0.31
2010-2012	0.50	0.13	0.35	0.26	0.43	0.51	0.32	0.12	0.30
2011-2013	0.51	0.13	0.34	0.25	0.42	0.47	0.30	0.12	0.29
Reduction AAE 1995-2013	0.64	0.34	0.42	0.56	0.71	0.73	0.57	0.24	0.49

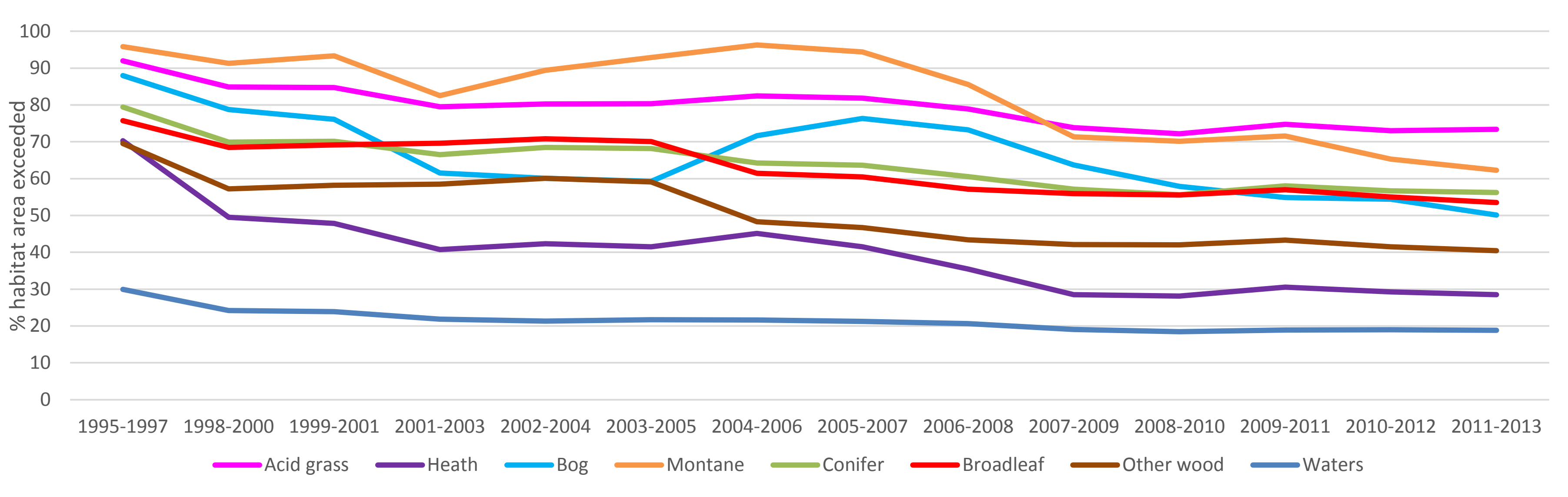

Figure 2.5: Acidity: Percentage area of habitats where acidity critical loads are exceeded in the UK by deposition dataset year.

