Cyfoeth Naturiol Cymru
Natural Resources Wales

Surveillance of the montane macrolichen *Thamnolia vermicularis* in Eryri, 2022

Alex Turner (Eryri Ecological Surveys)

Evidence Report No 670

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Mae'r adroddiad hwn yn darparu canlyniadau gwyliadwriaeth ar gyfer *Thamnolia vermicularis*, cen arctig-alpaidd sy'n tyfu mewn cymunedau gweundir mynyddig a glaswelltir. Dim ond ar bedwar mynydd yn Eryri y mae wedi ei gofnodi erioed - Yr Wyddfa / Snowdon, Mynydd Mawr, Cadair Idris a Pen Llithrig y Wrach.

Ailymwelwyd ag un safle yn 2020, fel rhan o wyliadwriaeth ar gyfer *Alectoria nigricans*, ac ymwelwyd â'r tri safle arall ar sawl achlysur rhwng Tachwedd 2021 a Rhagfyr 2022. Er gwaethaf chwilio systematig gofalus iawn, ni chafodd y cen ei adleoli'n gadarnhaol mewn unrhyw leoliad. Er ei bod yn anodd profi absenoldeb, mae tebygolrwydd uchel bod y cen wedi diflannu o safleoedd traddodiadol Cymru.

Tybir y gallai colli'r macrolich o'r safleoedd fod oherwydd cyfuniad o dri ffactor: pwysau pori trwm hanesyddol, dyddodiad gormodol o nitrogen atmosfferig, a newid yn yr hinsawdd.

Awgrymir, i gadarnhau'r golled, y dylid cynnal chwiliad ehangach mewn cynefinoedd addas ar uchderau uwch yn y tri safle.

Executive Summary

This report provides the results of surveillance for *Thamnolia vermicularis,* an arctic-alpine lichen which occurs in montane heath and grassland communities. It has only ever been recorded on four mountains in Eryri - Yr Wyddfa / Snowdon, Mynydd Mawr, Cadair Idris and Pen Llithrig y Wrach.

One site had been revisited in 2020, as part of surveillance for *Alectoria nigricans*, and the three other sites were revisited on several occasions between November 2021 and December 2022. Despite very careful systematic searching, the lichen was not positively relocated at any location. Although it is difficult to prove absence, there is a high likelihood that the lichen is extinct in the traditional sites in Wales.

It is surmised that the loss of the macrolichen from the sites could be due to a combination of three factors: historic heavy grazing pressure, excessive deposition of atmospheric nitrogen and climate change.

It is suggested that, to confirm the loss, wider searching in suitable habitat at higher altitudes at the three sites be undertaken.

Background

Description

Thamnolia vermicularis s.l., known as Whiteworm lichen in some English-speaking countries, is a macrolichen of the the Family Icmadophilaceae. It has a bipolar global distribution being found widely in the Northern Hemisphere in arctic and montain regions, but also in South America, Australia, and New Zealand.

The species is a fruticose macrolichen with a thallus of cylindrical, chalky-white, hollow, worm-like tubes which can be prostrate or decumbent on the soil surface or upright amongst vegetation. The branches are not or scarcely branched, pointed at both ends, and up to 5cm long and 1-2mm wide. Chemical tests are Pd+ yellow, K+ yellow, C- and UV+ white. The species is a host to the gall-forming fungus *Thamnogalla crombiei* (Hawksworth, 1980).

T. vermicularis is rated at Least Concern (LC) in Britain (Woods and Coppins, 2013), but in Wales it is rated as Vulnerable (VU) (Woods, 2010).

Traditionally, two subspecies have been recognised based on variation in secondary chemistry, with mutually exclusive chemotypes: var. *vermicularis* containing thamnolic acid, and var. *subuliformis* containing squamatic and baeomycesic acids (Smith *et al.*, 2009). This classification has been re-examined recently by Onuţ-Bränström *et al.,* (2017, 2018), and three separate cryptic species were identified: *T. vermicularis* s.s. (Alps, Tatra, and Carpathian Mountains), *T. subuliformis* s.s. (Bipolar worldwide) and *T. tundrae* sp.nov. (Eurasian tundra to Aleutian Islands). The distinction using secondary chemistry has been shown to be untenable.

The variety traditionally regarded as occurring in Britain was var. *subuliformis*, and this is still likely to be the case, but in the light of the phylogenetic work probably needs confirmation. Synonyms used for the British species in earlier works include *Cerania vermicularis* and *Thamnolia subuliformis*.

Although it had been thought that the species was sterile, and Smith *et al.* (2009) state that apothecia and pycnidia are unknown, Lord *et al*. (2013) have shown, in a study on Australian, Asian, and American samples, that the species actually has pycnidia. These had previously been overlooked as the reproductive features of lichenicolous fungi. It had been thought that the spread of the species in the UK was restricted to the distribution of fragments.

Distribution

The species was first recorded in Britain from 'the summits of the mountains' in the Lake District in the early nineteenth century by Turner and Dillwyn (1805) (quoted in Fryday, 1998).

In Wales, it was first noted on Cadair Idris, at the relatively late date of 1844, by Thomas Salwey (Pentecost & Williams, 2002). There are no records then until 1915 when William Watson found it on Yr Wyddfa (Snowdon) at 3200' (975m) (Watson 1917, 1920). It was also recorded on Yr Wyddfa in 1919 by James Alfred Wheldon who described it as occurring between 3200' (975m) and 3500' (1067m) in some abundance below the summit station (Wheldon, 1920). There is a mention of it occurring on Cadair Idris in 1922 by Watson, and by Evan Price Evans in the mid 1920s (Price Evans, 1932), where it is recorded as occurring locally on the summit plateau between 2600' (792m) and 2900' (884m).

Table 1 Summary of post-1960 records of *Thamnolia vermicularis* in Eryri

Recorder	Massif	Date (range)	No.locations	Source
Alan Pentecost	Snowdon	1972	3	Pentecost & Williams (2002)
Alan Pentecost	Snowdon	2002	2	Pentecost & Williams (2002)
Alan Pentecost	Mynydd Mawr	1970s	1 ?	Pentecost (1987)
Alan Pentecost	Cadair Idris	1970s	1 ?	Pentecost (1987)
Simon Davey	Cadair Idris	2001	1	BLS database via GBIF
Jack Grasse	Cadair Idris	1999-2003	5+	NRW & Jack Grasse
Alison Averis	Pen Llithrig y Wrach	2001	1	Averis (2002)

Following these records, there is gap until the 1970s when Allan Pentecost (1987) undertook much fieldwork in North Wales, and produced the Lichen Flora of Gwynedd. This listed three sites for *T. vermicularis* in four 1 km squares, with three locations mentioned on Yr Wyddfa, one on Mynydd Mawr and one on Cadair Idris. During the late 1990s-early 2000s, there are records for two locations on Yr Wyddfa, around five on Cadair Idris, and a new one on Pen Llithrig y Wrach by Alison Averis in 2001, but none after 2003. Figure 2 shows 1 km squares for the four recently known and historic sites. Although there are nine 1 km squares, it is likely the true number is eight as there are two squares for Mynydd Mawr due to uncertainty in the precise location.

In Britain, the headquarters of the species is in the Scottish Highlands. The most recent maps of the British Lichen Society show 155 occupied hectads, of which 54% are post-2000. It has been seen recently in 7 hectads in the Lake District which include records in 15 1 km squares (https://cumbrialichensbryophytes.org.uk/lichen-species-maps/#Thamnolia_vermicularis).

There is a nineteenth century record for the gall-forming lichenicolous fungus *Thamnogalla crombiei* on *T. vermicularis* from Merioneth (vc48) (Woods & Coppins, 2013), and a specimen collected on Cadair Idris by Watson in 1922 (Acton, 2018).

Figure 1. Historic hectad records for *Thamnolia vermicularis* in Wales.

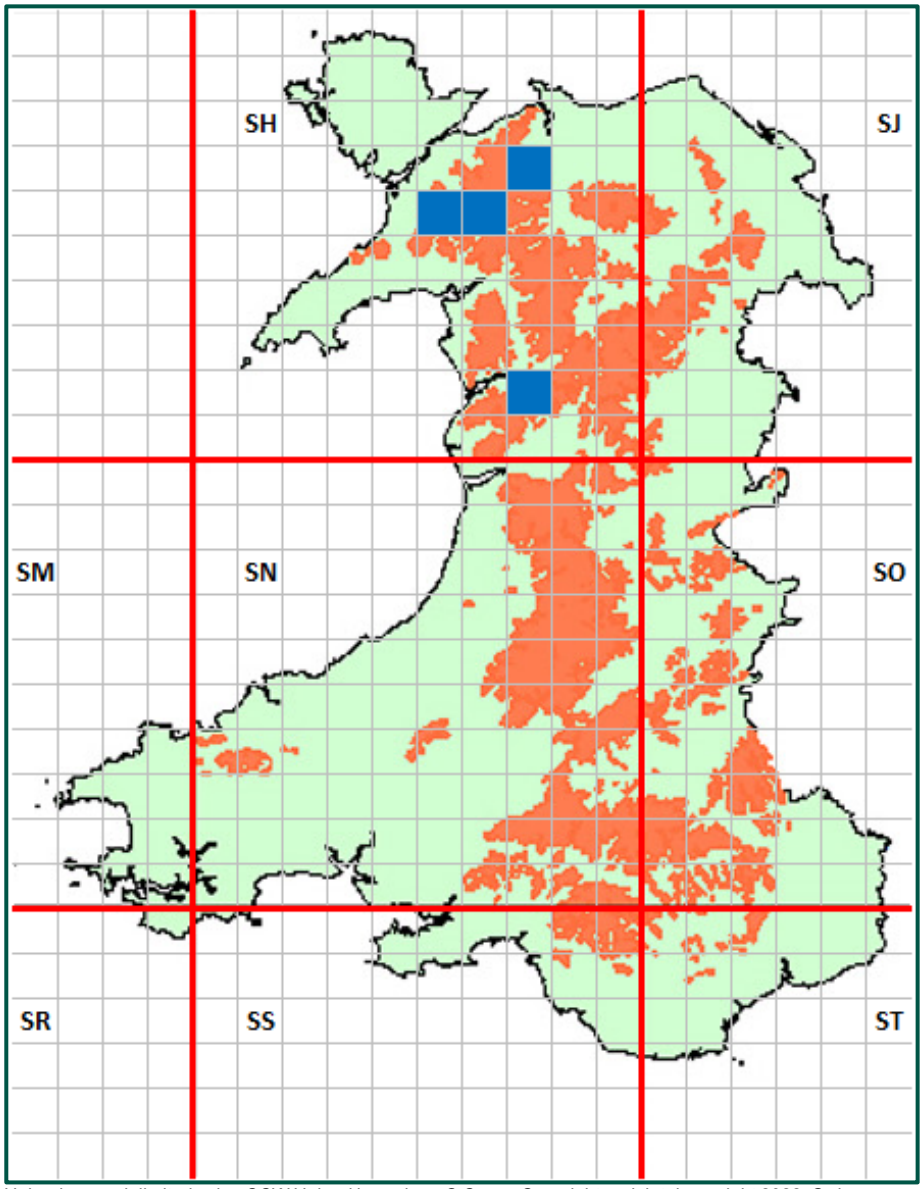
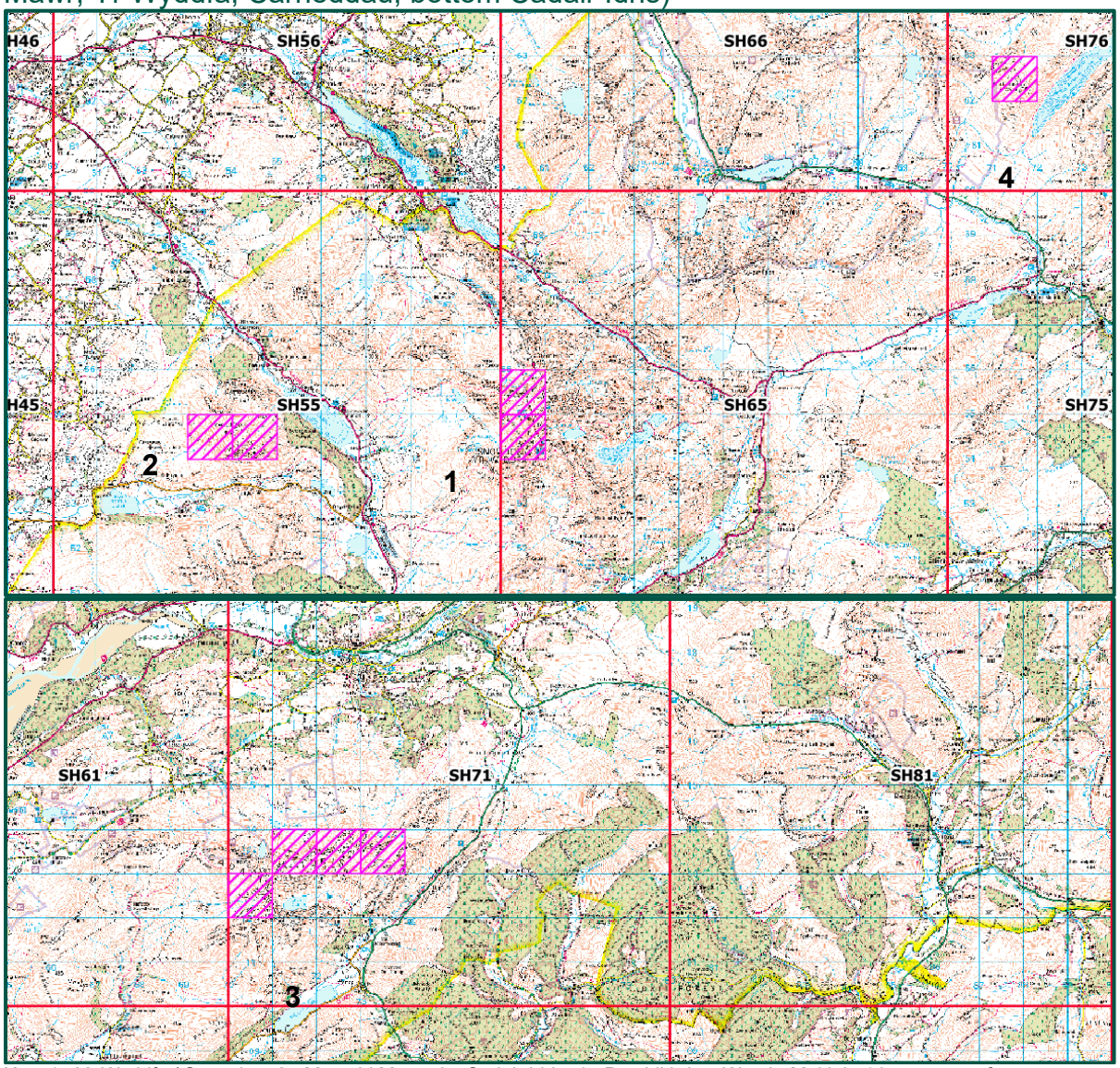


Figure 2. Locations of all records for *Thamnolia vermicularis* in Eryri (top Mynydd Mawr, Yr Wyddfa, Carneddau, bottom Cadair Idris)



Key: 1 - Yr Wyddfa / Snowdon, 2 - Mynydd Mawr, 3 - Cadair Idris, 4 - Pen Llithrig y Wrach. Multiple 1 km squares for some areas due to uncertainty of precise location of record.

