Issues with ammonia in Wales

Ed Rowe

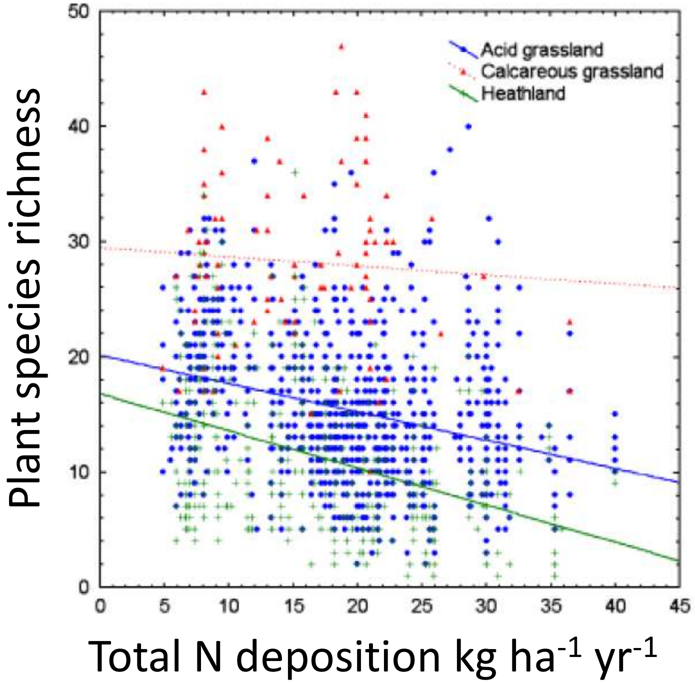
UK Centre for Ecology & Hydrology

Impacts of air pollution

Air pollution harms ecosystems through:

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

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

Ammonia toxicity

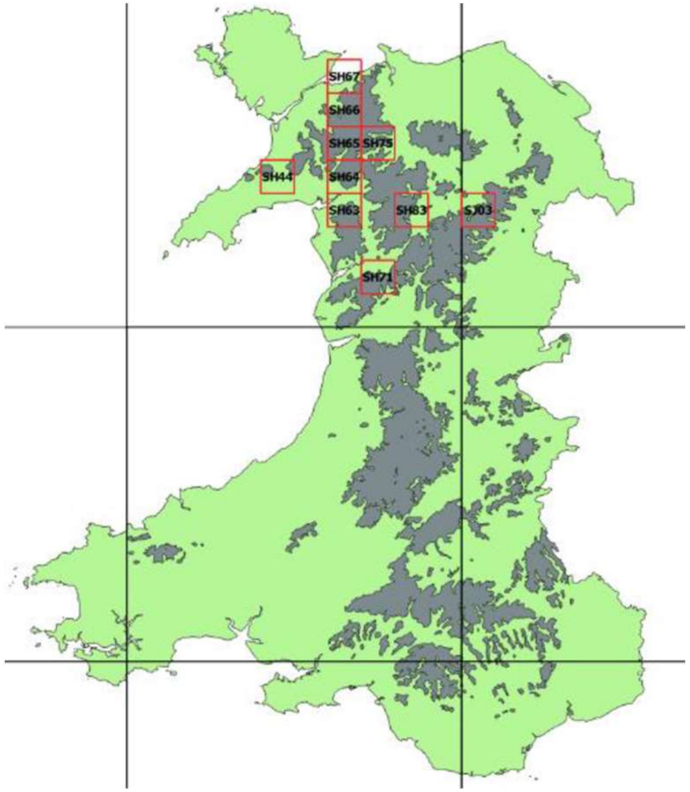
Ammonia directly harms plants and lichens through:
- Damage to the cuticle (waxy exterior)
- Increasing alkalinity within cells
- Decreased photosynthetic performance

Critical level – concentration above which harm is likely:
- 3 µg NH_3 m^{-3} (sensitive vascular plants)
- 1 µg NH_3 m^{-3} (sensitive lichens and bryophytes)

Current review (ICP Vegetation) may conclude that critical levels should be lower

