Empirical critical loads for nitrogen deposition - a review of their current status

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Empirical critical loads for nitrogen

- Critical load - deposition below which long-term harmful effects on ecosystem function or structure do not occur according to current knowledge
- Set by calculation of long-term ecosystem budgets (steady-state mass balance) or with reference to observed or experimentally-induced changes in ecosystems (empirical approach)

Evidence for empirical critical loads

- Field observations - but attribution of cause and effect is problematic
- Field manipulation experiments - but may not be of long-enough duration to detect effects except at highest deposition rates
- Considerable value judgement and uncertainties in interpreting the evidence
- Values set as range with indication of strength of supporting evidence

Revision of Empirical Critical loads

UNECE Workshop

Revised empirical critical loads for nitrogen, Berne, 11-13 November 2002

Linked to revision of Gothenburg Protocol

UK revision of mapping values

Adapting Berne recommendations for UK in terms of both mapping communities and assigning appropriate critical values

Berne outcomes

- Use of EUNIS categories - improved link to mapping?
- Identifying new communities for which CLs can be assigned - e.g. sand dunes, Racomitrium heath
- Modifying current critical load range (e.g. calcareous grassland, lowland heath)
- Changes in reliability of estimates
- Review of modifying factors and their effects

For forests, critical loads based on response (e.g. nitrate leaching, nutrient imbalance, ground flora, epiphytes)

Application in UK - mapping

- Mapping linked to revision of acidity critical loads
- EUNIS categories cross-linked to Biodiversity Action Plan broad habitats
- Distribution map based on combination of land-cover map, species and community maps, and soils maps as appropriate
- Some value judgement - does map look right?

Report and maps available at:
http://critloads.ceh.ac.uk/reports.htm

Application in UK - critical loads

Principles agreed to guide UK values

- No mapping values adopted for ‘expert judgement’ values except where UK evidence exists (moorlands)
- Middle of range from Berne selected as default
- Modified from mid-range when substantial body of relevant UK evidence exists (heathlands)
- Modified from mid-range with evidence that UK systems are more or less sensitive (bogs)

Implications of revisions

- Greater range of UK habitats with empirical critical loads assigned
- Reduction in UK mapping values for grasslands and lowland heath
- Greater degree of exceedance shown in UK maps
- Need to understand scientific basis of changes in critical loads (new evidence or new interpretation?)