Previous survey and monitoring

The only previous survey of the lichen is an unpublished one for the Countryside Council for Wales by Jack Grasse, a local botanist, undertaken on the population on Cadair Idris between June 1999 and July 2000 (Grasse, 2000). He recorded *T. vermicularis* in five main areas with an additional number of single records. In total he recorded 131 clumps of the lichen with information on the number of stalks, maximum size of the stalks and a list of the main associated species. The positions were given in terms of distance and magnetic bearing from a number of fixed points. A further 5 clumps were added to his maps in 2003.

Pentecost and Williams (2001) undertook a study into the microclimate of the two remaining colonies of the lichen on Yr Wyddfa, and described the population there as small and declining, 'perhaps as a result of acid deposition' possibly exacerbated by 'summer sheep grazing'

Paul Cannon (RBG Kew) and Nerys Hughes visited Cadair Idris in July 2019 and surveyed along a route crossing three of Jack Grasse's sites but failed to find the lichen (Paul Cannon, pers.comm.)

Habitat

In Europe and Greenland, *Thamnolia vermicularis* is found in open lichen-rich vegetation. Bültmann and Daniels (2009) examined *T. vermicularis* microcommunities (*Thamnolietum vermicularis* in the Braun-Blanquet scheme) from several locations within the Austrian Alps and Greenland. They found the species occurring mainly in association with wind-exposed, snow-free, dwarf-shrub associations, but also in *Racomitrium lanuginosum* stands. The species was found mainly on acidic bedrock, but also in some associations on calcareous bedrock. It was found in both open and semi-closed vegetation, and the associations were very species-rich in cryptogams.

Dierssen (1996), describing the vegetation of Scandinavia, places *T. vermicularis* amongst lichen-rich alpine heaths (*Loiseleurio-Vaccinietea*), alpine calcareous grasslands (*Carici rupestris-Kobresietea*), and at lower altitudes amongst xerothermic vegetation on the island of Öland.

In Britain, *T. vermicularis* most commonly occurs with the following species: *Vaccinium myrtillus* (Bilberry), *Empetrum hermaphroditum* (Mountain Crowberry), *Carex bigelowii* (Stiff Sedge), *Avenella flexuosa* (Wavy Hair-grass), *Alectoria nigricans, Cetraria aculeata, C. islandica, Cladonia arbuscula, C. uncialis* and *Ochrolechia frigida* (National Vegetation Classification database).

In the National Vegetation Classification (NVC hereafter) (Rodwell *et al.*, 1991-2000), *T. vermicularis* is found in the following communities:

H13 *Calluna vulgaris-Cladonia arbuscula* heath

H19 *Vaccinium myrtillus-Cladonia arbuscula* heath

U9 *Juncus trifidus-Racomitrium lanuginosum* moss-heath

U10 *Carex bigelowii-Racomitrium lanuginosum* moss-heath

Of these communities, only the last was recorded for Wales in the original classification. **H13** and **H19** have been mapped in subsequent upland surveys and generally occur in very small, fragmented stands (summarised in Turner, 2019), and **U9** only occurs in Scotland. Fryday (2001a) recorded *T. vermicularis* in **H13**, **H19** and **U9** in the Cairngorms, with the species most frequent in **H13**. Britton (2008) records it also occurring in **H14** *Calluna-vulgaris-Racomitrium lanuginosum* heath. Habitats in Acton (2018), a survey for *Thamnogalla crombiei*, appear to include those referable to lichen-rich forms of **H15**, **H16** and **H17**.

In Wales, the vegetation communities containing *T. vermicularis* are only poorly characterised; the main species are summarised below from various sources:

Wheldon (1919) recorded the following associates from Yr Wyddfa: *Salix herbacea* (Dwarf Willow)*, Racomitrium lanuginosum, Anthelia juratzkana, Marsupella profunda, Cladonia uncialis* and *Lecidoma demissum.*

On Cadair Idris, Price Evans (1932) placed it within a moss-lichen open association (*Gramino-Cladonietum*), whose main associates were *Vaccinium myrtillus, Diphasiastrum alpinum* (Alpine Club-moss)*, Huperzia selago* (Fir Club-moss)*, Galium saxatile* (Heath Bedstraw)*, Racomitrium lanuginosum* and *Cladonia* spp.

Allan Pentecost noted it growing among low-growing bryophytes such as *Pohlia nutans, Polytrichastrum alpinum, Racomitrium elongatum* and *R. lanuginosum* on the Snowdon sites (Pentecost and Williams, 2001).

Jack Grasse (2000) made lists of associates at every individual *T. vermicularis* clump, and in summary the main species seen were: *Vaccinium myrtillus, Diphasiastrum alpinum, Festuca ovina* (Sheep's Fescue)*, Galium saxatile* and *Racomitrium lanuginosum*, but *V. vitis-idaea* (Cowberry) and/or *Cladonia* spp. were also locally frequent.

Alison Averis (2002) recorded it in a **H19a** quadrat on Pen Llithrig y Wrach with the dwarf-shrub associates *Empetrum hermaphroditum, Vaccinium myrtillus,* and *V. vitis-idaea*, and the lichens *Cladonia arbuscula, C. gracilis, C. portentosa, C. uncialis* and *Ochrolechia frigida*.

From these British examples, together with the information from Bültmann and Daniels (2009), and Dierssen (1996), the optimum habitat for *T. vermicularis* in Wales would appear to be wind-exposed, open, and with short surrounding montane heathland or grassland vegetation, over gravelly soil, or shallow peat.

Contract objectives

The contractor was requested by Natural Resources Wales (NRW) to revisit the four locations, to relocate colonies of *Thamnolia vermicularis*, to assess the status of the populations at each site and to record up to 5 representative quadrats with the species. In addition, the contractor was requested to make records of any of the following list of montane lichens encountered while undertaking surveillance:

Alectoria nigricans, Allantoparmelia alpicola, Bryoria bicolor, *Bryoria chalybaeformis, Bryoria fuscescens, Cetraria ericetorum*, *Cetraria islandica, Cornicularia normoerica, Ochrolechia frigida*, *Stereocaulon tornense, Umbilicaria cylindrica, Umbilicaria hirsuta* and *Umbilicaria proboscidea.*

Methods

Taxonomy

Taxonomy follows Smith *et al.* (2009) for lichens, Hill (2008) for bryophytes and Stace (2019) for vascular plants. Names for National Vegetation Classification communities are from Rodwell (1991,1992), which uses an older taxonomy. The only exception was the use of *Empetrum hermaphroditum* for *Empetrum nigrum* subsp. *hermaphroditum.*

Desk preparation

Maps and imagery were manipulated and analysed using QGIS version 3.4.2 Madeira (QGIS, 2018).

Orthorectified field aerial imagery, at varying scales between 1: 1,250 and 1:5000, with labelled 100m x 100m grid overprinted (and for some sheets a 10m x 10m grid), was printed and laminated using writeable laminating pouches.

For Cadair Idris, Jack Grasse's compass directions and distances were converted to grid references using a magnetic declination correction and basic trignonometry. These were printed onto maps, as well as the positions from registered images of his maps. The text of his list was also printed out for use in the field.

Preprinted forms for quadrat recording and incidental locations of montane macrolichens were printed and laminated with writeable laminating pouches.

Field survey

Sites of interest were located/recorded with a hand-held GPS unit (Garmin GPSMAP 66s, Garmin Ltd, Olathe, USA), which generally reported an accuracy of 2-3 m. Incidental records of various macrolichen species were made using the GPSMAP 66s.

Two levels of surveillance were undertaken, both using parallel transects. If the ground allowed, parallel transects were walked at either (a) 5m intervals or (b) between 2m and 3m intervals, generally E-W or N-S, but in other directions depending on slope. The first coarse-grain search was used to cover an area more generally, while the second fine-grain search was used to check the areas around accurately referenced locations. The second level was used in particular around the Jack Grasse records with more than 20 podetia.

Direction while walking was maintained by a combination of using a sighting compass and frequent checking for deviations from fixed eastings or northings using the GPS.

Seven days of field work were undertaken between 8th July and the 30th November 2022, which included two visits to Yr Wyddfa /Snowdon, two to Mynydd Mawr and three to Cadair Idris. In addition, information from two visits to Yr Wyddfa and Mynydd Mawr prior to the start of the contract in November and December 2021 was included, as well as a visit to the summit plateau of Pen Llithrig y Wrach in October 2020 while undertaking surveillance of *Alectoria nigricans*.

Examination of potential *T. vermicularis* specimens was made by visual identification, and chemical spot-tests were not used. A variety of features considered including: colour, presence/absence of areolation, presence/absence of squamules, degree/type of branching, shape of podetia ends, and whether podetia were prostrate, decumbent, or upright.

In all the areas surveyed, there were frequent stems of a number of macrolichen species (principally *Cladonia uncialis, C. furcata*) torn-out by sheep, often sun-bleached and fragmentary, causing confusion, and requiring careful examination.

Results

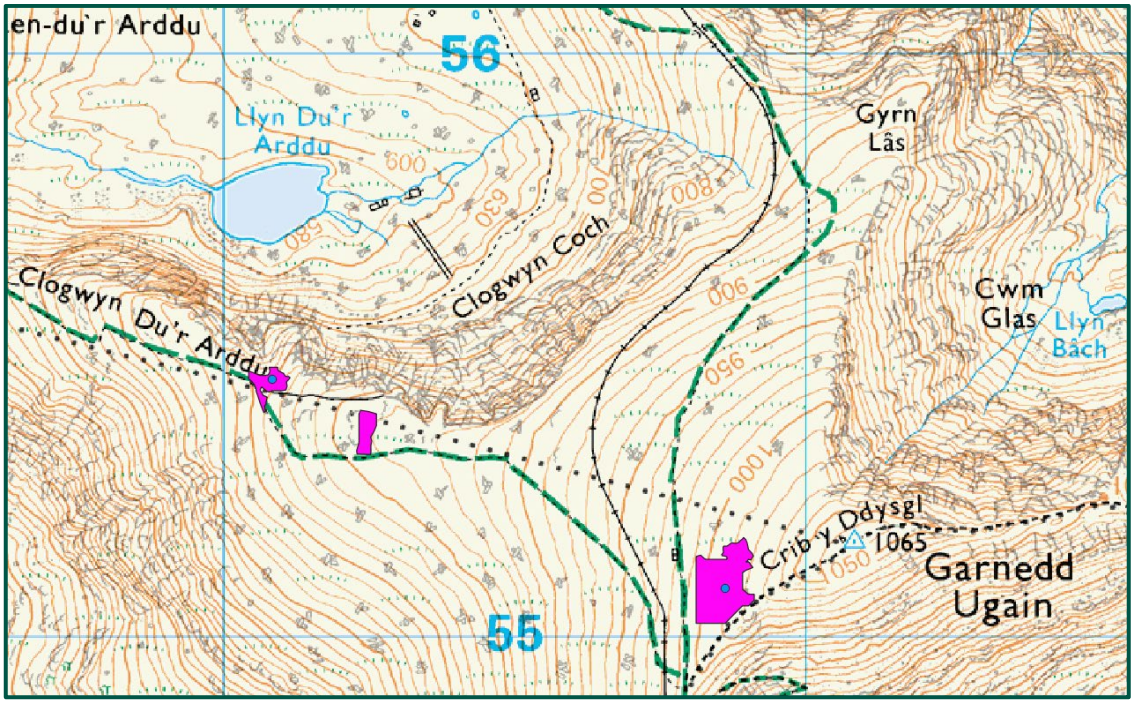
Details of searches for *Thamnolia vermicularis* at the four sites are given in sections 5.1 to 5.4 below. Photographs from each location are presented in Appendix 3. Incidental montane macrolichen records are listed in Appendix 4. Detailed maps of the search areas for each site are presented in Appendix 5.

Pentecost's three listed Welsh locations (Yr Wyddfa, Mynydd Mawr, Cadair Idris) for *T. vermicularis*, were found in four 1-km squares, and had an altitudinal range of 700m to 1050m (Pentecost, 1987).

Yr Wyddfa / Snowdon

Pentecost and Williams (2001) give 10m accuracy grid-references for two small sites on Snowdon - one on the upper slopes of Crib y Ddysgl above the Llanberis Path, and the other above Clogwyn Du'r Arddu close to the Snowdon Ranger path.

Figure 3. *Thamnolia vermicularis* historic locations and search areas on Yr Wyddfa / Snowdon



Pink polygon - 2022 search areas, blue circles - Pentecost and Williams (2001) locations. Grid © Crown Copyright and database right 2022. Ordnance Survey licence number 100019741. © Hawlfraint a hawliau cronfa ddata'r Goron 2022. Rhif Trwydded yr Arolwg Ordnans 100019741. Scale 1:12,800.

1.1.1. Crib y Ddysgl site

The Crib y Ddysgl site (SH60865508, 1015m OD) was surveyed on the 8th July and the 12th November 2022. A rectangular area of 80m x 110m surrounding the 2001 grid reference was intensively surveyed, with suitable habitat in the surrounding area closely walked over (Figure 4), but no *T. vermicularis* was seen.

The vegetation in the survey area was a mixture of boulder vegetation with frequent *Racomitrium lanuginosum*, grassy forms of **U10** *Carex-Racomitrium* moss-heath, and bryophyte-rich forms of **U4** *Festuca-Agrostis-Galium* grassland (**U4d**, **U4e**). Macrolichen species noted included rare to occasionally frequent *Cladonia uncialis* and *C. furcata,* frequently pulled-out, together with very frequently pulled-out grass tufts indicating heavy grazing pressure. The weather on both occasions was sub-optimal for survey with strong winds, low temperatures, and frequently low visibility.

