Cyfoeth Naturiol Cymru
Natural Resources Wales

Lichen Survey of Dinefwr NNR (VC 44 Carmarthenshire):

including re-monitoring the 2013 baseline, comments on air pollution and Ash Dieback.

April Windle & John R. Douglass

Evidence Report No 682

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Report series:	Evidence Reports
Report number:	682
Publication date:	March 2023
Contract number:	
Contractor:	April Windle & John Douglass
Contract Manager:	Ali Baird
Title:	Lichen Survey of Dinefwr NNR (VC 44 Carmarthenshire): including re-monitoring the 2013 baseline and comments on air pollution and Ash Dieback
Author(s):	April Windle & John R. Douglass
Technical Editor:	Sam Bosanquet
Peer Reviewer(s)	David Reed
Approved By:	Liz Halliwell
Series editor(s):	
Restrictions:	None

Distribution List (electronic only):

NRW Library, Bangor

National Library of Wales

British Library

Welsh Government Library

Nature Scot Bryophyte, Lichen & Fungus Specialist

Natural England Lichen & Fungus Specialist

NRW Environment Team for Carmarthenshire

National Trust Dinefwr

Recommended citation for this volume:

Windle A, Douglass JR. 2023. *Lichen Survey of Dinefwr NNR (VC 44 Carmarthenshire): including re-monitoring the 2013 baseline and comments on air pollution and Ash Dieback*. *NRW Evidence Report 682*, 186 pp, Natural Resources Wales, Bangor.

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1. Crynodeb Gweithredol

- **Amcanion:** Mae'r adroddiad yn manylu ar ganfyddiadau arolwg cennau ar draws Ystad Dinefwr (VC 44 Sir Gaerfyrddin), safle 224 hectar sy'n eiddo i'r Ymddiriedolaeth Genedlaethol ac sy'n cael ei rheoli ganddi. Mae Dinefwr yn dirwedd goediog helaeth, hynafol sy'n cynnwys parc ceirw gweithredol, coetiroedd pori, parc wedi'i dirweddu a chynefin coetir gwlyb, ac a nodweddir gan grynodiad trawiadol o fawr o goed derw aeddfed a hynod. Mae hirhoedledd y coed hyn wedi arwain at ddatblygiad eithriadol o gennau sydd ag arwyddocâd cenedlaethol a rhyngwladol.

- **Arolwg:** Cwblhawyd yr arolwg hwn dros chwe diwrnod ym mis Medi 2022. Fe'i llywiwyd yn bennaf gan arolwg a gynhaliwyd gan Neil Sanderson yn 2013, a oedd yn cynnwys llawer o fanylion i alluogi'r gwaith o ail-fonitro'r cennau. Yn ogystal, ymgynghorwyd â chronfa ddata Cymdeithas Cennau Prydain gan fod nifer o wyddonwyr cennau amlwg wedi gwneud ymweliadau maes dros y blynyddoedd. Amlinellir y gwaith o fonitro'r coed yn adroddiad 2013 Sanderson yn yr atodiadau.

- **Nodweddion y cennau:** Mae cymariaethau uniongyrchol o rywogaethau a chymunedau rhwng arolwg 2013 ac arolwg 2022 wedi'u rhoi ar ffurf tabl. Roedd y prif gennau a ganfuwyd yn cynnwys y canlynol: ***Cladonietum coniocraeae*** **(lignwm llaith):** *Cladonia incrassata* a *C. parasitica*; ***Calcietum abietinae*** **(lignwm sych):** *Buellia hyperbolica***,** *Chaenotheca stemonea* (newydd yn 2022) a *C. pusilla* (2013); ***Lecanactidetum premneae*** **(rhisgl sych hynafol):** *Cresponea premnea***,** *Enterographa sorediata* (2013), *Lecanographa lyncea*, *Milospium graphideorum*, *Inoderma* (*Lecanactis*) *subabietina*, *Snippocia nivea* a *Sporodophoron cretaceum*; ***Lobarion pulmonariae*** **(rhisgl tra-fasig):** *Agonimia octospora*, *A. allobata* (2013), *Arthonia vinosa*, *Bacidia biatorina*, *Catinaria atropurpurea*, *Dimerella lutea*, *Lobaria pulmonaria*, *Mycobilimbia epixanthoides*, *M. pilularis*, *Mycobilimbia pilularis*, *Opegrapha corticola*, *Pachyphiale carneola*, *Peltigera horizontalis*, *Porina coralloidea*, *Porina rosei*, *Ramonia chrysophaea*, *Rinodina roboris* amr. *roboris* a *Thelopsis rubella*; ***Parmelion laevigatae*** **(rhisgl sur):** *Arthonia anombrophila* (2013), *Cliostomum flavidulum*, *Micarea alabastrites*, *M. doliiformis*, *Opegrapha fumosa* (2013) a *Ropalospora viridis* (2013); a **chasgliadau ar olion clwyfau:** *Bacidia incompta* (tair coeden) a *Collema fragrans* (un goeden).

- **Rhywogaethau nodedig:** Rhwng 1972 (cofnod cynharaf Cymdeithas Cennau Prydain) a 2022, mae 345 o rywogaethau o gennau a ffyngau llawn cennau wedi'u cofnodi o fewn Gwarchodfa Natur Genedlaethol Dinefwr. Wrth gasglu data o'r 25 mlynedd diwethaf (2000–2022), mae 292 o rywogaethau wedi'u cofnodi. Mae hyn yn cynnwys 70 o rywogaethau a nodir, gyda thair o dan fygythiad (un mewn perygl a dwy dan fygythiad), 10 dan beth bygythiad, 49 sy'n genedlaethol anfynych, pump sy'n genedlaethol brin a 31 o rywogaethau â chyfrifoldeb rhyngwladol (o dan werthusiadau cadwraeth Prydain Fawr ac Iwerddon).

- **Sgoriau TNTN a SOWI:** Cymhwyswyd y Mynegai Dan Fygythiad, Dan Beth Bygythiad a Nodedig (TNTN) a Mynegai Coetir Cefnforol y De (SOWI) i'r

Warchodfa Natur Genedlaethol, gan gynnwys yr holl ddata o'r 25 mlynedd diwethaf. Mae'r cennau sy'n bresennol ar draws gwahanol ardaloedd Dinefwr yn sgorio 68 ar raddfa TNTN (mae'r trothwy yn 16) a 40 ar SOWI (mae'r trothwy yn 20). Mae sgôr Dinefwr ar gyfer ei gennau yn uwch na'r trothwyon ar gyfer cael ei bennu fel Safle o Ddiddordeb Gwyddonol Arbennig (SoDdGA) ar y ddau fynegai.

- **Rheoli'r safle:** Mae Ystad Dinefwr yn cynnwys holl nodweddion tirwedd tir parc. Mae'r bygythiadau i rywogaethau a chynefinoedd yn benodol i'r ardal ac mae angen mynd i'r afael â'r gwaith rheoli ar lefel yr uned. Wrth gymharu gorchudd y coetir o fapiau Arolwg Ordnans 1885 â ffotograffau o'r awyr o 2022, bu cynnydd cyffredinol yn y gorchudd coed, sy'n beth ffafriol. Mae amrywiaeth strwythurol y safle yn gyffredinol yn dda iawn, ond mae hyn yn dirywio yng Nghoed y Castell a rhai ardaloedd o'r parc sydd wedi'i dirweddu oherwydd lleihau/gwahardd pori. Ar draws y safle, mae'r amrywiaeth oedran a'r gorgyffwrdd o ran oed y coed yn rhagorol, gyda chrynodiad uchel o goed aeddfed a hynod, a datblygiad coed aeddfed a choed sy'n aeddfedu. Fodd bynnag, ychydig iawn o adfywiad diweddar neu goed derw ifanc sydd i'w gweld ac mae angen mynd i'r afael â hyn. Mae hyn yn arbennig o wir yn y parc sydd wedi'i dirweddu. Mae digonedd o bren marw yn Ninefwr ac mae'n nodwedd bwysig o'r cynefin. Mae'n hanfodol sicrhau nad yw coed marw yn cael eu cysgodi i raddau helaeth gan lystyfiant, a'u bod yn parhau i gael eu hawyru a'u goleuo'n dda. Er mai coed derw sydd drechaf, mae amrywiaeth dda o rywogaethau coed, ond dylai'r Ymddiriedolaeth Genedlaethol barhau i amrywio rhywogaethau coed ymhellach, yn enwedig yng ngoleuni clefyd (Chalara) coed ynn ac o ystyried pwysigrwydd castanwydd y meirch i rywogaethau ar y rhestr goch. Dylid ystyried gwaredu *Rhododendron* estron yn flaenoriaeth yng Nghoedwig y Gors, gan fod gan yr ardal hon botensial enfawr ar gyfer cytrefu ac ehangu *Lobaria pulmonaria*.

- **Pwysigrwydd coed ynn:** Mae'r onnen *(Fraxinus excelsior)* yn rhywogaeth bwysig o goed ar draws Ystad Dinefwr oherwydd ei chennau epiffytig. Y dderwen oedd y rhywogaeth amlycaf o'r rhywogaethau coed, gydag ambell onnen, ond roedd coed ynn yn dal i fod yn arwyddocaol ar gyfer cennau nodedig. Ymhlith y rhywogaethau nodedig a gofnodwyd ar goed ynn mae'r canlynol: *Leptogium lichenoides, L. teretiusculum, Lobaria pulmonaria, Mycobilimbia epixanthoides*, *M. pilularis* a *Peltigera horizontalis* (wedi'u crynhoi yn Nhabl 3). Mae gwaith rheoli a lliniaru wedi cael ei drafod yng ngoleuni clefyd (Chalara) coed ynn, i sicrhau bod y cynefin yn y cyflwr gorau posibl a bod amrywiaeth ehangach o goed yn lle coed ynn yn cael eu cyflwyno.

- **Llygredd aer:** Mae deall effeithiau llygredd aer ar rywogaethau a chymunedau cennau yn amlweddog ac yn gymhleth. Wrth ystyried **fflora brigau**, mae canfyddiadau Sanderson (2014) a Bosanquet (2017 a 2019) yn sicr yn cyd-fynd â chanfyddiadau arolwg 2022, ac yn dangos bod y coed hynny ar gyrion yr Ystad a'r ffermdir sy'n ffinio â hi yn cynnal yr helaethrwydd mwyaf o rywogaethau o gennau brigau sy'n gysylltiedig â chymunedau (nitroffilig) *Xanthorion* a *Physcietum*.

Mewn perthynas â'r **cennau ar foncyffion**, bu'n anodd penderfynu p'un a yw llygredd nitrogen yn effeithio ar y boncyffion, er mai dyma oedd un o nodau'r prosiect hwn. Bu twf parhaus o gennau hen goedwig ar y mwyafrif o'r boncyffion a arolygwyd ers arolwg Sanderson yn 2013. Cofnodwyd rhywogaethau a ystyrir yn rai "nitroffilig" ar y boncyffion, gan gynnwys *Pachnolepia (Arthonia) pruinata* a *Diploicia canescens*, ac yr oedd helaethrwydd y rhywogaethau hyn yn uwch nag yn arolwg 2013. Fodd bynnag, dylid bod yn ofalus wrth ddefnyddio'r rhywogaethau hyn, ac ni ddaethpwyd o hyd i unrhyw dystiolaeth bendant bod y cymunedau cennau ar foncyffion yn dirywio.

