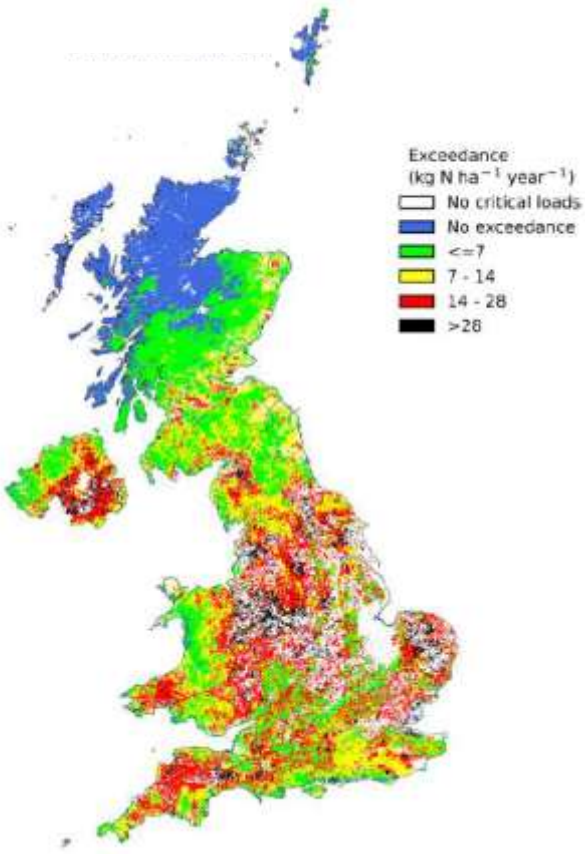
Trends in critical load and critical level exceedances in the UK

Ed Rowe

National Focal Centre for Modelling & Mapping of Critical Loads & Critical Levels,
UK Centre for Ecology & Hydrology,
Bangor.

Outline

1. Impacts of nitrogen (N) and sulphur (S) pollution on ecosystems
2. Critical Loads and Critical Levels
3. Modelling deposition, concentration and exceedance
4. Trends in CLo and CLe exceedance
5. Explanations and prospects



Average Accumulated Exceedance of Critical Load for nutrient-N, annual mean 2017-19

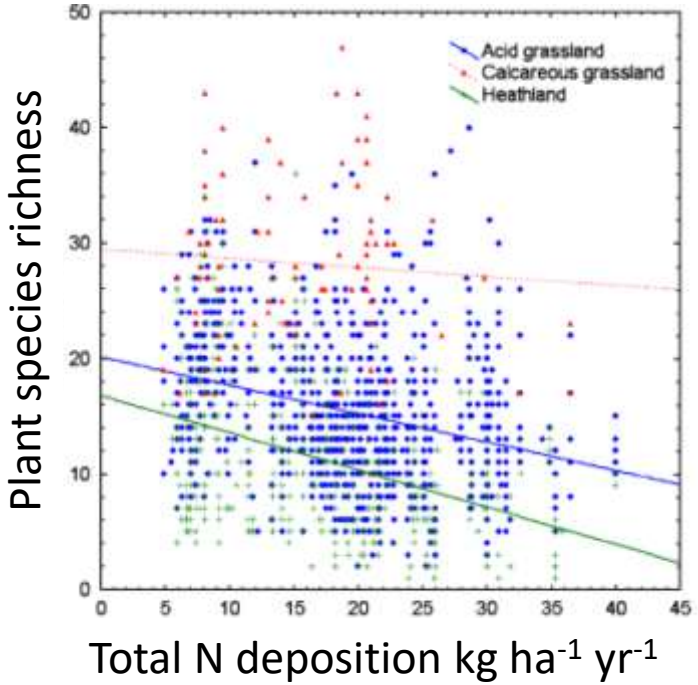
Rowe et al. (2021) Trends Report.
https://uk-air.defra.gov.uk/library/reports?report_id=1020

Ecosystem Impacts

Air pollution harms ecosystems through:

- eutrophication (N)
- direct toxicity (ammonia, ozone)
- acidification (N, S)
- accumulation (e.g. heavy metals)

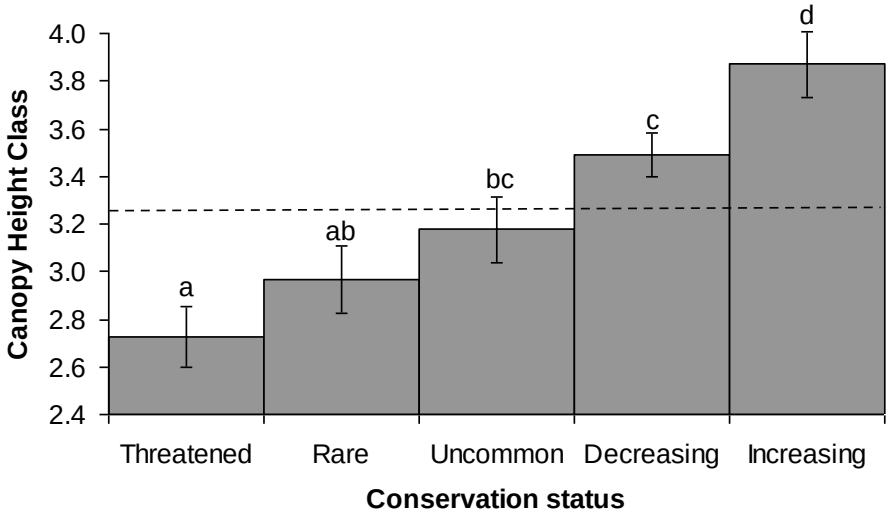
Effects of N deposition rate on plant species-richness in UK habitats (data from UKCEH Countryside Survey)



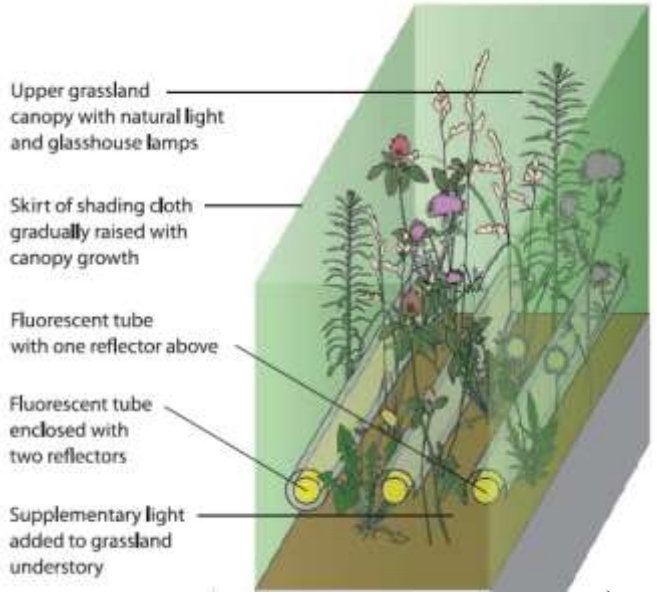
Maskell LC et al. (2010) *Global Change Biology* 16, 671–679