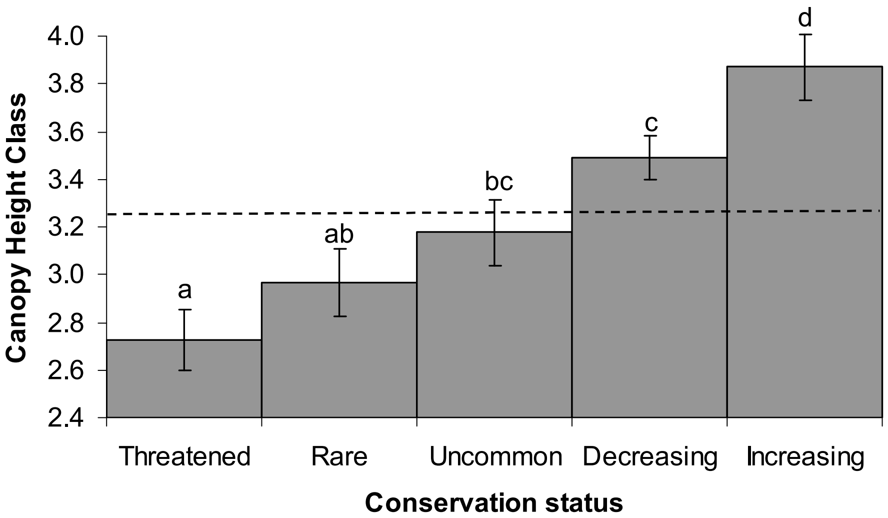
Case study – *Alectoria nigricans*

- Macrolichen occurring in montane heath
- 20th century records from 10 Welsh hectads (10 x 10 km squares)
- Recorded in only 4 locations since 1990
- Exhaustive search of these locations in 2020
- Only found at one site on Glyder Fawr

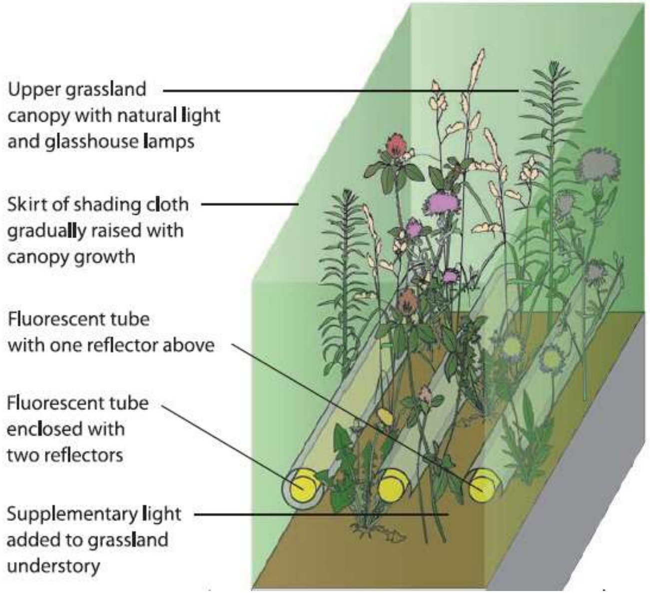


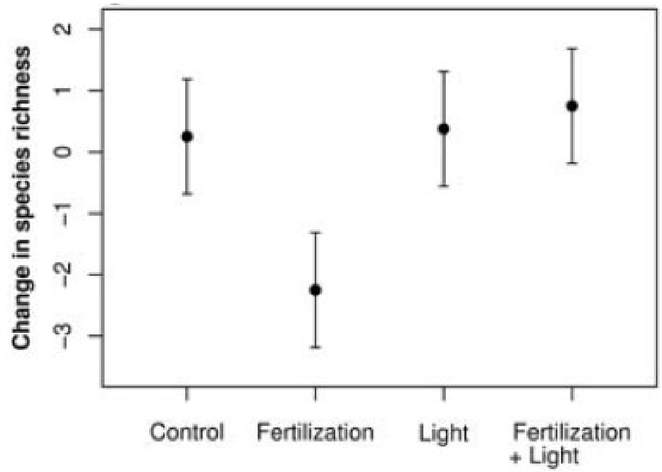
Eutrophication

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



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





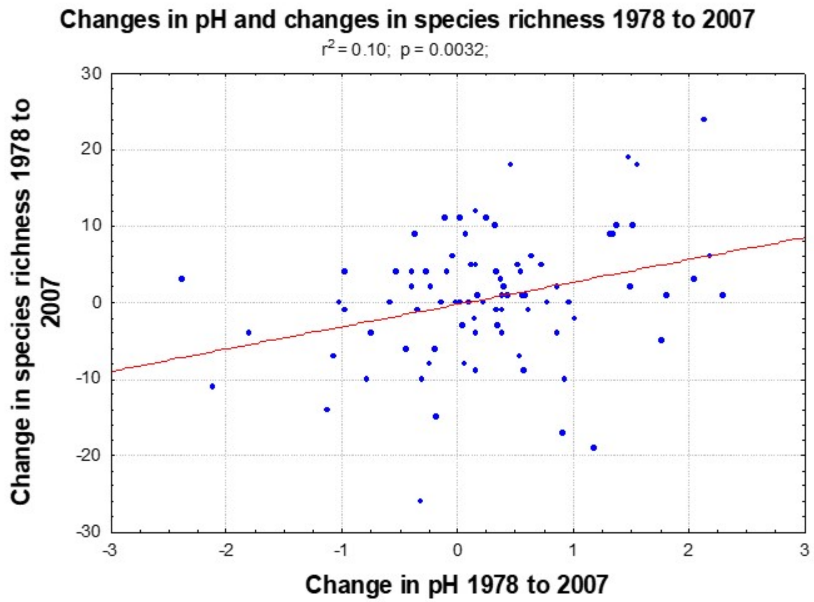
Hautier et al. (2009) Science 324 (5927) 636-638.