2. Executive Summary

- **Objectives:** The report details the findings of a lichen survey across the Dinefwr Estate (VC 44 Carmarthenshire), a 224 ha site that is owned and managed by the National Trust. Dinefwr is an extensive, ancient wooded landscape composed of a functioning deer park, pasture woodlands, a landscaped park and wet woodland habitat, which are characterised by an impressively large concentration of post-mature and veteran oak trees. This long continuity has resulted in an exceptional development of lichens that are both nationally and internationally significant.

- **Survey:** This survey was completed over 6 days in September 2022. It was mainly informed by the 2013 survey conducted by Neil Sanderson, which provided a huge amount of detail to re-monitor the lichen interest. In addition, the British Lichen Society database was consulted, because there have been a number of field visits by eminent lichenologists over the years. Monitoring of the 2013 Sanderson trees is outlined in the Appendices.

- **Lichen Features:** Direct comparisons have been tabulated of species and communities from the 2013 and 2022 survey. The main lichen interest included: ***Cladonietum coniocraeae*** **(damp lignum):** *Cladonia incrassata* and *C. parasitica*; ***Calicietum abietinae*** **(dry lignum):** *Buellia hyperbolica***,** *Chaenotheca stemonea* (new in 2022) and *C. pusilla* (2013); ***Lecanactidetum premneae*** **(ancient dry bark):** *Cresponea premnea***,** *Enterographa sorediata* (2013), *Lecanographa lyncea*, *Milospium graphideorum*, *Inoderma* (*Lecanactis*) *subabietina*, *Snippocia nivea* and *Sporodophoron cretaceum*; ***Lobarion pulmonariae*** **(base-rich bark):** *Agonimia octospora*, *A. allobata* (2013), *Arthonia vinosa*, *Bacidia biatorina*, *Catinaria atropurpurea*, *Dimerella lutea*, *Lobaria pulmonaria*, *Mycobilimbia epixanthoides*, *M. pilularis*, *Mycobilimbia pilularis*, *Opegrapha corticola*, *Pachyphiale carneola*, *Peltigera horizontalis*, *Porina coralloidea*, *Porina rosei*, *Ramonia chrysophaea*, *Rinodina roboris* var. *roboris* and *Thelopsis rubella*; ***Parmelion laevigatae*** **(acid bark):** *Arthonia anombrophila* (2013), *Cliostomum flavidulum*, *Micarea alabastrites*, *M. doliiformis*, *Opegrapha fumosa* (2013) and *Ropalospora viridis* (2013); and **Wound track assemblages:** *Bacidia incompta* (three trees) and *Collema fragrans* (one tree).

- **Notable Species:** Between 1972 (earliest BLS record) and 2022, 345 species of lichens and lichenicolous fungi have been recorded within Dinefwr NNR. Compiling data from the last 25 years (2000 – 2022), 292 species have been recorded. This includes 70 Notable Species, with 3 Threatened (1 Endangered & 2 Vulnerable), 10 Near Threatened, 49 Nationally Scarce, 5 Nationally Rare and 31 International Responsibility species (under the GB & Ireland conservation evaluations).

- **TNTN & SOWI Scores:** The Threatened, Near Threatened and Notable (TNTN) Index and the Southern Oceanic Woodland Index (SOWI) were applied to the NNR, including all data from the last 25 years. Here, the lichens present across the various areas of Dinefwr score 68 on the TNTN (threshold 16) and 40 on the SOWI (threshold 20). Dinefwr exceeds the thresholds for SSSI selection on both indices for its lichen feature.

- **Site Management:** Dinefwr Estate covers an entire parkland landscape. Species and habitat threats are area-specific and management needs to be addressed at the unit level. When comparing woodland cover from the 1885 Ordnance Survey maps to 2022 aerial photography, there has been an overall increase in tree cover, which is favourable. The structural diversity of the site in general is very good, but in Castle Wood and certain areas of the landscaped park, this is being lost due to the reduction / exclusion of grazing. Across the site, the age diversity and overlap in tree ages is excellent, with a high concentration of post-mature and veteran trees, and development of mature and maturing trees. However, there is very little recent regeneration or young oaks, which needs addressing. This is particularly the case in the landscaped park. Deadwood is in good abundance at Dinefwr and is an important habitat feature. It is crucial to ensure that deadwood is not heavily overshaded by vegetation, remaining well-ventilated and well-lit. Although oak is dominant, there is a good tree species diversity, however the National Trust should continue to diversify tree species further, particularly in the light of Ash Dieback and considering the importance of horse chestnut for red-listed species. The clearance of the non-native *Rhododendron* should be seen as a priority in Bog Wood, as this area has huge potential for the colonisation and expansion of *Lobaria pulmonaria.*

- **Importance of ash:** Ash *(Fraxinus excelsior)* proves an important tree species for its epiphytic lichens across the Dinefwr Estate. In terms of tree species composition, oak was the dominant species with occasional ash, but ash still proved significant for notable lichens. Noteworthy species recorded on ash include: *Leptogium lichenoides*, *L. teretiusculum*, *Lobaria pulmonaria*, *Mycobilimbia epixanthoides*, *M. pilularis* and *Peltigera horizontalis* (summarised in Table 3). Management and mitigation works have been discussed in the light of Ash Dieback, to ensure the habitat is in optimal condition and a wider variety of ash-substitutes are recruited.

- **Air pollution:** Understanding the impacts of air pollution on lichen species and communities is multi-faceted and complex. With regards to the **twig flora**, the findings from the Sanderson (2014) and Bosanquet (2017 & 2019) certainly coincide with the findings of the 2022 survey, where those trees on the periphery of the Estate and abutting farmland support the highest abundance of twig lichen species associated with the *Xanthorion* and *Physcietum* (nitrophilic) communities.

  In relation to the **lichens on trunks**, it proved difficult to determine whether nitrogen pollution is affecting the trunks, despite this being one of the aims of this project. There has been continued growth of old-forest lichens on the majority of the trunks surveyed since Sanderson's 2013 survey. On the trunks, there were species that were recorded which are considered "Nitrophilic", including *Pachnolepia (Arthonia) pruinata* and *Diploicia canescens*, where the abundance of these species was higher than the survey in 2013. However, these species should be used with caution, and no conclusive evidence of deterioration of trunk lichen communities was found.

3. Introduction

3.1. Background

The Dinefwr Estate is a 224 ha site in Carmarthenshire (VC 44) that is owned and managed by the National Trust. There is an extensive, ancient wooded landscape comprising a functioning deer park, pasture woodlands, a landscaped park and wet woodland habitat, which are characterised by an impressively large concentration of post-mature and veteran oak trees. This long continuity has resulted in an exceptional development of lichens that are both nationally and internationally significant. A detailed and very interesting land-use history of the park have been provided in the 2013 lichen survey by Neil Sanderson.

The SSSI citation for Dinefwr describes the Estate:

“Dinefwr Estate is of special interest because of its lichen and invertebrate assemblages which are principally associated with the parkland and woodland trees. The woodland and oxbows on the floodplain are also of special interest for their plant assemblages. The Estate is located immediately west of the town of Llandeilo and adjacent to the Afon Tywi. A large part of the site is a deer park, which is one of the finest examples in Wales of a pasture woodland with large veteran trees. The site is underlain by rocks of Ordovician age of which the Llandeilo series are also of special interest. Glacial drift covers the solid geology to a variable extent with river alluvium on the Tywi floodplain”.

Biology (in relation to lichens and associated habitat): “Lichen communities developing on the parkland and woodland trees are of considerable importance. Over 160 species have been recorded to date, many of which are indicative of woodlands which have a long history of ecological continuity. These include lichens such as *Catillaria atropurpurea*, *C. pulverea*, *Lecanactis* spp., *Schismatomma niveum* and *Thelotrema lepadinum.*”

“Also present are *Lobaria pulmonaria* and *Sticta limbata*, species which are very sensitive to atmospheric pollution. Nationally scarce species such as *Gyalideopsis muscicola*, *Phyllopsora rosei* and *Lecidea doliiformis* are also present as is the Red Data Book species *Collema fragrans.* This species is usually found on the nutrient rich bark of trees such as elm but has suffered a dramatic decline in recent years due to Dutch Elm disease.”

“The over-mature nature of the trees together with a preponderance of standing and fallen dead wood is also ideal habitat for invertebrate species. Dinefwr Estate is of national (UK) importance for its community of saproxylic (dead wood) invertebrates, mostly beetles. These comprise specialised and fastidious invertebrates which are of extremely localised occurrence and are intimately associated with sites supporting a continuum of decaying timber. The few localities where populations of these rare or scarce species persist are generally relict patches of pasture-woodland, including ancient deer parks as at Dinefwr (the deer park was created in its present form by enclosure in 1660)” (Countryside Council for Wales, 1999).

