Bioindicator methods for monitoring of nitrogen impacts on statutory nature conservation sites

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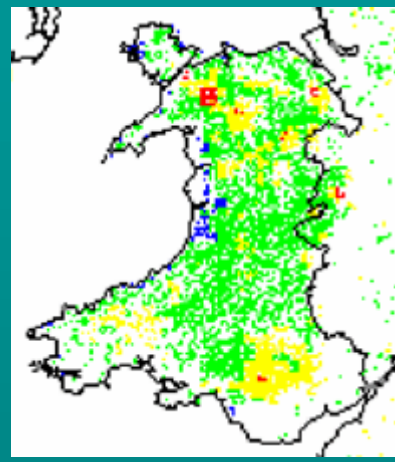
Assessing air pollution impacts: Critical loads & Bioindicators

- Critical loads & critical levels approaches
  - Mostly national, but can be site-based.
  - Essentially only a risk assessment.

  "Likelihood of change"
- Bioindicators & biomonitoring:
  - Actual measurement of ecosystem parameters
  - Relates directly to site "condition"
  - Can consider temporal changes at a site level



Uncertainties and needs

- Wide range of different views regarding the usefulness of bioindicators & biomonitoring for N.
- Potentially attractive for Agencies to help monitor site condition in relation to air pollution impacts and for local assessments
- Uncertainty regarding the specific benefits and limitations of the different methods.
- Need research…

JNCC & Agencies Research Project

- Stage 1:
  - Review existing methods
  - Test novel techniques at one site
  - Identify methods with high potential for further application by Agencies
- Stage 2:
  - Further test the practical application of methods recommended for application
  - Use 4 key sites for detailed methods (NH_3, NO_x, wet deposition and controlled dose comparison)
  - Simplest methods to be then applied at UK scale.

Definitions

- Can get easily hung up on definitions – keep it simple here
- Bioindicators:
  - General group of approaches where biological measurement used to indicate something (e.g. might be applied at one time for spatial comparison).
- Biomonitoring:
  - Repeated application of bioindicator methods over time (e.g. weeks to decades)

N bioindicators: What is being indicated?

- Several purposes for N bioindicators to estimate:
  - N deposition fluxes from the atmosphere
  - Air concentrations of N species (NO_x, NH_3 etc)
  - Environmental effects of N, including physiological and environmental changes

- Should consider biomonitoring in conjunction with physical monitoring
- Can use biomonitoring results as input for local application of the critical loads approach.

Types of N bioindicator methods

Biochemical methods

- Measure the accumulation of N or a chemical/physiological response in a plant/soil component

Species composition methods

- Record the presence of certain species previously categorized according to their N preferences and generate an overall site index

Transplant methods

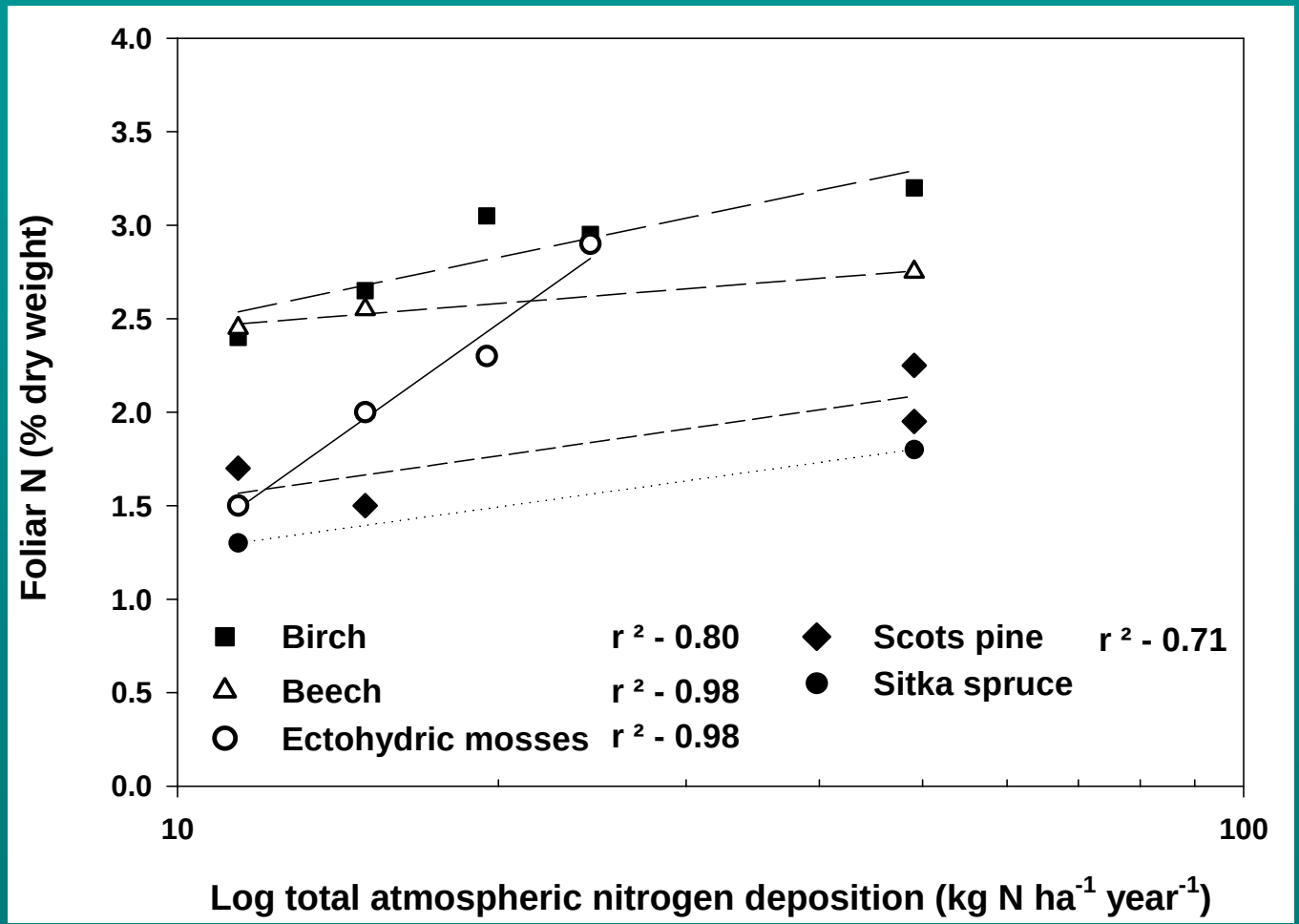
- Locally occurring or standardized plants are exposed to a range of N conditions and their responses assessed.

Biochemical bio-indicator methods for nitrogen

Foliar tissue N

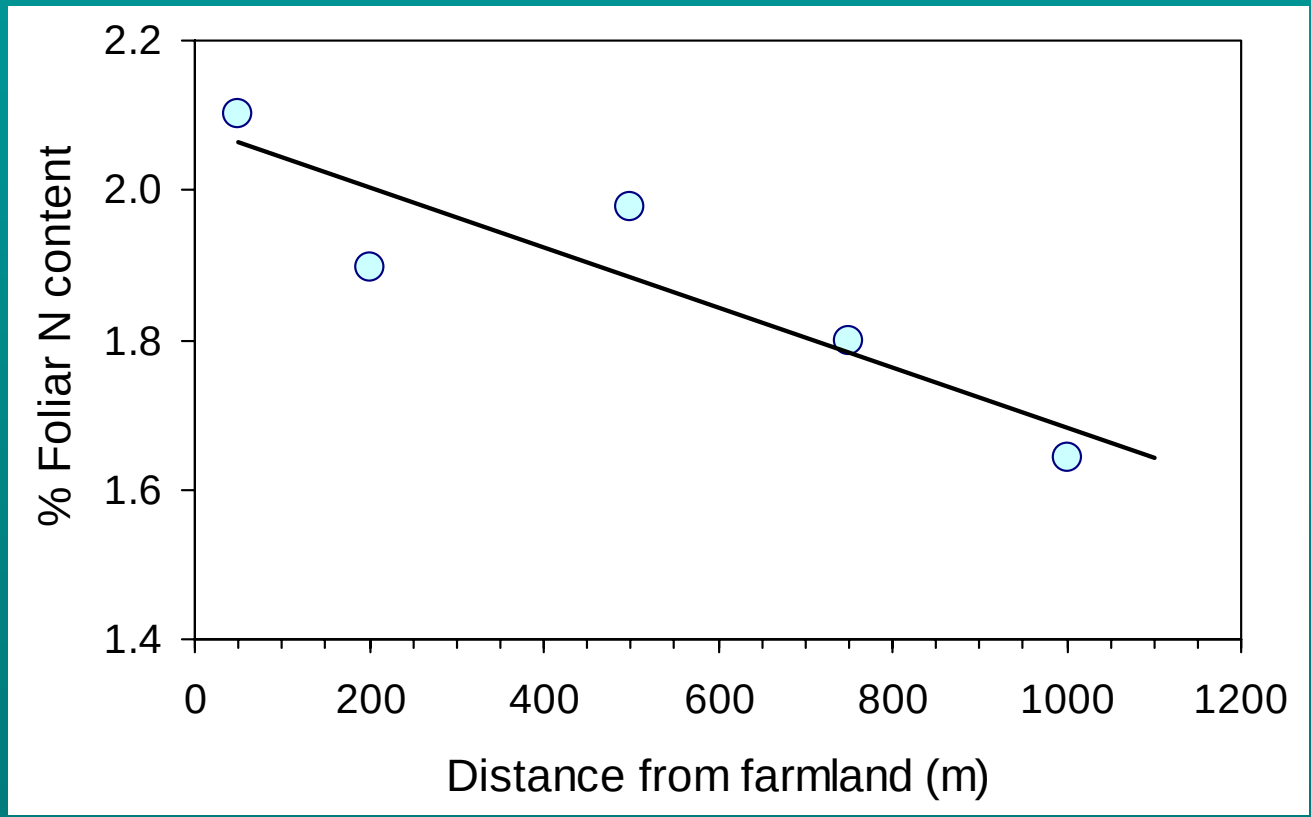
- Most extensively studied parameter
- Response to N deposition rather than concentrations
- Uncertainties in the past particularly related to need to standardize protocols and have robust reference estimates of N deposition.