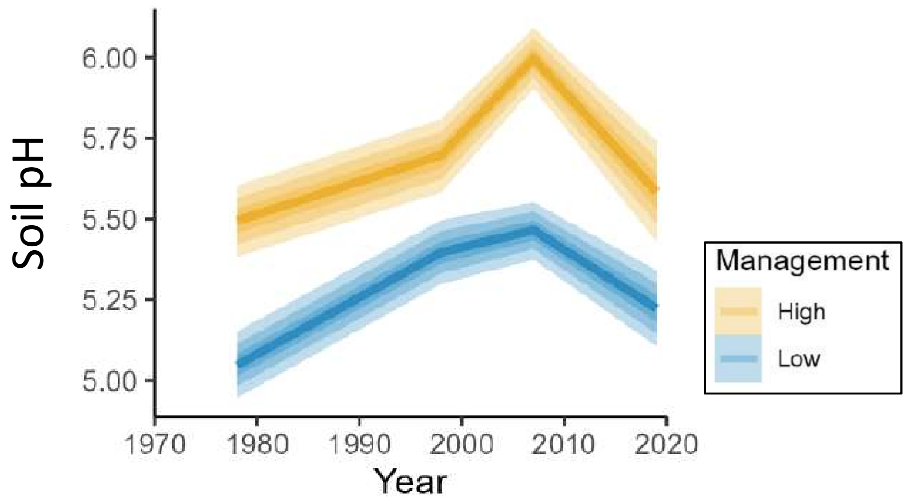
Acidification

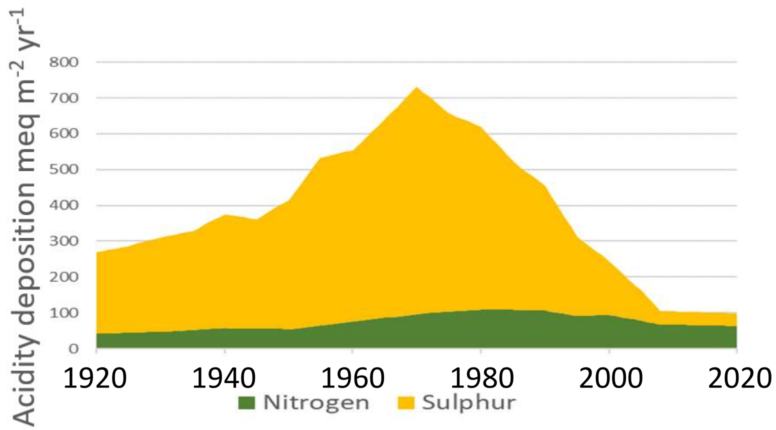
Species-richness tends increase with pH (although habitats on acid soils support distinctive species).

Recovery from acidification depends on soil type and ongoing rate of acidity pollution.

Around 90% of UK total acidity deposition is now nitrogen (73 % NHy, 19% NOx, 8% SOx)







Lindsay Maskell et al. (2010) Resilience of acidified ecosystems, UKCEH report; Fiona Seaton et al. (in press) Journal of Ecology; Sam Tomlinson UKSCAPE-SPEED project.

Ammonia interactions in the atmosphere

Ammonia gas (NH_3) may:

- Be taken up directly into plants and lichens
- Dissolve, and contribute to wet deposition of nitrogen, often close to the source

$$NH_3\ (g) + H_20 \leftrightarrow NH_4^+\ (aq) + OH^-\ (aq)$$

- React with acidic gases in the atmosphere…

$$\begin{aligned}
2NH_3(g) + H_2SO_4(aq) &\xrightarrow{k_S} (NH_4)_2SO_4(aq)\\
NH_3(g) + HNO_3(g) &\xrightarrow{k_N} NH_4NO_3(s) \text{ or } (aq)\\
NH_3(g) + HCl(g) &\xrightarrow{k_{Cl}} NH_4Cl(s) \text{ or } (aq)
\end{aligned}$$

…forming particulates, which have direct effects, and contribute to N deposition

Effects of changing atmospheric chemistry

Diagram showing greater vertical diffusion in 2015 than in 2001 – withheld because the study has not been published yet

Due to reduced interaction with NO_x and SO_x, NH_3 is now increasingly mixed vertically, and has a longer atmospheric lifetime

Eiko Nemitz, Massimo Vieno & Janice Scheffler (in prep.)

Trends in NH_3 emissions and surface concentrations

Emissions | **NH_3 concentration (EMEP4UK model)**

Diagram showing steep decline in SOx and NOx emissions, little change in NH3 emissions, 2000 – 2020

Diagram showing steep increase in NH3 conc, as predicted by EMEP4UK model, especially for grid cells > 350 m mean altitude.