3.2. Conservation Objectives

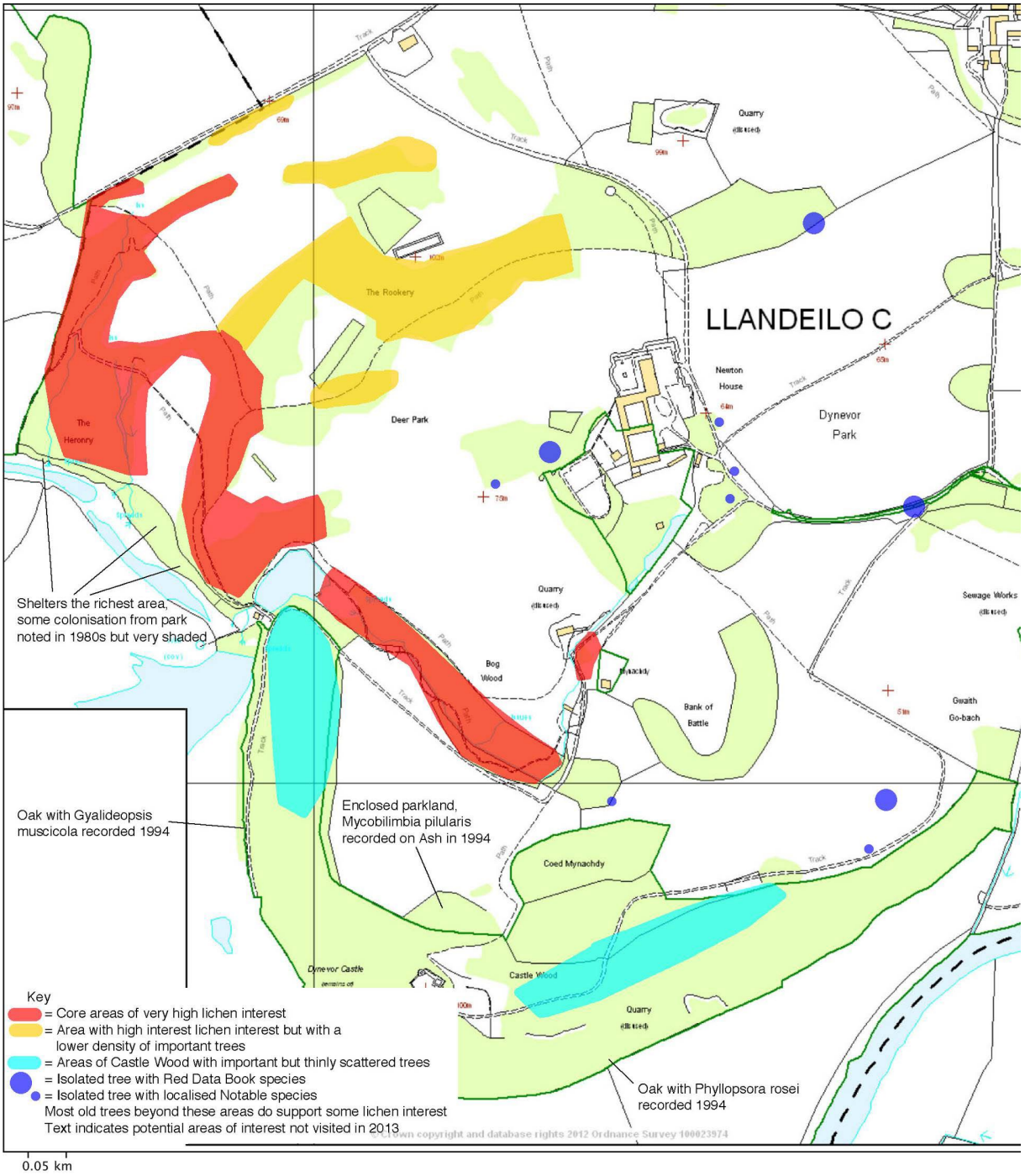
This survey was funded by Natural Resources Wales (NRW), with an aim to monitor the lichens of the Dinefwr Estate SSSI (VC 44 Carmarthenshire), which is considered the “richest parkland for epiphytic lichens in Wales” (Sam Bosanquet, pers. comm.). The project specification noted that a complete survey was not anticipated. However, considering the conservation importance of the site and time available, an attempt was made for maximum coverage of the Estate.

In 2013, Neil Sanderson conducted a survey which recorded epiphytic lichens on a tree-by-tree basis, acknowledging the biological richness and significance of the lichens inhabiting the post-mature and veteran trees. This provided an excellent baseline for lichen monitoring, which could inform whether epiphytic lichens are deteriorating, stable or improving in condition and abundance (Sanderson, 2014).

Subsequent to this, Sam Bosanquet has completed lichen studies on twigs in 2017 and 2019, which indicated the presence of Nitrophilic lichen species throughout the majority of the SSSI, claimed to be suffering from air pollution from neighbouring agricultural sources (Bosanquet 2017; 2019). Monitoring at Dinefwr, with its exceptional baseline survey from 2013 (Sanderson 2014), aims to determine whether N pollution is affecting the trunk lichens there as well as the twig lichens.

For this project, the specification by Natural Resources Wales included the following…

- Select sufficient trees within the richest three areas of Dinefwr Estate SSSI (see Map 1) to determine whether there are any trends in abundance, diversity or condition of trunk epiphytes.
- Produce a list of notable lichens for each selected tree, as in 2014, and also a list of N-tolerant lichens (if any) on those selected trees.
- Choose 10 trees for more detailed monitoring and produce annotated photographs to show the distribution and abundance of key species on each of those trees.
- Visit all Ash trees with known important lichens and provide recommendations for canopy reduction and/or felling if Ash Dieback was to occur.
- Visit other trees supporting the rarest of Dinefwr’s lichens and identify any proactive management that can be carried out to maintain or enhance those lichens.
- Write up the results in a report and produce a spreadsheet of records, where GPS readings must be British National Grid, not Lat-Long.



Map 1: The key areas of the Dinefwr Estate with the highest lichen interest (extract from Sanderson, 2014). The areas in red, yellow, blue and the purple circles were the focal survey areas in 2022, as specified by Natural Resources Wales.

4. Methods

4.1. Desk Study

4.1.1. Data Sources

The British Lichen Society (BLS) National Database was consulted for all existing VC 44 (Carmarthenshire) lichen records. A summary of historic surveys that have been undertaken across the Estate can be found in Sanderson (2014). In addition to this, unpublished literature for the site was consulted which included the following reports:

- Sanderson, N.A. (2014) *Epiphytic Lichen Survey of Dinefwr NNR Carmarthenshire, 2013*. A report for Plantlife.

- Bosanquet, S.D.S. (2017) *Dinefwr Park SSSI - a transect recording twig lichens to investigate current ammonia levels*. NRW Internal Report, Monmouth.

- Bosanquet S.D.S (2019) *Lichen surveys to investigate ammonia impacts*. NRW Evidence Report No: 298, 126 pp, Natural Resources Wales, Bangor.

4.1.2. Abbreviations

There are various abbreviations throughout this report relating to the conservation evaluations of lichens and lichenicolous fungi. The following information is extracted from Woods & Coppins (2012) and Sanderson *et al*. (2018).

- **IUCN Red List Threat Categories, Abbreviations: EX** – Extinct, **CR** – Critically Endangered (taxa that meet CR criteria and are at high risk of extinction in the wild), **EN** – Endangered (taxa that meet EN criteria and are at high risk of extinction in the wild), **VU** – Vulnerable (taxa that meet VU criteria and are at high risk of extinction in the wild), **DD** - Data Deficient (in most cases, species have recently been found in GB and there is insufficient data available for evaluation), **NT** – Near Threatened (when taxa do not qualify for CR, EN or VU status, but are close to qualifying least or is likely to qualify in the future, and **LC** – Least Concern.

- **Other abbreviations: NE** – Not Evaluated (conservation status of the taxa has not yet been evaluated), **E** – Endemic (i.e. taxa recorded only from the British Isles), **IR** – International Responsibility (likely Britain supports 10% of the extant European and/or global population, however, further research is required), **NR** – Nationally Rare (taxa that are recorded from 1-15 hectads), **NS** – Nationally Scarce (taxa that are recorded from 16 – 100 hectads, **P** – Priority BAP species (taxa listed within the Biodiversity Action Plan) and **S8** – Schedule 8 (taxa listed on Schedule 8 of the Wildlife & Countryside Act 1981).

- **Taxa on published lists of principal importance: Eng** – England (taxa listed under Section 41 of the NERC Act 2006), **Sc** – Scotland (taxa listed under Section 2 of the Nature Conservation Act 2004) and **Wa** – Wales (taxa listed under Section 7 of the Environment (Wales) Act 2016).

4.2. Fieldwork & Survey

4.2.1. Survey Dates & Weather Conditions

A total of six days fieldwork was completed between Thursday 22nd and Tuesday 27th September 2022. The weather conditions were generally dry, but there were occasional downpours. Rain either during or prior to fieldwork can make surveying difficult, especially regarding the identification of swollen crust-forming species on saturated bark.

4.2.2. Areas Surveyed

The areas surveyed in 2022 included most of those targeted by Neil Sanderson in 2013. The detailed tree-by-tree information provided exact localities for notable trees and these were relocated by the use of maps and GPS. For consistency, these areas correspond with those named areas in Sanderson (2014) including: Deer Park West (north, central & south), Deer Park Central (north & south), Deer Park East, Landscape Park and Bog Wood (Deer Park). The original maps that informed this 2022 survey can be found in Sanderson (2014) under Annex 4 - pg. 84 "Trees Recorded". The following area descriptions are copied direct from Sanderson (2014)

- **"Deer Park, West**: subdivided by 1km squares SN6022 and SN6122, pasture woodland and some isolated parkland trees, which includes The Heronry and strips of wood reaching east and north. This was subdivided into a southern area, south of the track above the spring, a central area along the valley to the north of the track and a strip of woodland to the north along the boundary. An intensive survey (Sanderson, 2014)".
- "**Deer Park, Central**: subdivided by 1km squares SN6022 and SN6122, pasture woodland and some isolated parkland trees, which includes The Rookery and woodland to the south of this. This was subdivided into a southern area, south of the track, a central area on the south side of the hill and an area to the north. An intensive survey (Sanderson, 2014)".
- "**Deer Park, Bog Wood**: entirely within 1km square SN6122, the wet pasture woodland and fringing drier edges in the bottom land along the southern edge of the park. An intensive survey (Sanderson, 2014)".
- "**Deer Park, East**: entirely within 1km square SN6122, an ornamental clump and some isolated trees within the deer park to the east. An intensive survey (Sanderson, 2014)".
- "**Castle Wood**: subdivided by 1km squares SN6021, SN6022, SN6121 and SN6122, woodland along a ridge. This survey a transect through the most open areas with old trees. Access was difficult due to combinations of Bracken, Bramble and Nettles. Very steep slopes were mostly also avoided, these lack old trees and were very difficult to access. Further survey in a season when the vegetation has died back would be required to fully cover this wood (Sanderson, 2014)".

- “**The Landscape Park**: subdivided by 1km squares SN6121 and SN6122, mainly isolated parkland trees. The intensive survey did not reach all areas, due to the lack of time due to recording the trees on the veteran tree survey. There are large areas to the north and east not visited, although old trees are thin in these areas (Sanderson, 2014)”.

4.2.3. Species Recording

Lichen interest was recorded using a Garmin GPSmap 64, with an accuracy ranging up to +/- 6m. This was recorded in a field notebook or the GPX files generated on the GPS device were exported to .CSV/.SHP format and the associated field notes were added to the waypoints. The survey routes were tracked by the Viewranger navigation app. The base mapping contains OS Open Zoomstack Data © Crown copyright and database right 2021. All records generated have been submitted to the British Lichen Society National Database, which subsequently makes its way on to the National Biodiversity Network’s Atlas.

4.2.4. Lichen Monitoring

In 2013, Sanderson established a baseline of epiphytic lichens on trunks throughout the Dinefwr Estate. This was an incredibly detailed survey, where a comprehensive list of notable lichens (plus additions) was generated on a tree-by-tree basis. This information allowed each tree to be monitored, to understand changes in trunk composition and abundance. As part of the current project, this information has been tabulated in the Appendices, where direct comparisons can be made between the 2013 and 2022 data. This notes species that were refound and those not refound, alongside any additions, plus general comments. Although an effort was made for complete coverage, a significant number of 2013 trees were not resurveyed in 2022. This information can be found for each area under the Appendices.