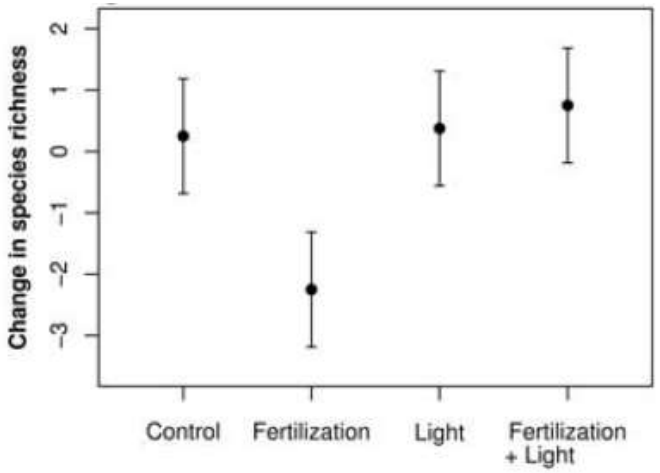
Eutrophication

Nitrogen favours the growth of tall, light-competitive species. Short species are lost.



Hodgson et al. (2014) *Functional Ecology* 28: 1284-1291





Hautier et al. (2009) Science 324 (5927) 636-638.

Air pollutants – how well are we doing, in UK and globally?

- CO_2 and other greenhouse gases
- Toxic metals (lead & mercury)
- CFCs (which affect stratospheric ozone)
- Ground-level ozone

- Sulphur (SOx)
- Reactive nitrogen: NOx
- NHy

Eutrophying

Acidifying

National Focal Centre for CLo & CLe modelling & mapping

UN-ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP)

→ International Cooperative Programme on Modelling and Mapping (ICP-M&M) of Critical Loads and Critical Levels

→ National Focal Centre (NFC)

ICP-Modelling and Mapping – aims:

(a) assess damage to forests, crops, natural vegetation, soils, surface and groundwaters, and materials by determining critical levels and loads for the response of these systems, with particular attention to the direct effects of air concentrations of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ozone (O_3), and the indirect effects of (long-term) deposition of sulphur and nitrogen compounds;

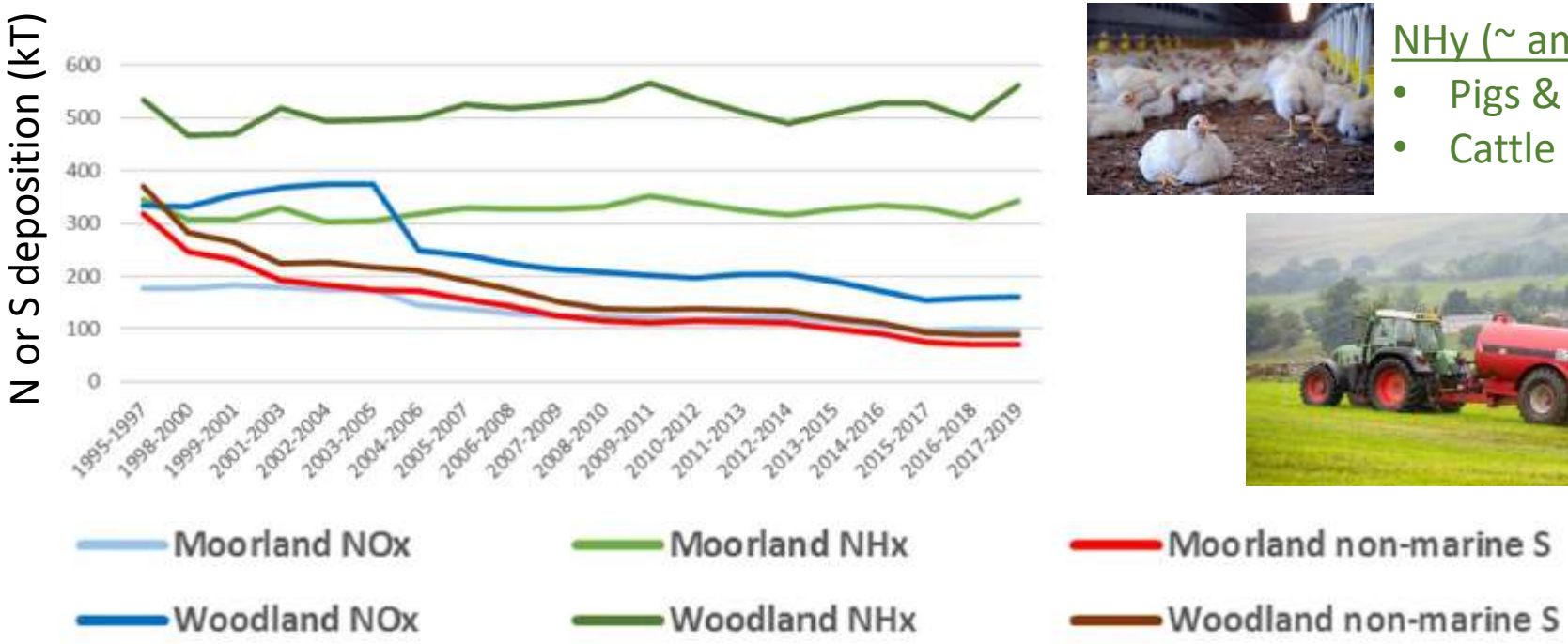
(b) map geographical areas to determine the scope and extent of pollutant depositions and concentrations which exceed critical loads and levels;

(c) establish appropriate methods as a basis for assessing potential damage.

National Focal Centre (UKCEH Bangor)

- Coordinates UK involvement in ICP-M&M, e.g. providing data to the Coordination Centre for Effects.
- Generates UK and DA-scale statistics for air pollution pressures on ecosystems.

Nitrogen pollution sources and UK trends 1996-2018



NHy (~ ammonia)

- Pigs & poultry
- Cattle & sheep

NOx (nitrogen oxides)

- Fossil fuel burning

Sulphur

- Fossil fuel burning
- Power stations
- Shipping

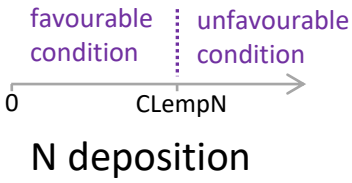
Rowe et al. (2021) Trends Report.
https://uk-air.defra.gov.uk/library/reports?report_id=1020

Critical Loads (CLo) and Critical Levels (CLe)

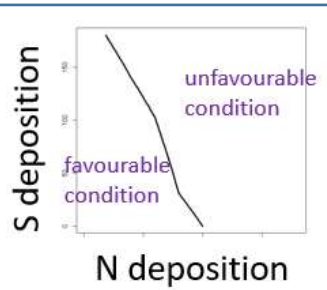
Critical Load: "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" Nilsson & Grennfelt (1988)

CLo (deposition, e.g. kg ha^{-1} yr^{-1})

- nutrient-N
- acidity (N plus S)
- heavy metals



1D critical load



2D critical-load function

CLe (concentration, e.g. µg m^{-3})

- NH_3
- Ozone (or based on modelled leaf influx)

Critical Loads and Levels take into account ecosystem **resilience**

Thresholds for "harm" are set by scientific consensus (e.g. a review of empirical Critical Loads for nutrient-N is in progress), to prevent harm *in the long term*

What values are used for CLo and CLe?