Umbilicaria cylindrica was noted on some of the larger boulders.

1.1.2. Clogwyn Du'r Arddu site

The given grid reference for the second site (at SH60085544, 820m OD) is located on steep slopes above the large cliffs of Clogwyn Du'r Arddu, but with more gently inclined slopes nearby. The site was visited on two occasions, 21st November 2021 and 12th November 2022, and suitable habitat in the zone above the cliffs was carefully surveyed on the second visit, as well as the more gently sloping ground nearby which supported areas of scree, boulders, stony acid grassland and montane grassland. Nearby stony montane grassland at 860m OD was also walked over, as well as stony ground between this site and the Crib y Ddysgl site. Macrolichens noted included frequent *Cladonia uncialis* and occasional C. *portentosa* both of which were frequently pulled out.

The vegetation in the survey area was a mixture of bryophyte-dominated **U4** *Festuca-Agrostis-Galium* grassland with locally frequent *Diphasiastrum alpinum*, scree and boulders with frequent *Racomitrium lanuginosum*. The nearby stony montane grassland at 860m had locally frequent *Carex bigelowii* and was referable to **U10** *Carex-Racomitrium* moss-heath.

No *Thamnolia vermicularis* was seen.

The weather was sub-optimal for surveying on both visits due to strong winds and low temperatures.

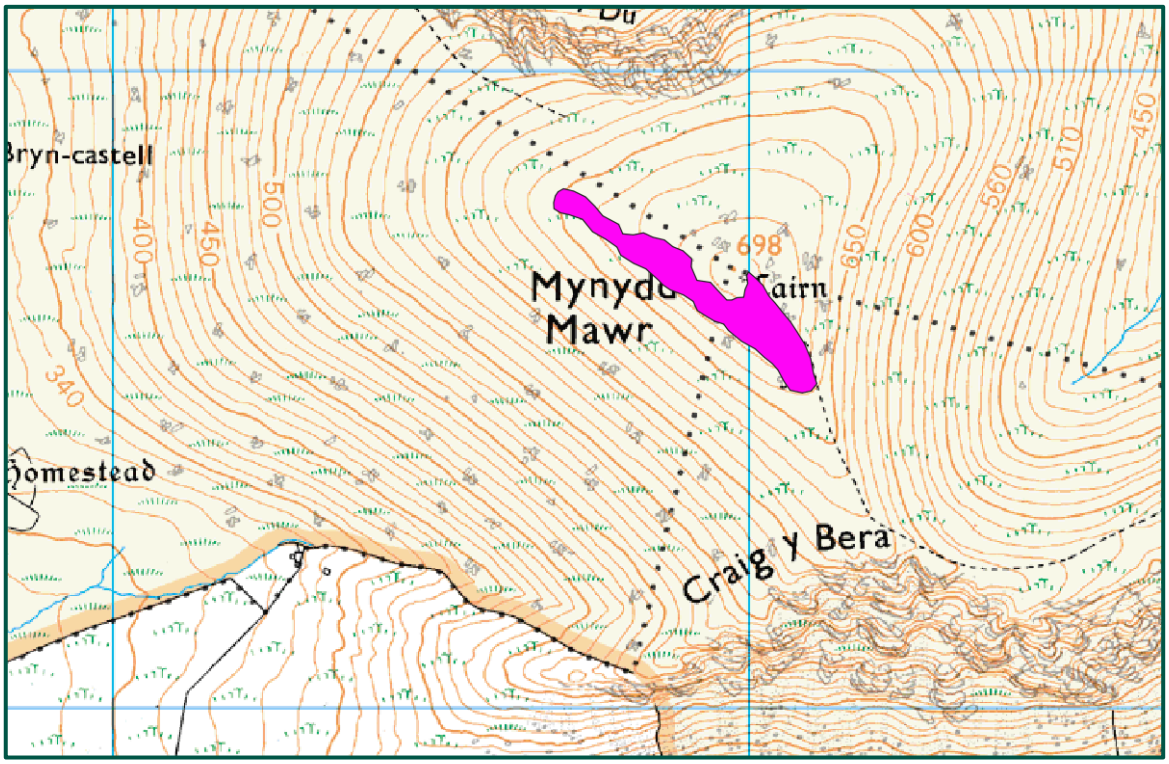
A further area below and to the east of Yr Wyddfa/Snowdon summit, between 1020m and 1060m OD, was visited on 8th July as a possible location for the

lichen, but the habitat was mainly macrolichen-poor **U4** grassland, and no *T. vermicularis* was seen.

Mynydd Mawr

The only record for Mynydd Mawr is from Pentecost (1987), for which he gives no location info. Elsewhere, however, he gives the altitudinal range as 700m to 1050m, and as Mynydd Mawr is only 698m OD, this implies the record was very near the summit.

Figure 4. *Thamnolia vermicularis* search area on Mynydd Mawr



Pink polygon - 2022 search area. Grid © Crown Copyright and database right 2022. Ordnance Survey licence number 100019741. © Hawlfraint a hawliau cronfa ddata'r Goron 2022. Rhif Trwydded yr Arolwg Ordnans 100019741. Scale 1:11,887.

The site was visited twice for surveillance on the 13th October and 3rd November 2022. A preliminary visit was made on the 5th December 2021.

The mountain has a triangular dome-shape, with relatively smooth upper slopes, over a solid geology of microgranite which produce very acidic soils. There is much dwarf-shrub heath on the lower slopes which grades into *Nardus*-dominated grassland higher up and north-east of the summit. A broad NW-SE-trending ridge crosses the summit, and along this the dwarf-shrub heath (**H12b** and **H18c**) grades into lichen-rich heath or lichen-rich acid grassland as exposure increases.

To the south-east of the summit there are locally patches of lichen-rich **U4e** *Festuca-Agrostis-Galium* acid-grassland (*Vaccinium* sub-community), which occasionally grades to grassy **H13** *Calluna-Cladonia* heath or grassy **H19** *Vaccinium-Cladonia* heath, with frequent to abundant *Cladonia uncialis, C. arbuscula*, frequent *C. furcata* and occasional *C. ciliata* ssp. *tenuis*. Closer to the summit the vegetation is very short, with frequent dung, but is more open and referable to a stony form of **U4e**. Here there is occasional to locally frequent *Cetraria aculeata*, frequent *Cladonia furcata* and occasional *C. portentosa*. Also, in this location (at SH5400254673), two small tufts of *Alectoria nigricans* were noted (see Figure 9, Appendix 4): a species which has only been found recently in Wales in one location (Turner, 2020).

North-west of the summit there is a broad strip of lichen-rich heathy and grassy vegetation. The heath is referable to **H12b** *Calluna-Vaccinium* heath (*Vaccinium-Cladonia* sub-community) and **H18c** *Vaccinium-Deschampsia* heath (*Racomitrium-Cladonia* s/community), while the grassland is **U4** *Festuca-Agrostis-Galium* which is locally *Racomitrium*-rich or has frequent to abundant *Diphasiastrum alpinum*. The **H12b** is locally prostrate, and some of the ground between bushes is stony and open. Amongst the macrolichens, *Cladonia uncialis* and *C. portentosa* are abundant, and *C. arbuscula* is frequent to abundant.

Although there is much suitable habitat on Mynydd Mawr, *Thamnolia vermicularis* was not seen. The grazing pressure, although high in places, does not seem to be excessive.

Cadair Idris

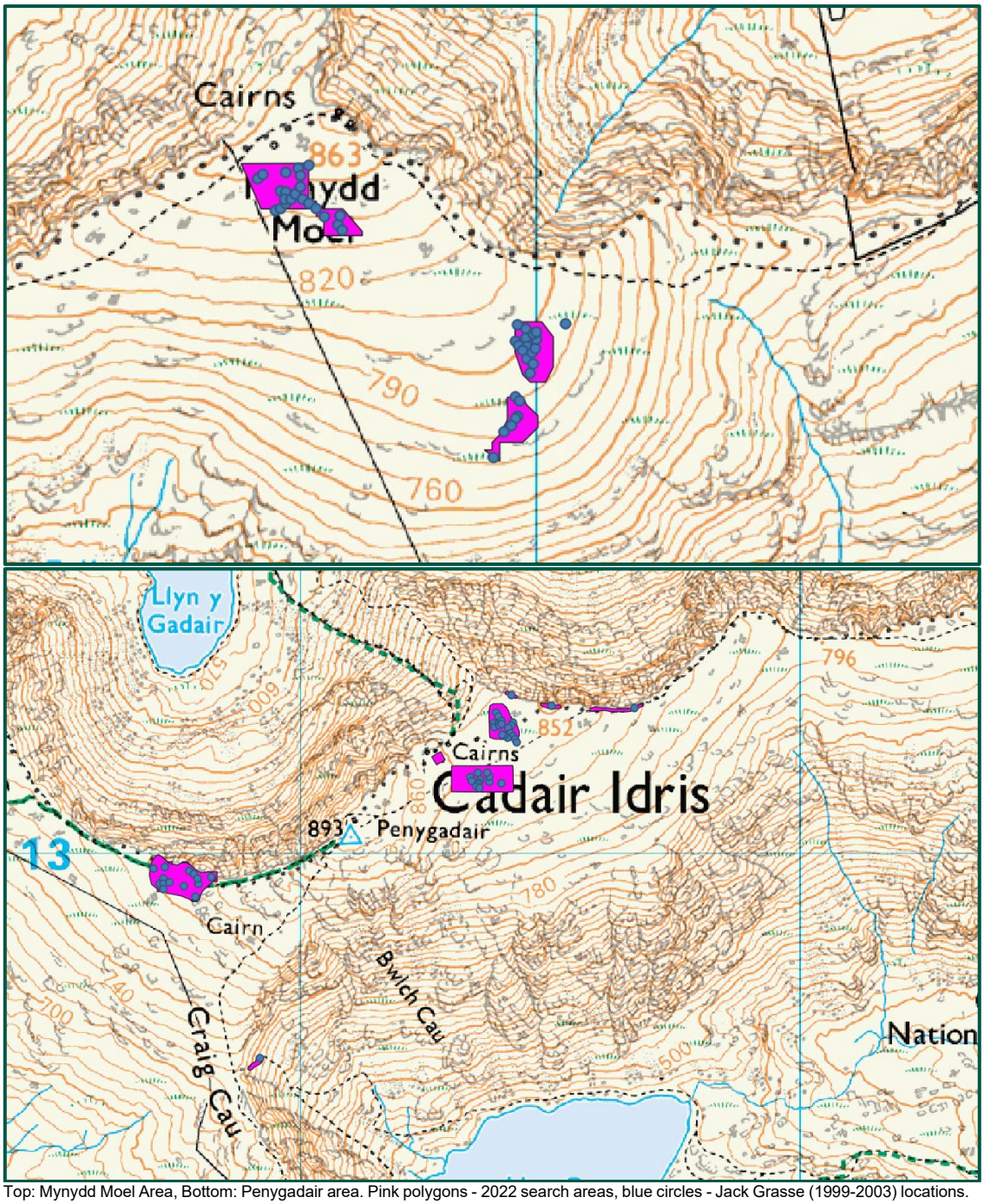
Cadair Idris has the most detailed Welsh records of *T. vermicularis* due to the efforts of Jack Grasse, a local botanist based in Upper Corris. Between June 1999 and July 2000, he surveyed the upper parts of the massif, both within and outside the Cadair Idris National Nature Reserve (NNR), and mapped five main areas of the macrolichen, together with several outlying locations with only a single clump (Grasse, 2000).

Grasse's records are in the form of distance measurements and bearings, some from obvious features, others from posts which themselves were located in relation to natural features. The records were also plotted on a 1: 10,000 scale maps, together with some extra records from 2003.

The site was visited three times for surveillance on the 25th October, 4th November, and 30th November 2022.

Two of the five colonies (Areas 1 and 5) are on the eastern side of the NNR boundary fence to the south of Mynydd Moel. Within the NNR, one colony (Area 2) is located to the west of Penygadair, and two colonies (Areas 3 and 4) are located to the west of the summit. There are also four isolated locations - three along the rim of the cliffs, and the fourth just below Bwlch Cau. Detailed maps are given in Figures 17-20 in Appendix 4.

Figure 5. *Thamnolia vermicularis* historic records and search areas on Cadair Idris



Top: Mynydd Moel Area, Bottom: Penygadair area. Pink polygons - 2022 search areas, blue circles - Jack Grasse (1999-2003) locations. Grid © Crown Copyright and database right 2022. Ordnance Survey licence number 100019741. © Hawlfraint a hawliau cronfa ddata'r Goron 2022. Rhif Trwydded yr Arolwg Ordnans 100019741.Scale 1:13,034.

1.1.3. Areas 1 and 5 - South of Mynydd Moel

Area 1 is located between 70m and 150m south-west of the summit of Mynydd Moel, between 835m and 855m OD, and was visited on 25th October for a coarse-grain survey, and again on the 30th November for a finer-grain survey covering the same area. The latter survey concentrated on trying to refind some of the locations which had the largest number of podetia in 1999-2000.

In 1999-2000, Jack Grasse recorded *T. vermicularis* in 34 locations and the main associates included *Vaccinium myrtillus, Diphasiastrum alpinum Festuca ovina*, *Galium saxatile* and *Racomitrium lanuginosum*. The only macrolichen associates he noted as seen then were *Cetraria aculeata* (1 loc) and *Cladonia ciliata* (1 loc). There were six locations with more than 20 podetia.

In 2022, the vegetation in this area was mostly closed with only occasional more open areas. It was a mosaic of *Racomitrium*-rich acid grassland (**U4e** with occasional patches of *Diphasiastrum alpinum*, and **U5e**) and montane grassland (grassy **U10a** with some large clones of *Carex bigelowii*), locally transitional to heath vegetation (**H18c**, **H20**). The fine-grain survey used 2m-3m interval E-W transects. Amongst the macrolichens noted were frequent *Cladonia uncialis*, occasional to locally frequent *C. portentosa*, and occasional *C. arbuscula* and *C. furcata.* There was much torn-out grass and pieces of *Cladonia*, and also some chewed off *C. uncialis* clumps. No sign of *T. vermicularis* was seen.