4.2.5. Field Materials & Equipment

- Species records, previous reports and distribution maps.
- OS map of the site and printed versions for annotation.
- Garmin GPSmap 64, Viewranger app (iPhone) and compass.
- Tape measure or something for scale.
- Olympus TG4 & TG6 cameras for macro photographs.
- Samsung S10 note for macro and landscape photographs.
- iPhone SE for landscape photographs.
- Pins and markers to highlight lichens in the field.
- X10 Lichen candelaris magnification lens.
- Chemicals including K (potassium hydroxide), C (Sodium Hypochlorite) & Pd (*para*-phenylenediamine).
- Lichens of GB & Ireland 2 (ID Guide – electronic).
- Historic reports for the site (electronic).
- Hammer and chisel, or knife for the removal of specimens.

5. Results

5.1. Lichen Species & Communities

Between 1972 (earliest BLS record) and 2022, 345 species of lichens and lichenicolous fungi have been recorded within Dinefwr NNR. During the 2022 survey, fourteen additional species were added to the lichen list, which include:

- **four notable species** added to this list during the 2022 survey, comprising *Chaenotheca stemonea* (LC NS), *Rinodina isidioides* (NT NS P Wa IR), *Ramonia chrysophaea* (NT NS P Wa IR) and *Strigula taylorii* (LC NS IR).

- **ten common species** (of Least Concern) added to this list, comprising *Hypotrachyna revoluta* s. str., *Lecanora aitema*, *Lecanora albescens*, *Lecanora persimilis*, *Lepraria membranacea*, *Micarea prasina* s. lat., *Opegrapha calcarea*, *Porina linearis*, *Usnea flammea* and *Vouauxiella lichenicola.*

Sanderson has provided a detailed account of "Lichen Habitat Assemblages" (Sanderson, 2014 – pp. 14-21) and "Lichen Species of Interest" (Sanderson, 2014 – pp. 21-31) in his 2014 report. Below, comments have been made on notable lichens, where new information has been made available through the 2022 survey. These findings have been outlined in this section.

- ***Bacidia incompta* (VU A P Wa)**

A crust-forming lichen with a granular, green thallus and black apothecia. This species occupies the nutrient-rich wound tracks of base-rich trees such as ash, elm, beech and horse chestnut etc. With the demise of these host tree species across Britain and Ireland, this lichen is now assessed as Vulnerable.

In 2013, *Bacidia incompta* was found new to the park on two horse chestnuts, including DI028 (SN 60765 22770) in the central area of the western deer park and DIV85 (SN 61738 21980) in the landscaped park. An additional tree was found to support this species in 2022, neighbouring DI028, with a grid reference of SN 60760 22778. Therefore, there are now three horse chestnuts at Dinefwr supporting *Bacidia incompta.*

- ***Chaenotheca stemonea* (LC NS)**

A small pin lichen, with a green, farinose thallus found growing on the lignum of an old oak tagged DV013 (SN 60762 22539 was SN 60762 22545). *Chaenotheca stemonea* is a Nationally Scarce species and was recorded new to the Dinefwr Estate and VC44 Carmarthenshire.

- ***Collema fragrans* (EN A, C NR P Wa IR)**

This species is a jelly lichen that is confined to the wound tracks of old, base-rich trees such as ash, elm, beech and horse chestnut etc. With the demise of these host tree species across the landscape, this lichen is now assessed as Endangered.

In Sanderson 2014, he details the history of this species at Dinefwr… *"At Dinefwr, it was recorded from a wound on a Sycamore in the east of Castle Wood by Orange (1994), it has not been seen in Wales since. In 2013 there was insufficient time to search Castle Wood in detail, but the very similar Leptogium subtile Nb (NS) was seen on a wound track on a Sycamore near the 1994 location. The Sycamores at Dinefwr had few wet wound tracks, and are very unlikely to support enough wound tracks to be able to maintain a population of Collema fragrans* (Sanderson, 2014)*".*

During the 2022 survey this species was recorded within the wound track on the snapped trunk of a horse chestnut (SN 60760 22778), and was seen to grow alongside *Bacidia incompta*. This tree was not recorded in 2013. This species was deemed extinct in Wales until it was recently recorded on oak during a 2021/22 survey of Llywn Madoc in Brecknock by Neil Sanderson (Sanderson, 2022), which was the first Welsh record in decades. Therefore, this makes Dinefwr the second extant locality in Wales for this species.

- ***Lobaria pulmonaria*** **(LC L IR)**

This is a large, leafy macro-lichen characteristic of old-woodland conditions that are subject to clean air. In 2013, this species was only recorded from a single ash and elm (DI080 - SN60971 22222) during Sanderson's survey. Since then, it was found on additional tree species: during the current survey it was seen on willow (SN 61074 22197) and hazel (SN 61213 2203), whilst subsequently it was recorded on the Castle Oak (SN 61200 22041) and on two sycamores (SN 60996 22229 & SN 60992 22242) in Bog Wood.

- ***Ramonia chrysophaea*** **(NT NS P Wa IR)**

A crustose lichen, with an immersed thallus and sunken apothecia that tends to be confined to base-rich, flushed and spongy bark. This species was recorded on two large post-mature oaks DIV839 (SN 60848 22355) and DI055 (SN60950 22325), both in the southern area of the central deer park. This species was recorded new to Dinefwr NNR and new to VC44 Carmarthenshire.

- ***Rinodina isidioides*** **(NT NS P Wa IR)**

A small, isidiate crust overgrowing the mosses of an old, post-mature oak in the southern area of the central deer park - DIV839 (SN 60848 22355). According to the BLS database, Dinefwr is now the only site in South Wales where this species has been recorded this century (post 2000).

5.2. Notable Lichen Species

Between 1972 (earliest BLS record) and 2022, 345 species of lichens and lichenicolous fungi have been recorded within Dinefwr NNR. Compiling data from the last 25 years (2000 – 2022), 292 species have been recorded. This includes 70 Notable Species with 3 Threatened (1 Endangered & 2 Vulnerable), 10 Near Threatened, 49 Nationally Scarce, 5 Nationally Rare and 31 International Responsibility species (under the GB & I conservation evaluations).

The Threatened, Near Threatened and Notable Species score for Dinefwr NNR is an impressive 68. This index is applied to those sites characterised by old trees in open-grown conditions (including parkland). The threshold for SSSI designation based on the lichen feature alone is 16.

Table 1: Notable speciess recorded in the 2022 survey and those listed across previous surveys in the last 25 years. Lichens recorded from the 2022 survey and the last 25 years scores an impressive 68, far exceeding the threshold of 16 for old trees in open grown places. During the 2022 survey, *Chaenotheca stemonea*, *Rinodina isidioides*, *Ramonia chrysophaea* and *Strigula taylorii* were recorded as new notable species for the site.

Lichens & Lichenicolous fungi	TNTN Score	Conservation Status	2000	2002	2006	2010	2011	2012	2013	2017	2022
Agonimia allobata	1	LC NS	No	No	No	No	No	**Yes**	**Yes**	No	No
Agonimia octospora	2	NT NS Sc L IR	No	No	No	No	No	**Yes**	**Yes**	No	**Yes**
Anisomeridium robustum	1	LC NS	No	No	No	No	No	**Yes**	**Yes**	No	**Yes**
Anisomeridium viridescens	1	LC NS Sc IR	No	No	No	No	No	No	**Yes**	No	No
Arthonia anombrophila	1	LC NS Sc IR	No	No	No	No	No	No	**Yes**	No	No
Arthrorhaphis aeruginosa	1	LC NS	No	No	No	No	No	No	**Yes**	No	No
Bacidia incompta	4	VU A P Eng Sc Wa	No	No	No	No	No	No	**Yes**	No	**Yes**
Bactrospora corticola	1	LC NS	No	No	No	No	No	**Yes**	**Yes**	No	No
Buellia hyperbolica	4	VU D1 NR P Eng Wa	No	No	No	No	No	**Yes**	**Yes**	No	**Yes**
Calicium lenticulare	1	LC NS Sc IR	No	No	No	No	No	**Yes**	**Yes**	No	No
Catillaria nigroclavata	1	LC NS	No	No	No	**Yes**	No	No	No	No	No
Chaenotheca stemonea	1	LC NS	No	No	No	No	No	No	No	No	**Yes**
Chaenothecopsis nigra	1	LC NS	No	No	No	No	No	**Yes**	**Yes**	No	No
Chaenothecopsis pusilla	1	LC NS	No	No	No	No	No	No	**Yes**	No	**Yes**
Cladonia cryptochlorophaea	1	LC NS	No	No	No	No	No	No	**Yes**	No	No
Cladonia incrassata	1	LC NS	No	No	No	No	No	**Yes**	**Yes**	No	**Yes**
Cliostomum flavidulum	1	LC NS Sc	No	No	No	No	No	**Yes**	**Yes**	No	**Yes**
Collema fragrans	4	EN A, C NR P Sc Wa IR	No	No	No	No	No	No	No	No	**Yes**

Lichens & Lichenicolous fungi	TNTN Score	Conservation Status	2000	2002	2006	2010	2011	2012	2013	2017	2022
Cresponea premnea	1	LC Sc IR	**Yes**	No	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**
Enterographa sorediata	2	NT NS E P Eng IR	No	No	No	No	No	No	**Yes**	No	No
Eopyrenula grandicula	1	LC NS Sc IR	**Yes**	No	No	No	No	No	**Yes**	No	No
Fellhanera bouteillei	1	LC NS	No	No	No	No	No	**Yes**	No	No	No
Illosporiopsis christiansenii	1	LC NS	No	No	No	No	No	No	**Yes**	No	No
Inoderma subabietinum	1	LC Sc IR	**Yes**	No	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**
Lecanographa lyncea	1	LC Sc IR	**Yes**	No	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**
Lecanora alboflavida	1	LC NS	No	No	No	No	No	No	**Yes**	No	No
Lecanora argentata	1	LC NS	No	No	No	No	No	No	**Yes**	No	No
Lecanora horiza	2	NT NS Sc	No	No	No	No	No	**Yes**	No	No	No
Lecanora sublivescens	2	NT NS P Eng Wa IR	No	No	No	**Yes**	No	No	No	No	No
Lepraria umbricola	1	LC NS	No	No	No	No	No	No	No	No	**Yes**
Leptogium subtile	1	LC NS	No	No	No	No	No	No	**Yes**	No	**Yes**
Lobaria pulmonaria	1	LC Sc L IR	No	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	No	**Yes**
Melaspilea amota	2	NT NR	No	No	No	No	No	No	**Yes**	No	No
Micarea alabastrites	1	LC Sc IR	No	No	No	No	No	**Yes**	**Yes**	No	**Yes**
Micarea doliiformis	1	LC NS	**Yes**	No	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**
Micarea viridileprosa	1	LC NS	No	No	No	No	No	No	**Yes**	No	No
Micarea xanthonica	1	LC NS Sc IR	No	No	No	No	No	**Yes**	No	No	No
Microcalicium ahlneri	1	LC NS	**Yes**	No	No	No	No	No	**Yes**	No	No
Milospium graphideorum	1	LC NS	**Yes**	No	No	No	No	**Yes**	**Yes**	No	**Yes**
Mycoblastus affinis	1	LC NS	No	No	No	No	No	No	**Yes**	No	No
Opegrapha corticola	1	LC IR	**Yes**	No	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**
Opegrapha fumosa	1	LC NS X Sc IR	No	No	No	No	No	No	**Yes**	No	No
Opegrapha viridipruinosa	1	LC NS	No	No	No	No	No	No	**Yes**	No	No
Opegrapha viridis	1	DD NS	No	No	No	**Yes**	No	No	No	No	No
Opegrapha xerica	1	LC NS	**Yes**	No	No	No	No	No	**Yes**	No	**Yes**
Pannaria conoplea	1	LC Sc L IR	No	No	No	**Yes**	No	No	No	No	No
Peltigera polydactylon	1	LC NS	No	No	No	No	No	No	**Yes**	No	No