Diagrams withheld because the study has not been published yet

Solid lines = UK (2020 NAEI)
Dashed lines = EU-28 (EMEP)
Asterisks = UK targets under NECD/Gothenburg Protocol

- Relative increase in ammonia concentrations is larger at higher elevation sites
- Decline in SOx and NOx emissions means NH_3 emissions would have to decrease even more strongly to reduce NH_3 concentrations and impacts

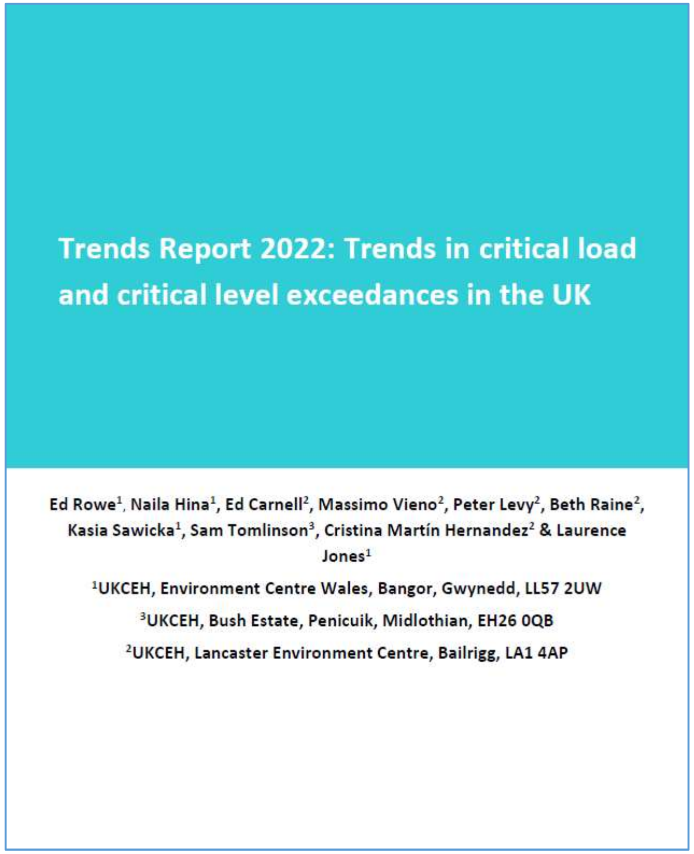
UK Centre for Ecology & Hydrology

Eiko Nemitz, Massimo Vieno & Janice Scheffler (in prep.)

National Focal Centre

The **UK National Focal Centre for modelling and mapping exceedances of critical loads and critical levels** (NFC) is responsible for:

- UK data submissions under the UN-ECE Air Convention (CLRTAP)
- Producing statistics for the UK and UK-countries in the annual “Trends Report”, including
  - Exceedances of critical load for acidity
  - Exceedances of critical load for nutrient-N
  - Exceedances of critical level for ammonia
  - Habitat-based exceedances
  - Exceedances for protected sites


Trends Report 2022: Trends in critical load and critical level exceedances in the UK

Ed Rowe[1], Naila Hina[1], Ed Carnell[2], Massimo Vieno[2], Peter Levy[2], Beth Raine[2], Kasia Sawicka[1], Sam Tomlinson[3], Cristina Martín Hernandez[2] & Laurence Jones[1]

[1]UKCEH, Environment Centre Wales, Bangor, Gwynedd, LL57 2UW

[3]UKCEH, Bush Estate, Penicuik, Midlothian, EH26 0QB

[2]UKCEH, Lancaster Environment Centre, Bailrigg, LA1 4AP

Updating atmospheric models (2022)

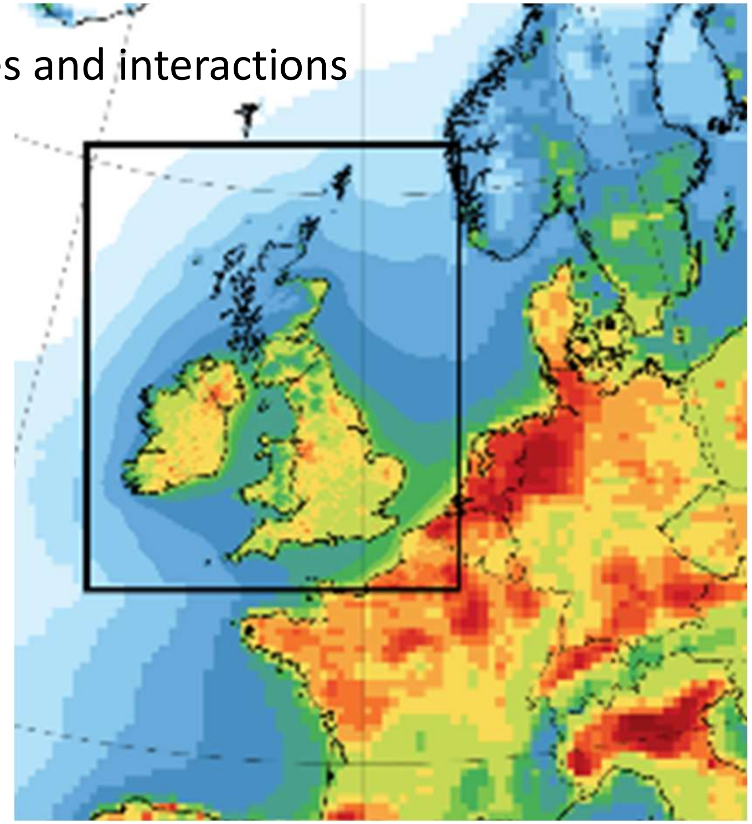
FRAME model no longer used

EMEP4UK model used to predict ammonia concentration

- More temporal resolution, more chemical species and interactions
- Based on emissions inventories
- Predicts well without calibration