Critical Load

- Habitat-dependent
- Acidity CLo values are based on the charge-balance and a chemical criterion (e.g. a critical value for pH)
- Nutrient-N CLo values are based (mainly) on evidence from experiments

Empirical CLo for nutrient-N, kg N ha^{-1} yr^{-1}

examples:

Montane (moss & lichen dominated) : **7**

Bog: **8-10**, depending on rainfall

Dry acid and neutral closed grassland: **10**

Semi-dry calcareous grassland: **15**

Saltmarsh: **25**

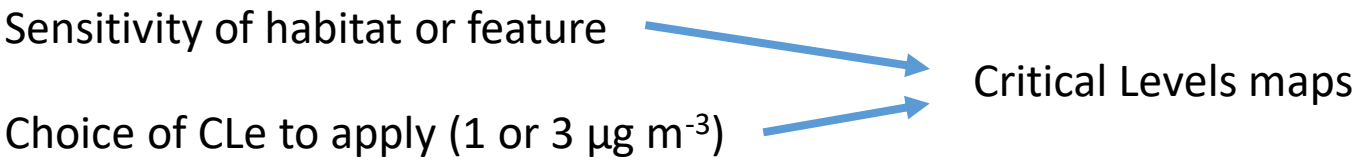
Critical Level for ammonia

- Species-dependent
- Lower for (sensitive) bryophytes and lichens than for vascular plants
- Which CLe is applied depends on the importance of bryophytes and lichens for the specific habitat

CLe for vascular plants: **3** µg NH_3 m^{-3}

CLe for bryos & lichens: **1** µg NH_3 m^{-3}

Mapping critical loads and levels



Mapping deposition and concentration

Emissions inventory / maps

Meteorology & Land-use

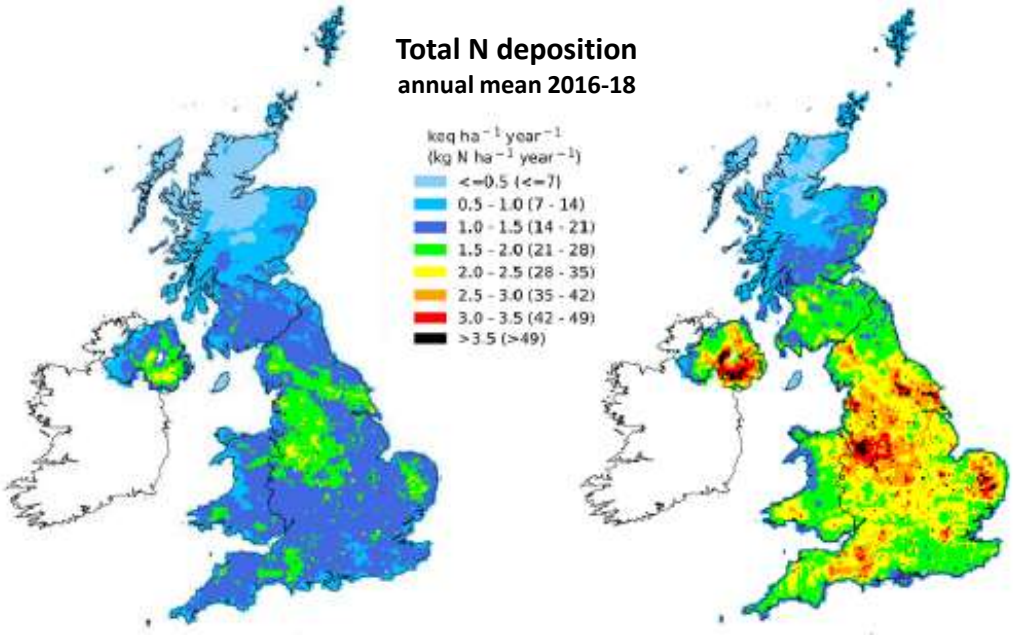
Observed chemistry (UKEAP)

FRAME

CBED

Concentrations map (N, S)

Deposition map (N, S)



Moorland
(unfertilised open habitats)

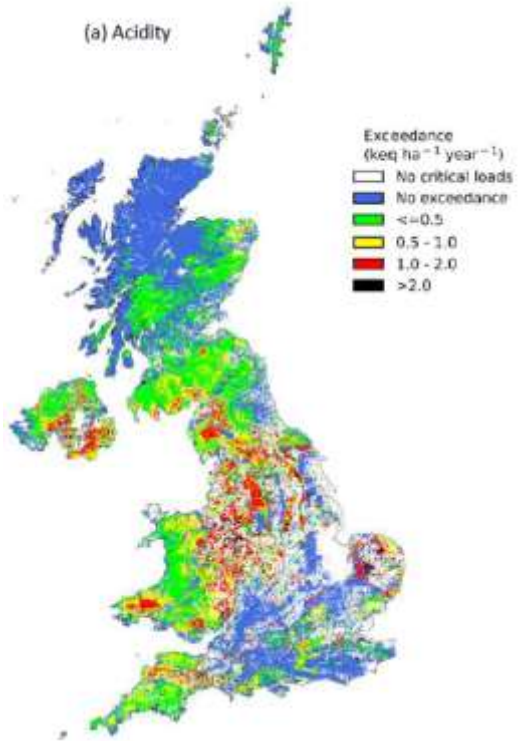
Woodland

EMEP4UK will be used instead of FRAME for the Trends Report 2022

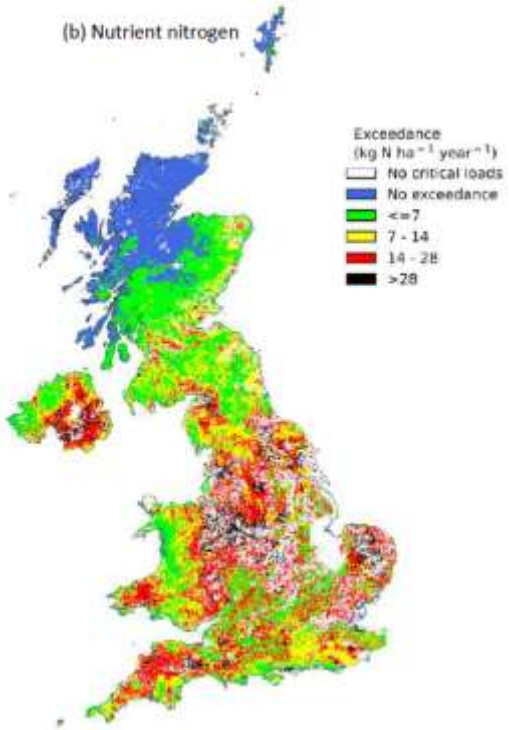
Spatial patterns of exceedances – latest data

