15. Assessment of nitrogen impacts on condition and integrity of four case study sites

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15.1. Introduction

The application of simplified biomonitoring methods in the intensive and UK-wide extensive studies (Sections 4-13) provided the opportunity to test these methods under field conditions in a wide range of habitats and N deposition levels distributed throughout the UK. Assessments of the individual methods used at the intensive and extensive UK sites are summarised in Sections 8 and 13. These sections determined the robustness and applicability of the selected biomonitoring methods for potential application by the conservation and environment agencies as additional monitoring tools for assessing N impacts site condition and integrity of designated statutory sites.

The objective of this section is to apply/link the results from the simplified biomonitoring methods and the atmospheric N and S inputs, to the condition and integrity of four case study sites in relation to the attributes for the interest feature of the specific habitat.

The four case study sites to be considered are Piddles Wood from the intensive study and Ariundle, Caldanagh Bog and Llanymynech and Llynclys Hills SSSI, three of the sites in the UK extensive study.

15.2. Background

15.2.1. Condition Assessment

The conservation agencies are responsible for the identification and protection of sites designated under national and European legislation (e.g. SSSIs, ASSIs, SACs, SPAs and Ramsar sites). Each site is designated on the basis of special interest feature/features, which could be a specific species, an assemblage of species, habitats, or earth science features. Once established as a designated site, one of the key roles of the conservation agencies is the continued protection of these designated sites. The condition of sites is assessed by the conservation agencies using common standards monitoring (CSM), whereby key attributes are identified and broad targets set for each feature at each designated site. The sites are monitored, on a six-year cycle, to assess the condition of the specific attributes and the feature as a whole.

Common standards monitoring is designed to be a 'simple, quick, judgement-based assessment of the feature condition' (www.jncc.gov.uk). It is important to note that the CSM assessment is for the feature of the designated site and not the site itself. CSM provides a number of categories for recording of the condition of interest feature.

- Favourable - maintained
- Favourable – recovered
- Unfavourable – recovering.

- Unfavourable – no change
- Unfavourable – declining
- Partially destroyed
- Destroyed

The CSM assessments from different sites are used to enable judgement to be made about whether the management of individual sites is appropriate and whether current legal, administrative and policy measures are effective.

CSM is not designed to detect and attribute the impacts of N deposition (or other air pollutants) on the features associated with the designated sites. One of the key aims of this current project was to determine if simplified N biomonitoring methods could be applied (in addition to CSM, environmental modelling or critical load assessment) at specific designated sites to determine if the feature/s are being impacted upon by increased N deposition.

The key requirements for the use of N biomonitoring methods would be a) simple to apply, and effective b) give added value (compared to critical load assessment) and c) be an integral part of the overall assessment of the condition and integrity of a designated site.

CSM defines a series of attributes and associated targets for each interest feature on site. An attribute is defined as 'a characteristic of a habitat, biotope, community or population of a species which most economically provides an indication of the condition of the interest feature to which it applies" (www.jncc.gov.uk).

Targeted biomonitoring methods will provide an indication of the level of exposure and/or effect of N at a designated site. However, to be interpreted in the context of the existing monitoring framework (i.e. CSM) the identified effect needs to be related to the attributes of the interest feature for that designated site. Ideally, this would be a direct relationship (i.e. a measured impact on one or more of the attributes of the interest feature). However, in many cases it will be indirect and based on a judgement or association between the biomonitoring method and an ultimate response/effect on the attributes of the interest feature.

15.3. Site Integrity

Under the Habitat Regulations (1991), a competent authority (for example SEPA) must undertake an appropriate assessment for a plan or project (for example a PPC permit), which has the potential to impact on a European site, in order to ascertain whether there will be an adverse effect on the integrity of the designated site.

The current approach for assessing the potential impacts associated with emissions (either reactive N gases or other air pollutants) in relation to the tests of the Habitats Regulations is based on a risk assessment using 'site-relevant' critical loads. Therefore, a further aim of this project has been to consider the application of biomonitoring methods for assessing impacts on site integrity in relation to Habitat assessment and permitting conditions of authorised installations.

The definition of integrity is taken from DETR's Planning Policy Guidance 9 where integrity at the site level is defined as "The coherence of its ecological structure and function, across its whole area, that enables it to sustain the habitat, complex of habitats and/or levels of populations of the species for which it was classified".

15.4. Cause and effect biomonitoring conceptual model

If a designated site is suspected of being impacted upon by gaseous N concentrations or N deposition it is important to identify the N source for that specific site. Following source attribution the pollution-impact interactions with the designated feature or other potential indicators can be used to assess condition and integrity. Figure 15.1 outlines the source to response pathway for N bioindicators. This is explained in more detail in Section 16. This figure highlights that the strength of the link to source attribution and site condition/integrity increases once a physiological response has been identified. The diagram will be used as a framework in the condition/integrity assessment of the four sites using N bioindicator methods.