Area 5 is located c250m south-east of Area 1, with an altitudinal range from 770m to c805m OD, and was located with reference to a prominent upstanding rock (Grasse's 'Rubbing Rock') at SH72981338. There are three areas, which supported a total of 30 colonies in 1999-2000, most of which were small with few podetia. Grasse's main associates noted were *Vaccinium myrtillus, Diphasiastrum alpinum Festuca ovina* and *Galium saxatile*. The main macrolichens he noted were *Cladonia uncialis* (3 colonies) and *C. portentosa* (4 colonies) plus one record for *Baeomyces rufus*.

In 2022, the area was searched using a coarse-grain survey on the 25th October, and a short follow-up search was made on the 30th November. The vegetation was more or less closed, with only a few more open areas present. The area has much **U5e** *Nardus-Galium* grassland (*Racomitrium* s/c) and *Racomitrium*-rich **U4e** *Festuca-Agrostis-Galium* grassland (*Vaccinium* s/c), with some grassy **U10a** *Carex-Racomitrium* moss-heath, all of which grades locally into **H18c** *Vaccinium-Deschampsia* heath (*Racomitrium-Cladonia* s/c) and grassy **H19** *Vaccinium-Cladonia* heath. The main macrolichen species present are frequent *Cladonia uncialis* and occasional to frequent *C. portentosa*. There

is much pulled-out vegetation including grasses, clubmosses and macrolichens. No *T. vermicularis* was seen.

1.1.4. Areas 3 and 4, and scarp locations - East of Penygadair

Areas 3 and 4 are close together, respectively at c250m and c350m north-east from the summit of Penygadair, at between 840m and 850m OD. In addition, there are three isolated locations along the edge of the scarp line where Jack Grasse recorded single colonies of *T. vermicularis*. The main associates recorded in 1999-2000 were *Vaccinium myrtillus, Festuca ovina* and *Galium* saxatile (Area 3), and *F. ovina* and *G. saxatile* (Area 4). Macrolichens were generally infrequent, the most frequent of which were *Baeomyes rufus* and *Cladonia squamosa* and rarely *C. uncialis*.

In 2022, the sites along the northern scarp were visited on the 4th November, and linear strips parallel with the edge were walked, these extending a short way downslope and back from the edge (Figure 11, Appendix 4). The vegetation along and below these areas was mostly closed, comprising acid grassland (**U4**, **U5**), and locally montane grassland (**U10a**) along the crest, and, on the downslope, with **H18c** *Vaccinium-Deschampsia* heath (*Racomitrium-Cladonia* s/c), and in places **H20** *Vaccinium-Racomitrium* heath (with abundant *Carex bigelowii*). The macrolichen component in these areas included *C. uncialis, C. portentosa, C. arbuscula* and *C. furcata*, but no *Thamnolia vermicularis*.

Area 4 is slightly higher, more exposed, and grassier than Area 3. Jack Grasse recorded 33 clumps of *T. vermicularis* in the area, mostly small with fewer than 20 podetia, but with two larger colonies (54 and 20 podetia). The area was searched at a coarse-grain level on the 4th November, and at a fine-grain level on the 30th. The vegetation is mostly closed, and comprises a mosaic of NVC communities including **U6c/d** *Juncus-Festuca* grassland (*Vaccinium* and *Agrostis-Luzula* s/cs), **U10a** *Carex-Racomitrium* moss-heath, *Racomitrium*-rich **U4e** (with locally frequent *Diphasiastrum alpinum*), and **H18c** heath (with abundant *Vaccinium vitis-idaea* and *Polytrichastrum alpinum*). Macrolichens are relatively infrequent, mainly *C. uncialis*, *C. furcata* and *C. portentosa*, and *Thamnolia vermicularis* was not seen.

Jack Grasse recorded 19 clumps in Area 3, with three larger than 20 podetia. This area was also searched on the 4th (coarse-grain) and 30th November (fine-grain), with the latter search restricted to the environs of the three historic locations with 20 or more podetia. The vegetation is mainly *Racomitrium*-rich and *Diphasiastrum alpinum*-rich forms of **U4e** grassland. Locally the vegetation grades into grassy **U10a**, **H18c**, **U5e**, **U4a** or **U6d**, the latter two near the path. Macrolichens were occasional, mainly *C. furcata* with some *C. uncialis.*

T. vermicularis was not seen. *Umbilicaria cylindrica* was noted in several places on boulders nearby

1.1.5. Area 2 - West of Penygadair, and Bwlch Cau location

Area 2 is located on both sides of the Pony Track at 800m to 820m OD close to the scarp edge. Jack Grasse recorded *T. vermicularis* in three places here between 1999-2003 which included 13 colonies. A further five were seen in 2003. The main *T. vermicularis* associates he noted were *Vaccinium myrtillus, Diphastrum alpinum*, *Festuca ovina* and *Galium saxatile*. Macrolichen associates were generally infrequent but included *Cetraria aculeata, Cladonia arbuscula, C. ciliata, C. portentosa* and *C. uncialis*. Two colonies had over 20 podetia.

This area was searched on the 4th (coarse-grain survey) and 30th November 2022 (localised fine-grain survey). The vegetation is mainly closed *Racomitrium*-rich and *Diphasiastrum alpinum*-rich forms of **U4e** grassland (with locally frequent *Cladonia uncialis* and *C. portentosa*), and some spreads of boulders. It becomes more open close to the footpath where there has been some erosion. *Thamnolia vermicularis* was not seen.

Jack Grasse made an isolated record of *T. vermicularis* just below Bwlch Cau at SH70911258 which is just above the path ascending from Cwm Cau. The area around the record location was searched on the 30th November. The search area lies along and above the line of the ascending path where it is eroded down to the bedrock which is semi-vegetated, locally steeply sloping, and slippery. This was a difficult area to search effectively and the search must be regarded as incomplete.

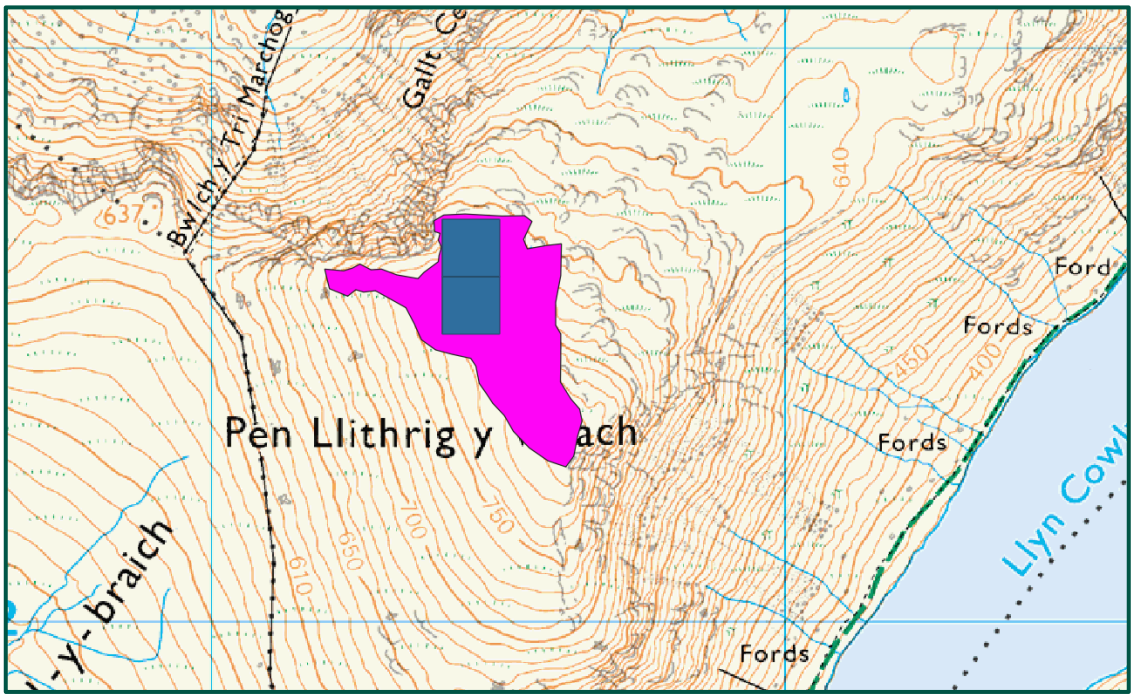
The vegetation in this area was **H12** *Calluna-Vaccinium* heath where less accessible to sheep, bryophyte-rich forms of **U4** where more accessible, and bare rock elsewhere. The macrolichen component included *Stereocaulon vesuvianum, Cladonia subcervicornis*, *C. uncialis, C. portentosa,* and *C. furcata*, but *T. vermicularis* was not seen.

Pen Llithrig y Wrach

Two records of *Thamnolia vermicularis* were made by Alison Averis in 2001 on Pen Llithrig y Wrach as part of an NVC survey of the Eastern Carneddau (Averis, 2002). They are in adjacent 100m x 100m squares, one a quadrat record (SH714626), the other a target note (SH714625), both recorded in **H19** *Vaccinium-Cladonia* heath.

The site was visited on the 1st October 2020 as part of a survey for *Alectoria nigricans* which was also recorded in the vicinity during the same survey. Vegetation types noted in the survey area included a form of **U4e** *Festuca-Agrostis-Galium* grassland, *Vaccinium* sub-community with frequent to abundant *Diphasiastrum alpinum* (Alpine Clubmoss), small areas, in mosaic, of **U10a** *Carex-Racomitrium* moss-heath, *Galium saxatile community* and elsewhere, also in mosaic, patches of **H19** *Vaccinium-Cladonia* heath.

Figure 6. *Thamnolia vermicularis* historic records and search area on Pen Llithrig y Wrach in 2020.



Pink polygon - 2022 search area, blue squares - Averis (2002) locations (6-figure grid references). Grid © Crown Copyright and database right 2022. Ordnance Survey licence number 100019741. © Hawlfraint a hawliau cronfa ddata'r Goron 2022. Rhif Trwydded yr Arolwg Ordnans 100019741. Scale 1:13,108.

Despite systematic searching, using parallel traverses, 5m altitude apart, across the northern slopes, no sign of *Thamnolia* was seen. There were small patches of lichen-rich *Vaccinium* heath (**H19**) on steeper rock outcrops with locally abundant *Cladonia arbuscula* and occasional *C. uncialis*, but much of the vegetation was unpromising, comprising closed tussocky **U5** *Nardus-Galium* grassland and **H18** *Vaccinium-Deschampsia* heath with very few macrolichens present and no montane species.

The search area was extended to also include all the montane heath and grassland habitat around the summit (Figure 6). There were few montane vascular plants in the area, with only single small colonies of *Salix herbacea* and *Carex bigelowii*.

The summit (799m) and the broad crest of the ridge to the north-west have large patches of **U4** grassland, either with frequent *Racomitrium lanuginosum* or very open and stony. This vegetation, which bears a strong similarity to degraded **U10** moss-heath, was searched carefully, but without success. The only montane macrolichen seen was *Ochrolechia frigida* at SH 71575 62354, not far from the summit.

Discussion

In brief, *Thamnolia vermicularis* was not found at any of its previously recorded sites in 2022 despite careful searching.

It has always been a relatively uncommon macrolichen in North Wales. The low number of records in the century and a half following its relatively late discovery in 1844 by Salwey indicate an always small population, perhaps not surprising as it is on the edge of its range.

Indications of a decline in the size of the population were first made in Pentecost and Williams (2001), who noted that it was much harder to find the lichen during their study, than when it was first recorded by Pentecost in the 1970s. Jack Grasse's survey of the lichen on Cadair Idris over 1999-2000 was perhaps too reassuring that the species was not under significant threat, despite the lack of subsequent records.

The habitat which supports *T. vermicularis* in Wales has been the subject of several surveys over the last 70 years, which include surveys by Ratcliffe (1953), the Wales Field Unit, in-house and contract NVC surveys, and SAC monitoring surveys, of which only one has produced a record (Averis, 2002). Montane grassland and heath vegetation in Wales is subject to a number of impacts, three of which are likely to be significant for the lichen: atmospheric Nitrogen deposition, high grazing pressure and climate change.

In brief, N-deposition has been shown to impact the condition of montane *Racomitrium*-heath on the Carneddau (Britton and Pierce, 2004), and the impact on terricolous alpine lichens was shown by Britton and Fisher (2010) through both load and concentration. Turner (2012) showed significant declines in several macrolichen species on the Carneddau from Ratcliffe's 1950s survey to 2011, and indicated how the changes coincided with increases in sheep numbers and level of atmospheric N-deposition. Further, Van der Wal *et al.* (2003) described a mechanism whereby a negative feedback loop increased the effects of atmospheric N-deposition via grazing (for more detail see Turner, 2020b).

Sheep numbers in Wales peaked in the mid-1990s at around 11.5 million, dropped to 8.2 million in the mid-2000s and have increased since to around 9 million (Welsh Government statistics). These relative changes in national level statistics are broadly replicated in the Welsh uplands, indicating a still considerable overall grazing pressure. Fryday (2001b), in an examination of the effects of grazing on upland/montane lichen vegetation in Great Britain found that with grazing, there was a significant decrease in the biomass of fruticose

lichens, which were also fragmented producing smaller colonies. Additionally, he found an inverse relationship between lichen species diversity and the height of the vegetation.

Finally, the effects of climate change are being felt in mountain areas throughout the world (e.g., Walther *et al.,* 2005), with the climate envelope of alpine species in particular, being drawn ever tighter due to increases in temperature and changes in the variability of the climate. Increases in temperature should manifest themselves in the lower sites (e.g., Mynydd Mawr) earlier than the higher sites (e.g., Crib y Ddysgl on Yr Wyddfa). It is not possible to definitively demonstrate the impact of changes in climate on *T. vermicularis*, however, the likelihood of an impact is high.

The impact of grazing pressure on the different historic sites is summarised in Table 2 with estimated grazing pressures and a rough summary of how much of the vegetation is open or closed.

At the various sites surveyed, there was evidence of high grazing levels from observations of the amount of pulled-out material seen. There was some variation, with Mynydd Mawr probably the lowest (as evidenced by the amount of dwarf-shrub heath present, and the relatively low levels of pulled-out plant material), and Crib y Ddysgl possibly the highest (lacking dwarf shrubs apart from *Salix herbacea*, and having much pulled-out material). There is also variation in the amount of open vegetation, an important characteristic of good *Thamnolia vermicularis* habitat, with little or none at several of the areas on Cadair Idris, but a mix of open and closed at sites such as Mynydd Mawr.

Although the level of atmospheric N-deposition is likely to be broad-scale, with little variation between sites, there maybe an intensification of the effect with increased grazing pressure. Increased N-deposition could account for the closed nature of the vegetation at several sites, having stimulated increases in cover and biomass of some of the vascular plants.