Only the blue areas are not exceeded

Acidity Critical Load (2018)

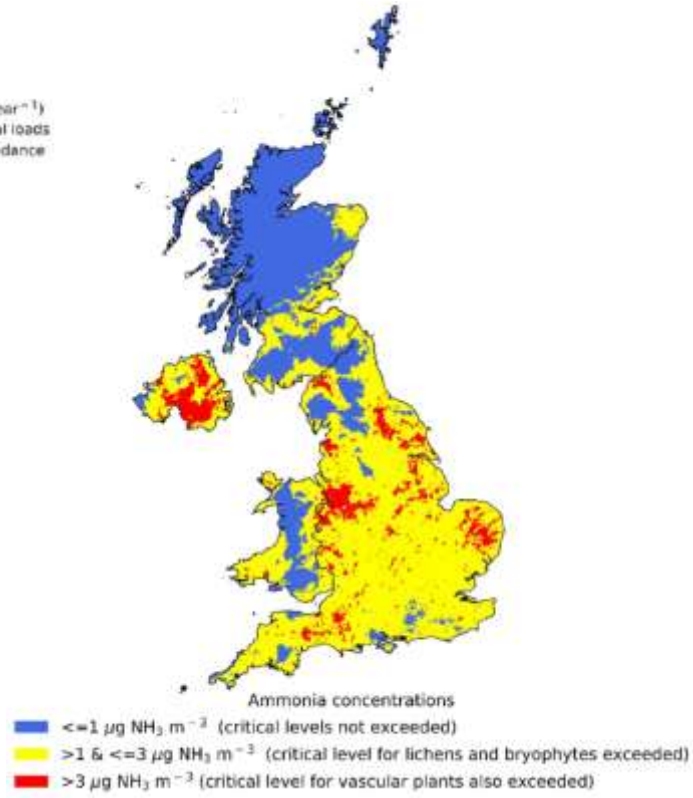


Nutrient-N Critical Load (2018)



Average Accumulated Exceedance, or "Excess N"

Ammonia Critical Level (2017)



Rowe et al. (2021) Trends Report.
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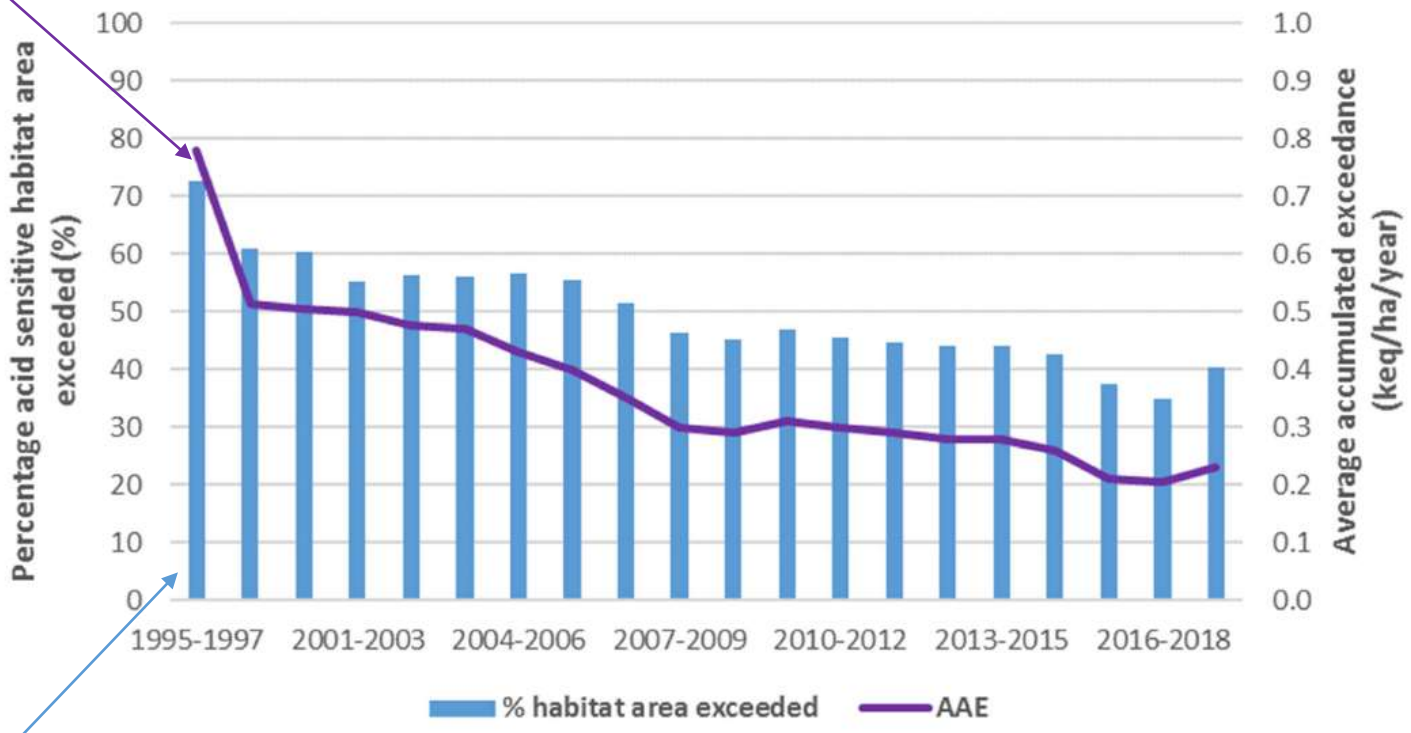
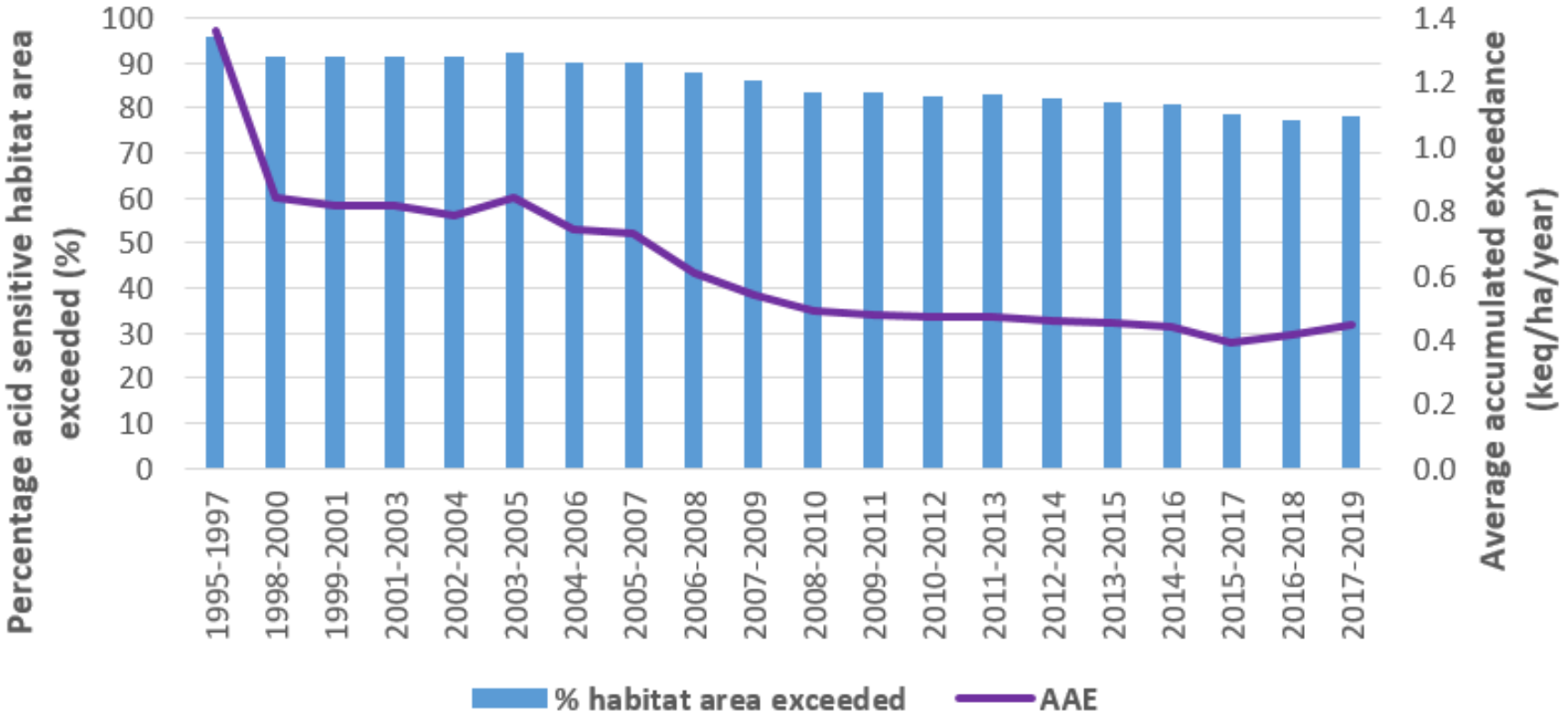
Trends in exceedances