Total foliar tissue N



Results near a farm at Earlston in Scotland

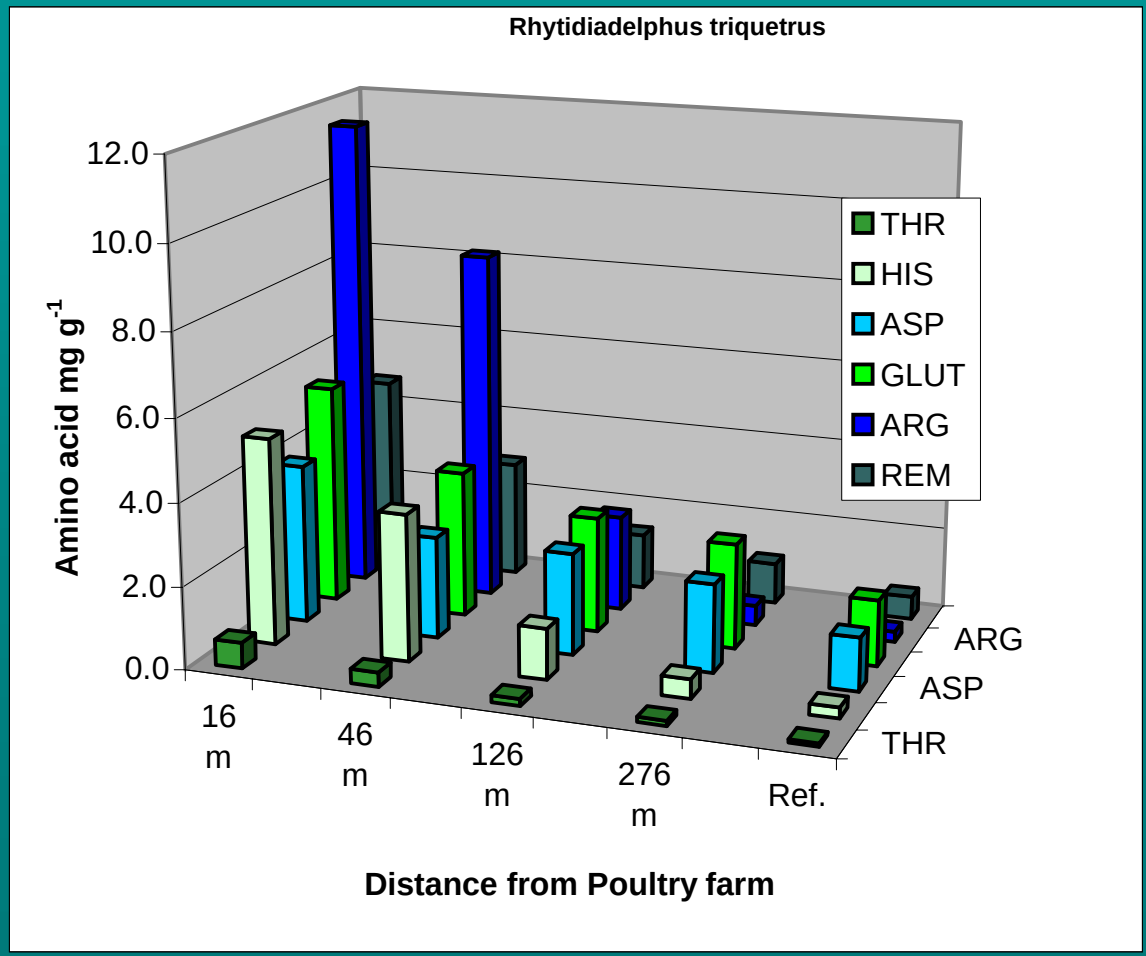
Spatial variability of foliar N



Results from Leende Heide, the Netherlands

Foliar amino acids

- Large rates of accumulation
- But amino acids accumulated different between species



“Substrate N” and foliar ammonium

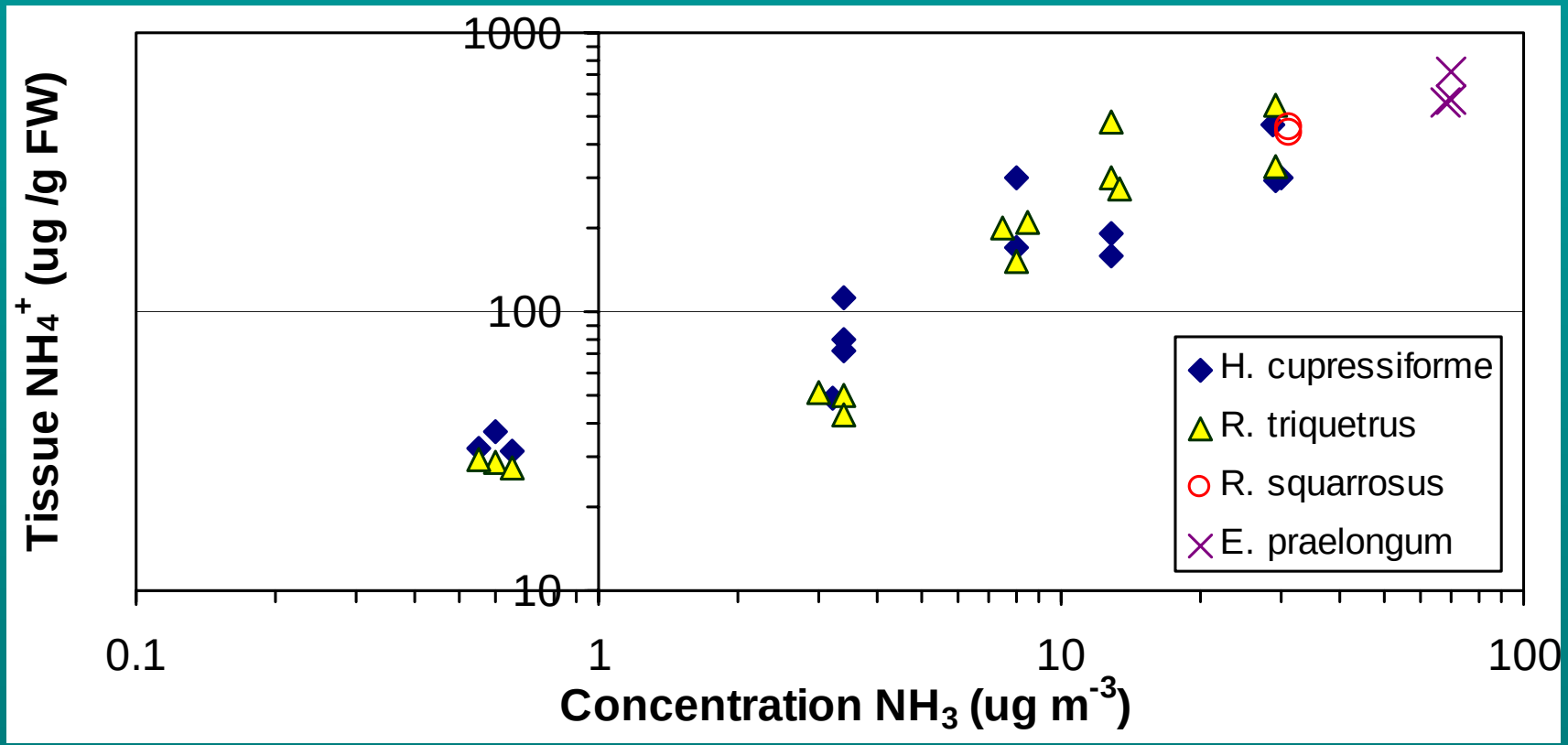
Substrate Nitrogen

- Total available N for growth expected to vary more than total N.
- Approximate substrate N by measuring total soluble N in leaves.
- More general than amino acids

