Cyfoeth Naturiol Cymru
Natural Resources Wales

Gathering twig lichen data for Powys SSSIs to investigate ammonia levels: Second phase

NG Bacciu & J McGill

Evidence Report No 676

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Arolygwyd naw SoDdGA ym Mhowys ar gyfer cennau ar frigau ym mis Ionawr 2023, yn dilyn fersiwn wedi'i haddasu o brotocol System Gwybodaeth am Lygredd Aer (Wolseley *et al*., 2017, Bosanquet, 2018). Cafodd pum coeden eu samplu ym mhob SoDdGA, yn cynnwys cyfanswm o 37 o goed derw, 2 bedwen, a 6 draenen wen. Yn seiliedig ar y data hyn, aseswyd lefelau llygredd amonia mewn lleoliadau a arolygwyd o fewn y SoDdGAau fel a ganlyn:

- **Glân** – Berwyn, ac Graig yr Allt Goch.
- **Mewn perygl** — Cwmsaise, a Gregynog.
- **Llygrwyd gan nitrogen** — Cors Farchwel, Gwaun Efail Wig, Roundton Hill, a Chreigiau Stanner.
- **Llygrwyd yn ddrwg gan nitrogen** - Breidden Hill.

Mae'r canlyniadau'n dangos bod newid mawr wedi bod mewn cymunedau cennau ar frigau mewn tirweddau lle ceir amaethyddiaeth ddwys. Mae gan hyn oblygiadau o ran cadwraeth cennau fel nodweddion dynodedig o fewn SoDdGAau, a cheir effeithiau posibl hefyd ar organebau eraill a gwasanaethau ecosystemau. Mae SoDdGA lle ceir digonedd o gennau yn gofyn am amddiffyniad cadarn rhag llygredd amonia, a ddylai fod yn seiliedig ar asesiad cywir o lefelau amonia o fewn y safle, yn hytrach na chrynodiadau wedi'u modelu ar lefel 5 x 5 km. Er y byddai'n ddymunol sefydlu parthau dim mewnbwn mewn ardaloedd o amgylch SoDdGAau sy'n llawn cennau, byddai hyn yn gofyn am newidiadau i'r fframweithiau rheoli tir presennol.

2. Executive Summary

Nine SSSI in Powys were surveyed for twig lichens in January 2023, following a modified version of the Air Pollution Information System protocol (Wolseley *et al*., 2017, Bosanquet, 2018). Five trees at each SSSI were sampled, comprising a total of 37 oaks, 2 birches, and 6 hawthorns. Based on these data, the ammonia pollution levels at locations surveyed within the SSSIs were assessed as follows:

- **Clean** – Berwyn, and Coed yr Allt Goch.
- **At risk** – Cwmsaise, and Greygnog.
- **N polluted** – Cors Farchwel, Gwaun Efail Wig, Roundton Hill, and Stanner Rocks.
- **Very N polluted** – Breidden Hill.

The results demonstrate that there has been wholesale change in the twig lichen communities in landscapes with intensive agriculture. This has implications for the conservation of lichens as designated features within SSSIs, and there are also potential effects on other organisms and ecosystem services. Lichen-rich SSSIs require robust protection from ammonia pollution, which should be based on accurate assessment of within-site ammonia levels, rather than modelled concentrations at 5 x 5 km level. Changes are required to existing land management frameworks to establish zero-input zones in areas surrounding lichen-rich SSSIs, otherwise there is a risk of significant ongoing damage.

3. Introduction

3.1 Background

This survey was commissioned by Natural Resources Wales (NRW) to gather data on the occurrence of ammonia-sensitive and ammonia-tolerant lichens in areas of Powys subject to varying concentrations of ammonia pollution. Ammonia is a gas produced naturally from decomposition of organic matter, and in soil by bacteria. While it is essential for many biological processes including amino acid and nucleotide synthesis, it can reach high concentrations in areas near animal farms, fertiliser production, and other sources of agricultural pollution.

Ammonia only stays in the atmosphere for a few hours once emitted, but it can also mix with other gases such as nitrogen oxides and sulphur dioxide (Defra, 2023). These form particulate matter which can exist for several days and be transported over long distances (Defra, 2023). Deposition of ammonia to the environment can happen either as a gas (dry deposition) or in precipitation (wet deposition) (Defra, 2023). This can cause long-term harm to sensitive habitats where organisms and soils cannot cope with increased exposure to nitrogen (Defra, 2023).