AAE or “Excess acidity” = area-weighted mean amount by which habitats are exceeded



Percent of total habitat area that is exceeded

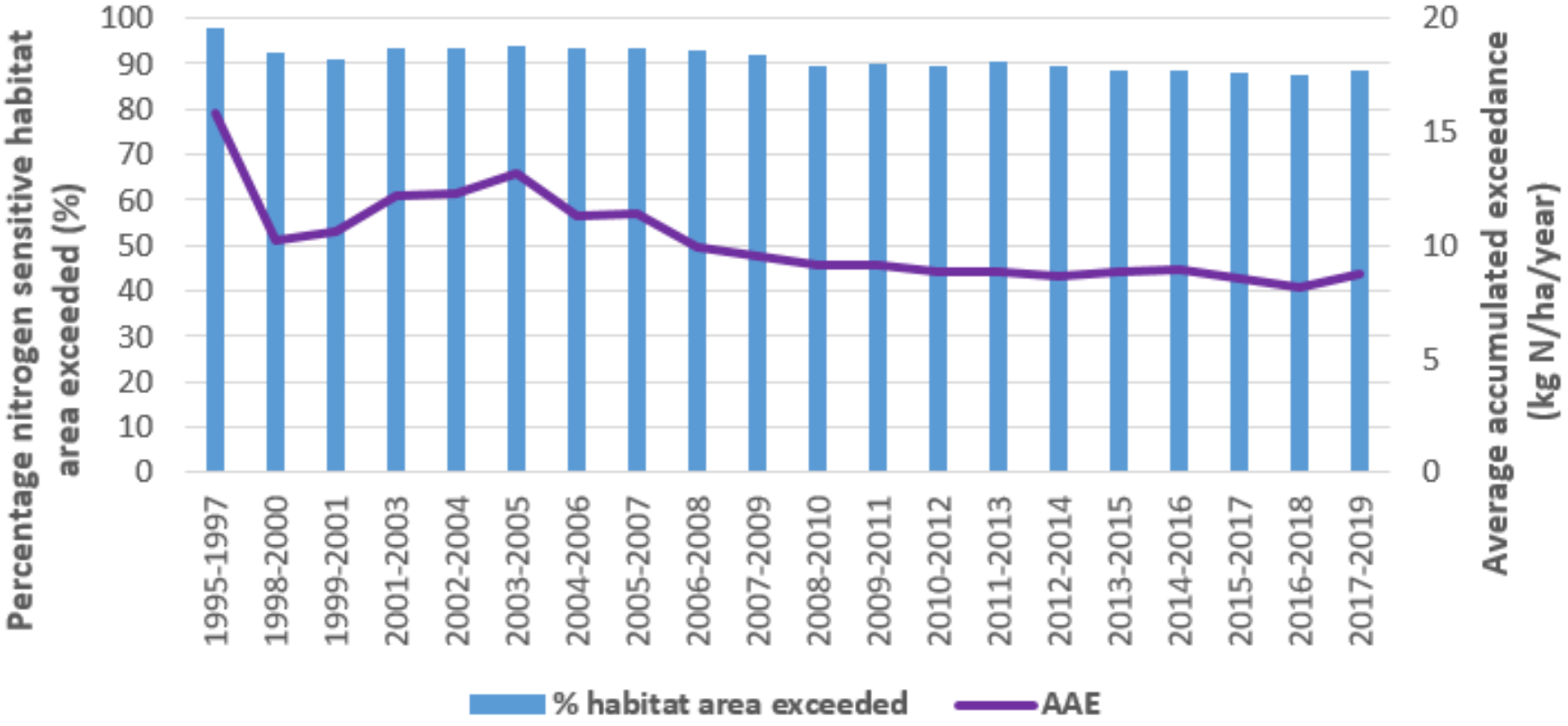
Trend in exceedance of CLo for Acidity in Wales



Area exceeded: 82.1 (2013) → 78.4% (2018), a relative 5% decrease

Excess acidity: 0.46 (2013) → 0.45 keq ha^{-1} yr^{-1} (2018), a relative 1% decrease