Foliar ammonium

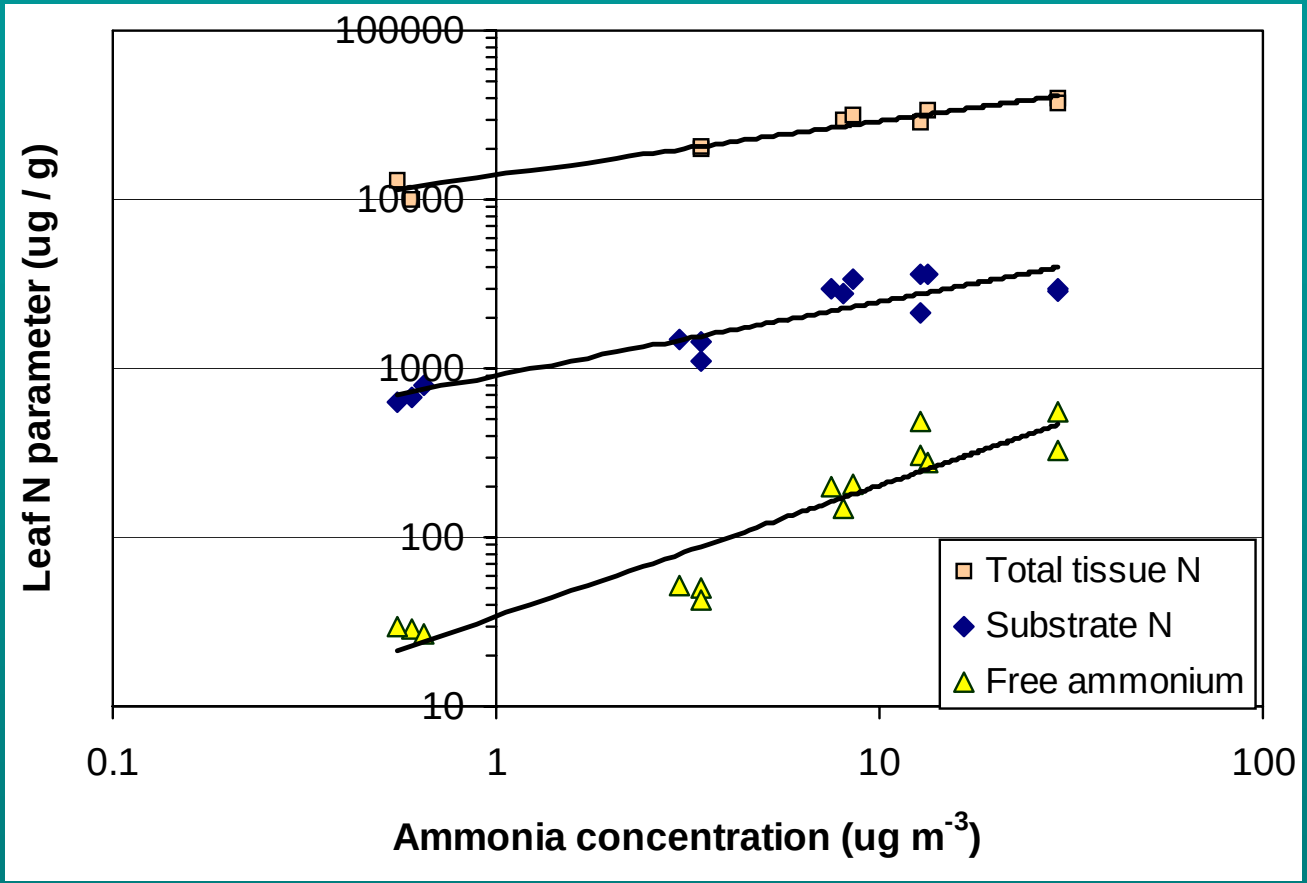
- Foliar ammonium represents primary pool for N compound synthesis and recycling
- Smaller pool expected to have larger response

Foliar ammonium



- Best results so far for bryophytes
- Species differences consistent with N habitat preferences
- Massive response of factor 20 over range tested.

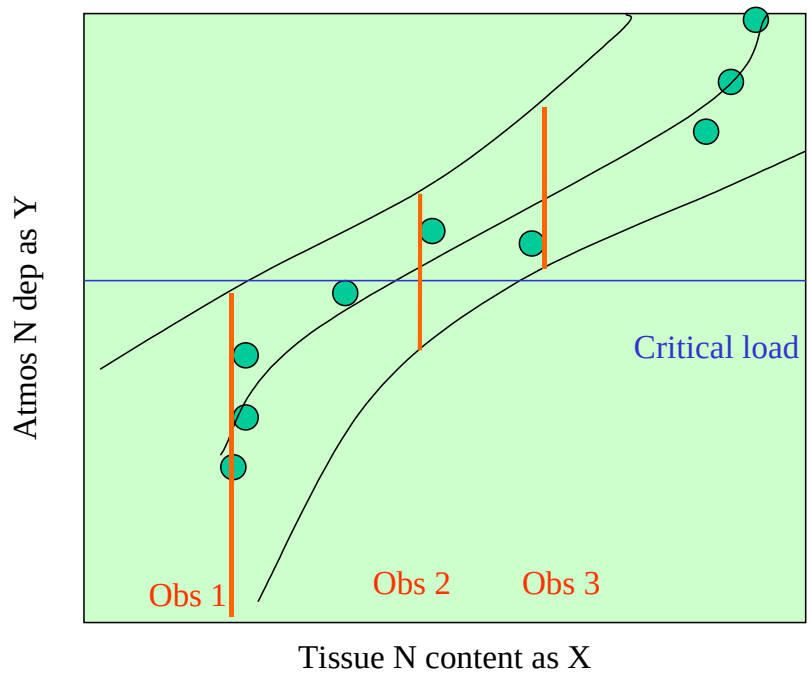
Response of different foliar N pools



- Larger response from the smaller pool size
- Smaller pools may also respond more quickly to change in N deposition
- Foliar ammonium potentially easier to measure

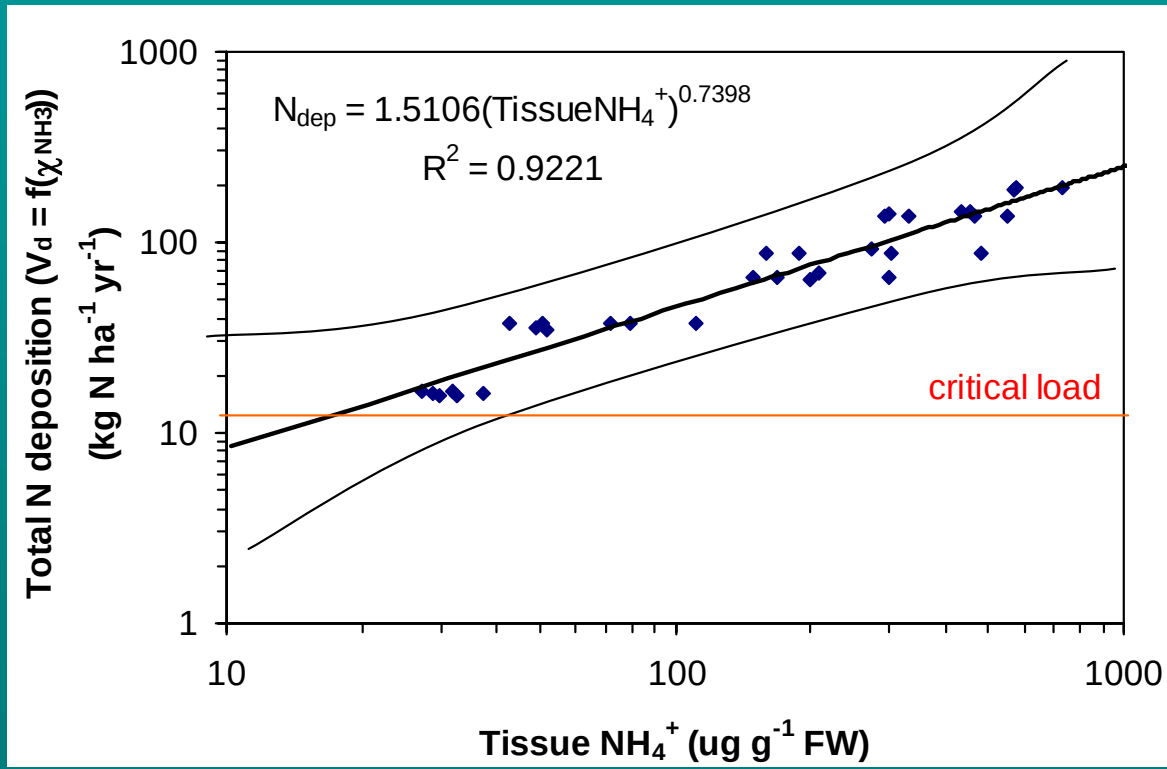
Combining Bioindicators with the Critical loads approach