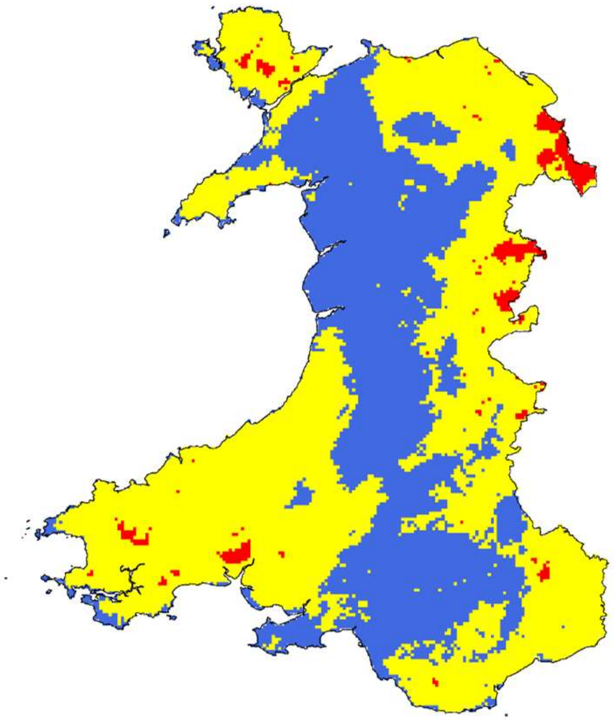
CBED model is still used to predict deposition rates

- Statistical interpolation

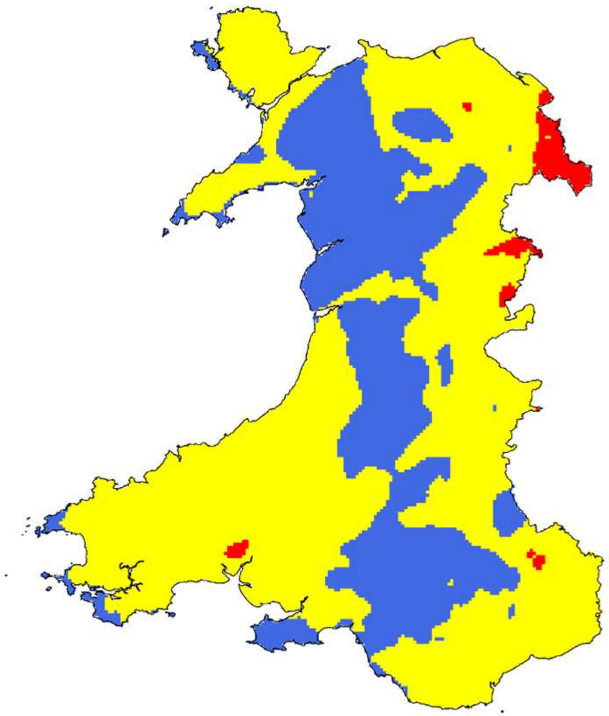


Changes in the ammonia concentration map

FRAME



EMEP4UK



$<=1\ \mu g\ NH_3\ m^{-3}$ (critical levels not exceeded)

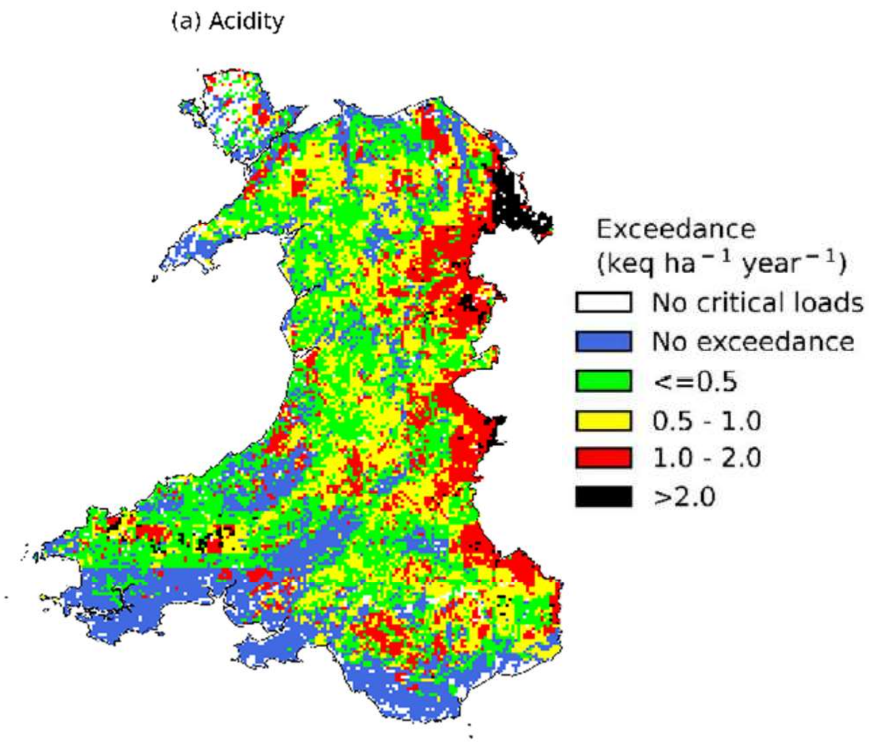
$>1\ \&\ <=3\ \mu g\ NH_3\ m^{-3}$ (critical level for lichens and bryophytes exceeded)