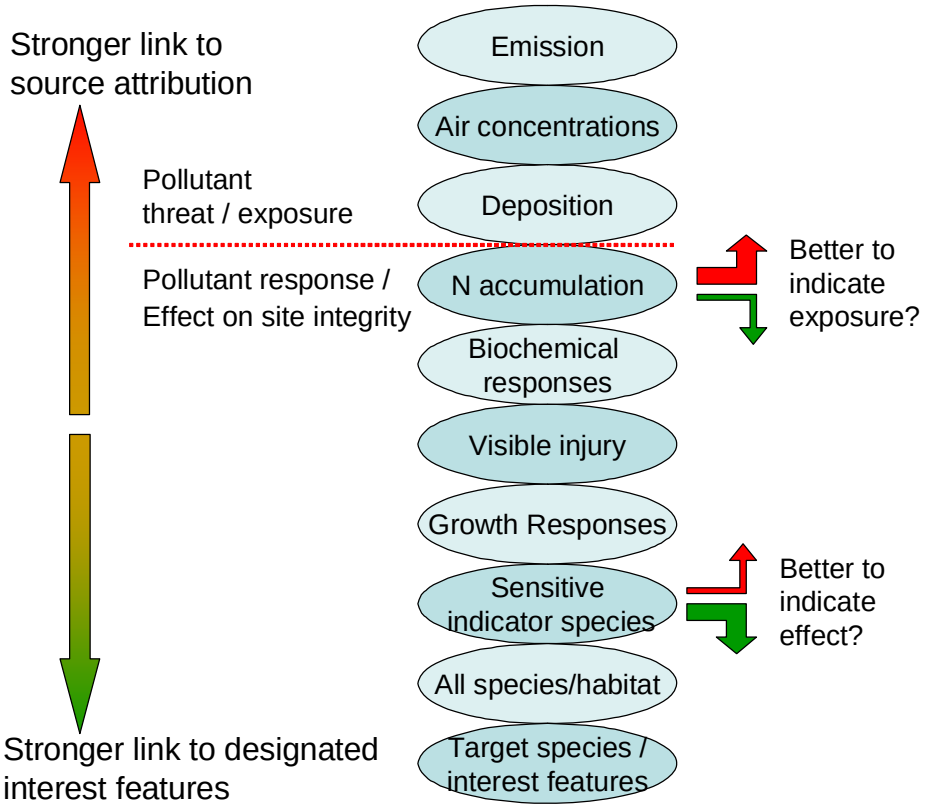

Figure 15.1. Cause/effect biomonitoring chain.

15.5. Piddles Wood SSSI

15.5.1 Nitrogen Source attribution

The major source of N deposition at Piddles Wood is gaseous NH_3 from the agricultural point source (poultry unit) situated in the SSW of the woodland. However, background deposition is also relatively high (26.2 kg N ha^{-1} y^{-1}) and exceeds the critical load for this habitat. The NH_3 concentrations and N deposition for this site are detailed in Section 3: Piddles Wood. There was a strong gradient in NH_3 concentration and total N deposition with distance from this point source (N deposition ranging from 1061 kg N ha^{-1} y^{-1} at 5 m from the poultry house to 26 kg N ha^{-1} y^{-1} at a distance of 250 m). It is recognized that there is a very high uncertainty in the largest deposition values at this site, for example due to the possibility of cuticular saturation effects, although this only becomes a major effect at deposition loads substantially larger than the critical load. For the

purposes of this assessment, the effects on condition and integrity are considered for the length of the transect only, and not the whole site.

15.5.2. Biochemical, physiological and ecological responses

Biochemical, physiological and ecological responses to elevated N in the form of NH_3 emissions from the adjacent point source were shown on the site by the use of a suite of biomonitoring methods including standardised plant growth and development, tissue N analysis (total N content and soluble NH_4-N concentration), pleurocarpous mosses, Ellenberg Index and lichen diversity.

15.5.3. Interest feature

The feature of interest for woodland is seldom a single vegetation type, as is the case for Piddles Wood, where the main habitat is a lowland broadleaved mixed and yew woodland. The site was notified as an SSSI largely because of its substantial oak woodland with coppiced hazel understorey. Thus the feature of interest could be said to be the woodland structure and species composition of woodland, shrub and ground layers. A full site description is given in Section 3.2.2.