- Currently feasible for foliar N and foliar ammonium
- Measured biomonitor data indicates whether a site is significantly above or below the critical load



Estimating N deposition based on foliar ammonium

- Bryophytes in woodland ground flora
- Needed for more data in clean conditions to improve confidence limits



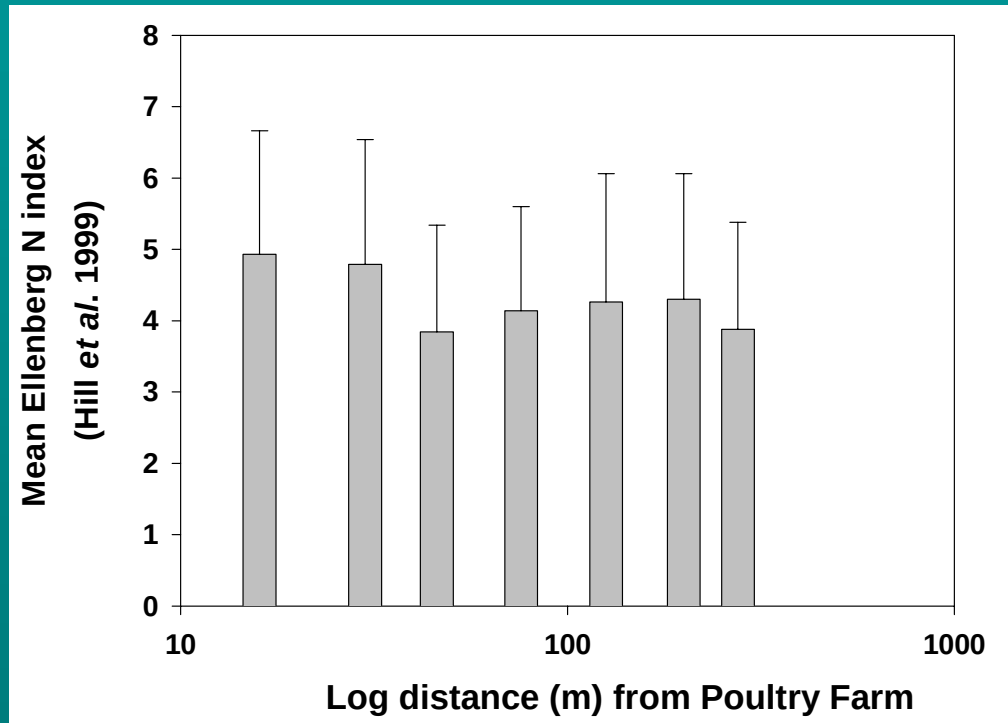
Biochemical bioindicators of plant N responses

- Response parameters include enzyme activities, soil emissions and bioassays of damage e.g. tests of frost hardiness or photsynthetic activity.
- Methods relevant to assess ecological impacts and for monitoring of general ‘condition’
- But less direct than accumulation methods and more affected by other factors, so generally less well suited to assess N deposition.

Species composition bio-indicator methods for nitrogen

Ellenberg Approach for Higher Plants and Bryophytes

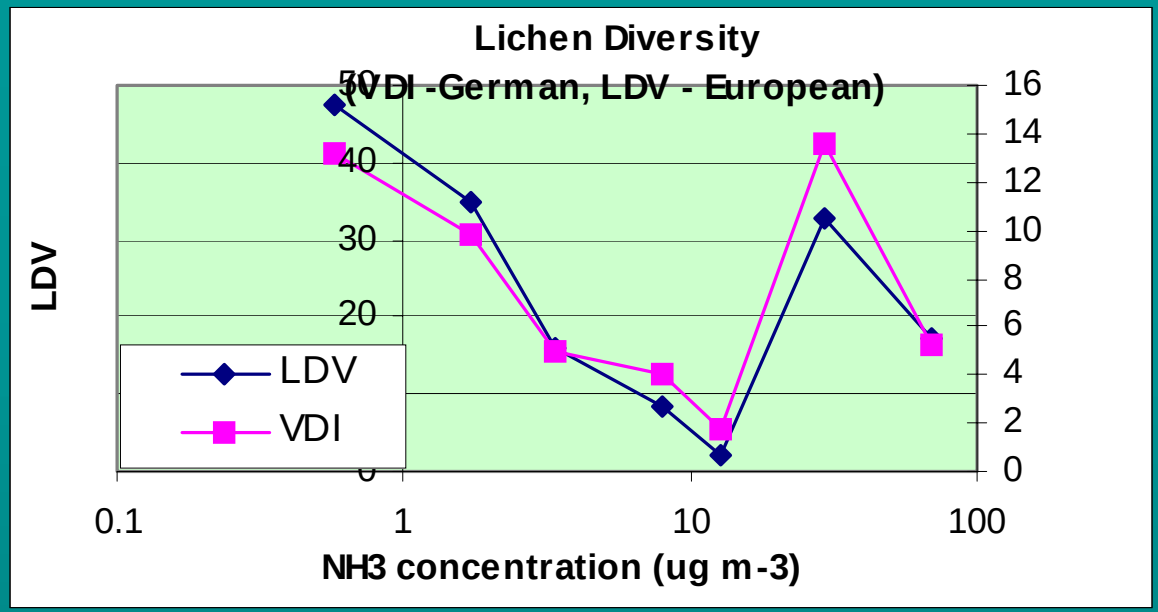
- Demonstrated close relationship to N deposition
- But species composition affected by many other factors, especially soil, management & light effects.
- Suited to local scale assessments and long term biomonitoring

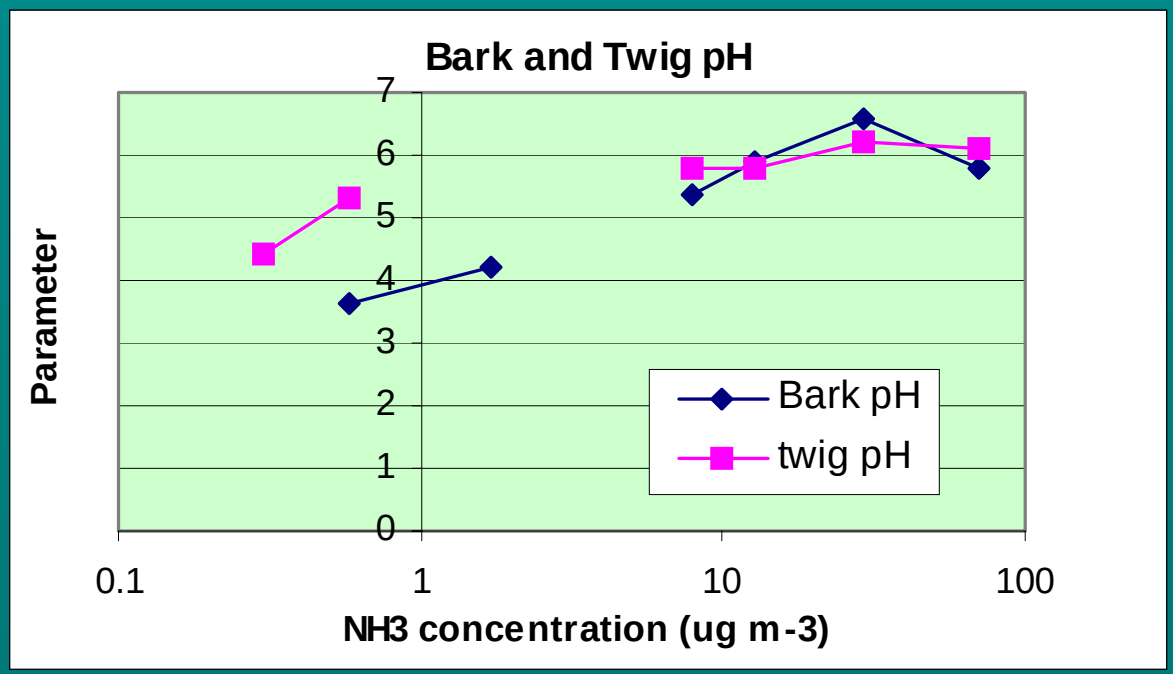


Lichens for assessing impact of atmospheric nitrogen

- Tested:
  - several overall biodiversity measures
  - Several N indicator methods inc.
    - Ellenberg (Wirth) values
    - French (Lallmont) scale
    - Van Herk (Acidophyte / Nitrophyte classification)
    - Compared Twigs and Trunks
    - Also assessed bark pH
- Some suggestion: Lichens are particularly responding to NH_3. Effects of NH_4^+ and NO_y are much less certain.
- Effect of NH_3 to *increase* bark pH is critical