Finally, climate change induced effects are likely to be broad-scale with little variation between sites, although affecting lower sites earlier and more strongly than higher sites.

Putting these observations together, it is surmised that the probable extinction of the lichen is due to three factors acting in tandem: (a) N-deposition and grazing acting to close up the habitat, (b) high grazing pressure with much physical removal of lichen biomass producing a hostile environment for the lichen, and (c) increased temperature allowing vascular plants and some bryophytes to attain greater cover, stature, and biomass due to a longer growing season and shorter duration of snow-lie.

Finally, although the areas were searched thoroughly, it is difficult to prove absence as (a) small specimens of *Thamnolia vermicularis* could have been overlooked, and (b) there is much suitable habitat elsewhere which was not searched on the four mountains surveyed, and also on several other high-level sites in Eryri. It is suggested that before the lichen is deemed definitely extinct in Wales, more targeted searching of suitable habitat at the highest altitudes is undertaken, particularly on exposed areas with open vegetation.

Table 2 Summary of impacts on vegetation at historic *Thamnolia vermicularis* sites

Massif	Location	1 km square(s)	Altitude (m)	Vegetation open/closed	Estimated exposure	Estimated grazing pressure	NVC communities
Yr Wyddfa/ Snowdon	above Clogwyn Du'r Arddu	SH6055	800 - 815	open and closed	Mod-High	Very High	U4eDa, U10aG, B, S; (L U4eR, U4eS)
Yr Wyddfa/ Snowdon	Crib y Ddysgl	SH6055	995 - 1020	open and closed	High	Very High	U4eR, U10aG, B, U4d
Nantlle Ridge /Moel Hebog	Mynydd Mawr summit (SE&C)	SH5454	680 - 698	open and closed	High	Mod - High	U4eL, U4eS; (L H13G, H19G)
Nantlle Ridge /Moel Hebog	Mynydd Mawr summit (NW)	SH5354	650 - 698	open and closed	High	Mod - High	H12b, H18c, U4eDa, U4eR; (L pH12b)
Cadair Idris	S of Mynydd Moel summit (Area 1)	SH7213	830 - 855	mostly closed	Mod-High	High	U4eDa, U10aG, U10aC, U4eR, U5e; (L H18c)
Cadair Idris	S of Mynydd Moel summit (Area 5)	SH7213, SH7313	770 - 805	mostly closed	Mod	High	U5e, U4eR, U10a C; (VL H19aG, H18c)
Cadair Idris	E of Penygadair summit (Area 3)	SH7113	840 - 850	mostly closed	Mod-High	Mod - High	U4eR, U4eDa, B; (L U10aG, H18c, U6d, U5b)
Cadair Idris	E of Penygadair summit (Area 4)	SH7113	845	mostly closed, some open	High	Mod - High	U6c/d, U10aG, U4eR, H18c; (L U4eDa)
Cadair Idris	W of Penygadair summit (Area 2)	SH7012	800 - 820	open and closed	High	Mod - High	U4e Da, U4e R, B
Carneddau	Pen Llithrig y Wrâch summit	SH7162	750	open and closed	Mod-High	High	U4eS, U5e, U10a G; (L H19)

Key: L (prefix) = locally, VL = very local; NVC community suffixes refer to condition variants: C = *Carex bigelowii* dominant, Da = *Diphasiastrum alpinum* (clubmoss), G = grassy, L - lichen-rich, R = *Racomitrium lanuginosum*, S = open stony,

Conclusions

Surveillance of *Thamnolia vermicularis,* a Vulnerable (VU) macrolichen in Wales that occurs in montane heath and grassland communities, was undertaken between 2020 and 2022 at the four locations where it has only ever been recorded in Wales.

Three of the four sites were revisited between July and November 2022, and the species was not found at any of these sites. The fourth site was surveyed in 2020 as part of the survey of another species, and *Thamnolia* was not found.

It is surmised that the loss of the macrolichen is due to a combination of heavy grazing pressure, climate change and the excessive deposition of atmospheric nitrogen acting in tandem.

Further targeted survey is suggested of suitable open habitat at the highest altitudes on the mountains where it was recorded, particularly in remaining areas of open vegetation. This would enable a more definitive assessment of the status of the Welsh population.

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Appendices

Appendix 1: National Vegetation Communities mentioned in text

Communities occurring in Wales

U4 *Festuca ovina-Agristos capillaris-Galium saxatile* grassland
- **U4a** Typical sub-community
- **U4d** *Luzula-Rhytidiadelphus* sub-community
- **U4e** *Vaccinium* sub-community

U5 *Nardus stricta-Galium saxatile* grassland
- **U5e** *Racomitrium* sub-community

U6 *Juncus squarrosus-Festuca ovina* grassland
- **U6c** *Vaccinium* sub-community
- **U6d** *Agrostis-Luzula* sub-community

U10 *Carex bigelowii-Racomitrium lanuginosum* moss-heath
- **U10a** *Galium* sub-community

H12 *Calluna vulgaris-Vaccinium myrtillus* heath
- **H12b** *Vaccinium vitis-idaea-Cladonia impexa* sub-community

H13 *Calluna vulgaris-Cladonia arbuscula* heath

H14 *Calluna vulgaris-Racomitrium lanuginosum* heath

H15 *Calluna vulgaris-Juniperus communis* ssp. *nana.* heath

H18 *Vaccinium myrtillus-Deschampsia flexuosa* heath
- **H18c** *Racomitrium-Cladonia* sub-community

H19 *Vaccinium myrtillus -Cladonia* spp. heath
- **H19a** *Festuca-Galium* sub-community

H20 *Vaccinium myrtillus-Racomitrium lanuginosum* heath

Communities occurring in Scotland

U9 *Juncus trifidus-Racomitrium lanuginosum* rush-heath

H16 *Calluna vulgaris-Arctostaphylos uva-ursi* heath

H17 *Calluna vulgaris-Arctostaphylos alpinus* heath

For further information, see Rodwell (1991,1992).

Appendix 2: Historic *T.* vermicularis vegetation data

Table 3 Historic *Thamnolia vermicularis* quadrat data

Quadrat data from survey of:	**Carneddau (East)**
Site name	Pen Llithrig y Wrach
Quadrat number	**H19aQ2**
Grid Reference	SH 714 626
Surveyor	A. Averis
Date of quadrat	2000
NVC classification	**H19a**
Empetrum hermaphroditum	4
Vaccinium myrtillus	7
Vaccinium vitis-idaea	4
Diphasiastrum alpinum	4
Huperzia selago	4
Carex pilulifera	3
Festuca ovina	5
Galium saxatile	4
Dicranum scoparium	2
Hypnum jutlandicum	4
Racomitrium lanuginosum	4
Ptilidium ciliare	1
Cladonia arbuscula	**8**
Cladonia gracilis	2
Cladonia portentosa	5
Cladonia uncialis	2
Ochrolechia frigida	2
Thamnolia vermicularis	3
No species	18
Altitude (m)	750
Slope (deg)	10
Aspect (deg)	327
Vegetation height (cm)	5
Quadrat size (field & ground layers)	2x2m

Appendix 3: Locations of notable montane macrolichens

Of the list of 14 species in the contract specification, the following were noted in one or more locations: *Alectoria nigricans*, *Ochrolechia frigida* and *Umbilicaria cylindrica*.

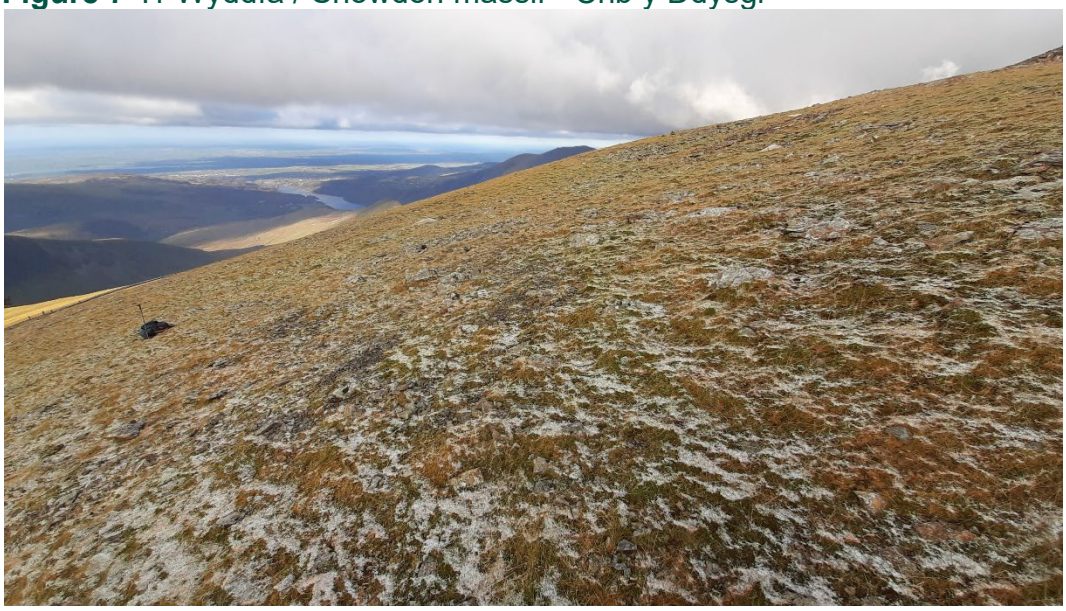
Table 4. Locations of other macrolichens recorded

Species	Date	Massif	Area	Grid reference	Alt (m)
Alectoria nigricans	03-Nov-22	Mynydd Mawr	SE of summit	SH5399754670	697
Ochrolechia frigida	01-Oct-20	Pen Llithrig y Wrach	nr summit	SH7157562354	795
Umbilicaria cylindrica	12-Nov-22	Yr Wyddfa	Crib y Ddysgl	SH6089155080	1012
Umbilicaria cylindrica	12-Nov-22	Yr Wyddfa	Crib y Ddysgl	SH6085555165	1002
Umbilicaria cylindrica	30-Nov-22	Cadair Idris	2	SH7078412960	812
Umbilicaria cylindrica	30-Nov-22	Cadair Idris	2	SH7080412961	816
Umbilicaria cylindrica	30-Nov-22	Cadair Idris	3	SH7138113111	833
Umbilicaria cylindrica	30-Nov-22	Cadair Idris	3	SH7129313133	847
Umbilicaria cylindrica	30-Nov-22	Cadair Idris	3	SH7129513176	849
Umbilicaria cylindrica	30-Nov-22	Cadair Idris	4	SH7140213287	839

Ochrolechia frigida was previously listed in Turner (2020)

Appendix 4: Photos of 2022 *Thamnolia vermicularis* search locations

Figure 7 Yr Wyddfa / Snowdon massif - Crib y Ddysgl



A poor photograph of the Crib y Ddysgl site under a light dusting of snow on 21 Nov 2021. The rucksack is at Pentecost & Williams (2001) grid reference. The vegetation in the surrounding hectare was a mixture of *Racomitrium*- and *Rhytidiadelphus*-rich **U4,** grassy **U10a** and *Racomitrium*-rich areas of boulders**.** The area had some open vegetation, but a majority was closed, and there was much pulled-out material including grasses, macrolichens and clubmosses. The site was sampled by parallel transects 2m-3m apart aligned N-S.

Figure 8 Yr Wyddfa / Snowdon massif

The bottom photo shows the general area around Pentecost and Williams' 2001 grid-reference (on 12th November 2022), which has much bare rock, boulders, scree, and some bare ground, amongst which the vegetation is mainly *Racomitrium-lanuginosum*-rich **U4** grassland. The top-left photo shows the flattish ridge above close to the Snowdon Ranger path, which is **U4e**, in places open and stony, but elsewhere close. The top-right photo shows the flattish ridge higher up at c860m where there is open grassy **U10a** montane grassland and **U4** acid grassland (both pictures on 21st November 21).

Figure 9 Mynydd Mawr

Top left (location, 03-Nov-22) and top right (detail, 05-Dec-21) show the location of *Alectoria nigricans.* The centre left (05-Dec-21) shows the lichen-rich acid grassland south-east of the summit, while the centre right (03-Nov-22) shows nearby acid grassland vegetation grading to heath. The bottom left (13-Oct-22) and bottom right (03-Nov-22) photos show the lichen-rich acid-grassland/heath vegetation on the north-west ridge.

Figure 10 Cadair Idris - Areas 1 and 5 - Southern slopes of Mynydd Moel

Top left is a general view (30-Nov-22) of Area 1 vegetation showing the mainly closed nature of the vegetation, with the top right photo (25-Oct-22) showing pulled-out grasses, clubmosses and *Cladonia* lichens in the same area. The bottom left photo (25-Oct-22) in Area 5 shows Jack Grasse's 'Rubbing Rock' at SH72988 13388. The bottom right photo (25-Oct-22), also in Area 5, showing the predominantly closed nature of the vegetation.

Figure 11 Cadair Idris - Areas 3 and 4 - East of Penygadair

The top left and top right photos (04-Nov-22) show the easternmost of the isolated Jack Grasse locations on the lip of the scarp overlooking Llyn Gafr. The vegetation is generally closed and is closer to acid grassland on the crest of the ridge, while becoming heathier on the upper slopes. The bottom left photo (04-Nov-22) is in Area 4 where the vegetation is predominantly acid grassland, locally open, but mostly closed, and with locally frequent to abundant *Polytrichastrum alpinum*. The bottom right photos (30-Nov-22) is of part of Area 3 where the vegetation is closed.