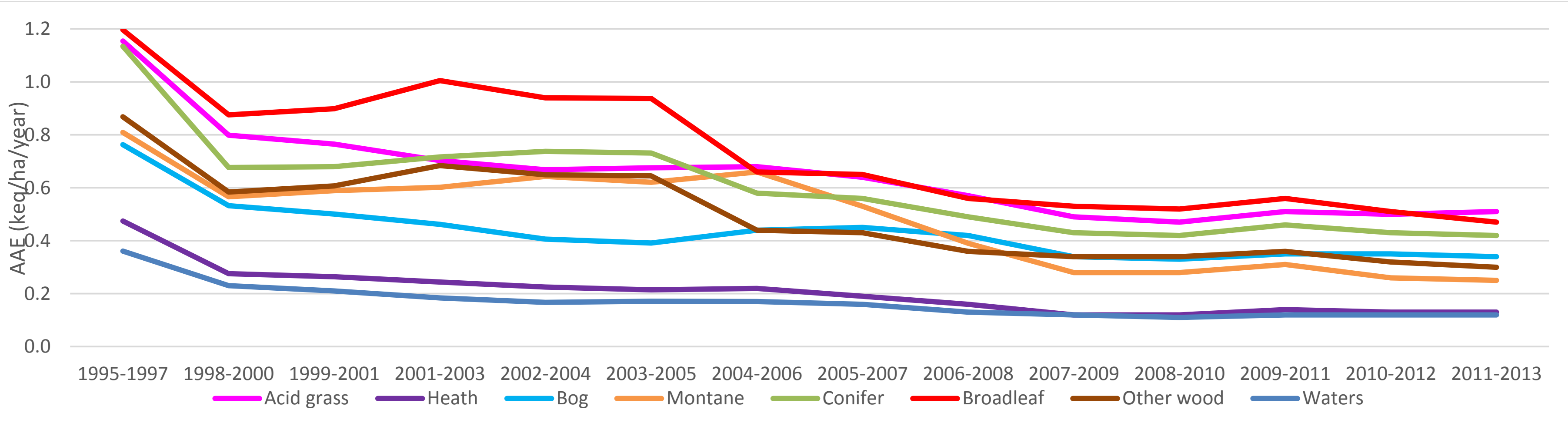

Figure 2.6: Acidity: AAE (in keq ha^{-1} $year^{-1}$) for the UK by deposition dataset year.

Table 2.8: Nutrient nitrogen: Percentage area of habitats where nitrogen critical loads are exceeded in the UK by deposition dataset year.

Year	Percentage habitat area with exceedance of nutrient nitrogen critical loads:											
	Acid grassland	Calcareous grassland	Dwarf shrub heath	Bog	Montane	Coniferous woodland (managed)	Broadleaved woodland (managed)	Fagus woodland (unmanaged)	Acidophilous oak (unmanaged)	Scots Pine (unmanaged)	Other unmanaged woodland	Dune grassland	Saltmarsh
1995-1997	72.6	97.5	59.1	54.2	96.7	95.4	98.4	100.0	98.9	61.1	96.5	70.6	2.0
1998-2000	61.3	95.5	49.0	45.1	95.7	90.5	97.4	100.0	97.0	38.9	95.1	44.8	1.1
1999-2001	61.4	95.5	51.1	45.0	97.1	92.8	97.8	100.0	98.1	52.3	95.5	46.9	2.1
2001-2003	63.1	95.5	47.8	44.6	89.0	90.6	97.4	100.0	96.1	49.7	95.5	41.9	1.0
2002-2004	64.3	93.9	49.8	44.9	92.6	93.0	98.1	100.0	98.2	66.5	95.7	36.1	1.1
2003-2005	64.8	93.9	50.6	45.2	90.5	92.1	98.0	100.0	98.1	67.8	95.7	33.5	1.1
2004-2006	64.8	90.6	54.5	45.9	96.6	90.2	97.5	100.0	95.6	58.0	95.5	29.3	0.8
2005-2007	64.2	89.4	54.3	54.6	96.2	91.0	97.4	100.0	95.5	52.6	95.6	31.8	0.8
2006-2008	60.0	87.7	49.5	55.4	95.5	89.4	97.1	100.0	93.8	34.2	95.5	31.1	0.8
2007-2009	56.3	89.6	43.9	47.1	82.7	86.9	96.7	100.0	89.8	30.7	95.2	29.2	0.9
2008-2010	55.7	91.2	42.7	45.6	81.0	86.1	96.7	99.9	88.5	30.5	95.1	34.7	0.9
2009-2011	61.1	92.3	45.0	45.8	82.1	88.2	97.0	99.9	91.5	32.4	95.3	37.6	0.9
2010-2012	59.7	90.4	42.2	44.8	74.4	86.5	96.8	99.9	87.7	26.2	94.7	34.0	0.9
2011-2013	60.8	87.6	41.6	43.1	71.2	86.4	96.8	100.0	88.6	24.2	95.0	29.2	0.8
Reduction in % area exceeded 1995-2013	11.8	9.9	17.5	11.1	25.5	9.0	1.6	0.0	10.3	36.9	1.5	41.4	1.2

Table 2.9: Nutrient nitrogen: AAE (in kg N ha^{-1} $year^{-1}$) by habitat for the UK by deposition dataset year.