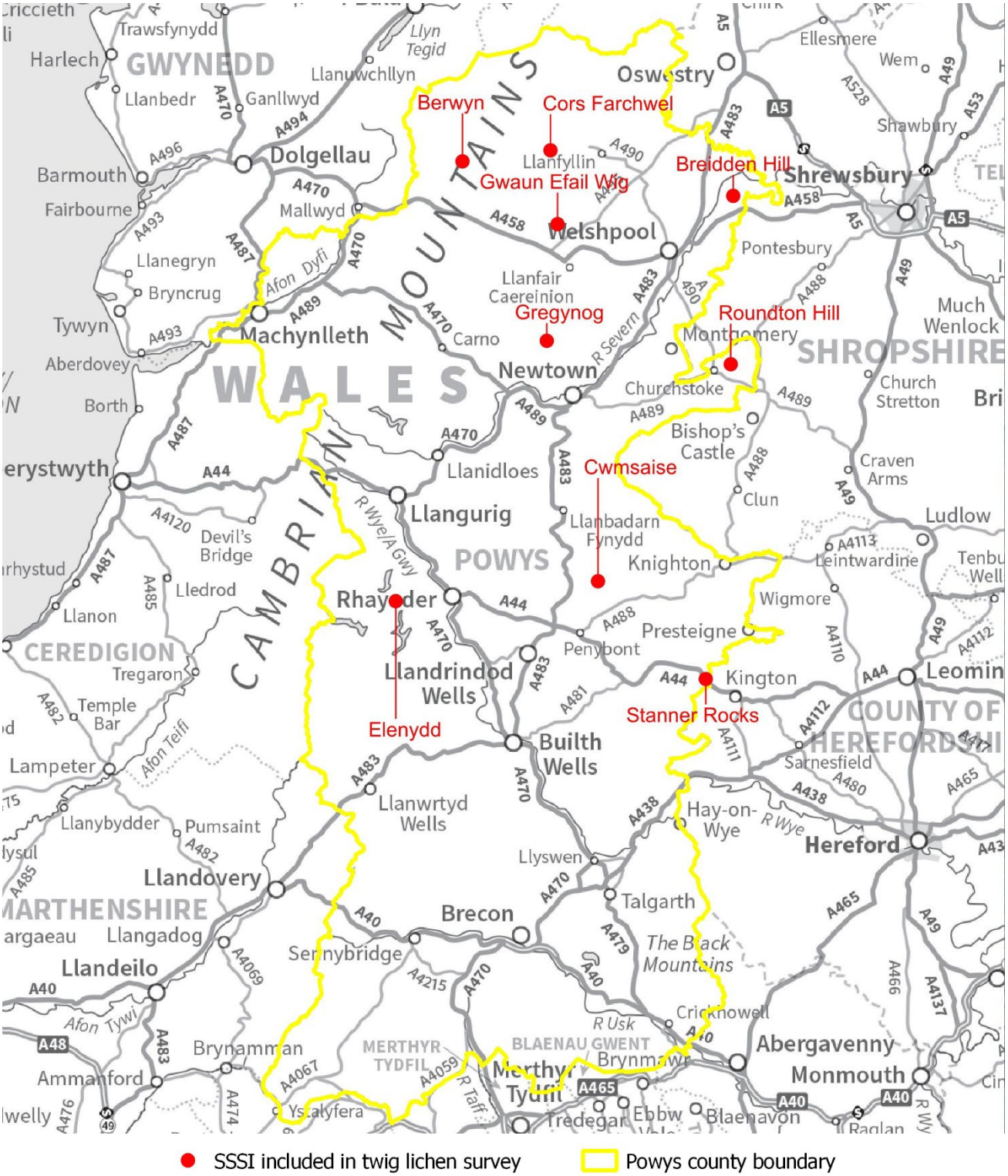
Exposure to ammonia can make the pH of the environment more basic, damaging the cells of some lichens which are only able to tolerate more acid conditions. High concentrations of ammonia can also lead to a decrease in the availability of other nutrients that are required for lichen growth. In addition, ammonia pollution can cause direct physical damage to the lichen thallus, reducing its ability to photosynthesise. In the long-term this can have impacts on other parts of an ecosystem, such as nutrient cycling and soil formation, and the diversity and abundance of other plant and animal species.

3.2 Previous surveys

Twig lichen survey to assess ammonia pollution have been completed at other SSSIs in Powys (Joe Hope, in Bosanquet, 2018). These have been used to assess effects of atmospheric pollution from defined point sources, and across the wider landscape in Powys.

3.3 Survey areas

Nine SSSIs within Powys were selected for survey by NRW, in areas subject to varying concentrations of ammonia pollution. The locations of the SSSIs are shown in Figure 1 and summarised in Table 1. Coed yr Allt Goch was surveyed in place of Penygarreg Woods (in Elenydd SSSI) due to confusion between the surveyors and NRW staff who provided access details.



SSSI included in twig lichen survey Powys county boundary

Figure 1. Map showing the nine Powys SSSIs included in the 2023 twig lichen survey to investigate ammonia levels. Contains OS data © Crown copyright and database rights 2023.

Table 1. The nine Powys SSSIs included in the 2023 twig lichen survey to investigate ammonia pollution, including grid reference, vice-county and whether lichens are a notified feature in the SSSI.

Site	SSSI	Grid reference	VC	Lichen Feature
Blaen Cownwy	Berwyn	SH 984 181	47	No
Breidden Hill	Breidden Hill	SJ 290 143	47	Saxicolous
Cors Farchwel	Cors Farchwel	SJ 090 154	47	No
Cwmsaise	Cwmsaise	SO 140 699	43	No
Coed yr Allt Goch	Coed yr Allt Goch	SN 913 673	43	Corticolous and saxicolous
Gregynog	Gregynog	SO 081 976	47	Corticolous
Gwaun Efail Wig	Gwaun Efail Wig	SJ 093 110	47	No
Roundton Hill	Roundton Hill	SO 293 949	47	Saxicolous
Stanner Rocks	Stanner Rocks	SO 263 585	43	No

3.4 Field survey

Nine days were spent surveying the SSSIs in January 2023. The dates, locations and weather conditions for each survey day are provided in Table 2. Survey tracks are provided in Appendix 3.