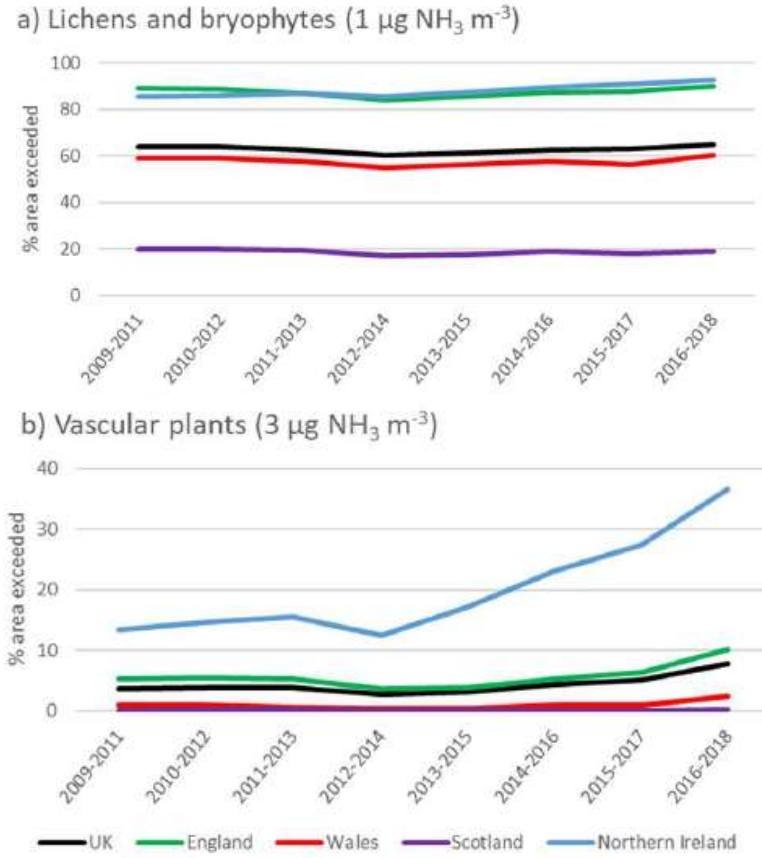
Trend in exceedance of CLo for Nutrient-N in Wales



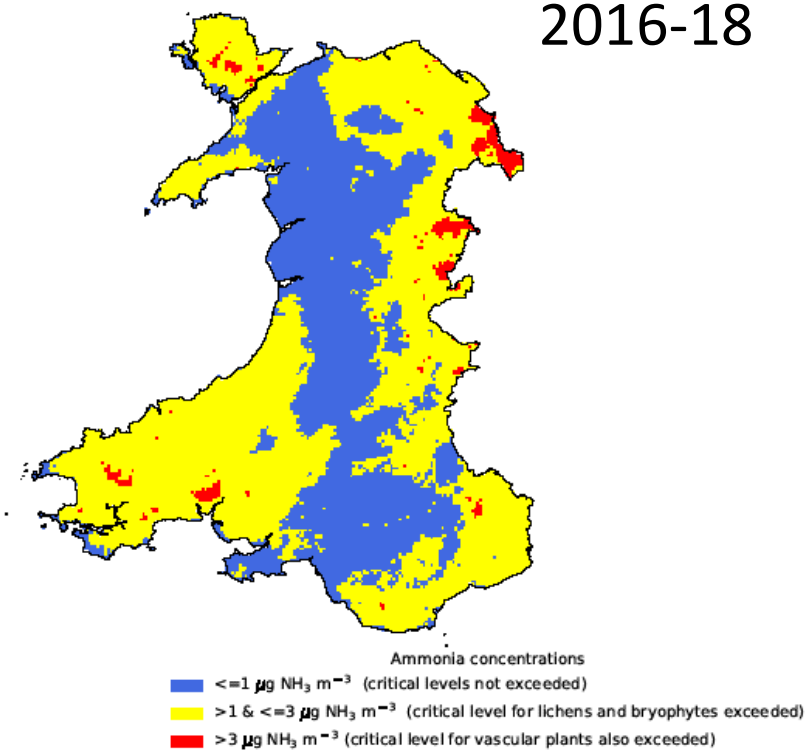
Area exceeded: 89.4% (2013) → 88.5% (2018), a relative 1% decrease

Excess nitrogen: 8.6 (2013) → 8.7 kg N ha^{-1} yr^{-1} (2018), a relative 1% increase

Trend in exceedance of CLe for ammonia in Wales



2016-18



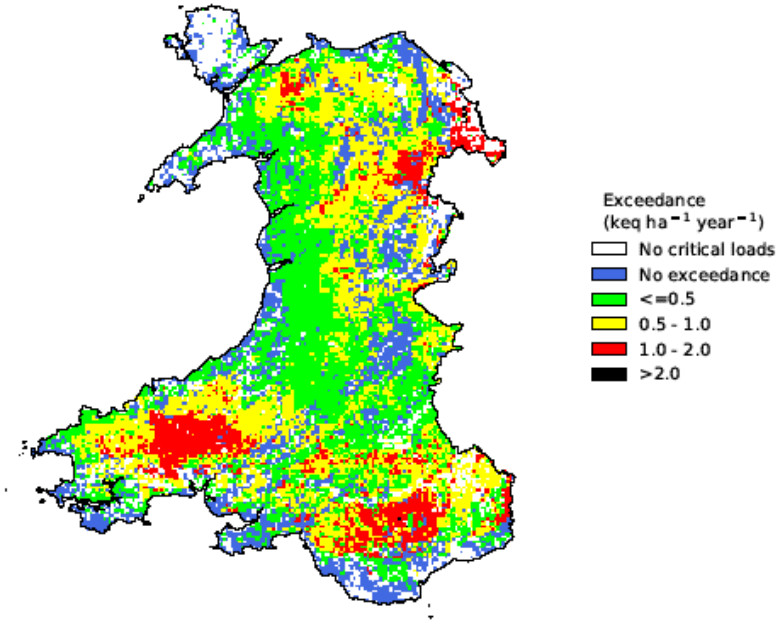
Area exceeding 1 µg: 57.6% (2012) → 60.2% (2017), a relative 5% increase