15.5.4, Site Condition: Attributes

The attributes for woodland are defined and described in JNCC's commons standard monitoring guidance (www.jncc.gov.uk/page-2203/common standards monitoring guidance). For most woodland habitats, the conservation objectives define five broad attributes, which are **extent; structure and natural processes; regeneration potential; tree and shrub composition** and **indicators of local distinctiveness**. These are described in more detail below. The results of the biomonitoring methods study are then evaluated in relation to the above attributes.

Extent
This feature includes the distribution of the woodland feature across the site and is concerned with assessing the gross changes in the overall habitat extent. At Piddles Wood, the tree composition varied across the site with the site being divided into 4 management units. The tree species composition was relatively consistent along the study transect, except at 100 m from the farm NH_3 source, where more mature oak were found.

The Ellenberg index would give an indication of change in tree species composition, which could be directly related to N deposition. However, Ellenberg Index is probably more applicable for use in the **composition** attribute (see below). Similarly, the lichen species diversity method would indicate changes in lichen species composition but it does not indicate change in extent of the interest feature at Piddles Wood. The species composition measures and the foliar N methods are not applicable to the extent attribute of this interest feature. On the whole there is little relationship between the biomonitoring methods and this attribute.

Structure and natural processes
This attribute includes the extent to which the structure should be determined by natural processes rather than defined by management; the level of dead trees and the balance between canopy and shrub layers. Ellenberg Index could have an important role to play in this attribute. Ellenberg Index would highlight changes in shrub composition changes, which would then potentially change the canopy shrub balance. Accumulation and physiological indicators are also relevant for this attribute, since they demonstrate an alteration of natural processes.

Regeneration potential

This attribute includes the level of saplings and young trees expected to be seen and the extent of coppicing. This is an important attribute at Piddles Wood, as much of the unit where the poultry unit is located is regenerated coppiced woodland. Changes in shrub and ground flora species composition due to the increased N deposition from the poultry farm could lead to a reduction in regeneration of interest feature species. Potential alteration of the soil pH may influence seed germination of interest feature species. An increase in ground flora and shrub species may also influence sapling regeneration through increased shading and competition.

The foliar N concentration of the moss species would give an early indication of any potential N impact on the site. The increased total N content in *E. praelongum* and *E. striatum* within the woodland indicates increased N deposition to the woodland flora. This highlights the potential effect on target species including regeneration potential.

Composition

In the context of the interest feature for woodlands, CSM only refers to the species composition trees and shrubs and not the lower plant species, such as the lichen and pleurocarpous mosses. This attribute is targeted at the maintenance of particular species, especially native species. For example, while the understorey or shrub layer is dominated by hazel in the study area, further from the farm unit both Maple and Wild Service Tree are also present. The persistence and health of the latter species, which is relatively uncommon, could be monitored within the aegus of Ellenberg and N content of mosses. The results of the Ellenberg Index have shown that changes are occurring in the interest feature at Piddles Wood. One of the objectives of this attribute is to alert the agency of any rapid decline in species due to new diseases or insect infestations.

In this context, increased N inputs at Piddles Wood could be seen as a potential factor, which would alter the composition of the interest feature. The large concentrations of both total N content and soluble NH_4-N concentration in pleurocarpous moss species, which could be attributed directly to the presence of the poultry unit at Piddles wood, would also indicate that the woodland is being impacted by N. Previous studies (Pitcairn *et al*. 1998) have shown that total tissue N is increased in mature tree foliage in the vicinity of intensive livestock farms. Large trees are buffered from the effects of small changes, but long-term increases could lead to increased susceptibility to pest and pathogen attack, thus resulting in direct implications for site integrity.

Indicators of local distinctiveness

This attribute includes the ground flora composition, but not more than four species of importance, which have contributed to the selection as a SSSI/ASSI. In general, this could include a particular species or a transition zone to another habitat. For most woodland features the ground flora target will correspond to the relevant NVC type for that specific woodland habitat type. It would be considered unfavourable if there were changes in species composition, which were not consistent with the recognised NVC classification.

Piddles Wood is classified as a NVC class W8 *Fraxinus excelsior*, *Acer campestre*, *Mecurialis perennis.* Comparisons with Nature Conservancy Council surveys carried out at Piddles Wood (1985 and 1991), prior to the installation of the poultry unit, indicate a change in ground flora species composition. *Mercurialis perennis* (characteristic of the NVC classification) *Luzula sylvatica and Carex sylvatica* have declined close to the poultry unit and have been replaced by *Lamiastrum galeobdolon and Glechoma hederacea,* which are more N loving species However, changes in light and competition levels may also have contributed to the changes.