PREVIOUS AND REVISED EMPIRICAL CRITICAL LOADS FOR NITROGEN (kg ha^{-1} yr^{-1}) FOR NON-FOREST ECOSYSTEMS IN UK

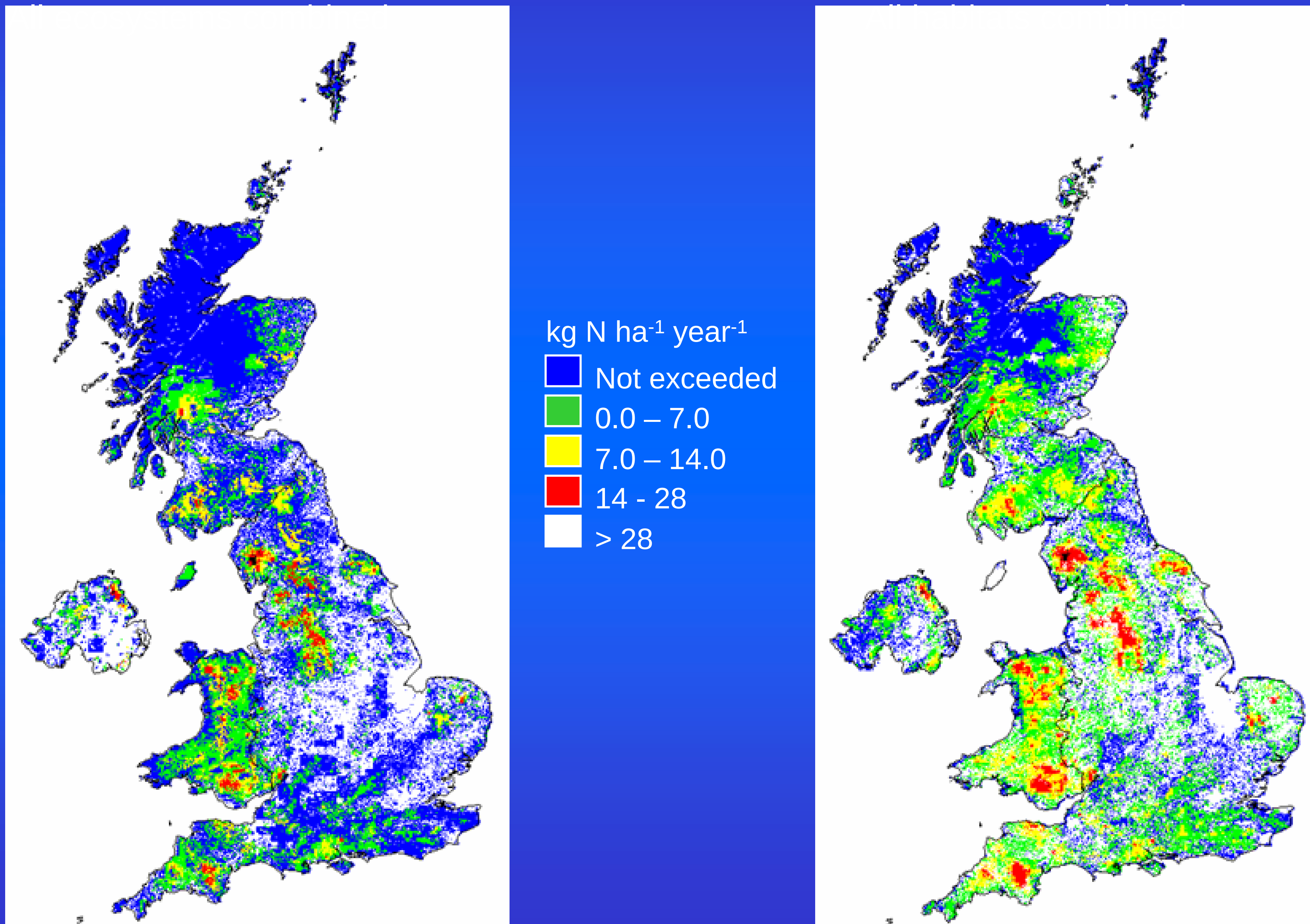
(a) Ecosystem	(b) 2000 UK mapping value	(c) Critical load range in 1996 Mapping Manual	(d) Critical load range from Berne workshop	(e) Revised UK mapping value
Grasslands				
Dry acid and newtral closed grassland	25	20-30#	10-20#	15
Calcareous grasland	25	15-35#	15-25#	20
Montane grassland	12	10-15(#)		
Moist/wet oligotrophic grass			10-20#	15
Nardus stricta swards			10-20#	15
Moss/lichen mountain summits			5-10#	7

(a) Ecosystem	(b) 2000 UK mapping value	(c) Critical load range in 1996 Mapping Manual	(d) Critical load range from Berne workshop	(e) Revised UK mapping value
Heathland/moorland				
Lowland dry heaths	17	15-20 #	10-20 #	12
Lowland wet heaths		17-22 #	10-25 #	15
Upland Calluna heaths	15	10-20 #	10-20 (#)	15
Arctic/alpine heaths	7.5	5-15 (#)	5-15 (#)	-
Coastal habitats				
Coastal stable dune grasslands		20-30 #	10-20 #	15
Shifting coastal dunes			10-20 #	15
Bogs, mires and fens				
Ombrotrophic and raised bogs	10	5-10 #	5-10 ##	10
Poor fens			10-20 #	15

Exceedance of 5th-percentile nutrient nitrogen critical loads

Figure 1.2

Previous (February 2001) Update (February 2003)