Area exceeding 3 µg: 0.7% (2012) → 2.4% (2017), a relative 240% increase

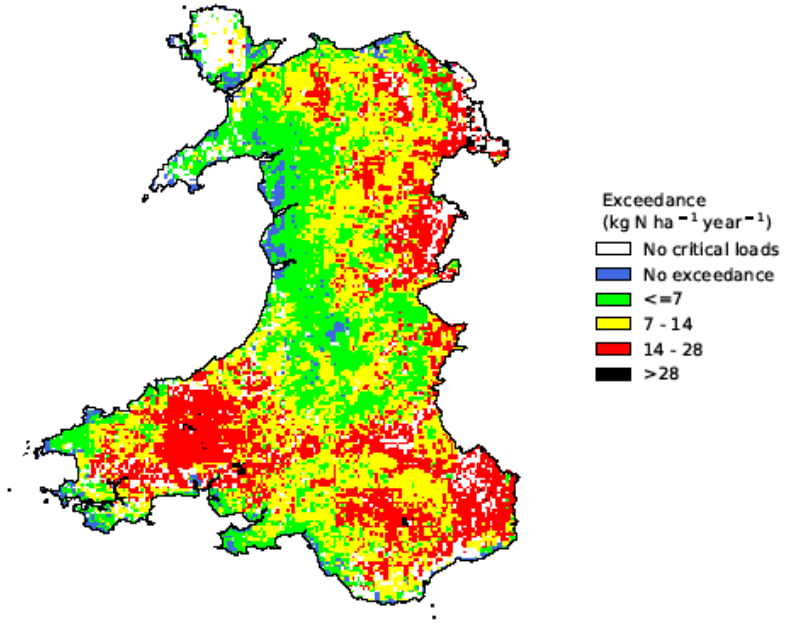
Changes in spatial pattern

2014-16

Acidity



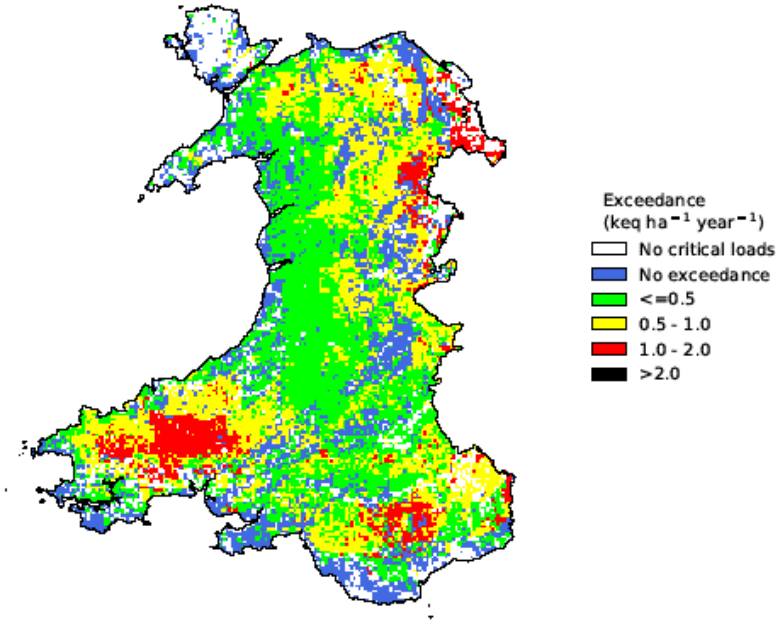
Nutrient-N



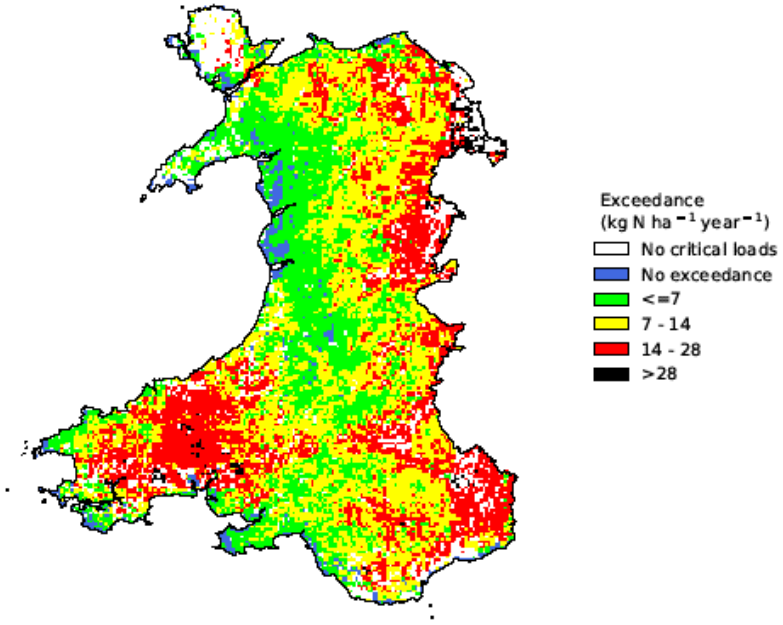
Changes in spatial pattern

2017-19

Acidity



Nutrient-N



General decline in acidity exceedance
Some increases in the SW

Some decreases in nutrient-N exceedance (Powys)
Some increases (e.g. Pembs, Carmarthenshire)

Explanations

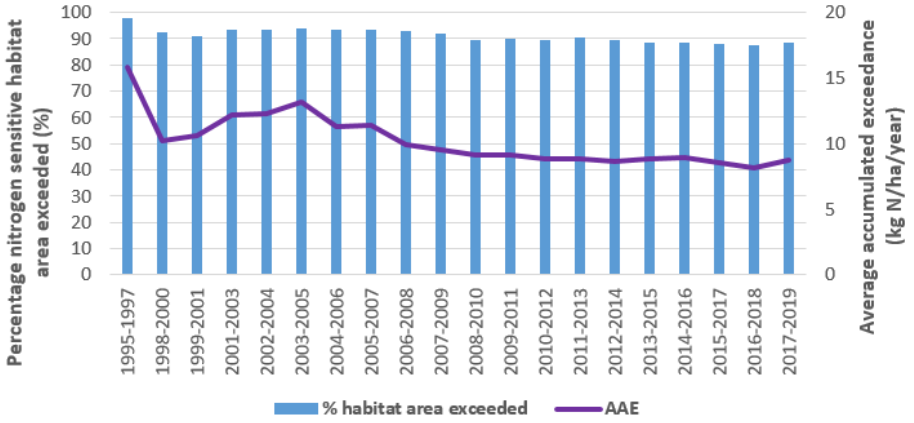
- Sulphur emissions: big decrease since 1980s, although shipping emissions continue
- NOx emissions: ongoing decrease
- NH_3 emissions: slight increase since 2002
- Weather conditions may have been a factor in the recent uptick in emissions

<u>Ammonia emissions</u>

Large pig and poultry units are regulated, but not cattle or sheep

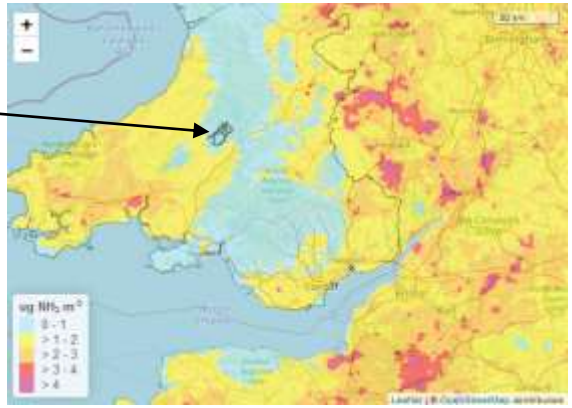
Transboundary pollution (mainly Eire and England)