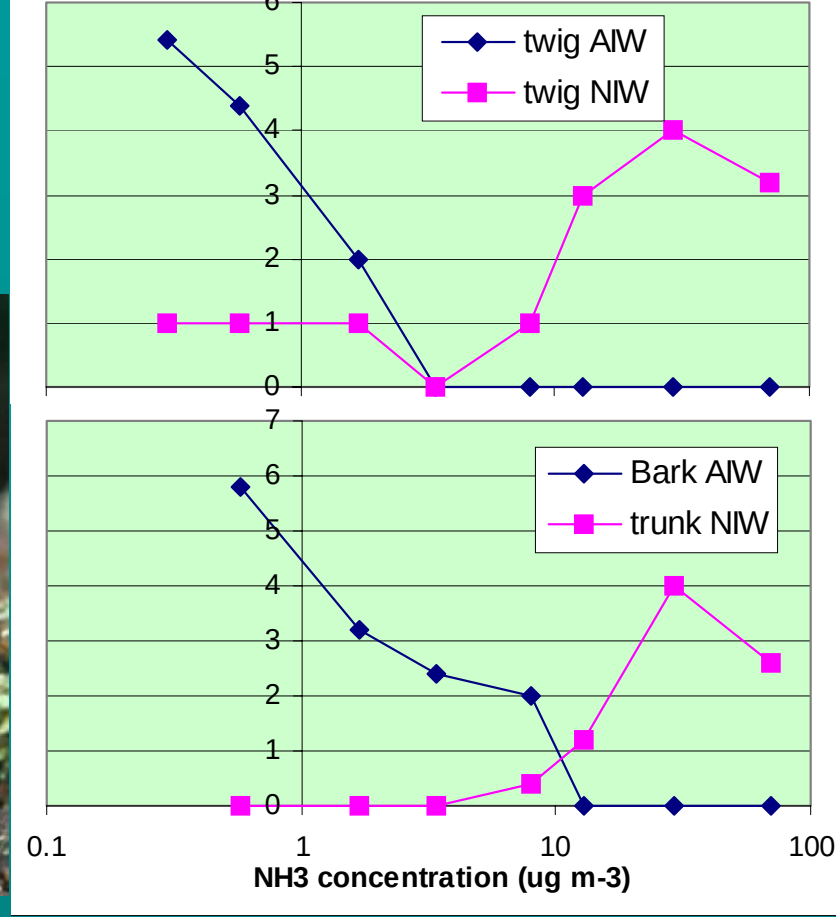
Total Lichen biodiversity and bark pH





Sensitivity of lichens to NH_3

Acidophytes (AIW) hate NH_3



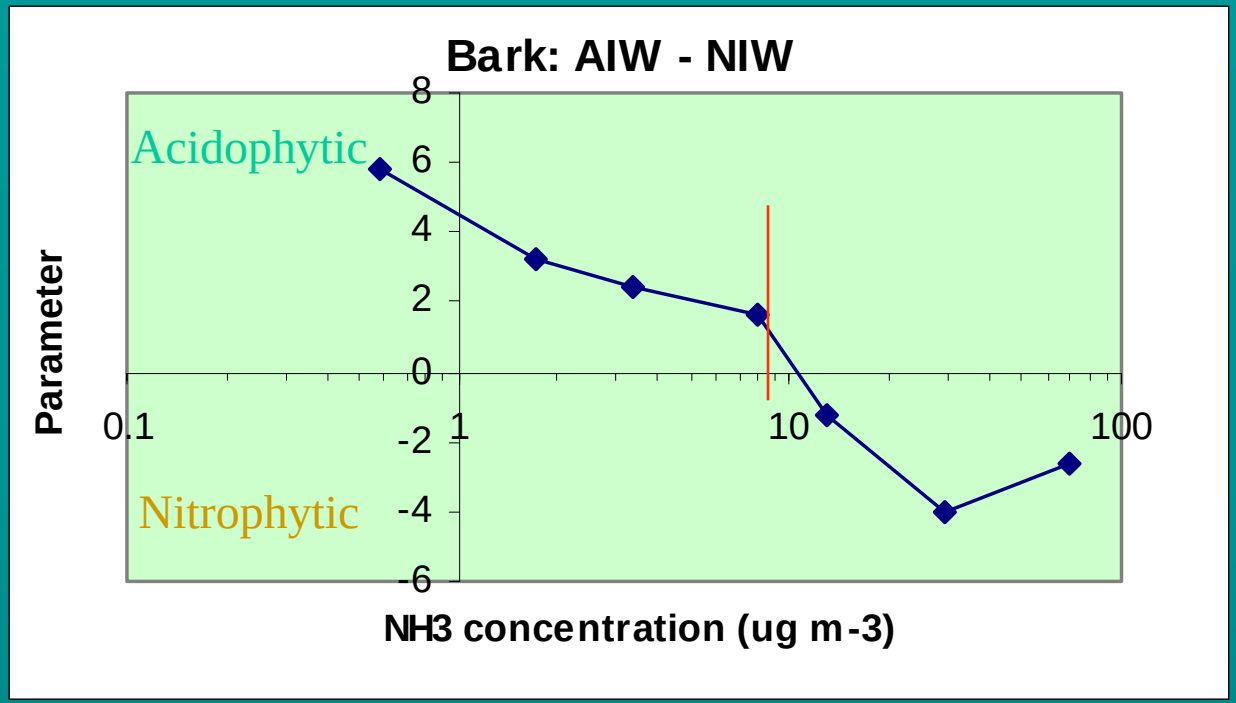
"**Troll's Beard**" (*Bryoria*):
disappearing from many sites