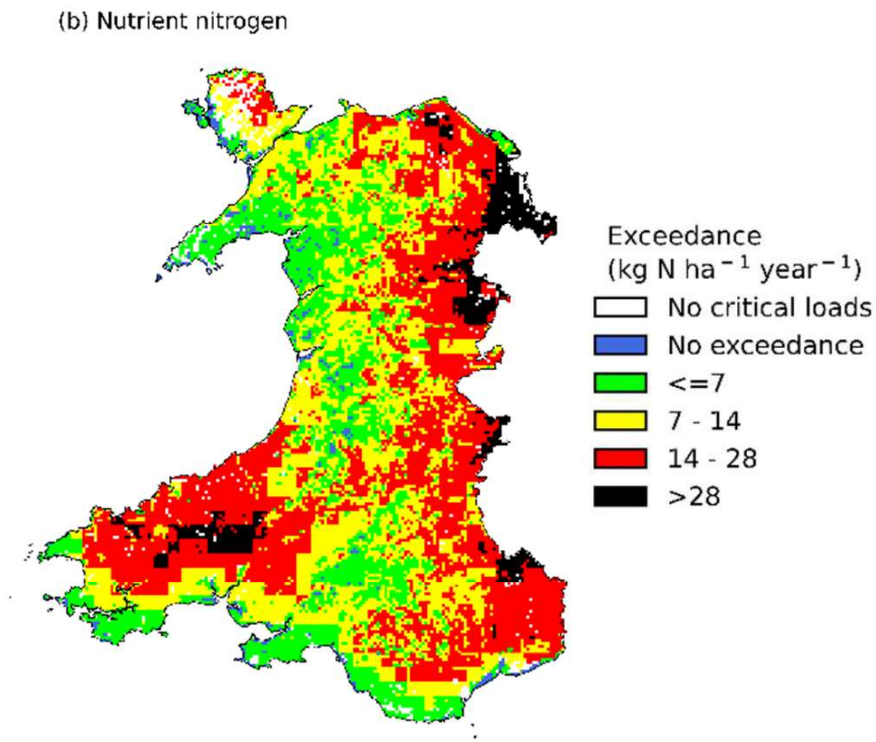
$>3\ \mu g\ NH_3\ m^{-3}$ (critical level for vascular plants also exceeded)