Lichens & Lichenicolous fungi	TNTN Score	Conservation Status	2000	2002	2006	2010	2011	2012	2013	2017	2022
Pertusaria amara f. *pulvinata*	1	NE NR	No	No	No	No	No	**Yes**	No	No	No
Phaeographis inusta	1	LC NS IR	No	No	No	No	No	No	**Yes**	No	No
Phyllopsora rosei	1	LC NS Sc L IR	No	**Yes**	No	No	No	**Yes**	**Yes**	No	**Yes**
Porina borreri	1	LC NS	No	No	No	No	No	**Yes**	**Yes**	No	**Yes**
Porina coralloidea	1	LC NS Sc L IR	No	No	No	No	No	No	**Yes**	No	**Yes**
Porina rosei	2	NT NS X IR	No	No	No	No	No	**Yes**	**Yes**	No	**Yes**
Ramalina fraxinea	1	LC Sc IR	No	No	No	**Yes**	No	No	No	No	No
Ramonia chrysophaea	2	NT NS P Eng Sc Wa IR	No	No	No	No	No	No	No	No	**Yes**
Rinodina biloculata	1	DD NR	No	No	No	**Yes**	No	No	No	No	No
Rinodina isidioides	2	NT NS P Eng Sc Wa IR	No	No	No	No	No	No	No	No	**Yes**
Rinodina roboris var. *roboris*	1	LC Sc IR	No	No	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**
Ropalospora viridis	1	LC NS	No	No	No	No	No	No	**Yes**	No	No
Schismatomma niveum	1	LC Sc IR	No	**Yes**	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**
Sphinctrina turbinata	1	LC NS	No	No	No	No	No	No	**Yes**	No	No
Sporodophoron cretaceum	1	LC Sc IR	**Yes**	No	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**
Stenocybe septata	1	LC Sc IR	No	No	No	No	No	No	**Yes**	No	No
Sticta limbata	1	LC Sc L IR	No	No	No	**Yes**	No	No	No	No	No
Strigula taylorii	1	LC NS Sc IR	No	No	No	No	No	No	No	No	**Yes**
Usnea articulata	2	NT P Eng Wa IR	No	No	No	No	No	No	No	**Yes**	No
Usnea florida	2	NT P Eng Sc Wa	No	No	No	No	No	No	No	**Yes**	No
Usnea wasmuthii	1	LC NS	No	No	No	No	No	No	**Yes**	No	**Yes**
Total Species: 68	**87**		**10**	**3**	**1**	**15**	**1**	**27**	**49**	**2**	**31**

5.3. Southern Oceanic Woodland Index

This replaces the New Index of Ecological Continuity (NIEC) (Coppins and Coppins 2002; Hodgetts 1992; Rose 1992). The list is designed to be applied across a wide swathe of southern oceanic Britain.

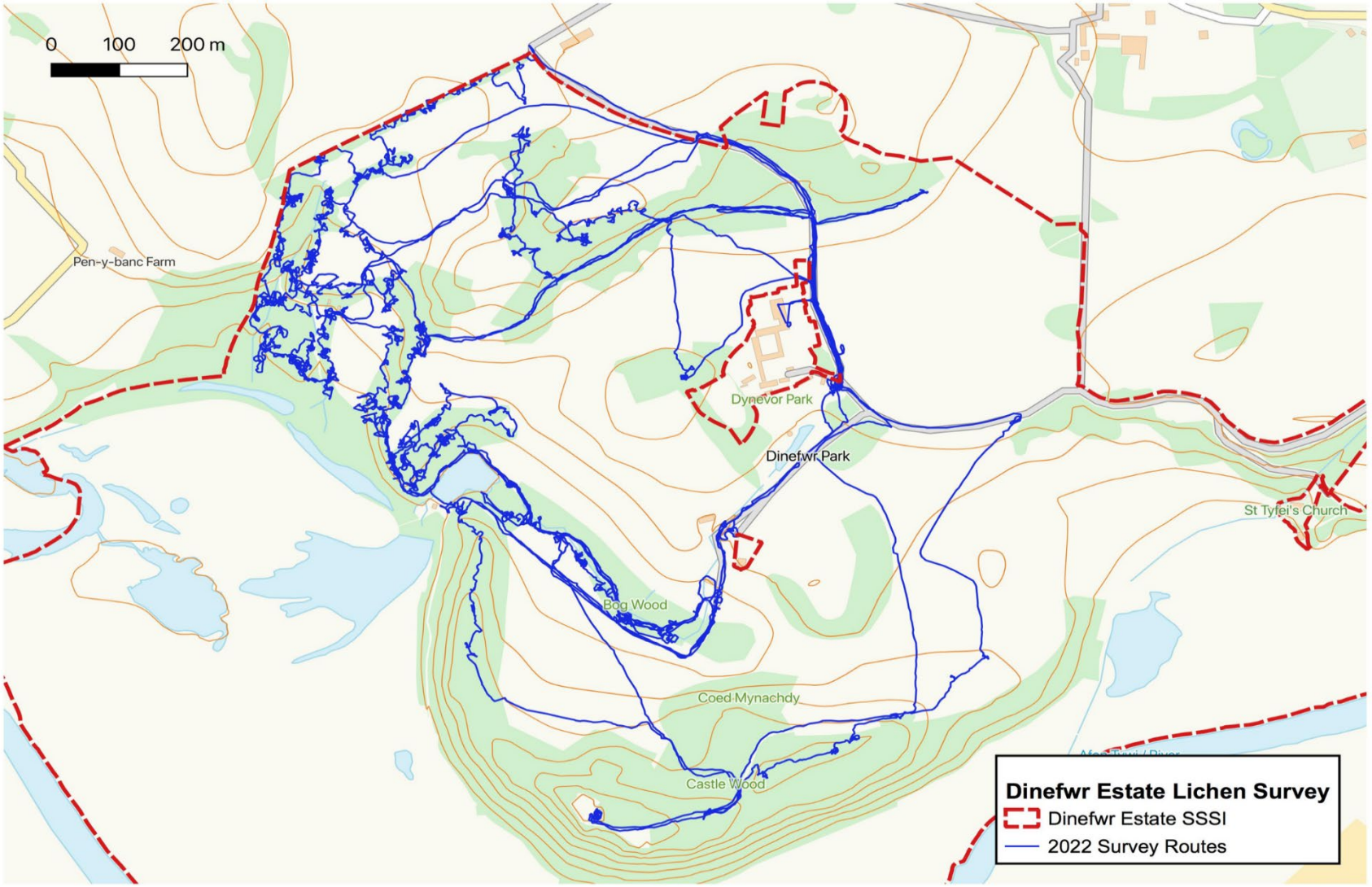
For the core areas of interest (associated with a strongly southern oceanic climate with clean air, in south-west England and north-west Wales), all sites with scores of 30 or more should be considered for notification. To the north and east of these areas, in south-east England, **the rest of Wales** and south-west Scotland (where the more strongly southern oceanic species are rare), all sites with **scores of 20 or more can be selected.**

Table 2: Lichen species listed on the Southern Oceanic Woodland Index (SOWI) recorded in the 2022 survey and those listed across previous surveys in the last 25 years. Lichens recorded from the 2022 survey and the last 25 years score an impressive 40, far exceeding the threshold of 20. During the 2022 survey, both *Chaenotheca stemonea* and *Rinodina isidioides* were recorded new for the site.

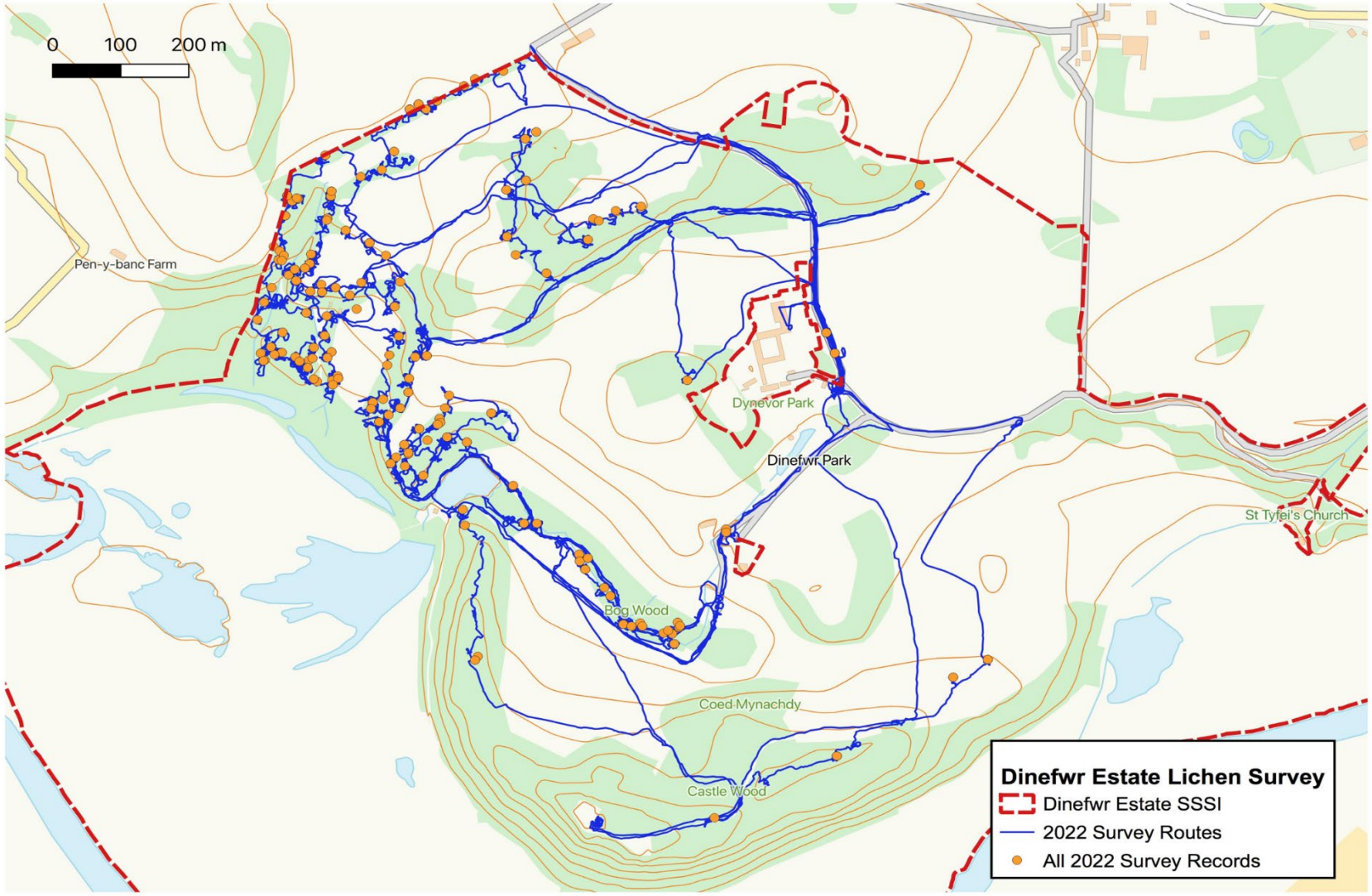
SOWI Species		2022	<25yrs
Agonimia allobata	LC NS	Not found	<25 yrs
Agonimia octospora	NT NS Sc L IR	2022	<25 yrs
Anisomeridium ranunculosporum	LC	2022	<25 yrs
Arthonia vinosa	LC L*	2022	<25 yrs
Bacidia biatorina	LC	2022	<25 yrs
Catinaria atropurpurea	LC L*	2022	<25 yrs
Chaenotheca brunneola	LC	2022	<25 yrs
Chaenotheca chrysocephala	LC	Not found	<25 yrs
Chaenotheca stemonea	LC NS	2022	Not found
Chaenotheca trichialis	LC	2022	<25 yrs
Cladonia caespiticia	LC	Not found	<25 yrs
Cladonia parasitica	LC	2022	<25 yrs
Cresponea premnea	LC Sc IR	2022	<25 yrs
Enterographa sorediata	NT NS E P Eng IR	2022	<25 yrs
Inoderma subabietinum	LC Sc IR	2022	<25 yrs
Lecanographa lyncea	LC Sc IR	2022	<25 yrs
Lecanora alboflavida	LC NS	Not found	<25 yrs
Lecanora jamesii	LC	2022	<25 yrs
Lecanora sublivescens	NT NS P Eng Wa IR	Not found	<25 yrs
Leptogium lichenoides	LC	2022	<25 yrs
Leptogium teretiusculum	LC L*	2022	<25 yrs
Lobaria pulmonaria	LC Sc L IR	2022	<25 yrs
Micarea alabastrites	LC Sc IR	2022	<25 yrs
Mycobilimbia epixanthoides	LC	2022	<25 yrs
Mycobilimbia pilularis	LC L*	2022	<25 yrs
Opegrapha corticola	LC IR	2022	<25 yrs
Pachyphiale carneola	LC L	2022	<25 yrs
Peltigera horizontalis	LC L*	2022	<25 yrs