The further development and application of an acidophyte/nitrophyte index, where acidophytes are largely positive indicators for site integrity whilst nitrophytes are considered negative indicators, may be of considerable benefit to agency staff in assessing site condition.

The use of the foliar N content and soluble NH_4-N concentration methods using the pleurocarpous mosses also indicate that N emissions were is impacting directly on the site, however, the evidence for a localised effect close to the poultry unit (i.e. within a radius of up to 200-250 m around the unit). By the nature of using such a transect, with the furthest site used as a reference, it is not possible to show from the transect whether or not the source has impacts on the furthest site.

15.5.5. Summary–Condition attributes

- **Ellenberg Index** is most closely related to attributes of composition and indicators of local distinctiveness, less so the other attributes
- **Lichens** – are not really linked directly to the designated attributes for Piddles Wood but by inference they are a potential indicator of long-term changes in environmental conditions (see Section 15.5.6 describing integrity), which also relate to changes in natural processes
- **Pleurocarpous mosses** are similar to the lichen in that they are not directly related to the interest feature attributes but may be a useful tool as an early warning indicator (see section below) also indicating changes in natural processes.
- **Standardised grass biomonitors** –are not linked to the site attributes but conversely provide a graphic indication of the current level of N impact on the SSSI as a whole.

15.5.6. Integrity of site

English Nature's condition assessment of the site (January 2004**:** www.english-nature.org.uk/special sssi/site documents.cfm) classifies three out of the four units of the site as favourable. The woodland block that includes the woodland adjacent to the poultry house, is judged to be unfavourable due to the composition target failing because of the extent of conifer plantation in this area. The impact of N was not considered in the context of the CSM assessment.

The biomonitoring methods, particularly Ellenberg, can be related to the attributes and therefore some judgement is possible about impacts on condition (see above). However, biomonitoring methods could play an important role in identifying/alerting the agencies to potential long term change in attributes of the interest feature at Piddles Wood. In this context they are an early warning of future impacts on the attributes.

The bioindicator methods used in parallel at Piddles Wood were concentrated in the area adjacent to the poultry unit and along a transect running in a NE direction away from the poultry unit. All the methods used indicate that N deposition is impacting on the woodland in 250 m radius from the poultry unit (based on the transect sampling approach used, it cannot be stated whether or not there are significant impacts beyond this distance). The high N levels in the pleurocarpous mosses close to the unit and the species present indicate that species composition changes have probably already occurred.

The lack of pleurocarpous moss species diversity close to the unit would indicate that only those species with a high N tolerance are now able to exist. Long-term N accumulation could lead to changes in the moss species composition. Work at the Whim moss manipulation study has shown accumulated NH_3-N deposition will reduce species composition at increasing distances away from the point source with time. The high N levels in the pleurocarpous mosses close to the unit also imply larger than normal concentrations of N in the soil, which will affect, not only species composition of the ground flora, but also the health and reproduction of the species of the shrub and tree layer.

The long-term integrity of the interest feature is thus expected to be affected by the N impacts. The results of the Ellenberg Index study indicate that N is currently impacting on the ground vegetation close to the poultry unit. Long-term accumulation of N deposition at this site would lead to an increase in nitrophytic species at greater distances from the poultry house, which is an indirect impact on site integrity but could have implications for the interest in the long term, including species composition changes.

The lichen survey has shown the importance of epiphytic lichens on twigs in assessing the impact of ammonia on twig lichen communities at distances of c. 250 m where the measured ammonia is only c.1.5 μg m^{-3}. The use of twig and trunk monitoring on acid barked tree species allows the assessment of the status of indicators of ecological continuity on the trunks and the long term potential for change from the lichen community on the twigs.

15.6. Caldanagh Bog ASSI

15.6.1. Characterisation of N inputs

The N inputs at this site are dominated by NH_3 dry deposition from agricultural sources (mean NH_3 concentration 2.58 μg m^{-3}) leading to an estimated NH_3-N dry deposition input of 13.9 kg N ha^{-1} $year^{-1}$. Overall, the mean total N deposition for this site including wet deposition inputs is 22.1 kg N ha^{-1} y^{-1}, which exceeds the critical load for a lowland raised bog (5-10 kg N ha^{-1} y^{-1}). The expected changes would be changes in species composition and N saturation of *Sphagnum* species.

15.6.2. Interest feature

The interest feature at Caldanagh Bog (Northern Ireland) is the lowland raised bog. The following citation was extracted from www.ehs.gov.uk/natural/designated/site view.asp.site noASSI123. 'Caldanagh bog is a compact lowland raised bog within the River Main series displaying a classic domed profile with minimal turf cutting around the periphery. An area of intact lagg along the north-eastern edge of the bog represents one of the most important features of the site. The intact surface supports a moderately well developed hummock/hollow complex and the surface of the bog is exceptionally wet supporting a dense and diverse cover of *Sphagnum* mosses.