Table 2. Weather conditions during the 2023 Powys twig lichen survey.

Date (2023)	SSSI	Maximum temperature (°C)	Rainfall (mm)	Maximum wind speed (mph)
20th January	Stanner Rocks	5	0	0
21st January	Coed yr Allt Goch	3	0	0
22nd January	Cwmsaise	3	0	6
25th January	Roundton Hill	8	0	11
26th January	Berwyn	5	0	11
27th January	Gregynog	4	2	6
28th January	Cors Farchwel	6	0	6
29th January	Gwaun Efail Wig	6	0	16
30th January	Breidden Hill	7	0	8

3.5 Methodology

The survey follows a minor variation on the Air Pollution Information System (APIS) methodology (Wolseley *et al*., 2017) that has been used in previous twig lichen surveys in Powys (Bosanquet, 2018).

Within each SSSI, five trees were selected for sampling, ideally fulfilling the following criteria:

1. Species – sessile oak *Quercus petraea*, pedunculate oak *Quercus robur*, or intermediates; downy birch *Betula pubescens*, or silver birch *Betula pendula*. Hawthorn *Crataegus monogyna* may be substituted if suitable oak trees are not available.
2. Situation – open and unshaded.
3. Form – single-stemmed and > 40 cm stem dbh.

4. Ivy – trees substantially covered in ivy to be avoided.
5. Branching – five branches in an open aspect must be accessible for examination along a 1.5 m length back from a terminal bud.

Likely sampling locations were identified on aerial photography, further informed by views on the approach to the site and the location of better-lit edges of tree clumps, south-facing hedges, and site boundaries. An effort was made to survey trees in different parts of each site, particularly with respect to the different levels of exposure to wind, and distance from the site boundary.

At each tree, indicator species were recorded on 5 accessible branches in Zone 1 (100-150 cm back from the tip), Zone 2 (50-100 cm), and Zone 3 (0-50 cm). The distances were measured with a tape measure and marked with drawing pins during the survey.

Lichens on the indicator list were recorded by searching with an illuminated x10 hand lens along the branch/twig from the thicker end to the terminal bud. The presence of a coating of green algae was also recorded when this was encountered. The lichen indicator species for this survey are listed in Table 3.

Table 3. Lichen indicator species for the Powys twig survey.

Nitrogen sensitive species	Nitrogen tolerant species
Bryoria fuscescens	*Amandinea punctata*
Evernia prunastri	*Arthonia radiata*
Graphis elegans/scripta	*Candelariella reflexa*
Hypogymnia physodes/tubulosa	*Lecidella elaeochroma*
Parmelia saxatilis	*Physcia adscendens/tenella*
Parmelia sulcata	*Punctelia subrudecta*
Pseudevernia furfuracea	*Xanthoria parietina*

In addition to the indicator species, all lichens within the branch zones were recorded, and casual records of other species were made while moving around the sites. Grid references were recorded using a Garmin eTrex 32x GPS accurate to approximately +/- 3 m. These were checked against aerial photography during data entry. The diameter at breast height (dbh) of the trees sampled was measured using a 5 m diameter tape. The trees sampled were also photographed.

The twig lichen records were subsequently converted into Lichen Indicator Scores and Nitrogen Air Quality Indices using the APIS protocol.

3.6 Survey equipment

Most lichens were identified macroscopically in the field, although some species were collected for subsequent identification by microscopy.

3.7 Species recording

The survey equipment used is listed below:

- Lichen candelaris x10 magnification lens.
- Hammer, chisel, and knife for removal of specimens.
- Packaging for storage of specimens.
- Sodium hypochlorite (C).
- Potassium hydroxide 10% solution (K).
- Paraphenylenediamine (Pd) as Steiner's solution.
- Alonefire SV003 10W 365nm UV Torch.
- Richter 5 m diameter tape.
- Compass.
- Garmin eTrex 32x GPS.
- Olympus TG5 camera.
- 1:25,000 Ordnance Survey map.

Taxonomic nomenclature follows the British Lichen Society (BLS) on-line Taxon Dictionary (British Lichen Society, 2023). The BLS data entry spreadsheet is not fully updated to match this, so some species are listed in different genera in the spreadsheet to this report. These changes are summarised in Table 4.

Table 4. Species name changes between the current BLS taxon dictionary and previous published names.

Current name	Previous name
Candelariella xanthostigmoides	*Candelariella reflexa*
Orcularia insperata	*Rinodina biloculata*

The records from this survey have been submitted to the BLS National Database, which is uploaded to the National Biodiversity Network.

3.8 Constraints

On large sites, it was not possible to examine the entire survey area in the time available. Trees meeting all selection criteria were few or absent on some sites, particularly the girth criteria for trees growing on steep slopes with thin soils, and the open-grown criteria where trees were in regenerating woodland. As a result, some suboptimal trees (e.g. partly shaded) were surveyed when these were encountered. These constraints were noted in previous surveys (Bosanquet, 2018) and are unlikely to have meaningfully affected the results.