Figure 12 Cadair Idris - Area 2 West of Penygadair

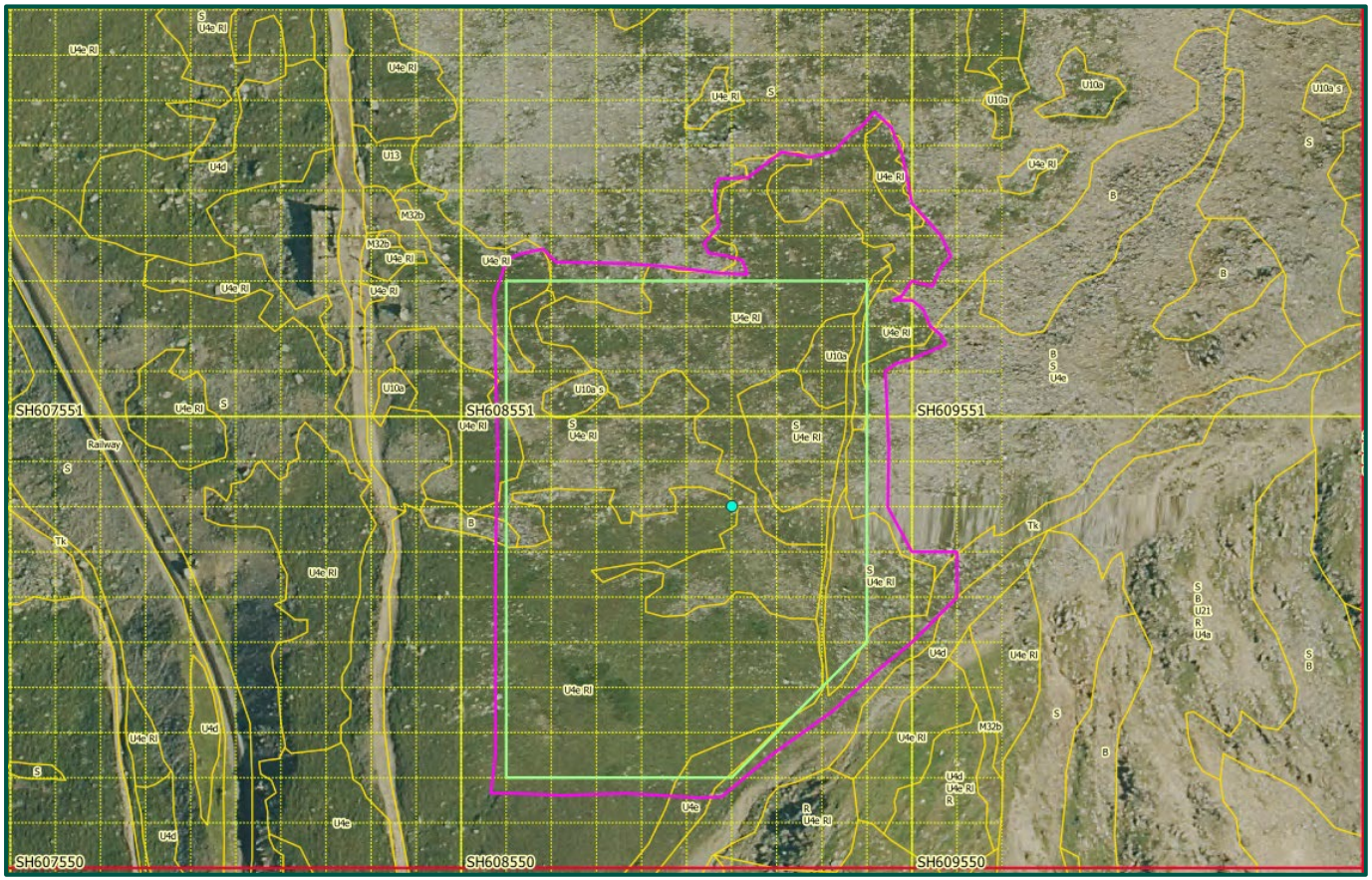
The top photo (04-Nov-22) is of the central of the three groups of Jack Grasse locations in Area 2 close to the ridge edge, and looking towards Cyfrwy. The vegetation is generally closed acid grassland, with *Racomitrium*-rich boulders in the foreground. The bottom left photo (30-Nov-22), shows where the path cuts through Area 2 and the vegetation is shorter acid grassland, open in places by virtue of the path erosion, but generally macrolichen-poor in these areas. The bottom right photo (30-Nov-22) shows the isolated Jack Grasse location below Bwlch Cau. There is steep rock, due the cumulative effects of path erosion, with locally frequent macrolichens, particularly saxicolous, but difficult to access, especially when damp.

Figure 13 Pen Llithrig y Wrach

Top picture shows the broad ridge running NW-SE towards the summit, in the southern 100m x 100m square with open, locally stony, generally macro-lichen-poor, **U4** grassland. The bottom photo was taken in the lower part of the northern 100m x 100m sqare, and is dominated by **U5** *Nardus-Galium* grassland, with tiny patches of **H19** *Vaccinium-Cladonia* heath sround a few of the rock outcrops.

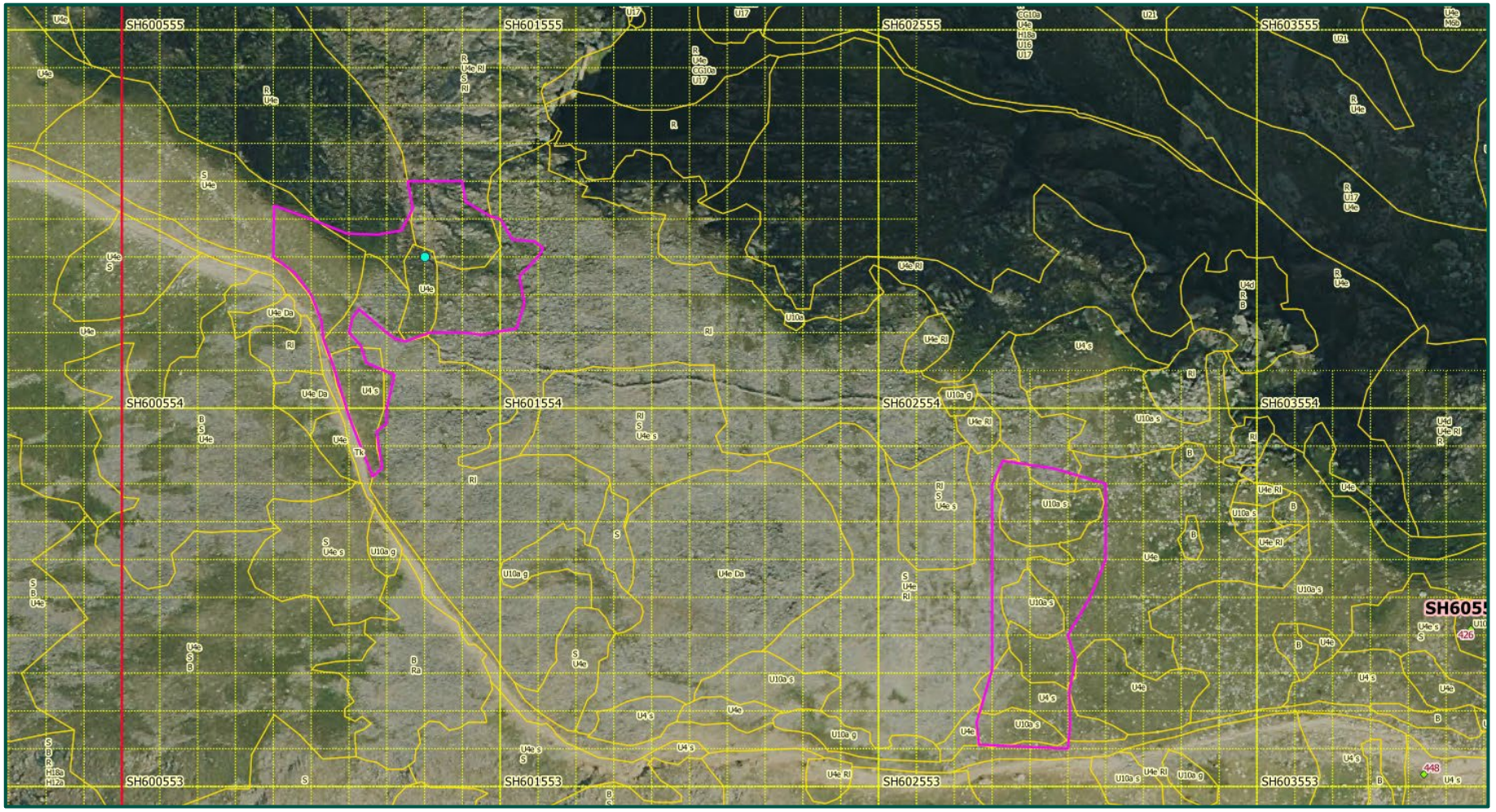
Appendix 5: Detailed aerial imagery of search areas and historic records

Figure 14. Search area for *Thamnolia vermicularis* on Crib y Ddysgl, Yr Wyddfa / Snowdon, 2022



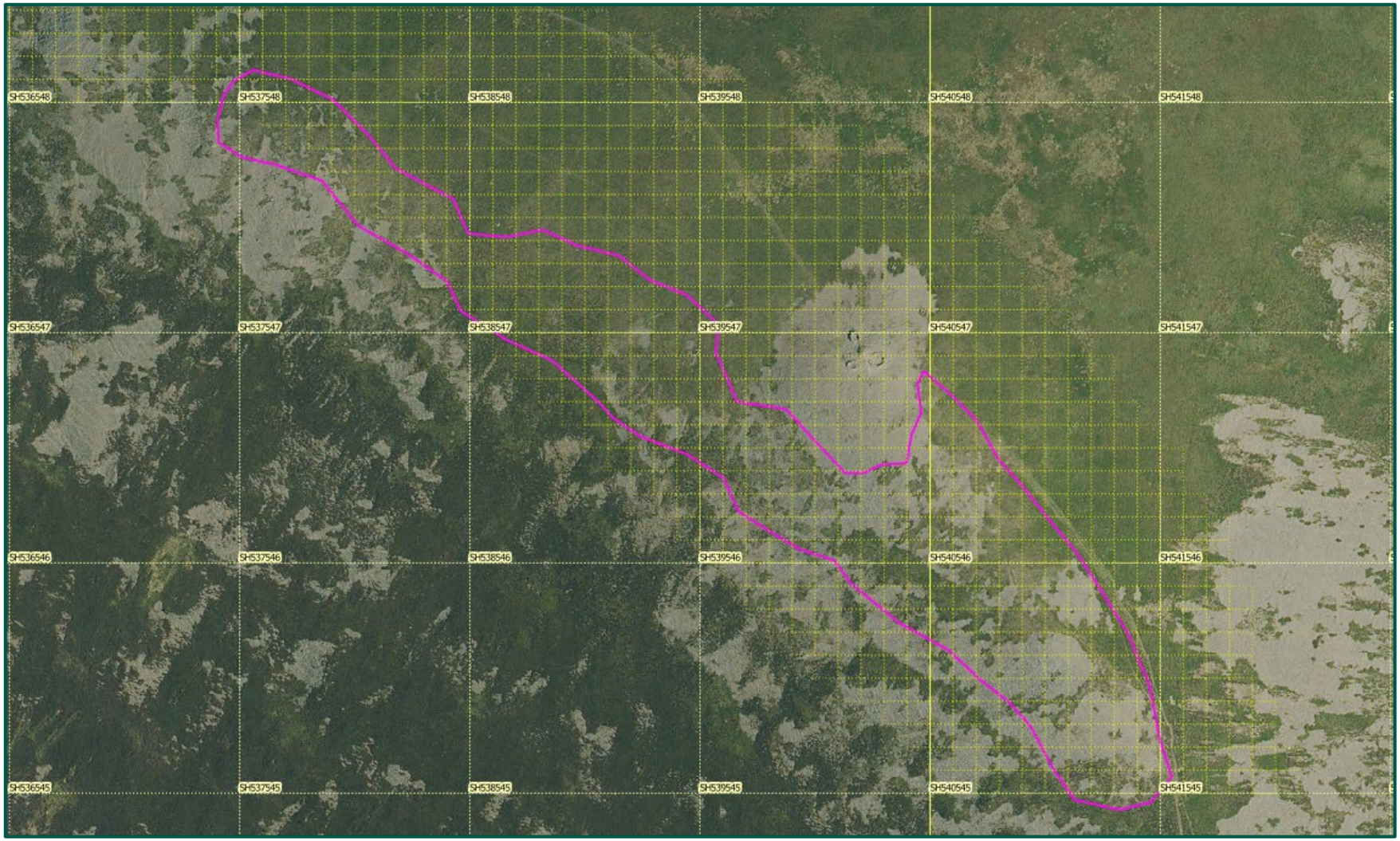
Key: Red square - 10 km squares grid, solid yellow squares - 100m grid, dotted yellow lines - 10m grid, pink polygon - Level 1 intensity survey, pale green polygon - Level 2 intensity survey, blue circle - Pentecost & Williams (2001) location. Other labels and yellow polygons - NVC survey (Turner, 2020). Grid © Crown Copyright and database right 2022. Ordnance Survey licence number 100019741. © Hawlfraint a hawliau cronfa ddata'r Goron 2022. Rhif Trwydded yr Arolwg Ordnans 100019741. Scale 1:1,667.