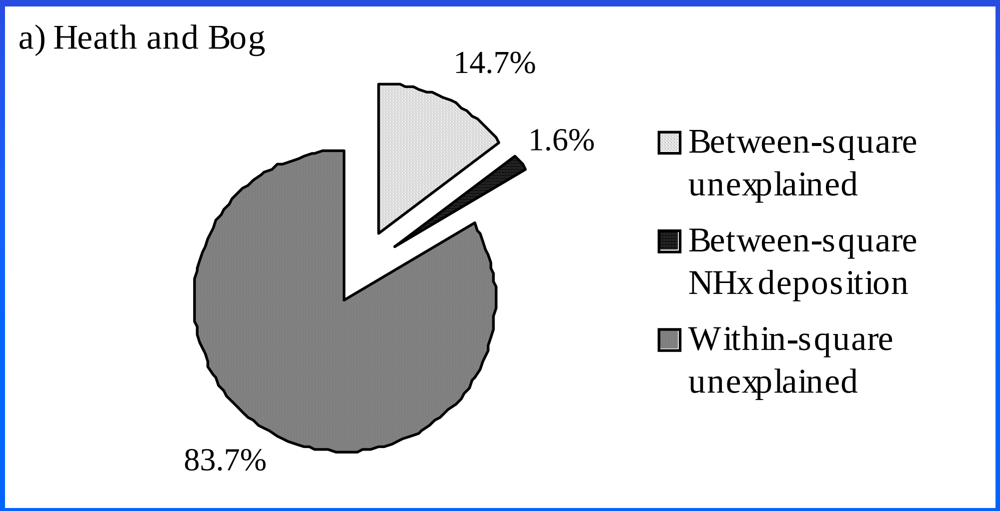
Critical loads for sensitive ecosystems are exceeded over significant areas of the UK

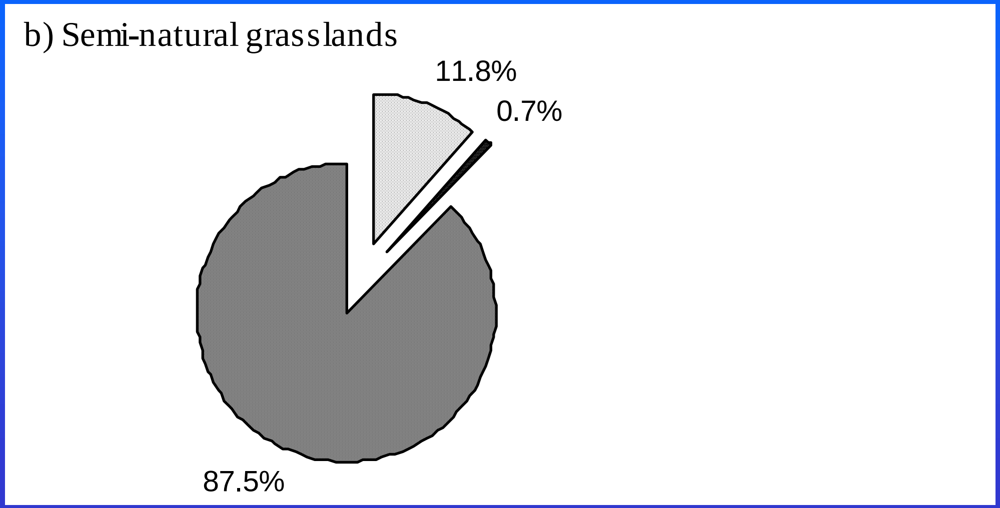
But what evidence is there that current N deposition is significantly affecting species composition?

Field data

- National vegetation survey (CVS) - species composition change over last 20 years is associated with reduced N deposition
- National lichen database - expansion of nitrophytic species (e.g. *Xanthoria polycarpa*) associated with higher rates of N deposition
- Grassland species diversity negatively related to N deposition