Of particular note, the nationally rare *Sphagnum pulchrum* is abundant in the hollows and the notable hummock-forming mosses *S. imbricatum* (*S. austinii* and *S. affine* are components of the *S. imbricatum* complex) and *S. fuscum* both occur. Some of the peripheral peat has been cut for turf in the past with vegetation communities ranging from deep artificial pools to *Molinia caerulea* dominated grassland.

The overall diversity of Caldanagh Bog is enhanced by a small esker ridge to the southwest, where the vegetation is dominated by a heath and grassland mosaic. The notable Burnet-saxifrage *Pimpinella saxifraga* grows on this esker ridge'.

In addition NVC communities are used as indicators of condition.

15.6.3. Attributes and targets

For all lowland wetlands the mandatory attributes are;

Habitat extent
The extent target should be no reduction in the area of the bog. Aerial photography surveys are the efficient means of surveying habitat extent. The biomonitoring methods would not give any indication of change in extent.

Habitat composition
This attribute is concerned with component habitats, whereby a site could have more than one component wetland type present. This is possibly the case with Caldanagh bog with the lagg fen feature. The target aim of this attribute is to sustain the variety and extent of the components. While aerial photography surveys will show changes in the extent of the habitats, the simplified acidophyte/nitrophyte Ellenberg N Index approach developed in this study could be used in this situation to determine changes in the balance of species particularly *Sphagnum* species and potential impacts from N. Such an adapted Ellenberg Index would concentrate on the presence/absence of key acidophyte and nitrophyte species. Foliar N concentrations could also be assessed on the *Sphagnum* species, using bioindicator methods, to provide an early indication of N impact, which may lead to a decline in the diversity of the *Sphagnum* species.

Habitat structure and natural processes
Deterioration in the raised bog structure can be caused by a variety of localised activities, such as peat cutting, drainage and over-grazing. The interest feature citation would indicate minimal turf cutting around the periphery of the raised bog. Visual estimates of exposed substrate could be included in an Ellenberg species determination. Again mosses and lichens are indicative of changed natural processes.

Vegetation composition
Recommended methods of assessment for positive and negative indicators include visual assessment of cover using a structured walk or transects and recording quadrats. Such an approach and the resulting species lists and cover estimates could be used for the purpose of determining a N Index for vascular plants, bryophytes and ground lichens. For more rapid assessment, a modified Ellenberg acidophyte/nitrophyte Index may be determined. If assessment was carried out along a transect across the bog, changes in the N index along the transect might indicate changes resulting from local sources of N.

A transect may be used for other bioindicator tests such as tissue N content and soluble NH_4-N concentration of pleurocarpous mosses and also transplantation tests. Although, considered a specialist technique, transplantation of *Sphagnum* moss from a known clean site to a test site and the subsequent monitoring of N accumulation can be readily carried out with the use of 'netlon' cylinders. Transplantation of Sphagnum has proved successful in the glasshouse (CEH) and field (Woodin, Press & Lee 1985, Mitchell *et al.* 2004, Leith *et al*. 2003)

Monitoring of species diversity changes in N sensitive bryophyte species could also be beneficial as an addition tool to CSM if a potential eutrophication problem was identified.

The results from the biomonitoring would give an early warning of potential N impacts to the habitat.

Indicators of local distinctiveness
This attribute is defined as the 'features of the heathland, that make it special but which are not covered by the attributes already described' (JNCC, CSM for Lowland Heathland 2004). A number of the N biomonitoring methods could be used under this attribute to add to the CSM assessments if the 'special' features were applicable to the N biomonitoring methods.

15.6.4. Integrity

The long-term integrity of the site is principally dependent on the continued ombrotrophic status of the raised bog. The characteristic N sensitive bryophytes and lichens species of the habitat are dependent on the maintenance of the hydrology state and the eutrophication status.

The use of regular foliar N monitoring could act as an early indicator of change in condition of the feature species. Long-term eutrophication will lead to species composition changes and loss of integrity. The current N deposition inputs to this raised bog indicate that N could be impacting on the condition of the bog. The levels of foliar total N measured in *R. squarrosus*, *Scleropodium purum* and *Thuidium tamariscinum* were 1.56% N, 1.14% N and 1.56% N respectively. These concentrations, which are higher than expected for a raised bog habitat, would suggest N is currently impacting on the bog and surrounding area. If these species are being affected by increased N, the potential impact for the feature *Sphagnum* moss species, which are more N sensitive than the pleurocarpous moss species, is much greater.