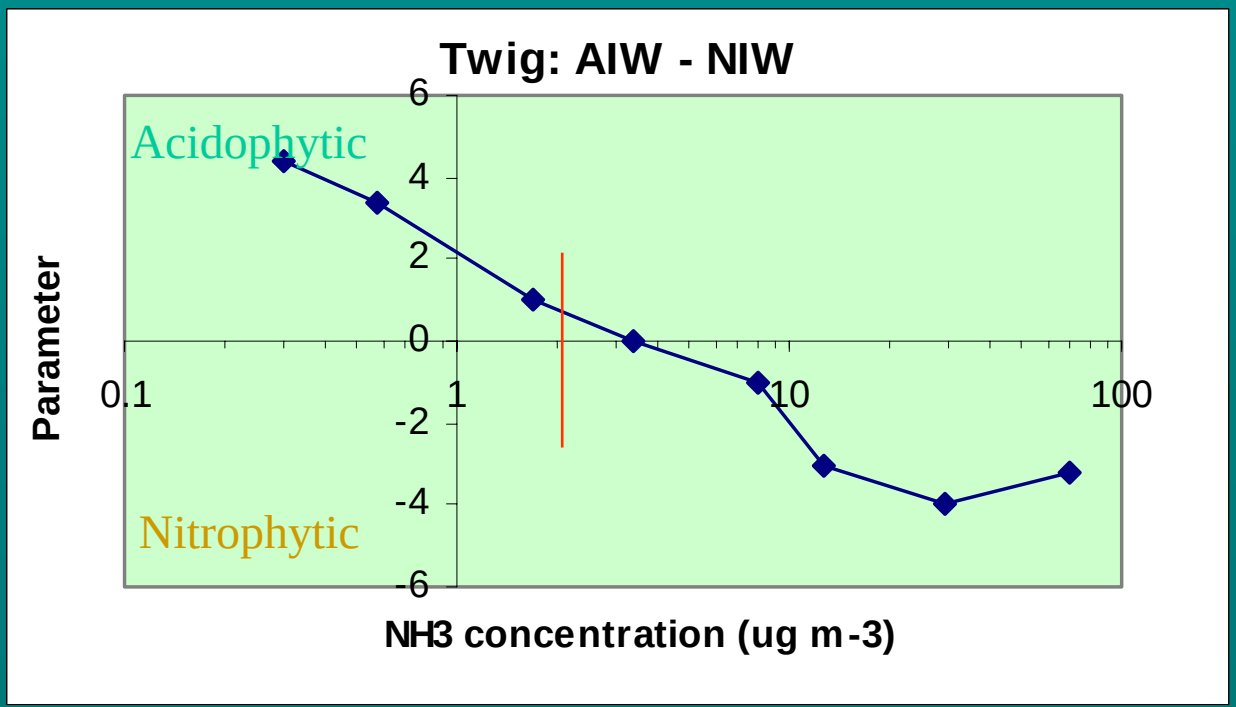
Cladonia

Nitrophytes (NIW) love NH_3

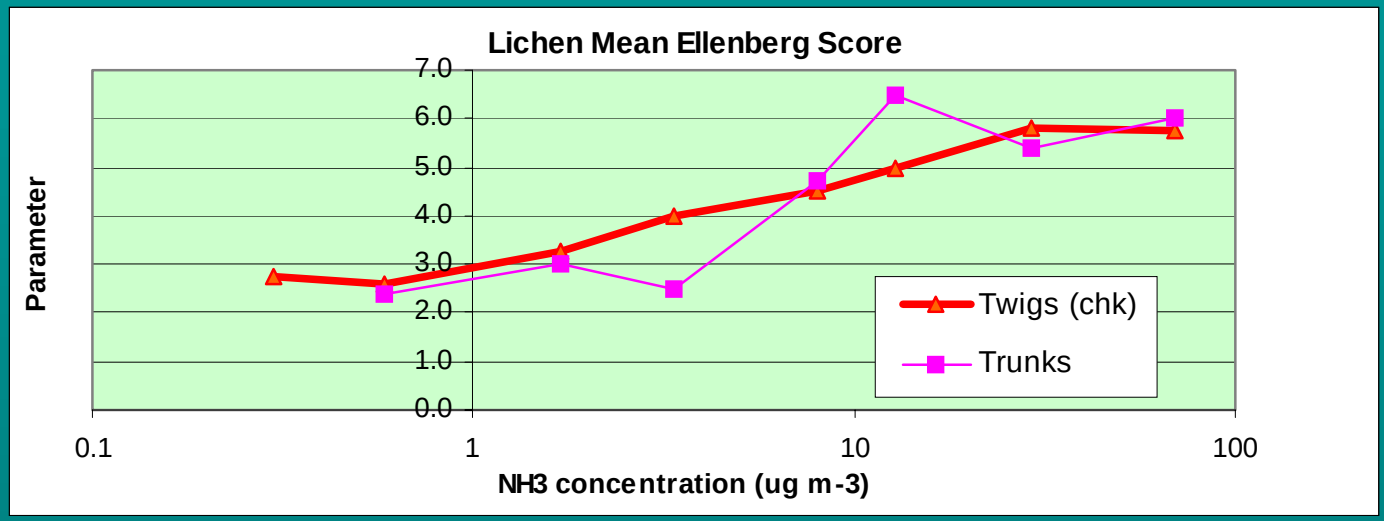
Xanthoria
thrives by farms

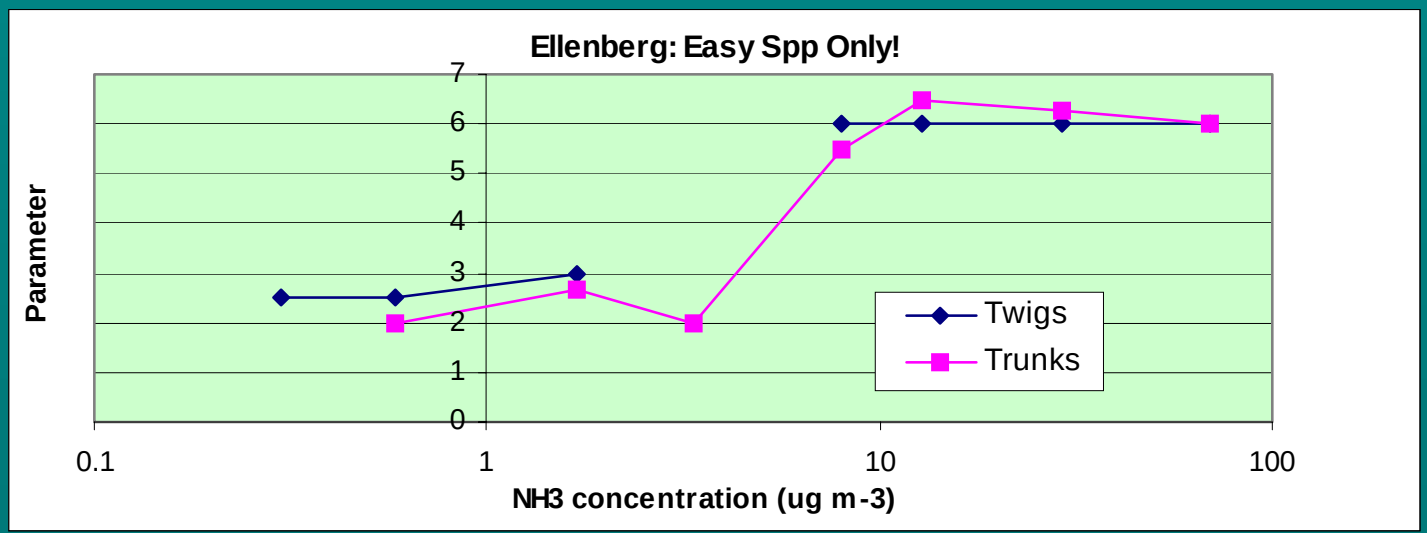
Combination of Acidophytes and Nitrophytes





Ellenberg (Wirth): detailed and potential simpler system

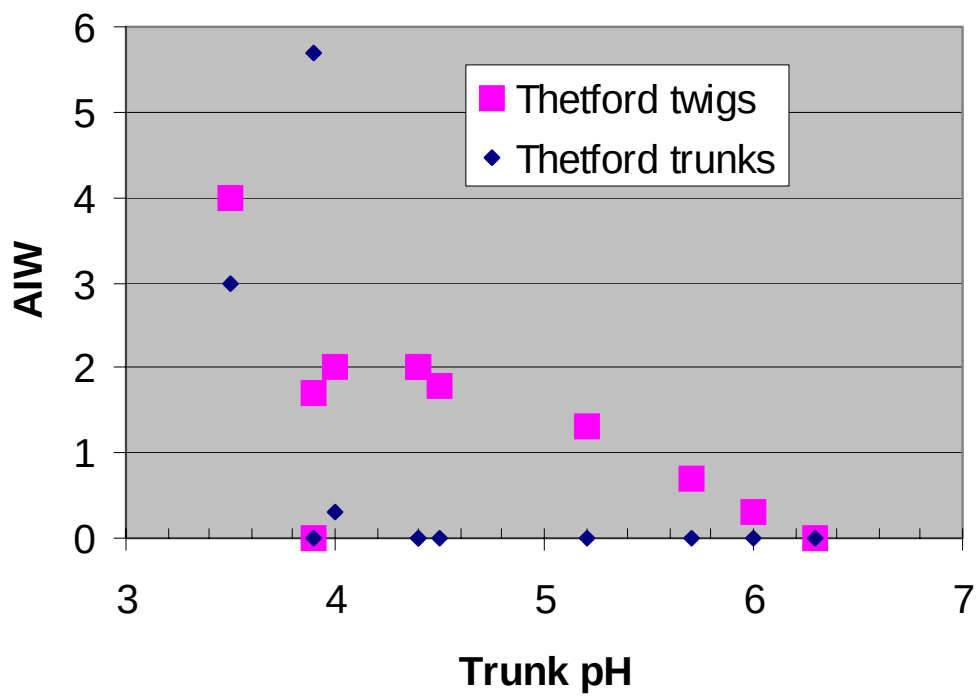


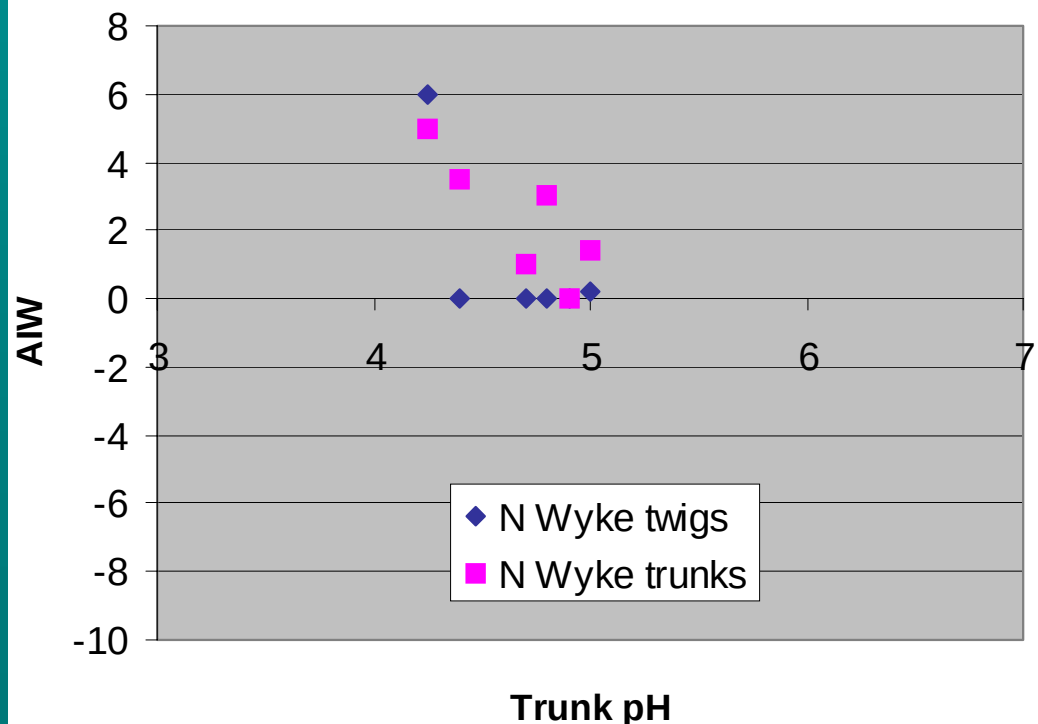


Critical bark pH for twig and trunk acidophytes

Twig acidophytes are completely excluded above a trunk pH of 4-4.2 This equates to an NH3 conc of around 2 ug m^{-3}.