CVS: Large-scale signal of N deposition in vegetation change between 1990-’98





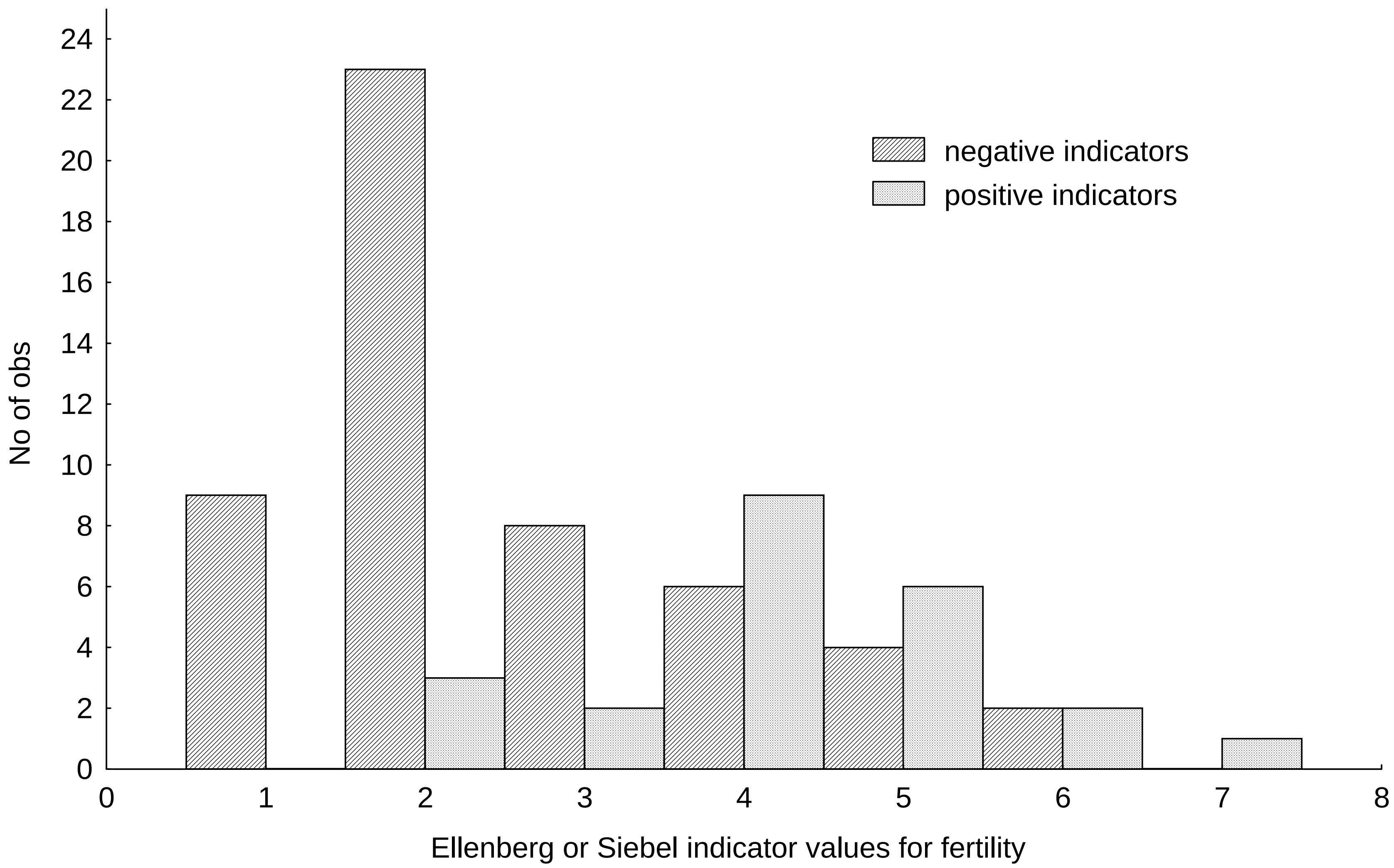
Response variable = cover-weighted Ellenberg fertility score