Additionally, the trunk and twig lichen assessments both indicated lichen flora dominated by nitrophytes. Although these measurements do not link directly to the designated features of Caldanagh bog, they provide useful biological additional evidence, which supports the interpretation that the integrity of this site is under significant threat from enhanced NH_3 and N deposition.

15.7. Ariundle SSSI

15.7.1. Characterisation of N inputs

Ariundle is situated in the west central Highlands of Scotland, an area dominated by high precipitation and diffuse wet N deposition. This site has the lowest ambient NH_3 concentrations (0.04 $\mu g\ m^{-3}$) of the 32 Extensive UK sites and one of the lowest total N deposition values (11.3 kg N $ha^{-1}\ y^{-1}$). Although, the NH_4^+ and NO_3^- concentrations in precipitation are low, these combined with the high annual precipitation inputs result in the annual mean N deposition of 11.3 kg N $ha^{-1}\ y^{-1}$.

15.7.2. Interest feature

The description below is based on the SNH information for the Sunart Site of SSSI, Lochaber, Highland. Using the JNCC guidance the designated interest feature will be the western acidic oak woodland and mixed woodland on alkaline soils associated with rocky slopes. This habitat type has rich lichen, moss and liverwort communities that are included in the site outline of non-vascular plant interest.

Ariundle is mature deciduous woodland dominated by oak, birch and ash with an understorey of rowan, hazel and holly. The moine rocks and acidic soils support a rich flora dominated by *C. vulgaris*, *Vaccinium myrtillus*, *Deschampsia flexuosa* and *Pteridium aquilinum.* Base rich flushes support *Parnassia palustris* and butterfly orchids *Platanthera* spp.. The western Atlantic oak wood is an internationally important habitat with a rich diversity of ferns, mosses, lichens and liverworts including many 'Atlantic' species in all groups including lichens *Biatora vernalis* (NR*) Degelia atlantica, Hypotrachyna taylorensis, Menegazzia terebrat* and *Pseudocyphellaria norvegica* (NS*)*, ferns; *Dryopteris aemula*, bryophytes *Dicranum scottianum* and *Sematophyllum micans.*

15.7.3. Attributes

The attributes used for Ariundle are based on the JNCC Common Standards monitoring Guidance for Woodland Habitats (www.jncc.gov.uk).

Extent
The Ariundle SSSI is part of the Sunart SSSI, which covers an area of 5500 hectares. Sunart SSSI is one of the most extensive areas of natural ancient semi-natural woodland in the UK.

There is no indication as to the extent status of this SSSI in the SNH documentation on this site. It is suspected that any change in extent could be driven by modifications in climatic factors, management practices as well as increased N inputs. In a diffuse wet N deposition dominated site such as this, the link to source attribution is very weak (Figure 15.1). With the presence of a rich diversity of non-vascular plants, biomonitoring methods could be utilised to give early warning of changes in extent. The exposure of *D. flexuosa* standardised plants would indicate if N deposition is impacting on the understorey vegetation. The advantage of using *D. flexuosa* is that this species occurs naturally in this habitat so any change in foliar N status could be directly related to N impacts on the SSSI. Changes in N status of mosses could also give early indication of potential changes.

Structure and natural processes
The Atlantic oak woodland habitat is dominated by the high rainfall and the mild climate of the west coast of the UK. Any major change in structure and natural processes is likely to result from modifications in these climatic factors. Although, it is difficult to directly assign effects of diffuse N deposition, it is important not to exclude the influence of N deposition on these habitats (Mitchell *et al*, 2004). The lichen and moss N concentrations could be used directly as part of the long-term monitoring of structure change in this habitat, since these represent key interest features to the structure of the site. In addition, any changes to the bryophyte and lichen communities are indicative of alteration in natural processes.

Regeneration potential
This attribute applies to the regeneration of the tree species and not ground vegetation. The regeneration oak woodland saplings at Ariundle are probably more dependent on the grazing pressures from the deer population and climatic conditions than from N impacts. However, changes in ground flora (moss and lichen species diversity) through increased N deposition could impact on regeneration potential by altering the microclimate on the woodland floor for seed germination/sapling growth. Biomonitoring could contribute to an early warning of potential change.

Composition
This attribution has importance for Ariundle as it considers change in natural species. The interest feature at Ariundle is the western acidic oak woodland and mixed woodland. As with regeneration potential other factors will have a greater influence on the composition of the feature than the N impacts.

Indicators of local distinctiveness
This attribute includes the ground flora, of which non-vascular plants are an important component, making it a species-rich site of international importance and a refuge for many species dependent on low nutrient budgets and high rainfall and relative humidity. Potential changes in species composition are an important additional factor in the assessment of this type of habitat.