SOWI Species		2022	<25yrs
Pertusaria multipuncta	LC	2022	<25 yrs
Phaeographis dendritica	LC Sc	Not found	<25 yrs
Phaeographis inusta	LC NS IR	Not found	<25 yrs
Phyllopsora rosei	LC NS Sc L IR	2022	<25 yrs
Porina coralloidea	LC NS Sc L IR	2022	<25 yrs
Porina rosei	NT NS X IR	2022	<25 yrs
Punctelia reddenda	LC L	2022	<25 yrs
Rinodina isidioides	NT NS P Eng Sc Wa IR	2022	Not found
Schismatomma niveum	LC Sc IR	2022	<25 yrs
Stenocybe septata	LC Sc IR	Not found	<25 yrs
Thelopsis rubella	LC L	2022	<25 yrs

Map 2: Ordnance Survey, six inch to the mile - Carmarthenshire Sheet XXXIII.SE. Surveyed: 1885 (Published: 1885). Reproduced with the permission of the National Library of Scotland. Creative Commons Attribution (CC-BY) licence.



Map 3: The Dinefwr Estate SSSI and 2022 survey routes.



Map 4: The Dinefwr Estate SSSI, 2022 survey routes and all records generated.

Cyfoeth Naturiol Cymru
Natural Resources Wales

5.4. Ash and notable lichens

Ash (*Fraxinus excelsior*) is an important tree species for its epiphytic lichens across the Dinefwr Estate. In terms of tree species composition, oak was the dominant tree species with ash only occasional, but ash still proved to be a significant tree species for notable lichens. In the light of Ash Dieback, the loss of ash from Dinefwr is expected through both natural and mechanical causes. With its base-rich bark, ash is an important substrate for the macro and crust forming species of the *Lobarion pulmonariae* community, where many species that constitute this assemblage are of international importance. Noteworthy species recorded on ash include the following: *Leptogium lichenoides*, *L. teretiusculum*, *Lobaria pulmonaria*, *Mycobilimbia epixanthoides*, *M. pilularis* and *Peltigera horizontalis* (summarised in Table 3).

In 2013, Sanderson notes that "no species of conservation interest are totally confined to Ash, but *Lobaria pulmonaria* Nb (IR) (Wales VU) has its only remaining large colony at Dinefwr on an Ash, with a small sub-colony on a young Wych Elm, making it very vulnerable (Sanderson, 2014)". Since then, *Lobaria pulmonaria* has been recorded as small thalli on hazel and willow during the current survey, and in large quantity high in the canopy of the Castle Oak and on two sycamores subsequently (Bosanquet & Barrett *in litt.*), with all new records generated from Bog Wood. This population, however still remains threatened, where a significant proportion of the population is recorded on one tree (Castle Oak) and those low-lying trees in Bog Wood becoming slowly inundated by unacceptable levels of *Rhododendron.* Urgent management here is required.

Table 3: The ash trees surveyed across the Dinefwr Estate supporting lichen species of interest. This relates to the various areas across the estate and provides management comments in relation to Ash Dieback.

Area	NS Tree No.	Grid Ref.	Lichen Interest	2022 Comments
Deer Park West (Northern Area)	DIV371	SN 60919 22850	*Normandina pulchella & Punctelia reddenda.*	Tree is now fallen. No action required.
Deer Park West (Central Area)	DIV9058	SN 60797 22556	*Peltigera horizontalis*	Prostrate ash. No management required. Foliage in the crown has reduced due to Ash Dieback.
Deer Park West (South Area)	DIV9089	SN 60874 22480	*Acrocordia gemmata*, *Bilimbia sabuletorum Cresponea premnea*, *Leptogium lichenoides*, *L. teretiusculum* and *Sporodophoron cretaceum*	Ash has fallen, no management is required.

Area	NS Tree No.	Grid Ref.	Lichen Interest	2022 Comments
Deer Park West (South Area)	DI010	SN 60781 22427	*Cresponea premnea*, *Lecanographa lyncea*, *Leptogium lichenoides*, *Milospium graphideorum*, *Mycobilimbia epixanthoides* & *Peltigera horizontalis.*	Ash looks in reasonable condition. Crown could be reduced if deemed necessary,
Deer Park West (South Area)	DIV006	SN 60747 22427	*Cresponea premnea*, *Lecanographa lyncea* & *Leptogium teretiusculum*	Canopy relatively healthy if a little thin.
Deer Park West (South Area)	DV014	SN 60746 22502	*Cresponea premnea*, *Mycobilimbia epixanthoides* & *Leptogium teretiusculum.*	No action.
Deer Park West (South Area)	DV006	SN 60746 22426	*Anisomeridium ranunculosporum*, *Cresponea premnea*, *Cliostomum flavidulum*, *Lecanographa lyncea and Leptogium teretiusculum.*	Relatively healthy, although the canopy is a little bit thin. No action required.
Deer Park Central (Northern Area)	DIV639	SN 61190 22693	*Cresponea premnea* and *Leptogium teretiusculum.*	Leaning ash by oak DIV639 – not action required.
Castle Wood	DI080	SN 60971 22222	*Lobaria pulmonaria*	Clear younger sycamore and cherry near ash, ideally all beech should be removed, leave sycamore further from ash and keep trees clear of ivy" (Sanderson, 2013)

Area	NS Tree No.	Grid Ref.	Lichen Interest	2022 Comments
Bog Wood (Deer Park)	DI 067	SN61279 22042	*Leptogium lichenoides*, *Mycobilimbia epixanthoides & M. pilularis*	Deterioration in conditions for lichens on the ash. *Rhododendron* needs to be urgently addressed. Management to ensure tree remains in situ for as long as possible.
Bog Wood (Deer Park)	DI 068	SN61277 22019	*Leptogium lichenoides & Mycobilimbia epixanthoides*	Deterioration in conditions for lichens on the ash. *Rhododendron* needs to be urgently addressed. Management to ensure tree remains in situ for as long as possible.
Bog Wood (Deer Park)	-	SN 61267 22027	*Cresponea premnea*, *Leptogium lichenoides & Mycobilimbia epixanthoides*	Deterioration in conditions for lichens on the ash. *Rhododendron* needs to be urgently addressed. Management to ensure tree remains in situ. Cut ash higher than marked.
Landscape Park	DIV80	SN 61459 21872	NA – but possible for *Bacidia incompta* to colonise from neighbouring horse chestnut.	Ensure this ash is in optimum condition for possible colonisation of *Bacidia incompta* from the neighbouring horse chestnut.

5.5. Air pollution

5.5.1. Background

One of the main objectives of this project was to examine sufficient trees within the richest three areas of the Dinefwr Estate NNR (see Map 1) to study the trunk epiphytes. Here, lists of notable lichens for each selected tree were produced (in direct comparison to 2013), alongside a list of any nitrogen tolerant lichens (if any) on those selected trees. For each tree surveyed, a list can be found in the Appendices under each location.

Understanding the impacts of air pollution on lichen species and communities is multi-faceted and complex. With their sensitivity to the surrounding environment, lichens

prove excellent indicators of air pollution, and it can be difficult to pinpoint the precise reason for the presence or absence of certain species, particularly when corresponding with short- and long-range effects of air pollution, especially nitrogen.

There is a multitude of studies that show species with high tolerance for nitrogen have been on the increase over recent decades (Bosanquet 2019). Lichen communities across large areas of Britain and Ireland have been changing in favour of nitrogen tolerant species (nitrophytes) versus nitrogen sensitive species (acidophytes). This is a result of a combination of factors including: fertilizer drift/dust, bark wounds, salt spray, animal excreta and fossil fuel combustion. It is however not always obvious whether localised sources are having a bigger effect than diffuse large-scale sources. Indeed, there must be interplay with both. Other factors also have effects on lichen communities e.g. local climate and climate change, age of the tree etc. A number of studies have shown that localised sources of ammonia are likely having a greater effect in certain areas (van Herk 2001, Purvis *et al*. 2005).