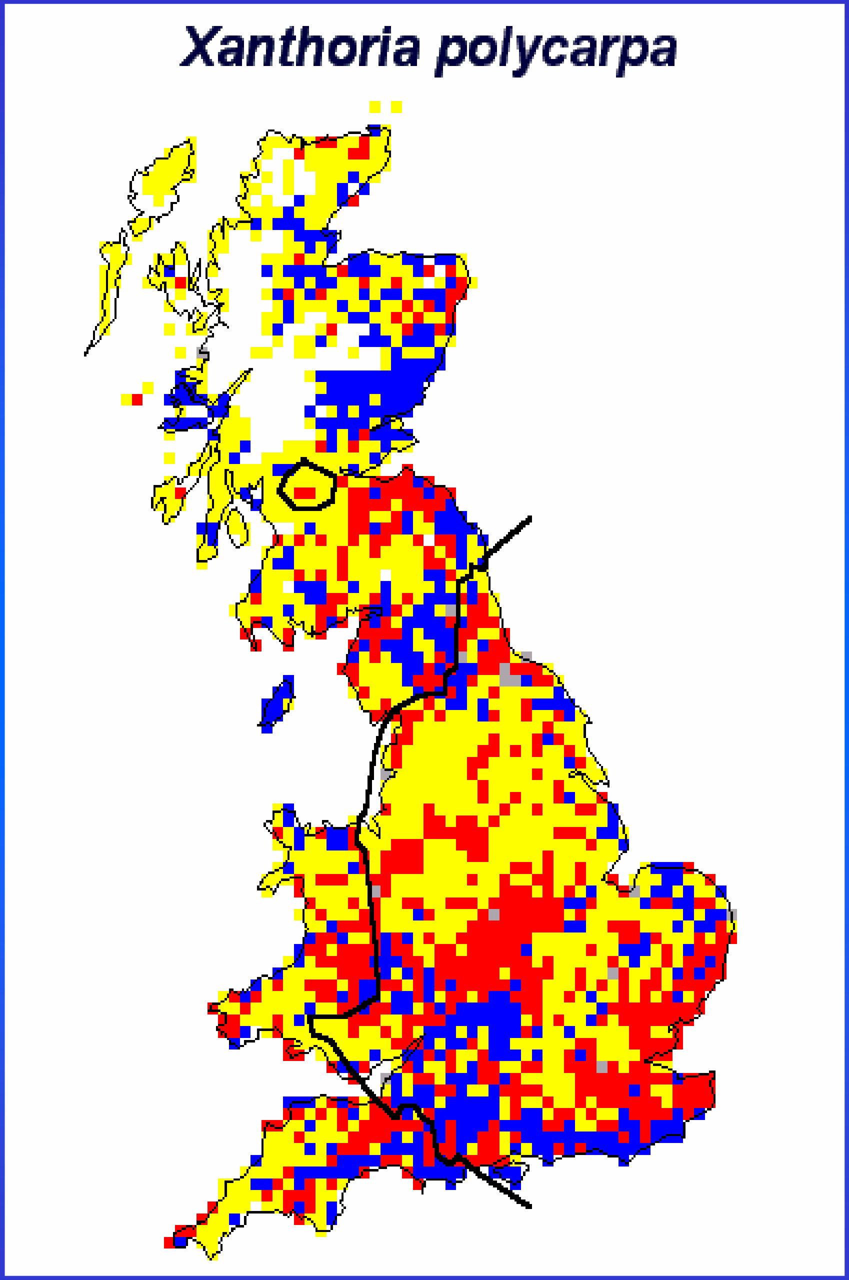
Small amount of explained variance but signal detectable.

NHx implicated rather than NOy.

Sheep grazing an important additional driver in uplands

CVS Analysis of indicator species - negative relationships with N deposition dominate in Ellenberg classes 1-3