Both based on 2016-18 emissions and meteorology data

Current exceedance of critical loads for acidity and N

Only the blue areas are not exceeded



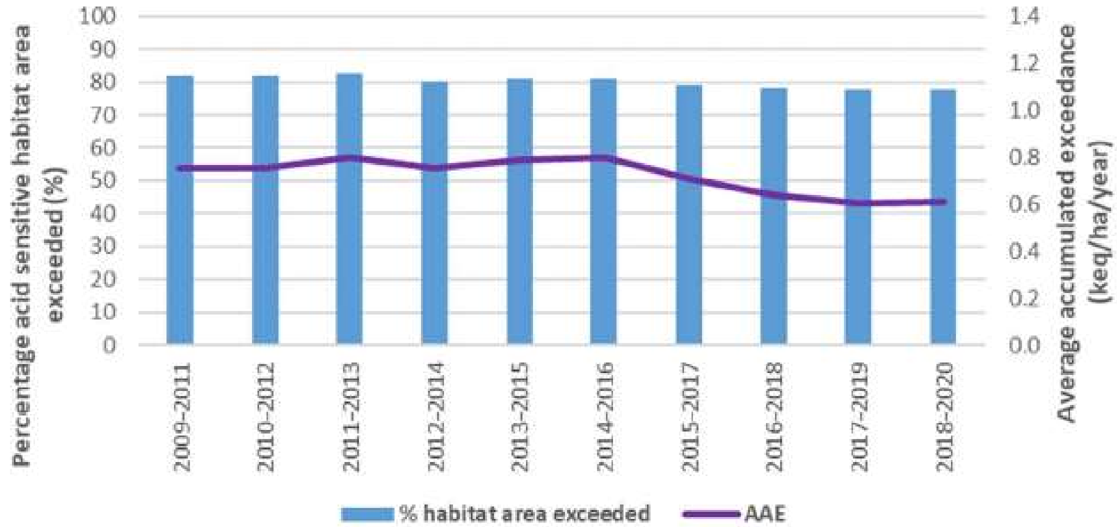


UK Centre for Ecology & Hydrology

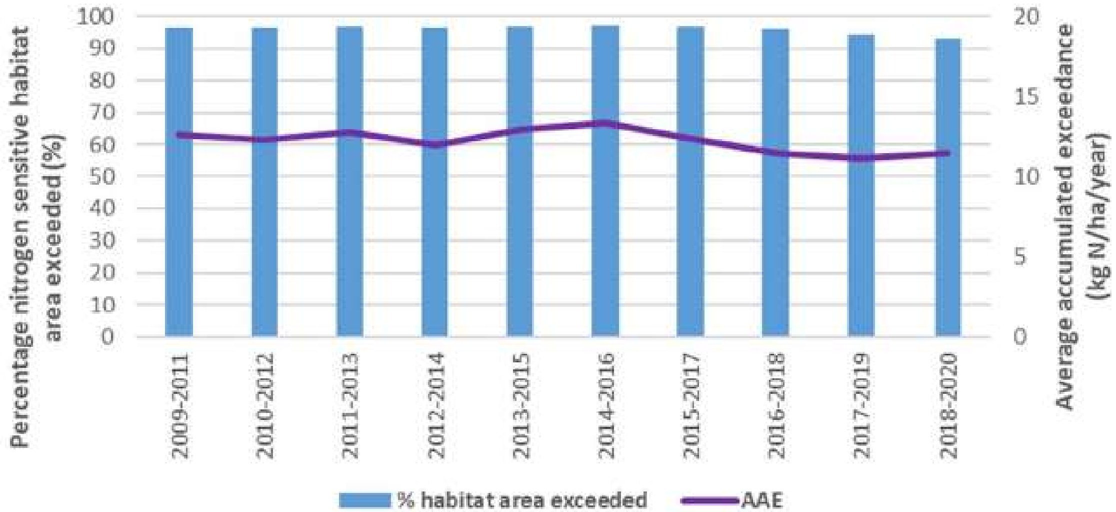
Rowe et al. (2022) *Trends Report 2022: Trends in critical load and critical level exceedances in the UK.* https://ukair.defra.gov.uk/library/reports?report_id=1087