Note outlier for Thetford trunks: rich Parmelion community (not in AIW)





Potential for two-tier Lichen approach for Nitrogen

- Detailed method: further develop van Herk approach, including application to twigs. Good for full site assessment by experts.
- Simpler method: refine simple Ellenberg approach, including application to twigs. Good for application by trained non experts to get indications at sites and for raising public awareness.

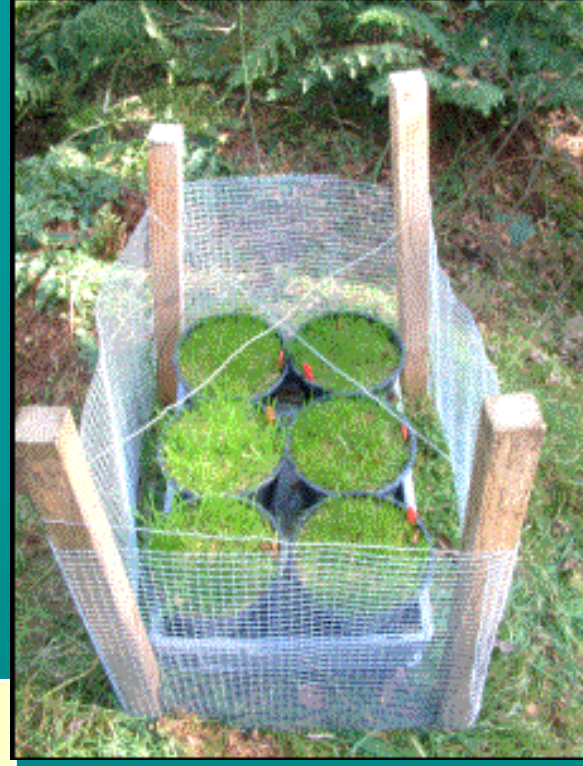
Transplant bio-indicator methods for nitrogen

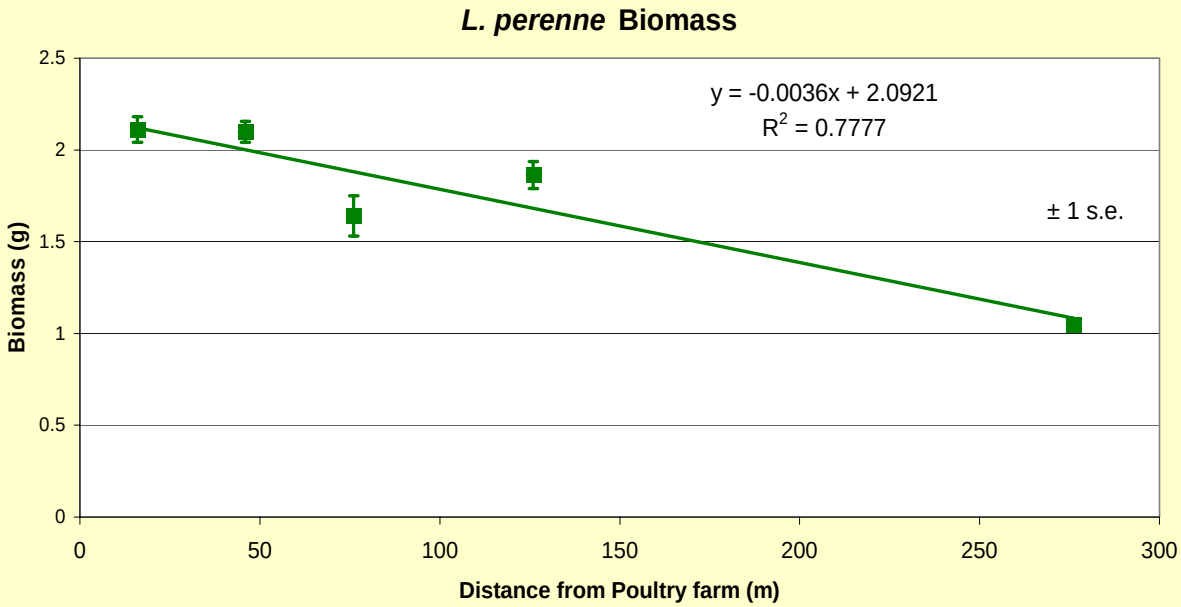
Native reciprocal transplants

- Works best for bryophytes – no soil attached and more robust than lichens
- Need two or more locations with similar climate
- Measure growth rates, and N content
- Observe reduced performance in polluted conditions or recovery in clean conditions
- Good for demonstration to stakeholders to show the benefits of emission abatement at a site level.

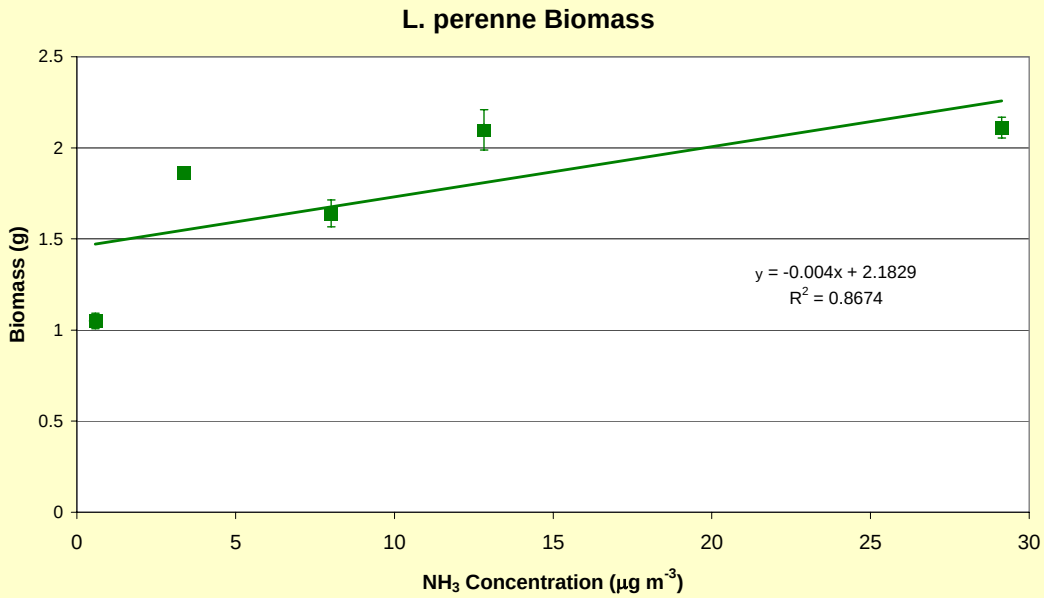
Grass biomonitors

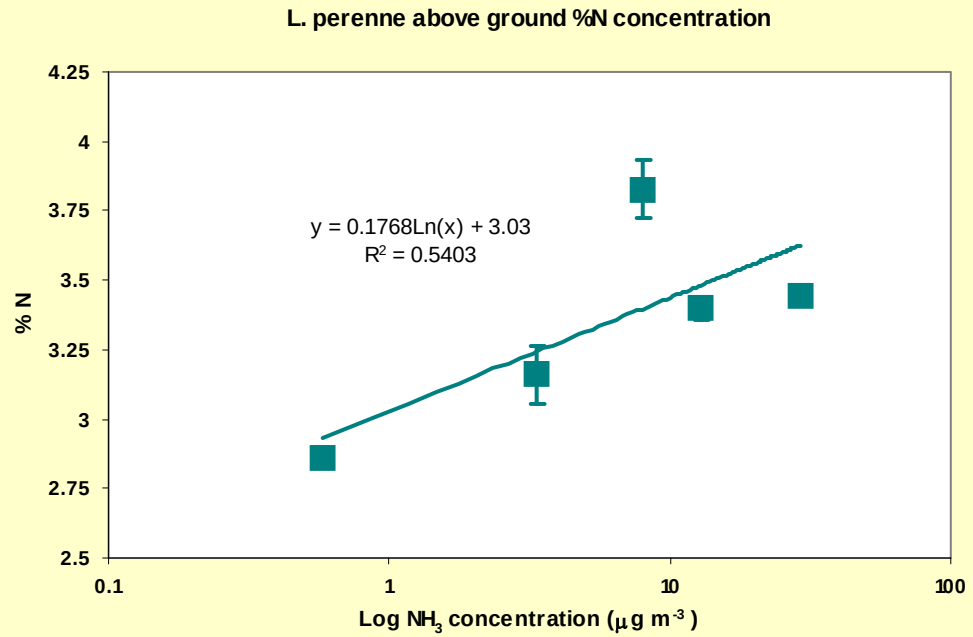
- Lolium perenne using EUROBIONET wicking system