4. Results

4.1 Survey coverage

Data were collected from each of the nine SSSIs, including five branches on five trees at each site. Although oak trees were preferentially sampled for consistency with previous surveys, these were not available at every site and so in some cases birch and hawthorn were included. The results from different tree species are not exactly comparable, although these are expected to be broadly similar. The results are summarised below, at SSSI and tree levels. Field data are provided in Appendix 1, plots of Nitrogen Air Quality Index (NAQI) values within sites are presented in Appendix 2, and survey tracks are shown in Appendix 3.

4.2 Summary

The mean values for the Lichen Index Score (LIS) and the Nitrogen Air Quality Index (NAQI) at each SSSI are presented in Table 5.

Table 5. LIS and NAQI means for each site, with pollution levels determined from NAQI means using the APIS protocol.

SSSI	LIS	NAQI	Pollution level
Berwyn	2.3	0.3	Clean
Breidden Hill	-1.7	1.4	Very N polluted
Cors Farchwel	-0.6	0.9	N polluted
Cwmsaise	0.1	0.8	At risk
Coed yr Allt Goch	2.5	0.2	Clean
Gregynog	0.8	0.6	At risk
Gwaun Efail Wig	-1.0	1.1	N polluted
Roundton Hill	-0.8	1.1	N polluted
Stanner Rocks	-1.1	1.2	N polluted

4.2.1 Berwyn

The Blaen Cownwy area was visited within Berwyn SSSI. This is a north-east facing slope and contained numerous open-grown trees. Oak was very scarce, while birch, hawthorn, rowan, and hazel were common. The LIS and NAQI results for the five trees sampled are shown in Table 6.

Table 6. The Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for five trees at Berwyn SSSI in January 2023.

Sample Code	Tree Species	Grid reference	LIS	NAQI	Pollution level
1	Hawthorn	SH 98043 18543	2.2	0.3	Clean
2	Hawthorn	SH 98194 18466	1.8	0.4	Clean
3	Birch	SH 98396 18360	2.8	0.2	Clean
4	Oak	SH 98446 18271	1.6	0.4	Clean
5	Birch	SH 98441 18260	3.0	0.1	Clean

There was a noticeable layer of algae on most twigs sampled, although currently this is not having an appreciable effect on the health of the twig lichens. This is likely to be a result of high rainfall in the area.

4.2.2 Breidden Hill

The south-easting facing slope of Breidden Hill was visited. This was one of only two sites with numerous accessible open-grown oak trees, as well as hawthorn, ash, and sycamore. Five pheasant feeders were present on land adjacent to the south-western border of the SSSI, and hundreds of pheasants were seen in surrounding woodland. The LIS and NAQI results for the five trees sampled are shown in Table 7.

Table 7. The Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for five trees at Breidden Hill SSSI in January 2023.

Sample Code	Tree Species	Grid reference	LIS	NAQI	Pollution level
1	Oak	SJ 29574 14221	-2.2	1.5	Very N polluted
2	Oak	SJ 29645 14323	-1.2	1.1	N polluted
3	Oak	SJ 29678 14325	-0.8	1.0	N polluted
4	Oak	SJ 29582 14342	-2.2	1.5	Very N polluted
5	Oak	SJ 29550 14317	-2.2	1.5	Very N polluted

Twigs at Breidden Hill were noticeably algae covered. This seemed to particularly affecting *Parmelia saxatilis*, possibly accumulating amongst the isidia in the centre of the thallus.

4.2.3 Cors Farchwel

This is a small area of marshy grassland in a shallow east-west valley. There were few open-grown trees, with only two accessible oaks on higher ground in the southern part of the site. The other trees sampled were hawthorns in defunct hedgerows bordering the SSSI. The LIS and NAQI results for the five trees sampled are shown in Table 8.

Table 8. The Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for five trees at Cors Farchwel SSSI in January 2023.

Sample Code	Tree Species	Grid reference	LIS	NAQI	Pollution level
1	Hawthorn	SJ 09003 15436	-1.0	1.1	N polluted
2	Oak	SJ 09068 15436	-0.4	0.9	N polluted
3	Oak	SJ 09056 15324	-0.4	0.9	N polluted
4	Hawthorn	SJ 09096 15334	0.6	0.7	At risk
5	Hawthorn	SJ 09101 15415	-0.8	1.0	N polluted

There was obvious nutrient enrichment on the field immediately north of the SSSI and a watercourse running west across the boundary had caused eutrophication in the bog.

4.2.4 Cwmsaise

This is an acid grassland site with wet flushes. There were no open-grown oaks, the five trees sampled were on field boundaries. Additional tree species present were ash, hawthorn, and sallow. The LIS and NAQI results for the five trees sampled are shown in Table 9.

Table 9. The Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for five trees at Cwmsaise SSSI in January 2023.

Sample Code	Tree Species	Grid reference	LIS	NAQI	Pollution level
1	Oak	SO 14075 69949	-1.0	1.1	N polluted
2	Oak	SO 14085 69955	-0.2	0.9	N polluted
3	Oak	SO 14085 69955	0.6	0.7	At risk
4	Oak	SO 14259 69969	-0.6	1.0	N polluted
5	Oak	SO 14254 69864	1.8	0.4	Clean

There was a marked difference between higher pollution levels recorded on an exposed south-facing slope (Trees 1, 2, and 4) and trees with lower pollution further downhill with shelter from other trees nearby (Trees 3 and 5).