The use of biomonitoring methods such as the foliar N concentration, modified Ellenberg acidophyte/nitrophyte Index and lichen indicators could give added value to the CSM of this habitat type. In particular, the detection of any loss of acidophyte lichen species would indicate a threat to all low nutrient species in this habitat prior to the arrival of nitrophytes.

The importance of the epiphytic twig flora should be emphasised, as this will provide a mechanism for detecting ongoing changes in atmospheric conditions in the vicinity of species-rich cryptogamic communities, while trunk communities provide information on ecological continuity. The routine application of the foliar N methods would give an early indication that N was impacting on the moss species and would also give an indication of the potential long-term threat to the interest feature from N deposition. Care would have to be taken in interpretation of the foliar N data because of climatic and seasonal variability in N concentration. Measurements would have to be carried out at the same time of year and when the hydrological status of the moss was consistent with previous samples.

15.7.4. Integrity

In the case of Ariundle, the regular use of N biomonitoring methods would provide a general early indication of potential long-term site condition change, through increased N impact, but not specific condition changes to the interest features. Recent work has shown the effect of long distance transport of NH_4^+ compounds on acidophyte species such as *Bryoria fuscescens* > 1000 km from source (van Herk 2003) suggesting that biomonitoring of acidophytic lichens will act as an early warning system to detect ongoing environmental changes. Although, the ground vegetation and especially the lichens and mosses are initially more sensitive to N impacts than the trees species, increased accumulated N deposition over a long period could impact on the interest features. The total N content (% N) and soluble NH_4-N concentrations measured in pleurocarpous mosses at this site indicate a low N impact on this habitat at present (foliar N contents < 1% N and NH_4-N concentrations < 4 μg g^{-1} FW). The effects on long term eutrophication on the soils of this habitat could be important for long term integrity of this site and merit regular biomonitoring.

15.8. Llanymynech and Llynclys Hills SSSI

15.8.1. Characterisation of N inputs

The measurements of NH_3 concentration at this SSSI have shown a mean value of 1.8 μg m^{-3}, with modelled total N deposition of 20.5 kg N ha^{-1} y^{-1}. Approximately 45% of the N input is as dry NH_3-N deposition. This is a hill site adjacent to intensive agricultural plains which provide a significant regional source of atmospheric ammonia.

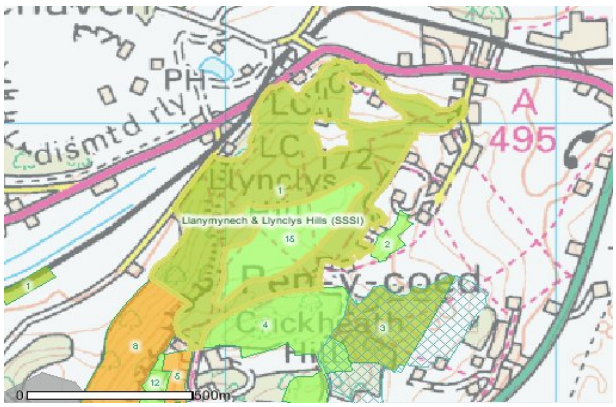

Figure 15.2. Map of Llanymynech and Llynclys Hills SSSI. (taken from www.en.gov.uk).

15.8.2. Interest feature

The Llanymynech and Llynclys Hills SSSI, in Shropshire is divided into 15 management units by English Nature, covering a total area of 106 ha (Figure 15.2).

It has been selected as one of the SSSI's to be assessed because it has a complex of interest features. They are: a) broadleaved, mixed and yew woodland upland, b) neutral grassland lowland c) calcareous grassland lowland.

The mosses and lichens were sampled in the broadleaved, mixed and yew woodland and the neutral grassland lowland.

Lowland calcareous grassland was selected as the interest feature for comment in this section because the site is particularly important for limestone plants. The grassland communities represented are extensive and varied and include many uncommon vascular species including orchids, lichens and grasses. As many as 10 NVC types are included within the Lowland calcareous grassland feature. From the limited material available, the exact NVC classifications for the areas of limestone grassland at this site are not known, but it is likely that more than one is represented.

Extent
The extent target should be no reduction in the areas of calcareous grassland. Aerial photography surveys are the efficient means of surveying habitat extent. While biomonitoring methods may not give any additional indication of change in extent, the rich diversity of vascular plants at this site could be measured by early warning of changes provided by biomonitoring methods. The exposure of *D. flexuosa* standardised plants or changes in the foliar N content of key bryophytes and lichens would indicate if N deposition is impacting on the understorey.