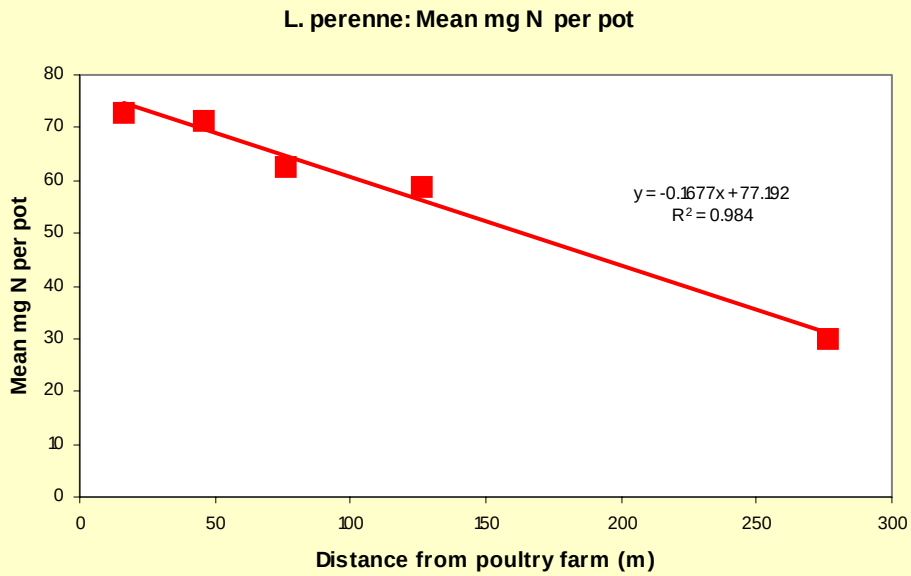


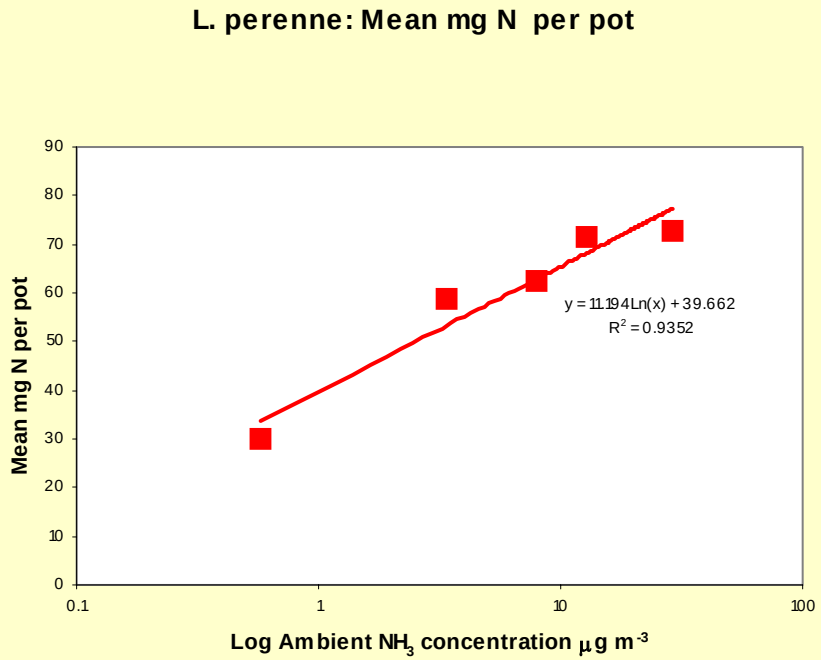
Grass biomonitors



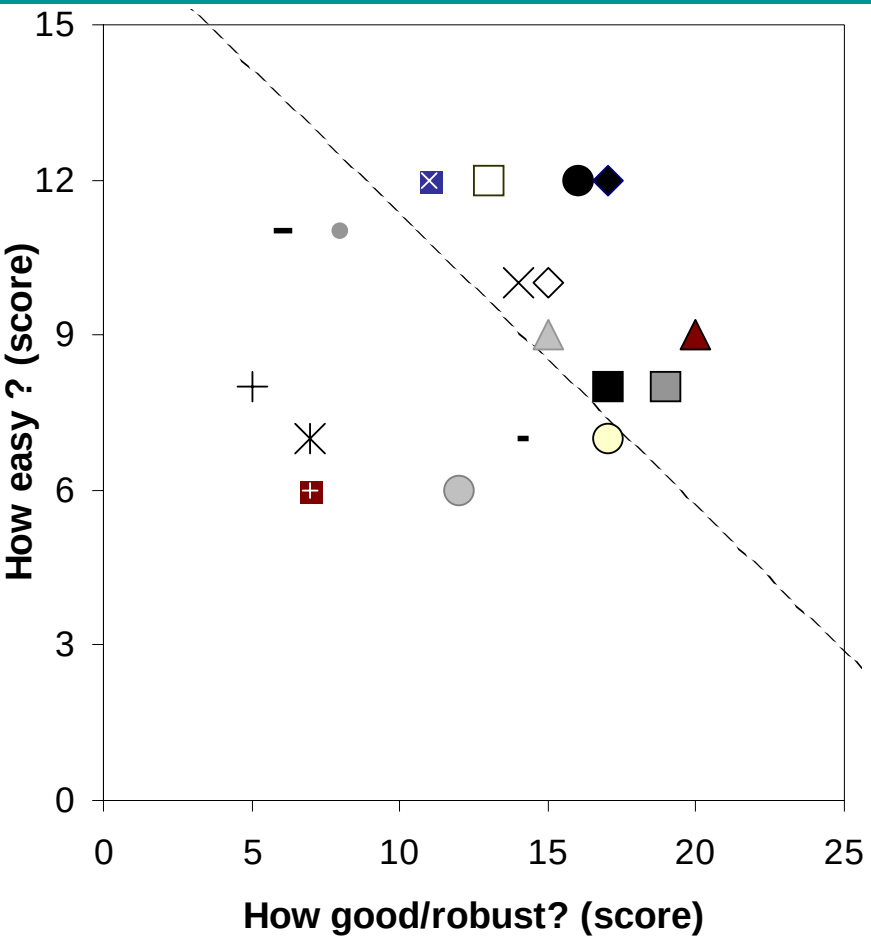


Grass biomonitors





Overview of methods tested and recommendations



- Foliar N conc.
- Foliar amino acids
- Enzyme Activity
- Substrate N of foliage
- Foliar N:P ratio
- Ellenberg (plants)
- Lichen diversity
- Lichens (van Herk)
- Lichens (Lallemont)
- Lichen (v. Hk modif for Twigs
- Lichen (Simplified Ellenberg)
- Standardized plant transplant
- Native transplant
- N isotope analysis
- Frost hardiness
- Chlor fluorescence
- Soil gas fluxes (N2O, NO)
- Soil invertebrates
- Selection limit

Classification of method types and recommendation for further development

- Chemical Methods
  - Total foliar N
  - Soluble foliar N/NH_4^+
  - Bark pH
- Diversity Methods
  - Ellenberg scale (Higher plants and bryophytes)
  - Van Kerk scale for lichens (inc for twigs)
  - Ellenberg (Wirth) scale for lichens (inc for twigs)
- Transplant Methods
  - Standardized grass transplants
  - (Native reciprocal transplants)

Conclusions

- Methods refer to different timescales – This affects the translation from bioindicating to biomonitoring.
- The methods by definition refer to an ecosystem or biological impact – therefore they give a direct implication of critical load / level exceedance
- The accumulation methods most quantitatively related to atmospheric deposition, but different different deposition components may have different effects.
- For application to statutory nature conservation sites the bioindicators can be best used for local sources with small scale transects into reserves (NO_x and NH_3 as sources).

Conclusions and next steps

- The assessment for elevated wet deposition is much less certain (due to linked altitude effects).
- The most robust assessments would use more than one method in parallel and complement physical monitoring efforts.

- Ongoing work is focusing at 4 sites for detailed methods, plus UK wide survey of simple methods.
- Contributors are invited across the Agencies to try out the simple methods next year.