Trends in exceedance of critical loads in Wales

Acidity



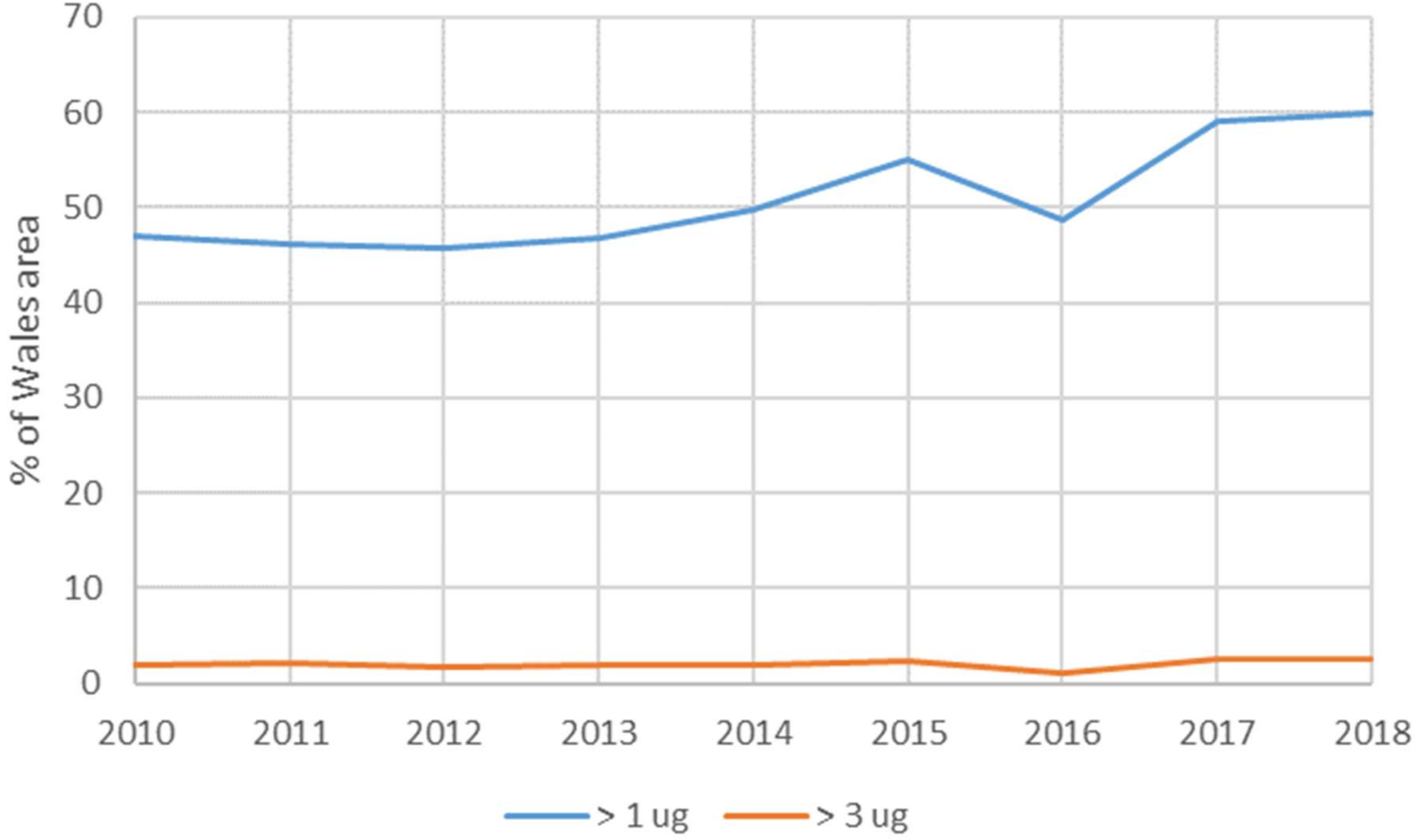
Nutrient-nitrogen



UK Centre for Ecology & Hydrology

Rowe et al. (2022) *Trends Report 2022: Trends in critical load and critical level exceedances in the UK.* https://ukair.defra.gov.uk/library/reports?report_id=1087

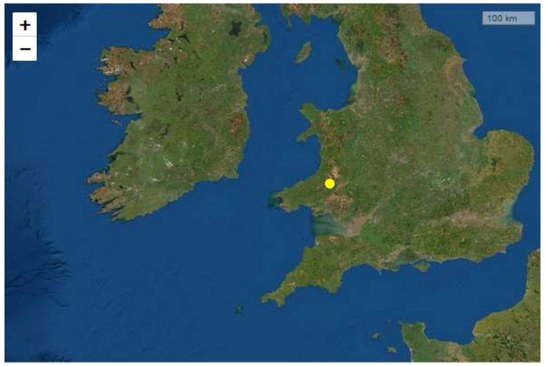
Trends in exceedance of ammonia critical levels

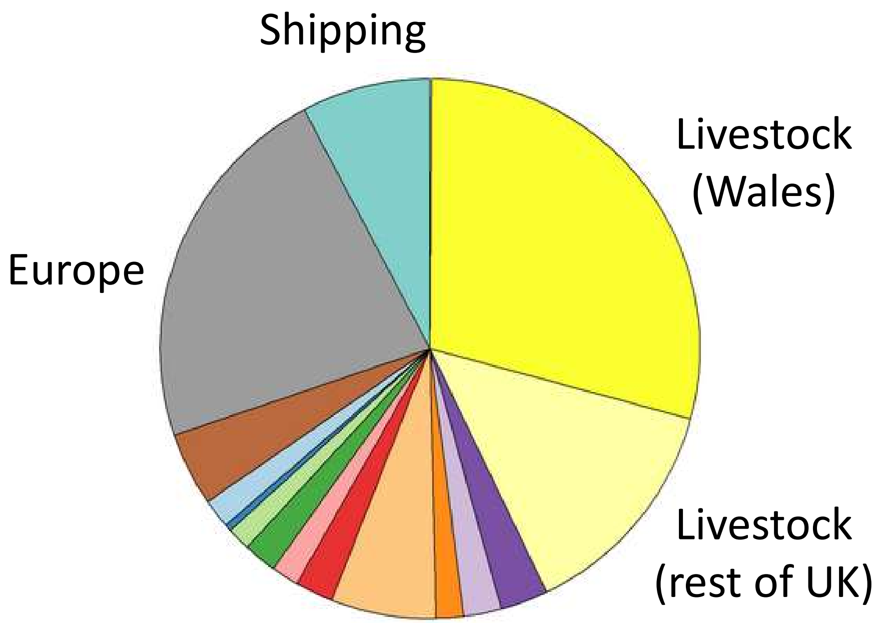


UK Centre for Ecology & Hydrology

Rowe et al. (2022) *Trends Report 2022: Trends in critical load and critical level exceedances in the UK.* https://ukair.defra.gov.uk/library/reports?report_id=1087

Sectors of origin for N pollution – e.g. Cwm Doethie SAC





Livestock (Wales)
Livestock (Rest of UK)
Fertiliser (Wales)
Fertiliser (Rest of UK)
Transport (Wales)
Transport (Rest of UK)
Non-agricultural abatable (Wales)
Non-agricultural abatable (Rest of UK)
Non-agricultural non-abatable (Wales)
Non-agricultural non-abatable (Rest of UK)
Other sources (Wales)
Other sources (Rest of UK)
Point sources
Europe
Shipping

UK Centre for Ecology & Hydrology

Dragosits et al. (2020) Nitrogen Futures. JNCC Report 665.
https://jncc.gov.uk/our-work/nitrogen-futures

Conclusions

- S and NOx pollution have declined over the last 10 years, but NHy has not.
- 93% of sensitive habitats in Wales receive N pollution above the critical load for nutrient nitrogen, 78% exceed the critical load for acidity.
- Ammonia pollution continues to damage Welsh habitats, and limits the potential for habitat restoration.