4.2.5 Coed yr Allt Goch

Although Penygarreg Woods in Elenydd SSSI was selected for survey, unclear access instructions led to Coed yr Allt Goch being surveyed instead. This is a sessile oak wood on a steep-south facing slope with a lesser component of hazel, birch, beech, and sycamore. Few of the trees were open-grown and many were below the girth criteria in the APIS methodology, although this is likely to be the result of growing on thin soils rather than the trees being too young. The LIS and NAQI results for the five trees sampled are shown in Table 10.

Table 10. The Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for five trees at Coed yr Allt Goch SSSI in January 2023.

Sample Code	Tree Species	Grid reference	LIS	NAQI	Pollution level
1	Oak	SN 90823 67634	2.2	0.3	Clean
2	Oak	SN 90674 67623	2.8	0.2	Clean
3	Oak	SN 90733 67651	3.0	0.1	Clean
4	Oak	SN 90677 67589	2.2	0.3	Clean
5	Oak	SN 90639 67586	2.2	0.3	Clean

4.2.6 Gregynog

This is an excellent example of wood-pasture with numerous open-grown oaks. Three trees were sampled in the western part of the SSSI in Great Wood, and two trees were sampled in the eastern part in The Warren. The LIS and NAQI results for the five trees sampled are shown in Table 11.

Table 11. The Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for five trees at Gregynog SSSI in January 2023.

Sample Code	Tree Species	Grid reference	LIS	NAQI	Pollution level
1	Oak	SO 08094 97457	1.2	0.5	At risk
2	Oak	SO 08015 97621	1.0	0.6	At risk
3	Oak	SO 08401 97799	0.2	0.8	At risk
4	Oak	SO 08779 97428	0.6	0.7	At risk
5	Oak	SO 08831 97499	1.0	0.6	At risk

4.2.7 Gwaun Efail Wig

This is a wet grassland site with no open-grown trees. The only oaks with accessible branches were on field boundaries, in hedgerows on the north side of the SSSI, and along a historic drove on the southern perimeter. Other tree species at the site included sallow and ash. The LIS and NAQI results for the five trees sampled are shown in Table 12.

Table 12. The Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for five trees at Gwaun Efail Wig SSSI in January 2023.

Sample Code	Tree Species	Grid reference	LIS	NAQI	Pollution level
1	Oak	SJ 09382 11136	-1.8	1.3	Very N polluted
2	Oak	SJ 09288 11025	-2.0	1.4	Very N polluted
3	Oak	SJ 09185 11015	-0.2	0.9	N polluted
4	Oak	SJ 09239 11025	-0.2	0.9	N polluted
5	Oak	SJ 09198 11022	-0.6	1.0	N polluted

There was obvious nutrient enrichment in a field immediately north of the SSSI boundary, and a pig farm was located on the hill to the west.

4.2.8 Roundton Hill

This is a steep hill that is volcanic in origin, and most open-grown trees were ash and hawthorn. There were very few accessible oaks, with some supressed trees growing on crags. The LIS and NAQI results for the five trees sampled are shown in Table 13.

Table 13. The Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for five trees at Roundton Hill SSSI in January 2023.

Sample Code	Tree Species	Grid reference	LIS	NAQI	Pollution level
1	Oak	SO 29105 94785	-1.6	1.2	N polluted
2	Oak	SO 29304 94634	-0.2	0.9	N polluted
3	Hawthorn	SO 29485 94672	-2.4	1.5	N polluted
4	Hawthorn	SO 29523 94643	-0.2	0.9	N polluted
5	Oak	SO 29377 94785	0.2	0.8	At risk

4.2.9 Stanner Rocks

This is another steep hill that is volcanic in origin. Few oaks were completely open-grown, and some of the trees sampled were within regenerating woodland. The LIS and NAQI results for the five trees sampled are shown in Table 14.

Table 14. The Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for five trees at Stanner Rocks SSSI in January 2023.

Sample Code	Tree Species	Grid reference	LIS	NAQI	Pollution level
1	Oak	SO 26167 58293	-3.0	1.6	Very N polluted
2	Oak	SO 26456 58790	-0.6	1.0	N polluted
3	Oak	SO 26428 58768	-0.4	0.9	N polluted
4	Oak	SO 26494 58743	-0.6	1.0	N polluted
5	Oak	SO 26402 58646	-1.0	1.1	N polluted

No acidophyte lichens were recorded from Tree 1 at base of the quarry. There was a large pile of rotting mangelwurzels on land between the junction of the A44 and the B4594, and the smell from this was noticeable at the base of the quarry.

4.3 New, rare, and interesting lichens

Two species of lichen and five species of lichenicolous fungi were newly recorded for Radnorshire (including two species of lichenicolous fungi new to Wales). Five species of lichen and 12 species of lichenicolous fungi were newly recorded for Montgomeryshire (including one species of lichenicolous fungus new to Wales). These species are summarised below.

4.3.1 Radnorshire (VC43)

Caloplaca asserigena – recorded on an oak twig at Stanner Rocks, the second record for the vice-county and the first this century.

Homostegia piggotii – a lichenicolous fungus parasitising *Parmelia sulcata* at Coed yr Allt Goch. New to the vice-county.

Lecanora barkmaniana – recorded on an oak twig at Stanner Rocks. New to the vice-county.

