high wet deposition inputs at this site (shown by the distinction between NH_3 and NO_x concentrations versus total N deposition). Even at the 200 m site, moss chemical parameters are already at the critical limit, although these are increased substantially by the presence of the road at the 10 m site for both total N and foliar ammonium. At the two Happendon Wood sites the lichen assessment gives rather unclear results, and this may be explained by three reasons: a) data for oak were not available for the 10 m site and the 200 m site shows significant scatter, but no clear effect, b) the remaining data are for pine, for which the lichen methodology is much more uncertain, c) the influence of roads and associated N on lichens is significantly different to that of NH_3 from agriculture.

A detailed Ellenberg assessment of the woodland ground flora was made at the Happendon Wood sites. This showed that while the site most distant from the motorway did not exceed the Ellenberg benchmark, the site adjacent to the motorway exceeded it substantially.

16.8. Conclusions

It is obvious that there is significant work needed to refine the intercalibration of nitrogen indicators. In addition to benchmarking the indicators, with critical thresholds, it is essential to ensure that the quantitative responses are comparable. This may seem obvious, but it actually requires careful design of the indicator scales to ensure comparability between such a wide range of different data types (e.g. concentration, deposition, foliar concentrations, injury, species diversity scores etc) and responses.

The choice of how to set such scales can be informed by considering the purpose of site assessments with bioindicators (c.f. Figures 16.4 and 16.5). Firstly, these focus on establishing an integrated quantification of the status of the system in relation to the benchmarks. Secondly, they provide a framework to monitor the success of policy and management actions to reduce atmospheric N deposition to sustainable levels. Given the importance of this second objective, the indicator scales should, as far as possible be set in proportion to the extent of pollutant exposure. Hence, in the example of Figure 16.4a, a reduction of current pollutant exposure of at least 75/175 = 43% would be required to bring the indicators within the critical values in the long term. As noted, scaling indicators by exposure also has the practical advantage in that the scales for air concentrations and N deposition are already well established ($\mu g\ m^{-3}$ and $kg\ N\ ha^{-1}\ y^{-1}$, respectively), with the critical values (critical levels and critical loads) being widely recognized.

Two elements to indicator the range calibration need to be addressed. The first is the *response intercalibration* of the indicators as normally measured. In this case, the objective is to relate quantitatively the response of one indicator to another, e.g. a lichen diversity indicator score to given NH_3 air concentrations. The second is the *unit normalization* of the indicator scores, so that measured values for different indicators can be interpreted on a common basis. In this case, the basic indicator value is transformed to a related measure and presented as a percentage of the critical indicator value in a way that aims broadly to maintain the proportionality between indicators for values above and below 100%.

Recommendations for future work

The following key recommendations are identified:

- The current study found that the selected bioindicator methods were robust at sites with defined N point sources. However, for sites with diffuse long-range N deposition it was more difficult to quantify the impacts of N. Therefore, further development of bioindcator methods needs to be targeted at sites with long-range and often wet dominated N deposition.

- The successful testing of epiphytic acidophyte and nitrophyte macrolichen indicator species against atmospheric pollution and environmental data will provide a basis for the development of a standardised method for widespread use in the UK. Therefore, there is a requirement to refine the simplified protocol and provide an illustrated guide for use by field officers either as part of the CSM or specifically targeted at sites identified as potentially at risk from atmospheric N impacts.

- The new acidophyte/nitrophyte index for vascular plants and bryophytes identified in the Ellenberg study of intensive sites requires further refinement using key species. The development of this approach using the sensitivity of key species in response to nitrogen requires a limited botanical training, could be a useful addition tool for site staff (including conservation and environmental agency staff). Analysis of existing datasets and additional field survey work are required to refine this approach.

- Bioindcators can provide an 'early warning' signal of potential N impacts to designated nature conservation sites. Establishing the response timescale to the 'end point signal' is also an important feature in using such indicator species. The use of bioindicators and their appropriate timescale in response to exposure requires testing across sites at risk from N deposition by regular monitoring using selected biomonitoring methods following specific examples of known changes in N deposition.

- The use of the biochemical method for detecting tissue soluble ammonium concentration proved to be a useful additional biomonitor tool for pleurocarpous mosses. However, further refinement of this method is required using an extended range of moss species in order to provide an index of the relationship between soluble ammonium concentration and atmospheric NH_3 concentration and N deposition.

- The UK extensive study showed that pleurocarpous mosses responded to changes in N and particularly NH_3-N concentrations. As NH_3 concentrations are very site specific, the relationship between moss foliar N concentrations and NH_3 should be further refined by sampling selected pleurocarpous moss species at the National UK Ammonia Network sites.

- The UK extensive study has shown that there are moss species-specific responses to both NH_3 concentrations and N deposition. Therefore, screening of the common moss species to determine their individual response to both NH_3 and N deposition is required. It is also recognised that there is seasonal variation in N concentrations in pleurocarpous mosses. This variation may be species-specific and repeated seasonal measurements at key sites.

- The current study identified that a defined pleurocarpous mosses tissue N content and soluble ammonium concentration could be determined for specific habitats. This was based on a limited number of sites and habitats. Additional work is required to further refine the N concentrations for those habitats already identified and to also include additional habitats.

- The UK scale lichen assessment provided a remarkable new dataset demonstrating the sensitivity of lichen responses to NH_3 at a UK scale and the interactions with bark pH. The method is so far based only at 32 sites, and should be extended by further testing at other locations across the UK. In particular, use of the other sites in the National Ammonia Monitoring Network could allow the calibration to be improved by recording at a further 50+ sites (depending on local availability of suitable trees).

- The lichen assessment highlights the increased sensitivity of lichens on twigs compared with those on trunks of the same tree species, linked to the differences between bark pH.

It has been suggested that there is an association with the age of the substrate and that lichen communities of the trunk may carry relicts of former conditions while colonisers of the new twig substratum are associated with present conditions. This expectation needs to be properly tested by sampling at sites following a known perturbation (e.g. monitoring change after the installation of a new farm source).

- This report has also provided a theoretical analysis of approaches to improve robustness in biomonitoring and the applicability of results. It is evident that further effort needs to be placed in refining the benchmarking and intercalibration of indicators in order to refine an integrated operational approach to nitrogen indication.