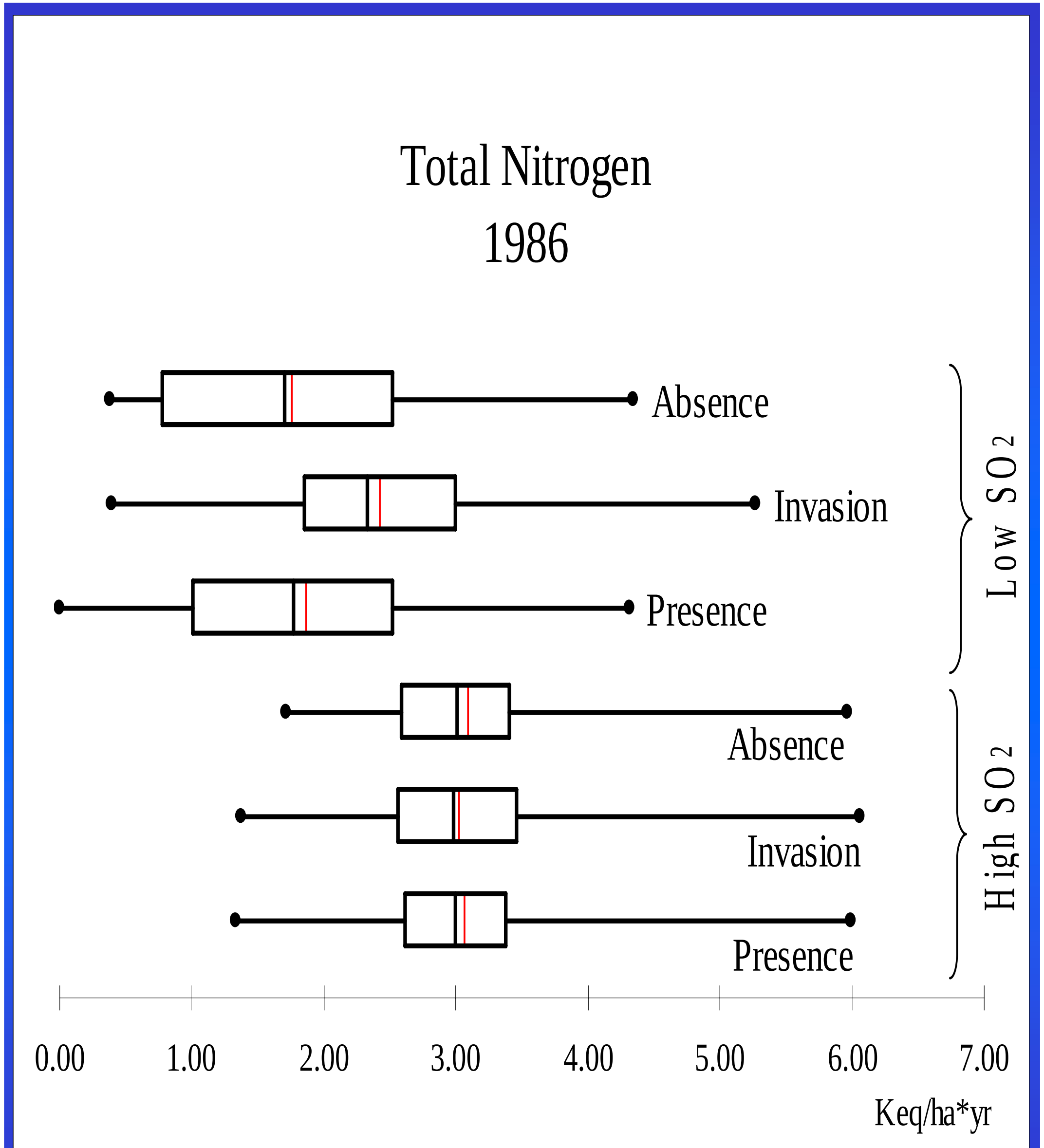


	Low SO_2	High SO_2
New Hectads	241	408
Abent Hectads	591	510

Xanthoria polycarpa

Absence v. New	Low SO_2	High SO_2
Total Nitrogen	+++	n.s
Dry Sox	+++	---
Dry NOx	+++	---
Dry NHx	+++	n.s
Total Ca+Mg	---	n.s
Total H+	n.s	---