In 2017 Plantlife published a booklet entitled 'We Need to Talk About Nitrogen' The opening statement is reproduced here:

> *'Amid the clamour about climate change and carbon emissions, another alarm bell, largely unheard, has been sounding for some time. Global pools of reactive nitrogen have been building in the atmosphere, soils and waters from the burning of fossil fuels and intensive farming. This excess of reactive nitrogen is now being deposited throughout the biosphere, significantly impacting our most precious semi-natural habitats, changing their plant communities and the very functions these ecosystems provide.'*

Sulphur Dioxide
Historically, sulphur dioxide pollution was a major factor in determining lichen distribution in the UK, where the toxic nature was the main factor affecting lichens rather than a decrease in bark pH (Hawksworth and Rose 1970, Ferry and Baddeley 1976, Bates & Farmer 1992, van Herk 2001). However, the long-term effects of bark acidification are still noted today. Since the Clean Air Act was implemented, sulphur dioxide levels have been decreasing for several decades in the UK, resulting from a change in fuel use from coal to gas and the use of flue gas desulphurization units in power stations (NAEI 2020, Pescott *et al* 2015).

Nitrogen Pollution
Nitrogen forms c.78% of the atmosphere and is mostly an inert gas. Nitrogen can also occur in a reactive state, where it is found in two chemical forms **(1)** oxidised and **(2)** reduced, with both forms exhibiting different physical properties. This reactive nitrogen can be deposited on land or water bodies as dry or wet deposition.

- Dry deposition (gaseous state) – gas within the biosphere. This is often more local, but can travel considerable distances
- Wet deposition (dissolved state) – clouds, rainfall and mist. This can usually travel greater distances from the point source.

1. Oxidised Nitrogen (NO_x). Are produced by the burning of fossil fuels in power stations, motor vehicles, factories, offices and homes. Here, these oxides can further

react with water molecules and convert to nitric or nitrous acid which lowers bark pH (acidifies) and reduces the capacity of lichens to photosynthesise (Frahm *et al* 2009). Oxides of nitrogen (NOx) are not directly assimilated by lichens, however, reduced nitrogen in the form of gaseous ammonia (e.g. from farm fertilizers or generated from petrol engines with catalytic converters) combines with NOx (e.g. generated from diesel engines, in the presence of water vapour and ozone) to form ammonium nitrate, a fine particulate which can persist in the atmosphere and can be absorbed by lichens. Ammonium nitrate can be deposited as dry deposition several km away from the point source (Langmann *et al* 2014, Frahm *et al* 2009, Lovett *et al* 2009). Oxides of nitrogen also impact the environment by causing acidification of habitats including bark, rock and soil. This effect is most acute in areas of high rainfall and acid bark, rocks and soils which cannot buffer against their effects.

2. Reduced Nitrogen (NH_x). The main sources of ammonia (NH_3) are from livestock manures together with organic and inorganic fertilizers. Today, there is more reactive nitrogen produced by human activities than by natural sources, with far-reaching effects for ecosystems and human health (Sutton *et al* 2011, Erisman 2013). Ammonium (NH_4^+) derived from ammonia (by combination with a hydrogen ion) has no effect on bark pH. However, ammonia deposition on bark increases bark pH, albeit not benefitting Lobarion species which require higher pH but low bark nutrient levels, but when deposited into soil, ammonia is transformed to nitric acid by soil bacteria in a process known as nitrification which lowers soil pH (van Herk 1999). Increase of bark pH due to ammonia deposition is significant in lichen community change (Farmer *et al* 1992, van Herk 2001, Sanderson 2014, Wolseley *et al*., 2006), but declines in sulphur dioxide may be a stronger factor in the recent increase in nitrogen loving species (van Dobben & ter Braak, 1998, 1999). Ammonia causes eutrophication of habitats, with the effects greatest in areas of intensive agriculture. Excessive amounts of ammonia results in the loss of acidophyte lichens which have evolved very efficient mechanisms of absorbing nitrogen compounds. Lichens sensitive to nitrogen have been listed in various publications (including van Herk 1999, 2001, Davies *et al* 2007, Loppi 2003, OPAL 2013, Wolseley *et al* 2006 & 2017).

- ***Trentepohlia:*** Another effect of increased nitrogen loads is the increasing abundance of the free-living alga *Trentepohlia* and in crustose lichens which contain *Trentepohlia* as a photobiont. These phenomena have been observed on a European scale (Aptroot & van Herk 2007, Bengtsson & Paltto 2014). This increase is partly attributed to climate change and the decline in sulphur dioxide pollution, the later may also be a reason for a decline in acidophilus lichens & an increase in *Trentepohlia* & Trentepohloid lichens.

- ***Hormidiopsis*** (old name: *Klebsormidium*) are members of the Charophytes within the phylum *Streptophyta*. This is a common cosmopolitan genus of filamentous green algae occurring in a wide variety of terrestrial and freshwater habitats including rocks, soil and tree bark (Stapper 2010; Martins Lemes-Da-Silva *et al*. 2010; Rindi 2011; Ryšánek *et al.* 2016). It appears that members of this genus respond favourably to both the eutrophicating effects of reduced nitrogen and acidification (Stapper 2010).

  This genus sometimes occurs on the surface of lichens, thus reducing their ability to photosynthesise. Lichens with large colonies of *Hormidiopsis* spp.

growing on top of them often appear necrotic. This necrosis may be due to a number of factors including the effects of eutrophication and/or acidification as well as loss of available light. Further research needs to be undertaken into the specific reasons for the apparent increase in *Hormidiopsis* spp., together with its habitat preferences and Phytosociology.

Lichen communities

In response to air pollution generally, at a community level, there is likely a marked decrease overall in nitrogen sensitive communities e.g., *Lobarion pulmonariae*, *Parmelion laevigatae*, *Pseudevernietum furfuraceae* and *Usneion barbatae* communities, which appear to be declining across large areas of Great Britain and Ireland (Wolseley & Douglass 2008; Vilsholm *et al*. 2009; Coppins & Coppins 2019). Under scenarios where nitrogen pollution is elevated, this transitions to nitrophilic communities including the *Xanthorion parietinae* alliance, including sub-alliances such as *Buellietum punctiformis*, *Physcietum ascendentis* etc.

5.5.2. Dinefwr Results

During Sanderson's 2013 survey, he makes comment on the lichen flora in relation to the oak twigs across the Estate, where an extract has been copied from his report below (Sanderson, 2014).

> "*At Dinefwr Oak twigs were examined wherever accessible, the Nutrient Rich Bark Community (Physcietum ascendentis) was only rarely well developed. The strongest development was on twigs on isolated trees in the south of the landscape park, which were used as shelter by large sheep herds. This is a local effect, the parkland trees along the northern edge of Castle Wood have well developed Exposed Acid Bark Communities (Pseudevernietum furfuraceae) and local development of the Sheltered sub-canopy Community (Usneetum articulato-floridae var. ceratinae) with Usnea subfloridana and Usnea wasmuthii Nb (NS) indicating low ammonia on trees here. They are sheltered by a woodland from the prevailing winds. Across the park similar communities occur in the low-lying sheltered areas of the park. In exposed areas moderately nutrient demanding species such as Ramalina farinacea and Ramalina fastigiata are typically frequent with the more demanding Physcia tenella occasional and the nitrogen resistant highly resistant species, Xanthoria parietina and Physcia adscendens rare or absent. The nitrogen avoiding species such as Evernia prunastri, Usnea subfloridana and Parmelia saxatilis were still present but tended to be occasional. The very sensitive Usnea florida NT (S42), was recorded by Orange (1985 & 1988) was recorded in the 1980s as present but not frequent, however, it was not refound in 2013 and is either lost or much reduced.*"

> "*The twig flora suggests moderate background ammonia deposition from adjacent farmland, which is being attenuated locally within the park in sheltered areas (ammonia is a very short range pollutant). This is supported by the "APIS" website, which gives the background levels of ammonia pollution at 1.65 µg m^3, above the critical level for impact on lichens of 1.0 µg m^3. Serious impacts kick in over 2 – 3 µg m^3, with the complete loss of nitrogen sensitive species*" (Sanderson, 2014).

In 2017 and 2019 Sam Bosanquet completed lichen studies on twigs, which indicated the presence of Nitrophilic lichen species throughout the majority of the SSSI, which was claimed to be suffering from air pollution from agricultural sources (Bosanquet 2017; 2019). This report states…

> "*Lichen survey in Dinefwr Park SSSI and its surroundings demonstrates clearly that ammonia levels are very low in the middle of the Deer Park, but are higher on the edges of the SSSI. These edges have experienced the same zero input management as the middle of the park, differing in their proximity to external sources of ammonia rather than in past management. The presence of ammonia-tolerant lichens and a lower abundance of Usnea on twigs is indicative of ongoing impacts from outside the SSSI on the notified, nationally significant lichen feature* (Bosanquet, 2019).

From the 2017 survey, Bosanquet notes the relationship between the Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for four areas of the Dinefwr Estate, where the oak trunks studied at the north and the south of the transect (Dinefwr A & D) are "Nitrogen polluted" and those in the centre of the transect (Dinefwr B & C) are "at risk". The twig flora is partially reflective of this, where the north and south of the transect (Dinefwr A & D) are "at risk" and those in the centre of the transect (Dinefwr B & C) are clean. A table and associated map for this can be found in Table 4 and Map 5 below. Subsequent survey by Bosanquet (2019) showed ongoing deterioration, including two trees that were 'clean' in 2017 being classified as 'at risk' in 2019 because of increased nitrophiles.

Table 4: Table extracted from Bosanquet (2017) summarising the relationship between the Lichen Indicator Score (LIS) and Nitrogen Air Quality Index (NAQI) for four areas of the Dinefwr Estate. For NAQI: 0-0.5 = Clean, 0.5-0.85 = at risk, 0.85-1.25 = N polluted, 1.25-2.0 = Very N polluted). See map below in relation to area.

	N inputs	Trunk LIS	Trunk NAQI	Twig LIS	Twig NAQI
Dinefwr A	Zero	0.6	0.9 (N poll)	0.8	0.6 (at risk)
Dinefwr B	Zero	1.4	0.7 (at risk)	2.2	0.3 (clean)
Dinefwr C	Zero	1.4	0.7 (at risk)	1.8	0.4 (clean)
Dinefwr D	Zero	0.4	1.0 (N poll)	0.2	0.8 (at risk)

Map 5: Map extracted from Bosanquet (2017) – figure 3.3 (report 3 - pg. 6) showing the transect across Dinefwr Deer Park, with lichens on trunks (five green circles) and twigs (one orange square) recorded at four locations (A–D).

With regards to the **twig flora**, the findings from the Sanderson (2014) and Bosanquet (2017 & 2019) certainly coincide with the findings of the 2022 survey, where those trees on the periphery of the Estate and abutting farmland supported the highest abundance of twig lichen species associated with the *Xanthorion* and *Physcietum* (nitrophilic) communities. This is of course expected, considering the close proximity to the agricultural pollution source. *Xanthorion* and *Physcietum* communities were also more prominent on those trees abutting open pastures within the Estate, but this appears to be quickly buffered out as one moves into denser areas of pasture woodland. There were still a reasonable number of twigs that supported clean-air *Usnea* spp. and these were encountered throughout the site, even on the more peripheral areas where *Xanthoria / Physcia* species are present. The open-grown parkland trees also had an elevated abundance of Nitrophilic species, but this is assigned to localised nutrient input from sheltering livestock.