Figure 15. Search areas for *Thamnolia vermicularis* above Clogwyn Du'r Arddu, Yr Wyddfa / Snowdon, 2021-2022



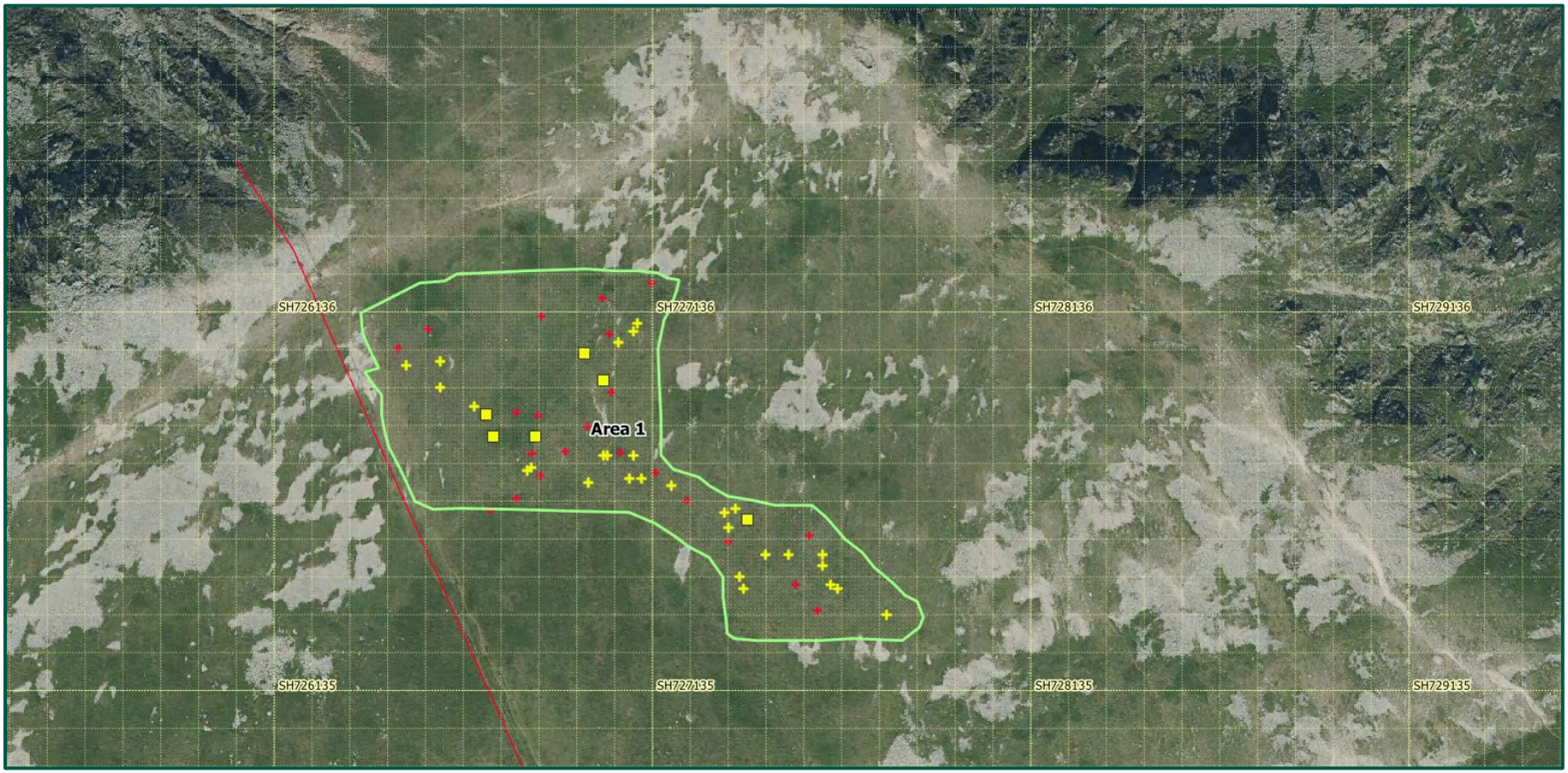
Key: Red square - 10 km squares grid, solid yellow squares - 100m grid, dotted yellow lines - 10m grid, pink polygon - Level 1 intensity survey, blue circle - Pentecost & Williams (2001) location. Other labels and yellow polygons - NVC survey (Turner, 2020). Grid © Crown Copyright and database right 2022. Ordnance Survey licence number 100019741. © Hawlfraint a hawliau cronfa ddata'r Goron 2022. Rhif Trwydded yr Arolwg Ordnans 100019741. Scale 1:1,708.

Figure 16. Search area for *Thamnolia vermicularis* on Mynydd Mawr, 2021-2022



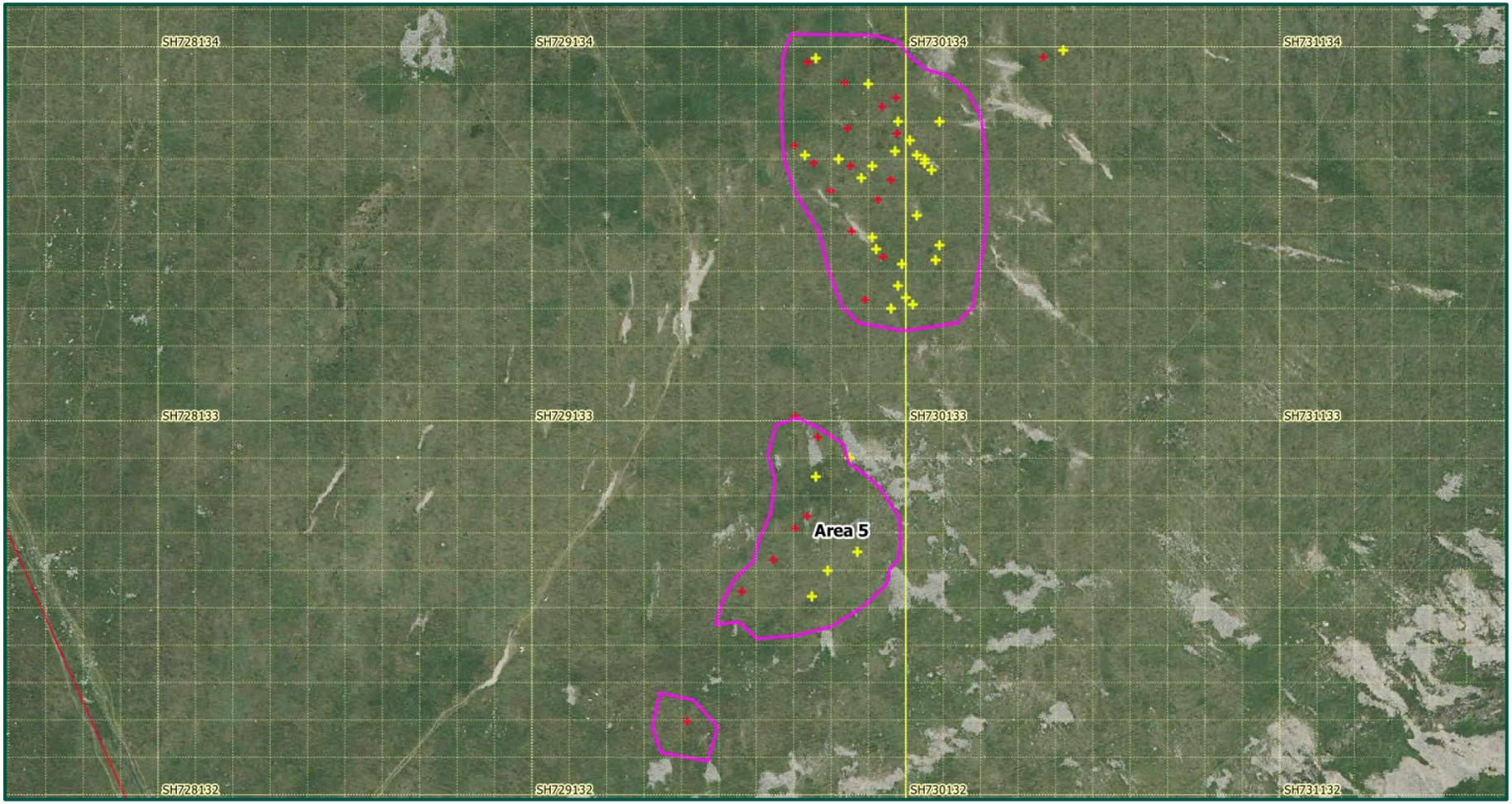
Key: large yellow squares - 100m grid, small yellow squares - 10m grid, pink polygon - Level 1 intensity survey. Grid © Crown Copyright and database right 2022. Ordnance Survey licence number 100019741.
© Hawlfraint a hawliau cronfa ddata'r Goron 2022. Rhif Trwydded yr Arolwg Ordnans 100019741. Scale 1:2,500.

Figure 17. Search areas for *Thamnolia vermicularis* on Cadair Idris, (Area 1 SW of Mynydd Moel summit) 2022.



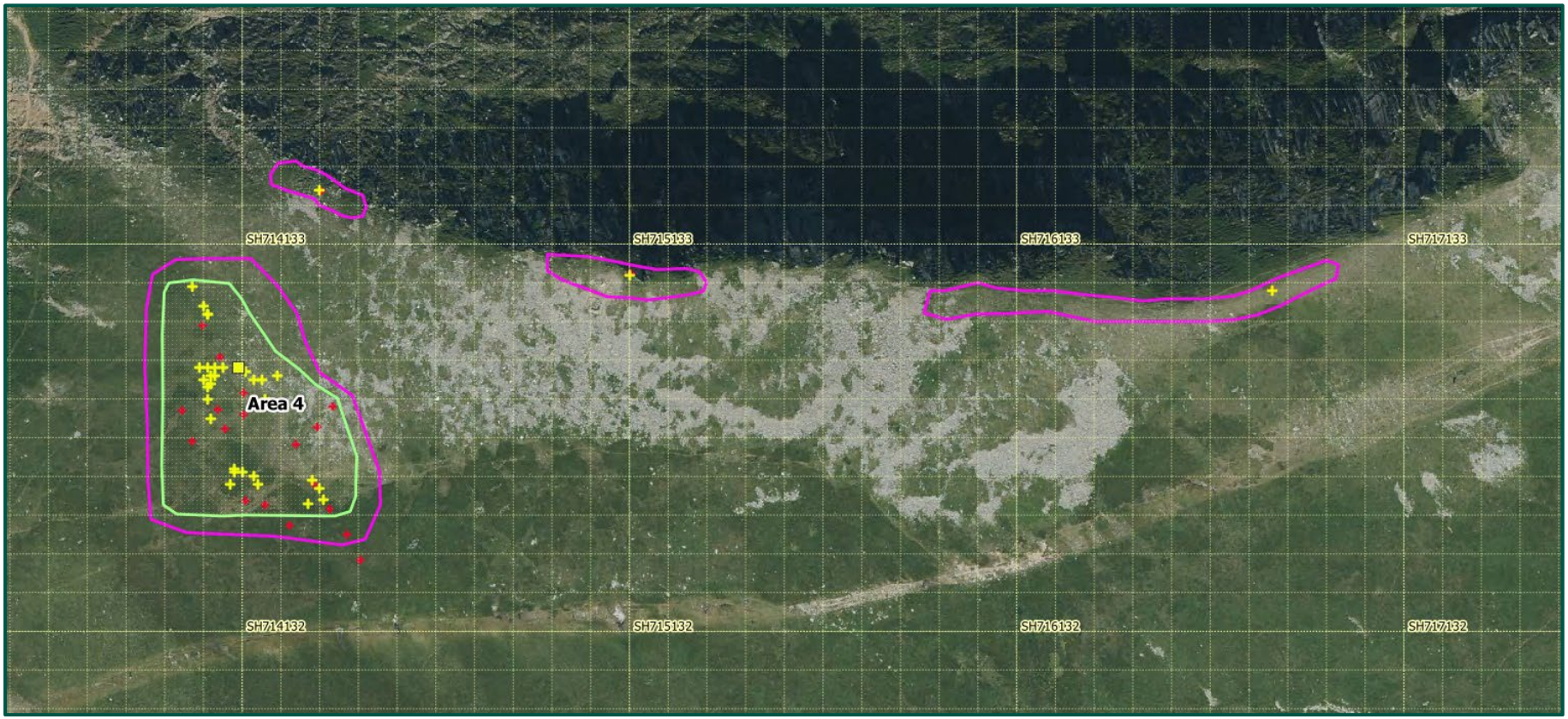
Key: Yellow cross - Calculated position of 1999-2000 Jack Grasse (JG) Thamnolia colony, yellow square - large JG colony (>=20 podetia), red cross - JG colonies from original map, pale green polygons - fine-grain (2m-3m intervals) search areas, yellow squares (solid line) - 100m grid, yellow squares (dotted line) - 10m grid, red line - boundary fence from OS map. Grids © Crown Copyright and database right 2023. Ordnance Survey licence number 100019741. © Hawlfraint a hawliau cronfa ddata'r Goron 2023. Rhif Trwydded yr Arolwg Ordnans 100019741. Scale 1:1,708.

Figure 18. Search areas for *Thamnolia vermicularis* on Cadair Idris, (Area 5 S of Mynydd Moel summit), 2022.



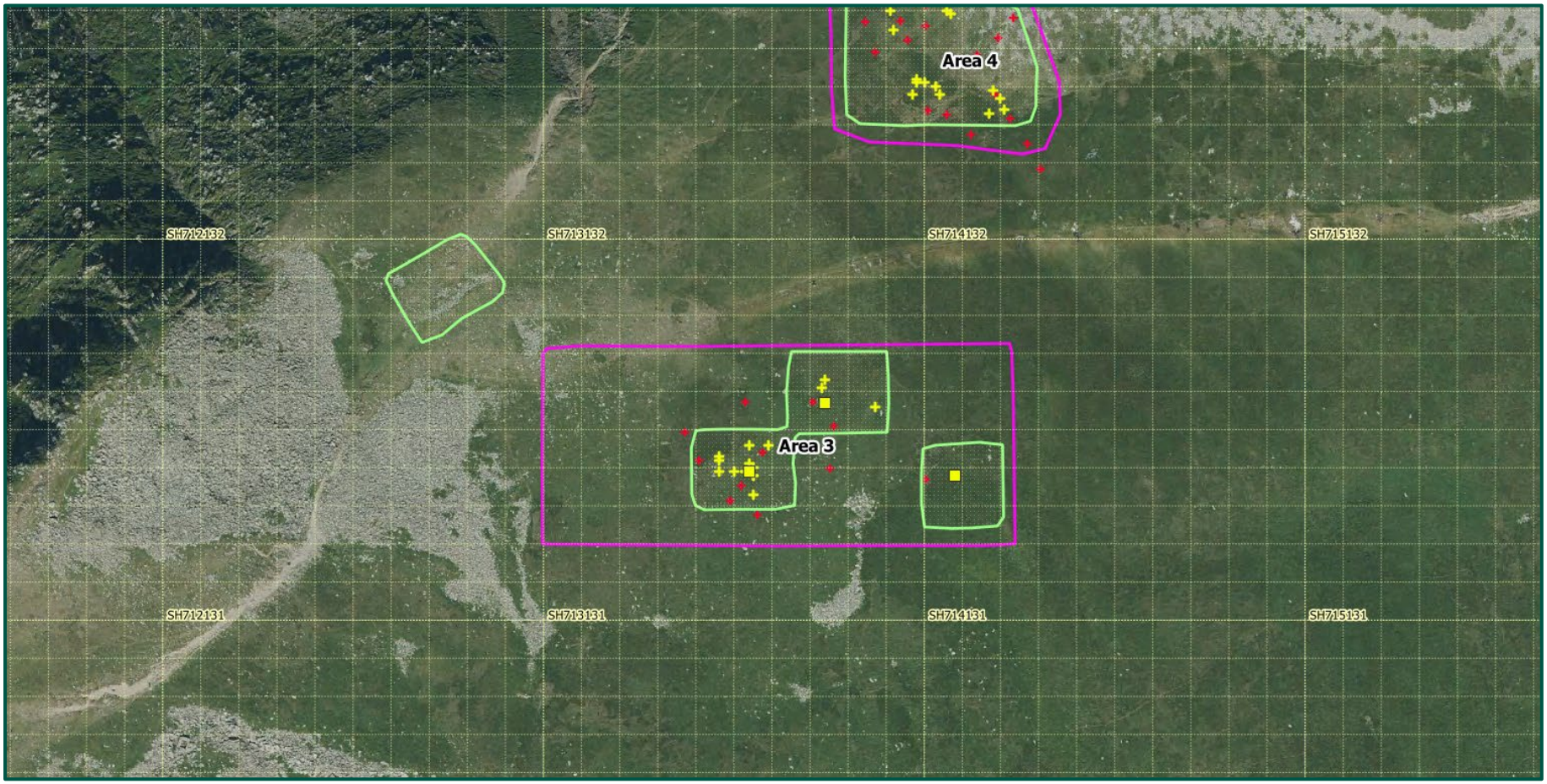
Key: Yellow cross - Calculated position of 1999-2000 Jack Grasse (JG) Thamnolia colony, red cross - JG colony from original map, pink polygons - coarse-grain (5m intervals) search areas, yellow squares (solid line) - 100m grid, yellow squares (dotted line) - 10m grid, red line – boundary fence from OS map Grids © Crown Copyright and database right 2023. Ordnance Survey licence number 100019741. © Hawlfraint a hawliau cronfa ddata'r Goron 2023. Rhif Trwydded yr Arolwg Ordnans 100019741. Scale 1:1,667.