- Sensitive to SO_2
- Nitrophyte



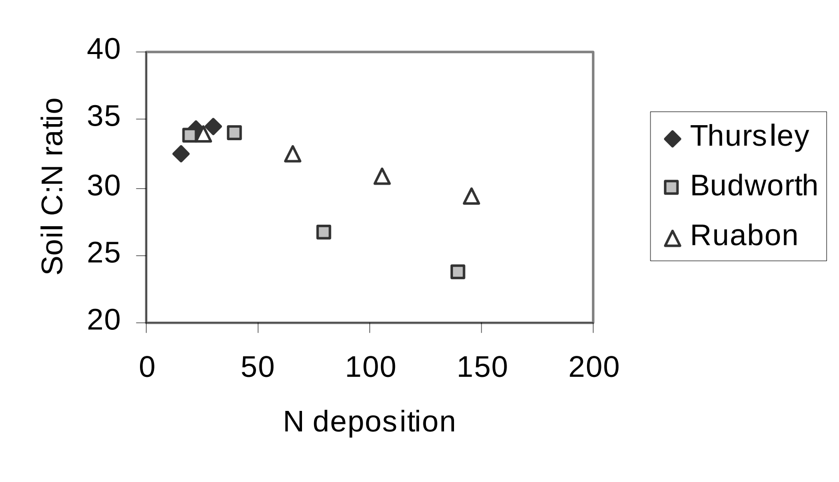
Field manipulation review

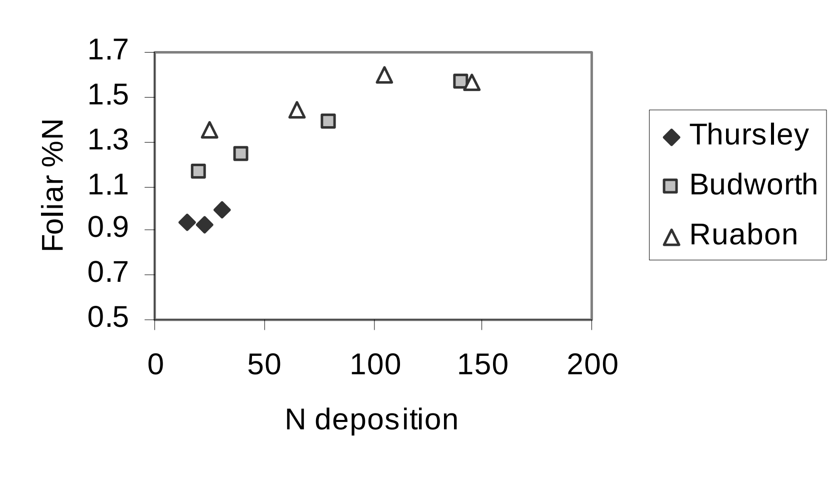
- Published as JNCC Report no. 331
- Aimed to review new evidence of the scale and nature of impacts of N deposition from field manipulation experiments
- Evaluated issues in design and interpretation of field experiments
- Contributed to revised critical loads
- Identified priorities for future work

Field manipulation – key conclusions

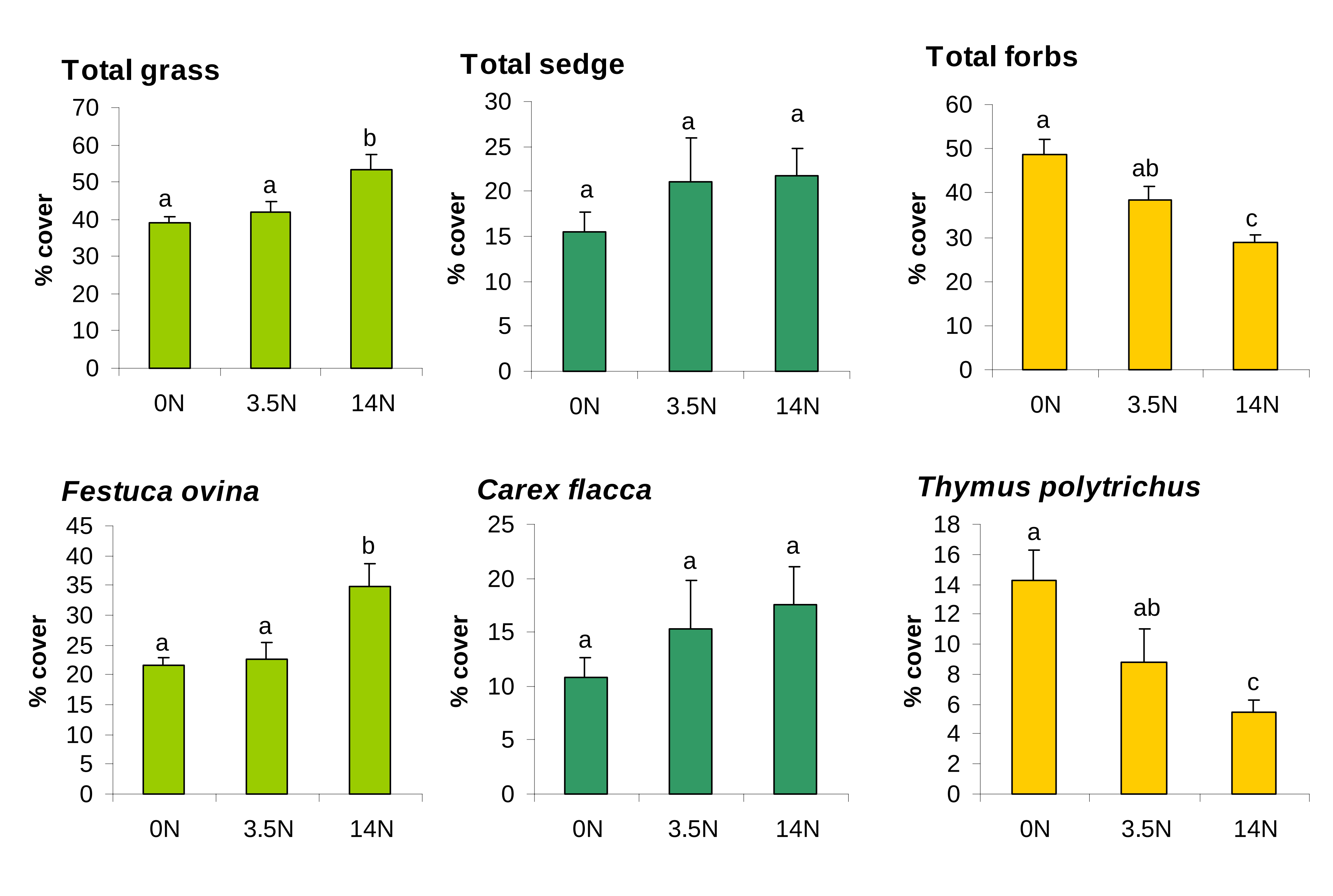
- Consistency in responses between experiments – e.g. UK heaths and moors
- Rapid changes in indicator parameters (e.g. N content) but major changes in higher plant species composition only after 10 years or more
- Importance of interactions with P and management
- Sensitivity of lichens and bryophytes
- Site deposition history important for interpretation
- Results overall suggest cause for concern on impacts of N deposition on sensitive UK sites