Sward composition-Grass: herb ratio
This attribute is usually carried out by some method of structured observation. A modified Ellenberg acidophyte/nitrophyte index at fixed points could contribute to this assessment:

Frequency of positive indicators
Monitoring of this attribute involves selecting 2-6 representative species and monitoring their frequency. For this site, species such as *Primula veris, Helianthemum nummularium*, *Scabiosa columbaria,* orchid species and *Cladonia* lichen species might be chosen. These species have low Ellenberg numbers and could all be considered as acidophytes.

Frequency of negative indicators
There are 5 groups of negative indicators: agricultural weeds, agriculturally favoured species, rank grasses, introduced species and native scrub and tree species. Species from the first 3 groups are likely to have above average Ellenberg N scores and could be considered nitrophytes. For example, *Brachypodium pinnatum* while scarce at this site is not uncommon at other Midland sites. This species is known to respond to increased N deposition at the expense of low growing species (Pitcairn *et al*. 1991) and hence may affect the species diversity of the sward. It is clearly important that such a species is regularly monitored. While it may be preferable to monitor each negative species, an acidophyte/nitrophyte index would provide a more rapid test, which could be applied more regularly.

Indicators of local distinctiveness
The maintenance of existing populations of rare/scarce species could be included in the application of a modified Ellenberg Acidophyte/nitrophyte index. Height, litter and bare ground parameters could be incorporated into an Ellenberg or modified Ellenberg cover survey.

15.8.3. Integrity

Ellenberg N Index has proved a useful indicator of temporal change in species diversity. Annual application of this test and/or a modified acidophyte/nitrophyte index would contribute considerably to assessment of site integrity. Changes in epiphytic lichen communities on calcareous substrata have still to be assessed in a national context in terms of their association with atmospheric nitrogen especially if bark pH is affected and in conditions where acidophytes are infrequent.

Within this section foliar N content of key bryophytes and lichens could provide a clue to the health of the positive indicators. The current total N content (1.1% N) and soluble NH_4-N concentrations (< 4 $\mu g\ g^{-1}$ FW) measured in pleurocarpous mosses indicate a low N impact at this site at present. However, the measured lichen species composition at this site indicate that the site is affected by nitrogen eutrophication, with AV-NV scores of -0.2 and -1.2 for trunks and twigs, respectively. These conflicting results may indicate a site, which is on the borderline of adverse effects on its integrity. Continued biomonitoring should provide a valuable indication of long-term integrity of the site.

15.9. Conclusions

- The conservation agencies are responsible for identification and protection of sites designated under national and European conservation legislation. Sites are designated for their specified interest features.

- The condition of sites is assessed by the agencies using common standards monitoring (CSM), which focuses on simple quick monitoring of key attributes, carried out on a 6 year cycle. CSM is not designed to detect and attribute the impacts of atmospheric nitrogen deposition or other air pollutants.

- Biomonitoring methods for nitrogen could be applied in addition to CSM at specific designated sites to support the assessment of whether interest features are being impacted by increased atmospheric nitrogen concentrations and deposition. For this purpose they should be a) simple and effective, b) give added value compared with modelled critical loads assessment and c) be an integral part of the assessment of condition and integrity of a designated site.

- Biomonitoring approaches can be considered in the context of the pathway from the source to ultimate effects on designated interest features. The concept of a "biomonitoring chain" highlights how a carefully designed program of biomonitoring can both make the link to source attribution and demonstrate impacts on relevant interest features.

- Five key attributes are relevant for the CSM, to which N bioindicators may be related:
    - Extent of the interest feature in a designated site
    - Structure of the interest feature and natural processes
    - Regeneration potential
    - Tree and shrub composition (or composition of other key interest features)
    - Indicators of local distinctiveness.

- Four examples sites are considered from the present study to address the relevance of nitrogen biomonitoring to site condition assessment. The sites chosen were Piddles Wood (Dorset), Caldanagh Bog (Northern Ireland), Llyncis Common (Shropshire) and Ariundle (Scottish Highlands).

- The examples demonstrate how different bioindicator methods make the link to site condition either directly (e.g. Ellenberg indicators for higher plants) or indirectly (e.g. moss chemistry as an indicator of altered natural processes). They also demonstrate the problem that in some cases relevant bioindicators are not directly relevant to the interest features: For example, moss and lichen assessment is directly relevant to the designated Atlantic flora at Ariundle, but not directly relevant to the designated woodland habitat at Piddles Wood. In these cases, such biomonitoring methods still have value (by increasing the robustness of the assessment), and can be taken as "early warning" of changes to the designated features.