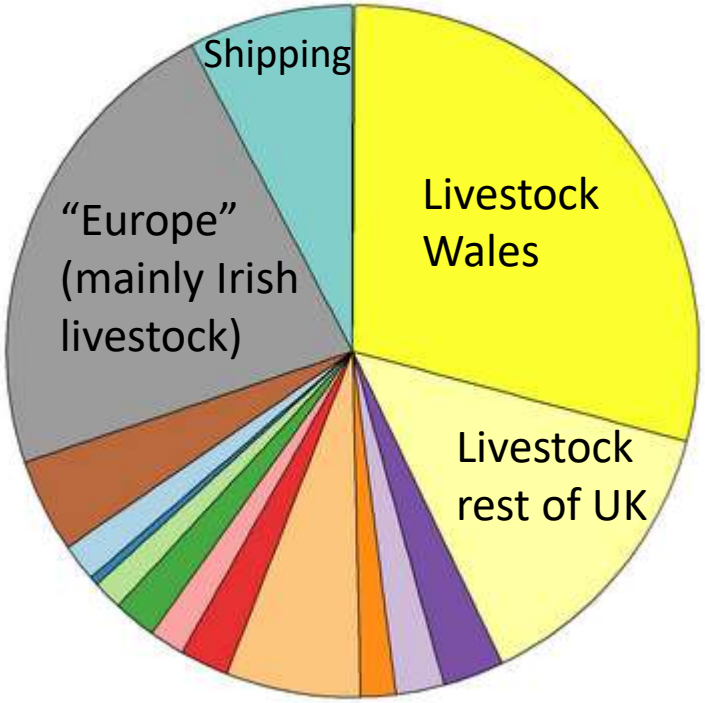
Nutrient-nitrogen exceedance in Wales

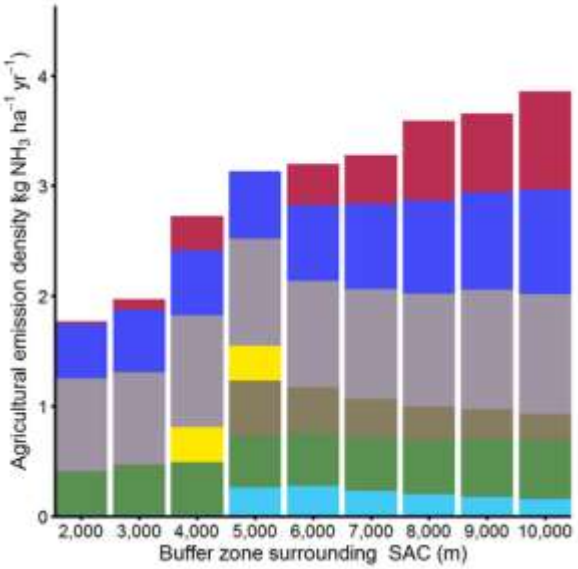


Source attribution

e.g. total N deposition at Cwm Doethie





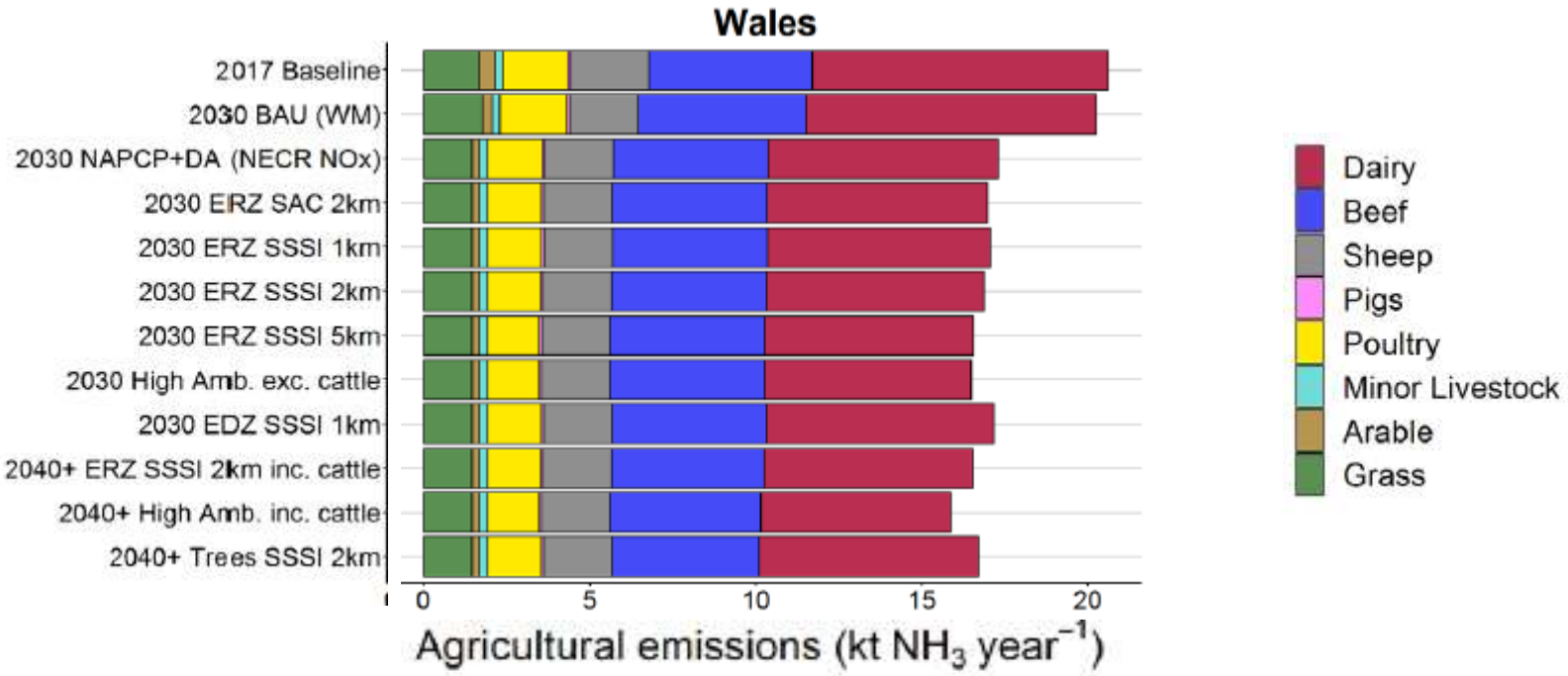


UK Centre for Ecology & Hydrology

Dragosits et al (2020) Nitrogen Futures. JNCC Report 665.

Future prospects

- The JNCC “Nitrogen Futures” project explored scenarios with more agricultural measures to decrease ammonia emissions (slurry store covers, slurry injection etc.)
- Even the most ambitious scenarios achieved limited reductions in NH_3 emissions
- Meeting targets (e.g. NECD, CAS, 25YEP) is likely to require decreases in livestock production



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Acknowledgements

The National Focal Centre for modelling and mapping critical loads and critical levels is supported by the UK Department for the Environment, Food and Rural Affairs (Defra) under Contract AQ0849.