Synthesising experimental results: soil C:N and foliar N responses at three heathland sites





Species change: calcareous grassland



Field manipulation – future priorities

- Need to maintain UK long-term experiments
- New experiments needed for sensitive ecosystems
- Need to assess long-term responses to decrease in N deposition
- Assess fate, turnover and long-term significance of N accumulation in soil pools, and interaction with P availability
- More focus on responses of lichens/bryophytes, directly and indirectly (cover/substrate chemistry)
- More use of modelling for interpretation and prediction

Use of modelling

- Models allow long-term implications of experimental results to be assessed
- Models allow the modifying effects of some factors to be evaluated
- Models demonstrate that interactions with management are of critical importance in heathlands and moorlands
- Dynamic models confirm long time scales (decades) for vegetation change and for recovery

From detecting a signal to predicting the future?

- N deposition can influence UK species composition
- Vegetation change may reflect long-term N accumulation not current N deposition
- Responses to decreased emissions uncertain
- Many research needs to provide improved prediction, but integration of field studies, experiments and modelling is crucial
- Critical loads are a crude tool for national-scale risk assessment, and have no predictive value

Critical loads- key future issues

- More experimental and field evidence
- Better tools to assess implications of exceedance
- Estimating N deposition – need consistency between experiments, field surveys and models
- Management - implications for critical load values and dynamics of response
- Differential effects of reduced and oxidised N
- Modifying factors such as P status and rainfall
- Predicting responses to decreased N deposition

Local-scale application?

- Empirical critical loads developed for use in national and international risk assessment
- UK mapping values designed for national screening of levels of risk but are not appropriate for application to specific sites
- Refer to Berne workshop – more detail of appropriate value for a wider range of habitats
- **MAJOR ERRORS OF JUDGEMENT WILL ARISE IF UK MAPPING VALUES ARE APPLIED UNCRITICALLY IN LOCAL SITE ASSESSMENTS**

Acknowledgements

- For critical loads and exceedance maps: CEH Monks Wood (http://critloads.ceh.ac.uk) and CEH Edinburgh
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- For experimental data on grasslands: Gareth Phoenix and Paul Horswill (University of Sheffield)