Figure 19. Search areas for *Thamnolia vermicularis* on Cadair Idris, (Area 4 E of Penygadair summit), 2022.



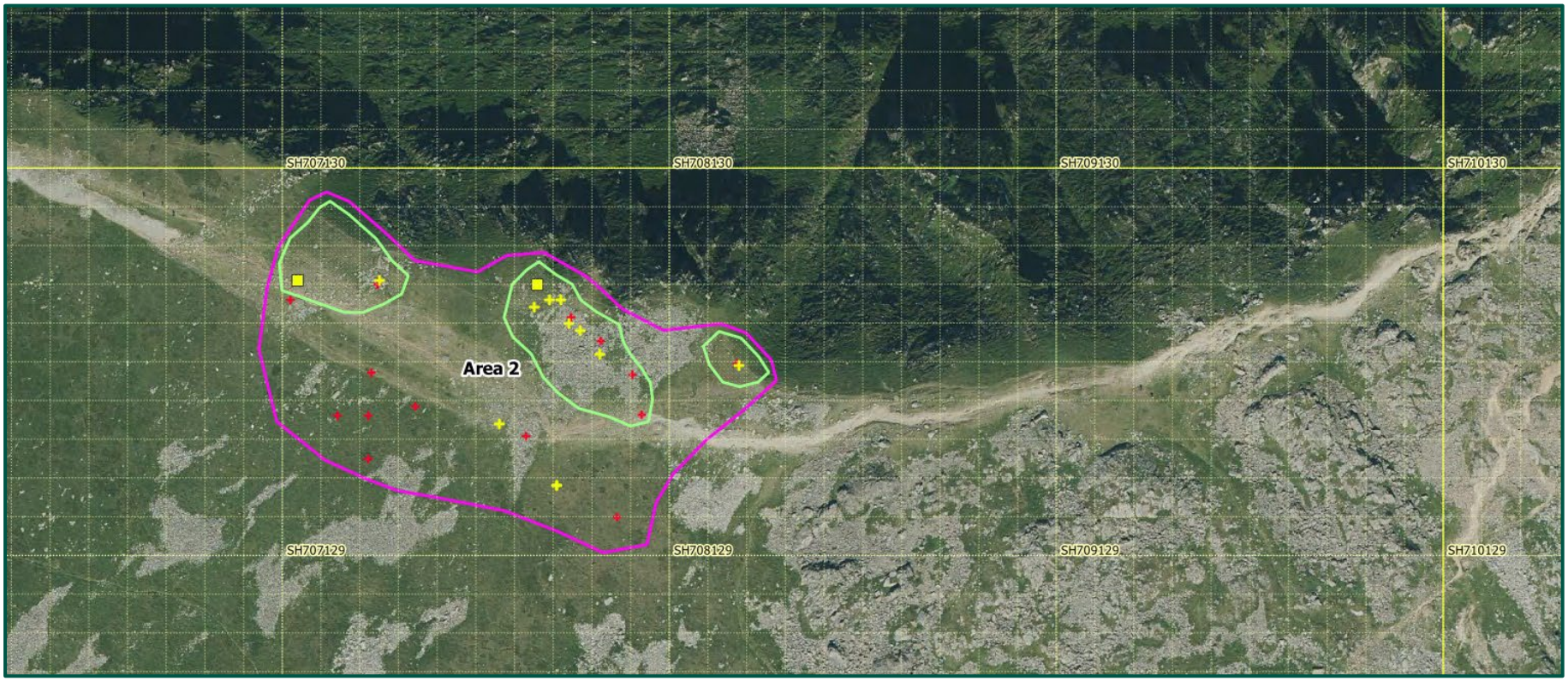
Key: Yellow cross - Calculated position of 1999-2000 Jack Grasse (JG) Thamnolia colony, yellow square - large JG colony (>=20 podetia), red cross - Jack Grasse colonies from map, pink polygons – coarse-grain (5m interval) search areas, pale green polygons - fine-grain (2m-3m interval) search areas, yellow squares (solid line) - 100m grid, yellow squares (dotted line) - 10m grid. Scale 1:1,667.

Figure 19. Search areas for *Thamnolia vermicularis* on Cadair Idris, (Area 3 E of Penygadair summit), 2022.



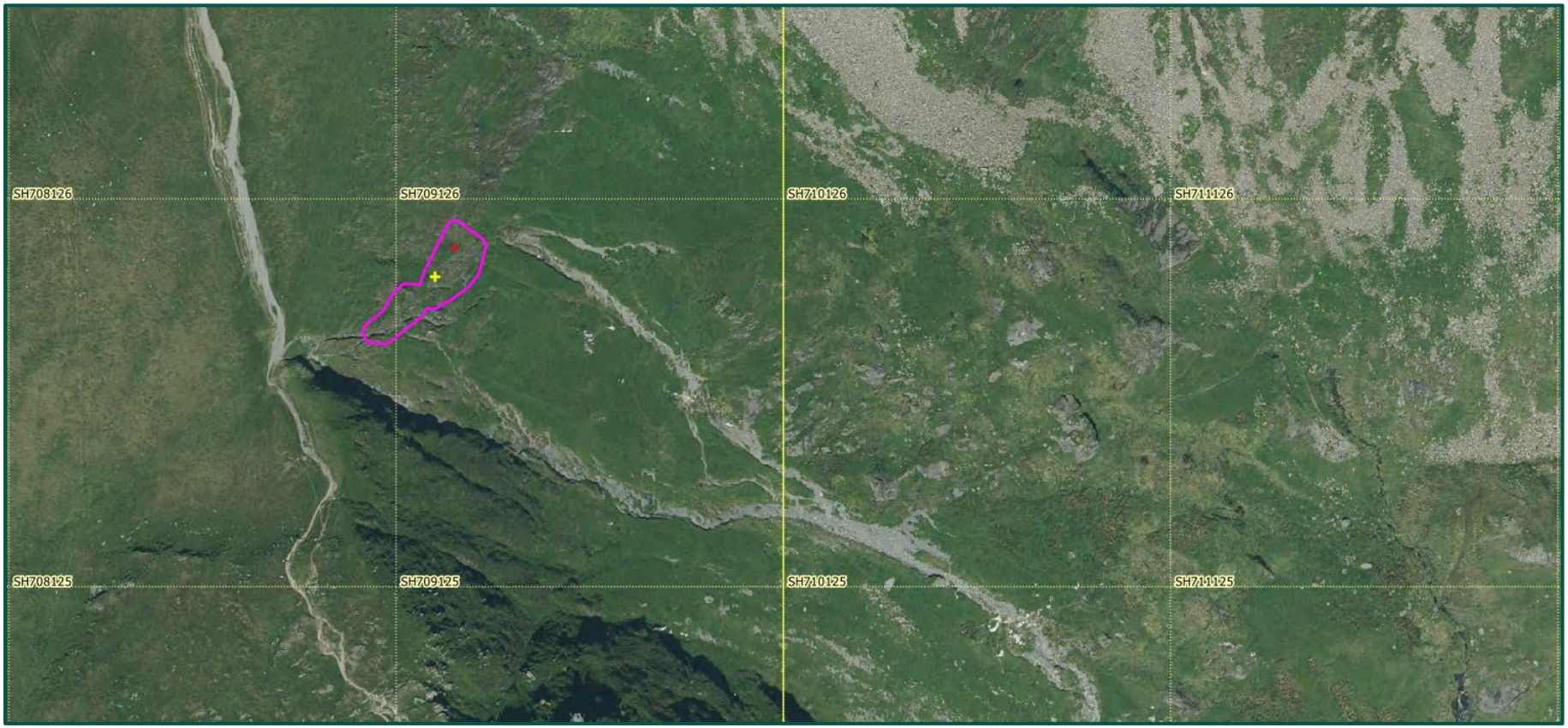
Key: Yellow cross - Calculated position of 1999-2000 Jack Grasse (JG) Thamnolia colony, yellow square - large JG colony (>=20 podetia), red cross - Jack Grasse colonies from map, pink polygons – coarse-grain (5m interval) search areas, pale green polygons - fine-grain (2m-3m interval) search areas, yellow squares (solid line) - 100m grid, yellow squares (dotted line) - 10m grid. Scale 1:1,667.

Figure 20. Search areas for *Thamnolia vermicularis* on Cadair Idris, (Area 2, W of Penygadair summit), 2022.



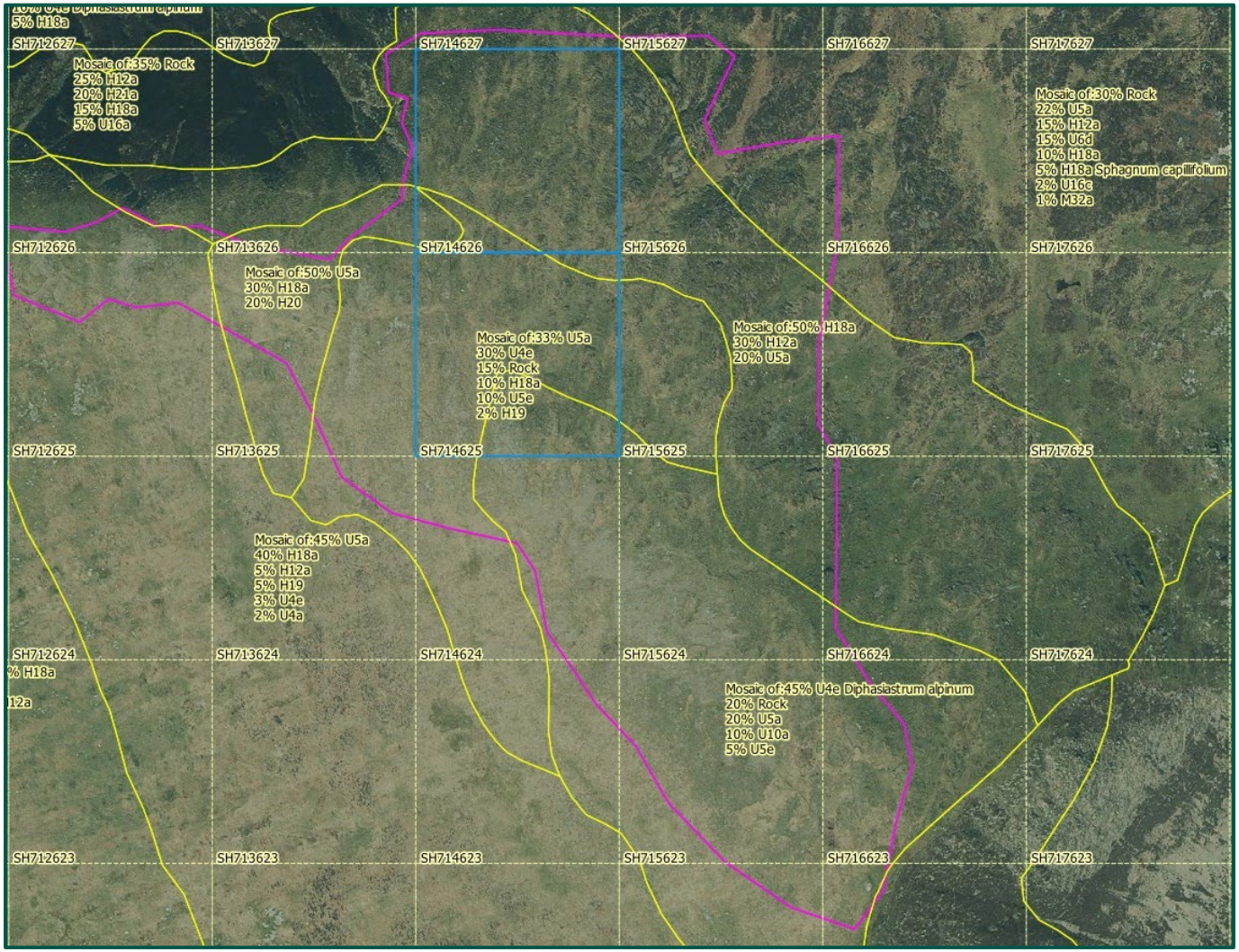
Key: Yellow cross - Calculated position of 1999-2003 Jack Grasse (JG) Thamnolia colony, yellow square - large JG colony (>=20 podetia), red cross - Jack Grasse colonies from map, pink polygon - coarse-grain (5m interval) search areas, pale green polygons - fine-grain (2m-3m interval) search areas, yellow squares (solid line) - 100m grid, yellow squares (dotted line) - 10m grid. Scale 1:1,667.

Figure 20. Search areas for *Thamnolia vermicularis* on Cadair Idris, (Bwlch Cau), 2022.



Key: Yellow cross - Calculated position of 1999-2000 Jack Grasse (JG) Thamnolia colony, red cross - Jack Grasse colonies from map, pink polygon - coarse-grain search area, yellow squares (solid line) - 100m grid. Grid

Figure 21. Search area for *Thamnolia vermicularis* cells on Pen Llithrig y Wrach, 2020.



Key: yellow squares - 100m grid, pink polygon - coarse-grain search area, blue squares - Averis (2001) 6-figure grid references. Records, yellow polygons – vegetation mapping from Averis (2001). 1:2,500.

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 125497.

Further copies of this report are available from library@cyfoethnaturiolcymru.gov.uk