In relation to the **lichens on trunks**, it proved difficult to determine whether nitrogen pollution is affecting the trunks, even though this was one of the aims of this project. Since Sanderson's 2013 survey, there has been ongoing development of old-growth lichens on the majority of the trunks surveyed, where additional species were consistently recorded that were not noted in 2013. These include the crustose members of the *Lobarion pulmonariae* (old base-rich bark) and *Lecanactidetum premneae* (ancient dry bark) communities. Here, these species and communities were in good health, viable and exceptionally abundant throughout the Dinefwr Estate.

On some trunks there were species that were recorded which are considered "Nitrophilic", including *Pachnolepia* (*Arthonia*) *pruinata* and *Diploicia canescens.* In 2013, Sanderson systematically recorded *P. pruinata* and made comment where appropriate on levels of *D. canescens* on the tree. In 2022, these species appeared in higher abundance across the site, and they were recorded on trees where they had not been noted in 2013. However, it is important to use these species as "Nitrophilic" indicators with caution, for the following reasons.

- The habitat of *Diploicia canescens* is described as “on dry rocks and stonework, and dry bark in nutrient-enriched or calcareous habitats” (Smith *et al.* 2009). At Dinefwr, this species was recorded on dry bark, likely in response to external pollution sources, but also occurred on bark that was naturally nutrient-enriched e.g. on base-rich flushed bark associated with the liverwort *Metzgeria furcata*. Here, it is important to distinguish between the two, where the latter isn’t necessarily influenced by nitrogen pollution, but due to the microhabitat conditions. As a tree ages, more microhabitats develop including some with more base-rich conditions.

- The habitat of *Pachnolepia pruinata* is described as “on dry bark of tree trunks, especially *Acer* and *Quercus*, often dominating the side of the tree” (Smith *et al*. 2009). More widely, this species is known as a dry bark species and has been recorded in both nutrient enriched and clean-air settings, so its reliability as a nitrophile is questionable. It tends to appear on veteran oaks when the bark has lost its ability to retain water, resulting in dry bark, a particularly niche habitat which very limited species have the ability to occupy.

It is evident, from various survey efforts discussed here, that air pollution is having a direct impact on lichen species and communities across the Dinefwr Estate. Although, at present it appears to be having no significant impact on the lichen SSSI feature itself, considering the conservation significance of Dinefwr for its concentration of veteran trees and their associated lichen interest, it is essential for nitrogen input around the periphery of the site to be reduced. The feasibility of this is not certain. It is hugely important to note the “buffering” effects of trees and shrubs, and perhaps as an alternative (and if there is absolutely no other option), tree planting could be considered on adjacent land to buffer the impacts of air pollution on the Dinefwr Estate. This is discussed further under “air pollution” in the management section.

6. Management Recommendations

The habitat management guidance within this section should be used in conjunction with the information found in the Appendices and Section 4.4 & 4.5 (air pollution & Ash Dieback). This guidance should be integrated with other management objectives for the general biodiversity of the site. SSSI recommendations for each attribute / target that is set by JNCC (JNCC, 2005) are listed below.

Niche availability: Dinefwr is an ancient wooded landscape comprising a functioning deer park, pasture woodlands, a landscaped park and wet woodland habitats, which are characterised by an impressively large concentration of post-mature and veteran trees. When comparing current aerial photography to the 1885 historic OS maps there appears to be an increase in woodland cover across the Estate. As a lichen-rich woodland, this site certainly exceeds JNCC targets of 20% tree cover. It is important to ensure that open-grown veteran trees and historically/currently grazed pasture woodlands are not jeopardised in order to increase closed-canopy woodland cover across the SSSI. Certain areas where grazing has been excluded, such as Castle Wood and enclosed areas within the deer park, are declining in condition due to the reduction of grazing, resulting in a dense understory and high levels of epiphytic ivy overshading the lichen interest. A long-term recommendation should be to restore these areas through reinstating suitable levels of grazing/browsing, whilst gradually and mechanically managing undergrowth within pasture woodlands.

Stand Structure. Dinefwr showcases a mosaic of different woodland stands, that are characterised by veteran and post-mature trees characteristic of an extensively grazed system. The structural diversity of the site is, in general, very good, where conditions are kept open through a functioning deer park and domesticated livestock grazing the landscaped parkland. Structural diversity is being lost, however, in Castle Wood and enclosed areas of the landscaped park, where grazing has been excluded, where a dense and in some areas, impenetrable understory is establishing. This will result in a break in habitat continuity, which is fundamental to lichen development, due to the constant and stable light levels being threatened.

For lichen-rich woodlands, it is recommended that the canopy cover of a typical woodland stand should cover 30-70%, where 30% of the stand (as a minimum) should consist of gladed habitats (Coppins & Coppins, 2002). This is the case for the majority of Dinefwr, but not for these exclosed areas. It is important to note that appropriate levels of grazing and/or browsing are fundamental when considering the structure of these woodlands, but in these areas, mechanical management including ivy removal from trees that previously supported rare lichens (before re-instating grazing) will be required to return these woodland compartments into a favourable state.

Across the site, the age diversity and overlap in tree ages is excellent, with a high concentration of post-mature and veteran trees, and development of mature and maturing trees. However, there was very little recent oak regeneration or young oaks encountered and this could threaten habitat continuity going forward.

The landscaped park is the main concern here with regards to age diversity, where there is an absence of next generation trees to replace existing veterans. There have been a variety of tree planting efforts, but this has been completed as large, dense

blocks of closed-canopy woodland, as opposed to establishing open-grown pasture trees. Tree planting is absolutely essential in this compartment to ensure the continuity of this parkland setting, but this should be as groups of a few trees or even individual oaks rather than as larger blocks.

For Castle Wood, the lack of young oaks / regeneration is not reflective of overgrazing, this is assigned to a dense and impenetrable understorey of holly and bramble, and high levels of epiphytic ivy casting deep shade in the woodland compartment. Oak is a light demanding species that is currently being outcompeted by the understory. Thinning here is essential, not only to restore open conditions around current veterans, but also to establish space for younger trees to mature and veteranise.

At Bog Wood, the levels and extent of *Rhododendron* threatens the recruitment of willow, hazel, alder and oak with its dense, evergreen leaves.

Fallen and standing deadwood is in plentiful supply across the SSSI and proves an important habitat feature for lichens. Tree senescence will ensure the natural continuation of deadwood within these woodlands and any management works that results in the creation of deadwood should be retained. Deadwood should always be piled away from trees so this does not overshade the trunk (through direct shading or by permitting bramble to establish). Fallen and standing deadwood should remain devoid of overshading scrub, well-ventilated and well-lit. The deadwood lichen flora is of huge importance here, and there were multiple times, particularly in the landscaped park, that the deadwood was becoming engulfed in overshading vegetation – removal of bramble and reinstatement of grazing is therefore recommended.

Stand composition. At a landscape level, a diversity of tree species within the canopy and sub-canopy provides a variety of different bark textures and bark pH. This increases lichen diversity by providing a variety of niches available for colonisation. There is a relatively good mix of tree species at Dinefwr, where the dominant tree species across the majority of the site is oak, but other tree species present include ash, elm, sycamore, willow, hazel, holly, hawthorn, beech, horse and sweet chestnut. Encouraging more horse chestnut across the site is certainly recommended for the red-listed species recorded, including *Bacidia incompta* and *Collema fragrans.* Lime and field maple were surprisingly limited / absent from the landscape, and recruiting these trees could be important for their bark properties in the light of Ash Dieback.

Negative indicators: shade. Native or near native species such as holly, ivy, beech, conifers and bramble are important for the general biodiversity of the wood. However, inappropriate levels of these species cast dense shade and adversely affect lichen diversity. This can occur both directly (e.g. holly casting permanent shade on a tree trunk) and indirectly (e.g. high levels of epiphytic ivy creating dark and shaded conditions within a whole woodland). Across Dinefwr, there has been a long history of grazing and this farming practice has positively influenced the development of lichen-rich woodlands and field boundaries. In Castle Wood, grazing / browsing have been reduced or excluded, where exclosures are having unfavourable impacts on the lichens. In general, permanent exclosures and the exclusion of grazing / browsing are strongly discouraged, as this often results in a dense thicket of vegetation. JNCC state “no more than 10% ivy and/or bramble”. This target is acceptable for the site, but not

in Castle Wood. Again, *Rhododendron* is a huge issue in Bog Wood and needs addressing as a matter of priority.

Negative indicators: air pollution. It is evident from various survey efforts discussed here in this report, including Sanderson (2014) and Bosanquet (2017 & 2019), that air pollution is having a direct impact on lichen species and communities across the Dinefwr Estate. Although, at present it appears to be having no significant impact on the SSSI lichen feature itself because that is restricted to trunks, considering the conservation significance of Dinefwr, the priority would be for nitrogen input around the periphery of the site to be reduced. The feasibility of this is not certain so other options need to be explored, such as tree / shrub belts outside of the SSSI, to "buffer" the impacts within the site. Alternative farming practices could also be explored, to reduce the impacts of ammonia e.g. slurry injection vs. slurry spreading. Again, feasibility and various options would need to be discussed with surrounding farmers and other land managers.

Ash Dieback: Although oak is the dominant tree species at Dinefwr, ash is an important substrate for lichens of base-rich bark. One of the most notable lichens on ash here is *Lobaria pulmonaria*, although since 2013 this has now been recorded also on oak, hazel, willow and sycamore. This makes the population slightly more stable, whereas it was only recorded from ash and elm during the 2013 survey. Other notable species on ash include *Leptogium lichenoides*, *L. teretiusculum*, *Mycobilimbia epixanthoides*, *M. pilularis* and *Peltigera horizontalis*. Here, when the ash falls or is felled, translocation efforts should be attempted to safeguard populations. Although ash is an irreplaceable tree, there are various substitutes with similar bark properties, such as old oaks, willow, sycamore, field maple, hazel, rowan etc. to which material could be transplanted.

However, this is a reactive approach to lichen conservation in the light of Ash Dieback. What is desperately required at Dinefwr is for proactive management to ensure favourable woodland conditions and this should be an absolute priority for Bog Wood. The tree species composition in Bog Wood is predominantly those with base-rich bark, e.g., willow, sycamore, hazel, old oaks. However, this woodland unit is in unfavourable condition due to the unacceptable levels of *Rhododendron*, which have increased since Sanderson's survey in 2013, where direct comparisons can be seen in fixed-point photography, 10 years apart. Removal of *Rhododendron* here should be seen as a matter of urgency for the National Trust.

6. References & Additional Literature

References & Additional Literature

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7. Appendices

The Appendices of data tables and location photographs have been removed from this version of the report because it is not possible to make them comply with Accessibility legislation. Full PDFs of the report are stored by the Natural Resources Wales Library and the National Library of Wales.

Data Archive Appendix

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

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats;

[B] A spreadsheet of lichen records in Microsoft Excel format.

The metadata for this project is held as record no 125506.

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