Year	AAE (kg N ha^{-1} $year^{-1}$) by habitat:												
	Acid grassland	Calcareous grassland	Dwarf shrub heath	Bog	Montane	Coniferous woodland (managed)	Broadleaved woodland (managed)	Fagus woodland (unmanaged)	Acidophilous oak (unmanaged)	Scots Pine (unmanaged)	Other unmanaged woodland	Dune grassland	Saltmarsh
1995-1997	6.3	7.6	4.5	5.3	5.5	16.8	24.5	22.7	19.9	3.3	23.2	2.71	0.04
1998-2000	3.9	7.3	3.1	3.8	4.4	12.1	21.8	19.5	16.4	2.0	21.1	1.63	0.05
1999-2001	4.0	7.7	3.2	3.9	5.0	12.8	22.7	20.3	17.3	2.8	22.0	1.74	0.06
2001-2003	4.5	8.9	3.6	4.4	5.7	14.4	25.8	22.9	18.8	3.2	25.2	1.52	0.03
2002-2004	4.2	6.9	3.4	3.8	6.1	14.7	24.5	22.1	19.1	4.0	23.8	0.93	1.66
2003-2005	4.4	6.9	3.4	3.8	6.1	14.8	24.8	22.6	19.4	3.7	24.1	0.93	1.67
2004-2006	4.4	5.7	3.4	3.9	6.4	12.2	19.3	15.8	15.5	2.6	18.7	0.75	0.03
2005-2007	4.3	5.7	3.3	4.0	5.5	12.3	19.4	15.4	15.4	2.3	19.1	0.80	0.04
2006-2008	3.9	5.2	3.0	4.0	4.3	11.5	18.2	14.0	14.2	1.9	18.1	0.74	0.04
2007-2009	3.5	5.3	2.6	3.5	3.3	10.8	18.3	14.4	13.9	1.6	18.5	0.77	0.04
2008-2010	3.4	5.5	2.6	3.5	3.3	10.9	18.5	14.6	13.9	1.7	18.9	0.86	0.05
2009-2011	3.9	5.9	3.0	3.9	3.6	11.8	19.4	15.2	14.7	1.9	19.9	1.04	0.06
2010-2012	3.7	5.3	2.8	3.7	2.9	11.2	18.1	13.9	13.7	1.6	18.4	0.91	0.05
2011-2013	3.7	4.9	2.8	3.7	2.9	11.0	17.3	13.3	13.5	1.5	17.5	0.76	0.03
Reduction in AAE 1995-2013	2.6	2.7	1.7	1.6	2.7	5.8	7.2	9.4	6.5	1.7	5.7	1.95	0.01