Lichenochora aipoliae – a lichenicolous fungus parasitising *Physcia aipolia* at Cwmsaise and Stanner Rocks. New to Wales.

Lichenochora physciicola – a lichenicolous fungus parasitising *Physcia tenella* at Cwmsaise and Stanner Rocks. New to Wales.

Polycoccum minutulum – a lichenicolous fungus parasitising *Trapelia placodioides* growing on pre-Cambrian igneous outcrops at Stanner Rocks. Second record for Wales and the first for the vice-county.

Unguiculariopsis thallophila – a lichenicolous fungus parasitising *Lecanora hybocarpa* at Stanner Rocks. New to the vice-county.

4.3.2 Montgomeryshire (VC47)

Arthonia epiphyscia – a lichenicolous fungus parasitising *Physcia adscendens* at Roundton Hill, and *Physcia tenella* at Breidden Hill and Gwaun Efail Wig. New to the vice-county.

Arthonia parietinaria – a lichenicolous fungus parasitising *Xanthoria parietina* at Gwaun Efail Wig. New to the vice-county.

Caloplaca asserigena – recorded on oak twigs at Blaen Cownwy and Roundton Hill. New to the vice-county.

Catillaria nigroclavata – recorded on oak twigs at Cors Farchwel and Gwaun Efail Wig. New to the vice-county.

Chaenotheca brachypoda – recorded on an oak trunk at Gregynog, a species not seen at this site since 1979. The second record for the vice-county and the first this century.

Cladophialophora parmeliae – a lichenicolous fungus parasitising *Hypotrachyna afrorevoluta* at Cors Farchwel. New to the vice-county.

Epicladonia sandstedei – a lichenicolous fungus parasitising *Cladonia polydactyla* at Gregynog. New to the vice-county.

Erythricium aurantiacum – a lichenicolous fungus parasitising *Physcia* species at five SSSIs: Breidden Hill, Cors Farchwel, Gregynog, Cors Farchwel, Roundton Hill, and Gwaun Efail Wig. New to the vice-county.

Heterocephalacria physciacearum – a lichenicolous fungus parasitising *Physcia tenella* at four SSSIs: Blaen Cownwy, Cors Farchwel, Gregynog, and Gwaun Efail Wig. First modern record for the vice-county.

Illosporiopsis christiansenii – a lichenicolous fungus parasitising *Physcia tenella* at four SSSIs: Breidden Hill, Gregynog, Gwaun Efail Wig, and Roundton Hill. New to the vice-county.

Japewiella tavaresiana – recorded on oak twigs at Blaen Cownwy and Gregynog. New to the vice-county.

Lichenochora aipoliae – a lichenicolous fungus parasitising *Physcia aipolia* at Cors Farchwel. New to the vice-county.

Lichenochora physciicola – a lichenicolous fungus parasitising *Physcia tenella* at Breidden Hill and Cors Farchwel. New to the vice-county.

Lichenodiplis lecanorae – a lichenicolous fungus parasitising *Caloplaca cerinella* at Gwaun Efail Wig. New to the vice-county.

Lichenodiplis pertusariicola – a lichenicolous fungus parasitising *Pertusaria leioplaca* at Gregynog. New to the vice-county.

Marchandiomyces corallinus – a lichenicolous fungus parasitising *Parmelia sulcata* at Blaen Cownwy. New to the vice-county.

Melanohalea laciniatula – recorded on an oak branch at Cors Farchwel. New to the vice-county.

Nectriopsis physciicola – a lichenicolous fungus parasitising *Physcia aipolia* at Cors Farchwel. New to Wales.

Orcularia insperata – recorded on oak twigs at Gregynog and Cors Farchwel. New to the vice-county.

5. Discussion

5.1 Ammonia pollution

The Convention on Long Range Transboundary Air Pollution and National Emissions Ceiling Regulations require the UK to reduce ammonia emissions from 2005 levels by 8 per cent in 2020, and by 16 per cent in 2030 (Defra, 2023). Ammonia emissions have fallen by 16 per cent since 1980, to 259 thousand tonnes in 2020 (Defra, 2023). This is largely the result of changes to farming practices and herd sizes, although annual emissions have remained relatively stable since 2007 and increased by 7 per cent between 2013 to 2017 (Defra, 2023). The ceiling for ammonia emissions was 257.6 thousand tonnes in 2020, and so the UK only achieved a 7 per cent reduction since 2005, although there has been an application to adjust the total downwards based on revised emission inventory methods (Defra, 2023).

Emissions from agriculture accounted for 87 per cent of total UK ammonia emissions in 2020, which has remained relatively unchanged over the past decade (Defra, 2023). The spreading of organic and inorganic fertilisers is a significant source of ammonia emissions from agriculture and increased from 124 thousand tonnes in 2010 to 131 thousand tonnes in 2020 (Defra, 2023). The only ‘clean’ sites recorded during this twig lichen survey were in upland western Powys (Coed yr Allt Goch and Berwyn). The latter is a large SSSIs (Berwyn is 24267.5 ha) with extensive areas of very low-intensity land management, whilst the former is surrounded by the large Elenydd SSSI. Lowland sites on the eastern side of Powys were ‘N polluted’ (Stanner Rocks) or ‘Very N polluted’ (Breidden Hill). Two sites in the north of the county were also ‘N polluted’ (Cors Farchwel and Gwaun Efail Wig) and two sites in the centre were ‘At risk’ (Gregynog and Cwmsaise).