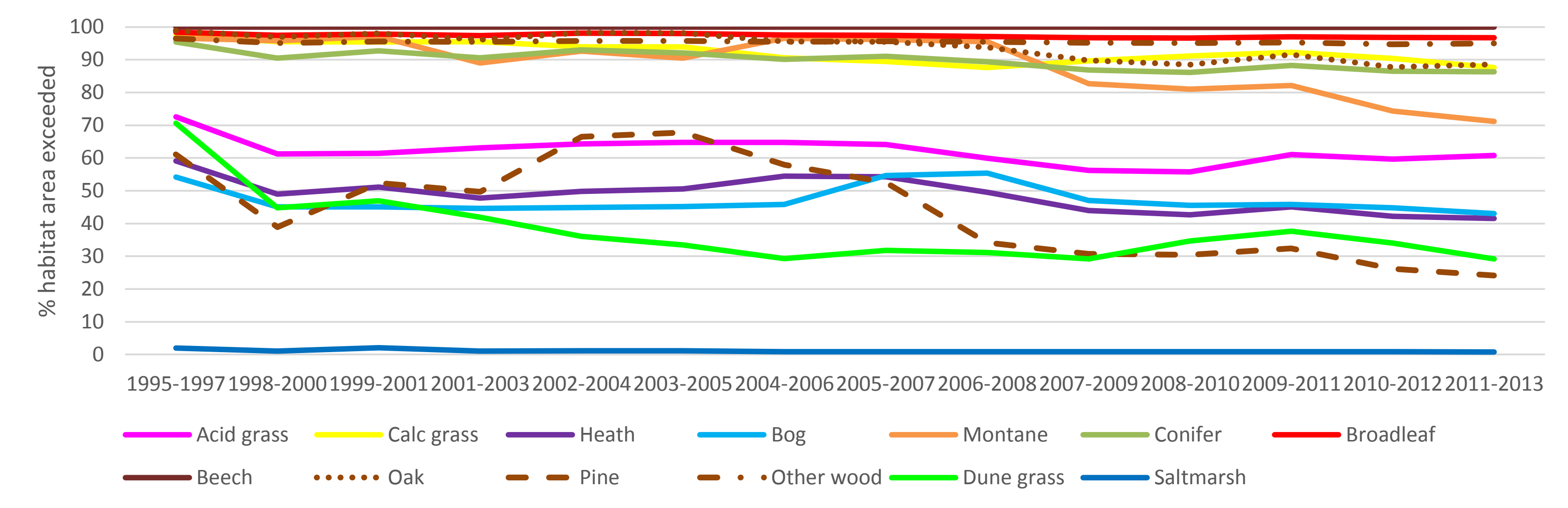

Figure 2.7: Nutrient nitrogen: Percentage area of habitats where nutrient nitrogen critical loads are exceeded in the UK by deposition dataset year.

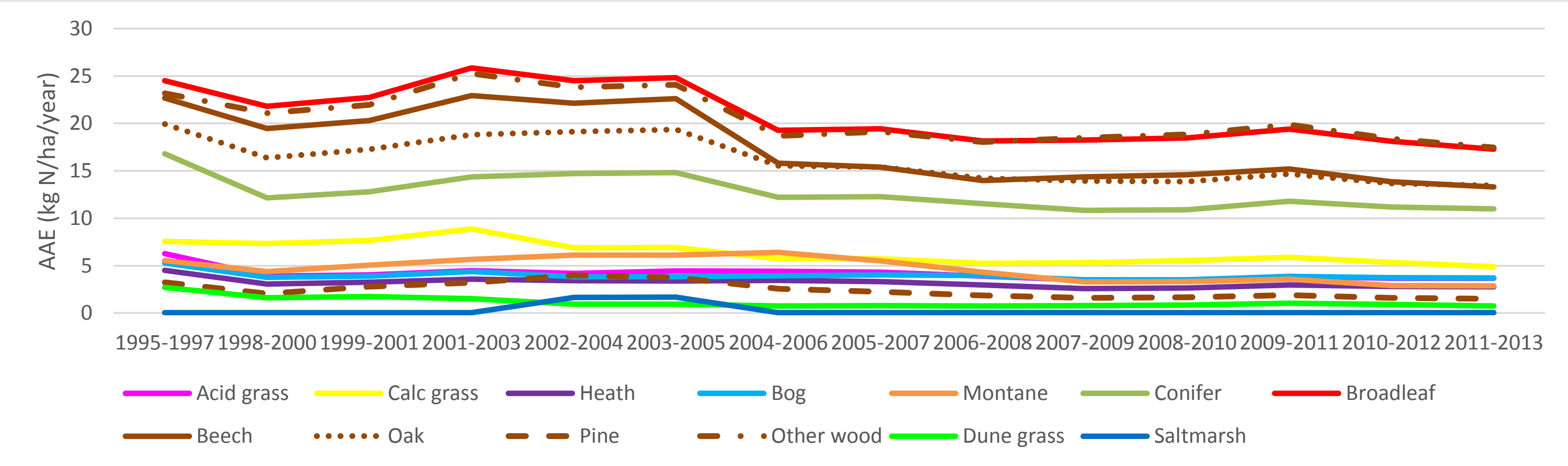

Figure 2.8: Nutrient nitrogen: AAE (in kg N ha^{-1} $year^{-1}$) for the UK by deposition dataset year.

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