Gregynog was also surveyed in 2017 to assess the effects of ammonia pollution on twig lichens (Bosanquet, 2018). This found oak trees within the SSSI that were ‘Clean’, ‘At risk’, and ‘N polluted’. The trees surveyed in 2023 were all ‘At risk’ rather than ‘N polluted’, although no trees were assessed as ‘Clean’. Coed yr Allt Goch was also surveyed in 2017, when the NAQI was 0.2 (‘Clean’), as was the case in January 2023. Other sites in central and north Powys were similarly ‘At risk’ or ‘N polluted’ in 2017 (Bosanquet, 2018) which supports the findings in the current survey. The twig lichen communities at sites located in landscapes with intensive agriculture are clearly experiencing substantial effects from ammonia pollution.

The ammonia concentration modelled by the Air Pollution Information System (APIS, 2023) in the period 2018-2020 for 5 x 5 km squares containing the SSSIs is shown in Table 15.

Table 15. The ammonia concentration modelled by the Air Pollution Information System (APIS, 2013) for 5 x 5 km squares containing the SSSIs in the 2023 Powys twig survey.

Site	SSSI	Grid reference	Ammonia concentration (µg m-3)
Blaen Cownwy	Berwyn	SH 984 181	1.11
Breidden Hill	Breidden Hill	SJ 290 143	3.30
Cors Farchwel	Cors Farchwel	SJ 090 154	1.58
Cwmsaise	Cwmsaise	SO 140 699	2.41
Coed yr Allt Goch	Coed yr Allt Goch	SN 913 673	1.02
Gregynog	Gregynog	SO 081 976	2.01
Gwaun Efail Wig	Gwaun Efail Wig	SJ 093 110	2.07
Roundton Hill	Roundton Hill	SO 293 949	2.57
Stanner Rocks	Stanner Rocks	SO 263 585	2.27

There is a broad positive correlation between modelled ammonia concentrations and increasing Nitrogen Air Quality Index at site-level, as shown in Figure 2.

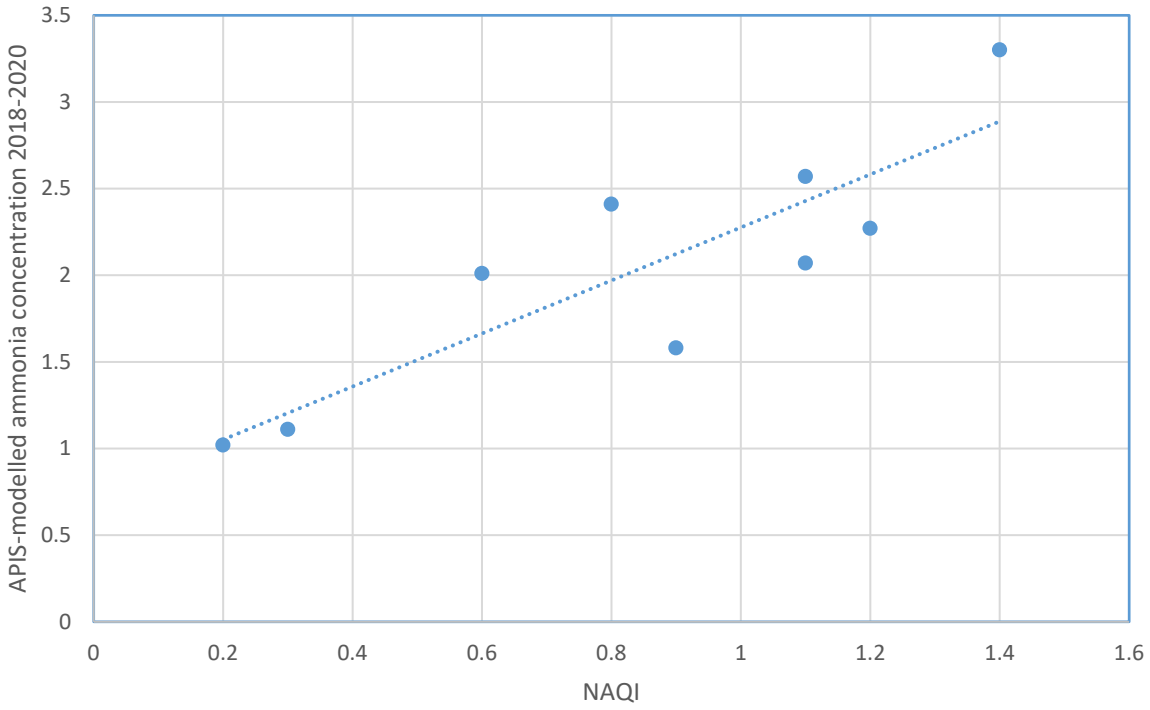


Figure 2. Scatter plot of NAQI values in the 2023 Powys twig lichen survey and APIS-modelled ammonia concentrations for 2018-2020 in 5 x 5 km squares containing the nine sampled SSSIs.

Variation from predicted values is inevitable as the ammonia concentration is averaged over a 5 km x 5 km area and this is unlikely to accurately represent levels within the SSSIs. This is evident where individual trees within a few hundred metres show differing levels of response to ammonia pollution. It also does not take account of the potential for persistent ammonia plumes due to weather effects such as temperature inversions, the potential toxicity of intermittent higher doses of ammonia, or the screening effects of other trees within and around sites. The critical ammonia level for lichen-rich communities has been proposed as 1 µg m^{-3} (Cape *et al*., 2009), although some species may be damaged even at lower concentrations.

The Environment (Wales) Act 2016 includes a duty for NRW to “prevent significant damage to our ecosystems” and to “maintain and enhance biodiversity”. Lichens are key components of many Special Area of Conservation (SAC) habitats and are designated features within 85 SSSIs in Wales (Bosanquet, 2018). Gregynog SSSI is notified for wood-pasture/parkland habitat including associated epiphytic lichens, and the twig lichen community has already undergone substantial negative effects. Existing emissions sources around this site include three intensive poultry farms within 3 km, and dairy farms which spread slurry on silage fields adjacent to the SSSI (Bosanquet, 2018). In the wider landscape an entire community of foliose lichens has been replaced by ammonia-tolerant species. This potentially also affects nutrient cycling at the ecosystem level, and some invertebrates that require the structural complexity of lichens on twigs and branches (Gunnarson *et al*., 2004; Pescott *et al*., 2015).

The effects of ammonia pollution on twig lichens are well-documented (Wolseley *et al*., 2003). It is unclear whether lichens on siliceous rocks might also be affected. This should be considered, as some of the sites in this survey (Breidden Hill and Stanner Rocks) are in part notified for saxicolous lichen assemblages. These sites are of volcanic origin, with rocks of variable base-richness. In addition, there is potential for damage to other SSSI designated features including higher plants and mosses. Algae have been observed encrusting cushions of the moss *Weissia levieri* at Roundton Hill, and this species is listed on Section 7 of the Environment (Wales) Act 2016 (Bosanquet, 2018).

In Wales at present, smaller poultry or pig units are subject to planning permission but do not require a permit under Environmental Permitting Regulations. The cumulative effect of multiple units is considered for units controlled by the same operator, but not different operators. This is potentially problematic as smaller, non-regulated poultry units subject to planning permission had a greater impact on local ammonia concentrations than a much larger regulated intensive unit (Aazem & Bareham, 2015). This is partly because regulated poultry units have to meet higher pollution control requirements, and it has major implications for assessing environmental impacts on protected designated sites and the wider countryside (Aazem & Bareham, 2015).

5.2 Methodological issues

During this survey three species of lichen with small black apothecia were recorded from young oak twigs: *Amandinea punctata* at Roundton Hill and Gwaun Efail Wig, *Catillaria nigroclavata* at Cwmsaise, Cors Farchwel, Gwaun Efail Wig, and Stanner Rocks; and *Orcularia insperata* at Cors Farchwel and Gregynog.

Superficially the thallus of *Amandinea punctata* is variable. It can be thin, or thicker and composed of tiny grey warts with apothecia that are convex when mature. The apothecia in *Catillaria nigroclavata* are in general smaller and more crowded than those in *Amandinea punctata*, remaining flatter on maturity and retain a narrow apothecial margin. The thallus in *Catillaria nigroclavata* is thin and often described as scurfy. Unlike the leceidine fruits of *Amandinea punctata* and *Catillaria nigroclavata*, the apothecia of *Orcularia insperata* have a very narrow lecanorine margin which is difficult to see in the field and is excluded on maturation or when saturated.

These species could easily be misidentified in the field, especially in wet conditions. It is therefore recommended that microscopy is used to separate these three species in future surveys. Further scientific studies would be required to clarify the suitability of *Amandinea punctata* as a nitrogen-tolerant indicator species. The potential for including other acidophyte lichen species such as *Platismatia glauca* could also be explored.

6. Conclusions

This survey has identified ongoing negative effects of ammonia pollution across large areas of Powys. These are causing significant changes in twig lichen communities, and only sites in landscapes with low ammonia emissions are not currently affected. NRW has a statutory duty to take account of protected site features, and it is hoped that the results of the current survey will lead them to examine the non-lichen features of the studied SSSIs to identify whether high levels of ammonia are causing damage.

Twig lichen surveys provide valuable data to rapidly demonstrate the effects of different ammonia levels and should be required to provide a baseline wherever intensive agriculture proposals are made close to lichen-rich designated sites. Ammonia concentrations should be accurately assessed where lichens are a designated feature of protected sites, rather than relying on broad-scale modelling. The cumulative impact of intensive agricultural proposals should be assessed regardless of ownership, and the potential for applying stricter emissions control standards at all intensive agricultural developments should also be considered.

7. Acknowledgements

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6. Appendices

The raw data tables have been removed from this Accessible copy of the report because it is not possible to format them in a way that meets Accessibility requirements. Full copies of the report are available electronically from the NRW Library.

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Natural Resources Wales

Data Archive Appendix

Data outputs associated with this project are archived in DMS on server–based storage at Natural Resources Wales.

The data archive contains:

- The final report in Microsoft Word and Adobe PDF formats;
- A spreadsheet of lichen records.

The metadata for this project is held as record no 125502.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue https://libcat.naturalresources.wales (English Version) and https://catllyfr.cyfoethnaturiol.cymru (Welsh Version) by searching 'Dataset Titles'.

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