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Eryri snowbed bryophyte monitoring 2023



Rory Hodd (Nimbosa Ecology)

Evidence Report No 739

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Frontispiece: Clockwise from top right: *Marsupella stableri*, Pant Ifan; *Schistochilopsis opacifolia*, Ffynnon Llyffant; *Pohlia ludwigii*, Glyder Fawr; *Kiaeria falcata*, Glyder Fawr.

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1. Crynodeb Gweithredol

Mae'r adroddiad hwn yn rhoi canlyniadau monitro bryoffytau o gynefinoedd gwelyau eira ar ddau safle yn Eryri, Ffynnon Llyffant ar Carnedd Llewelyn yn y Carneddau a Phant Ifan ar Glyder Fawr yn y Glyderau. Dewiswyd y safleoedd hyn i'w harolygu gan mai arolygon blaenorol oedd y safleoedd pwysicaf ar gyfer bryoffytau gwelyau eira yng Nghymru. Mae gan Gymru fflora bryoffyt gwely eira bach o'i gymharu â'r Alban, oherwydd ei lleoliad mwy deheuol, gyda llai o dir uchel. Nodwyd bod chwe bryoffyt gwely eira (*Marsupella stableri*, *Schistochilopsis opacifolia*, *Pohlia ludwigii*, *Kiaeria falcata*, *Scapania paludosa* a *Conostomum tetragonum*) yn digwydd yng Nghymru, gyda dau ohonyn nhw heb eu gweld yn ddiweddar ac mewn perygl o ddiflannu yng Nghymru. Yn sgil natur fregus a chyfyng y cynefin y mae'r rhywogaethau hyn yn byw ynddo, credir eu bod yn arbennig o agored i newid yn yr hinsawdd, ac mae'n hanfodol bod trefniadau'n cael eu gwneud i fonitro newidiadau yn y poblogaethau hyn yn y tymor hir.

Ymwelwyd â'r ddau safle arolygu rhwng 30 Mai a 2 Mehefin 2023. Aethpwyd â llwybr drwy bob safle i ddechrau, i ailddarganfod poblogaethau a gofnodwyd o'r rhywogaethau targed yn flaenorol ac, yn ail, ymchwiliwyd i ardaloedd lle mae poblogaethau pellach o'r rhywogaethau hyn yn debygol o ddigwydd, yn enwedig lle gwyddom fod eira yn gorwedd yn hwyr yn y flwyddyn. Ym mhob poblogaeth o rywogaethau targed, cofnodwyd union gyfeiriadau grid, tynnwyd lluniau a gwnaed nodiadau ar eu hecolog, digonedd ac iechyd cyffredinol. Cofnodwyd lleiniau monitro mewn is-set o boblogaethau er mwyn gallu canfod newidiadau yn amllder a chynefin y rhywogaethau hyn yn y dyfodol. Cofnodwyd tair rhywogaeth brin arall o fflwsilod mynyddig (*Bryum weigeli*, *Philonotis seriata* a *Scapania uliginosa*) yn fanwl hefyd, gan fod eu cynefin hefyd yn cael ei ystyried yn fregus iawn.

Cofnodwyd poblogaethau o bedair rhywogaeth bryoffyt arbenigol gwely'r eira (*Marsupella stableri*, *Schistochilopsis opacifolia*, *Pohlia ludwigii* a *Kiaeria falcata*) ar draws y ddau safle, gyda nifer o boblogaethau newydd wedi'u canfod ar gyfer pob rhywogaeth. Canfuwyd nad oedd y rhywogaethau hyn yn ffurfio cymuned gwely eira mewn cysylltiad â'i gilydd, ond roedden nhw'n tyfu fel clytiau cyfyngedig yn y rhan fwyaf o achosion. Cafwyd hyd i nifer o safleoedd hefyd ar gyfer y rhywogaethau tyfiant montane, yn enwedig yn Ffynnon Llyffant. Yn Ffynnon Llyffant y prif fygythiad i'r rhywogaethau hyn yw potsio a sathru gan dda byw, gyda nifer o farciau carnau mewn tyfiannau, llygaid ffynhonnau wedi byrstio a chlustogau bryoffyt wedi'u codi, gyda cholled a difrod i rywogaethau'r tyfiannau hyn. Gall y difrod hwn waethygu gan fwy o ddigwyddiadau dyddodiad eithafol, sy'n deillio o newid yn yr hinsawdd. Ym Mhant Ifan, y prif fygythiad a welwyd yw erydiad oherwydd sathru gan gerddwyr mynydd sy'n anelu at gopa

Glyder Fawr, gyda nifer o lwybrau'n ymwreiddio trwy'r cynefin hynod fregus ac ansefydlog. Yn y ddau achos, byddai gwahardd sathru yn fuddiol i'r bryoffytau prin sy'n bresennol.

Dylid defnyddio'r adroddiadau rhywogaethau, y ffotograffau a'r lleiniau monitro sydd wedi'u cynnwys gyda'r adroddiad hwn yn y dyfodol i fonitro newidiadau yn y poblogaethau hyn yn rheolaidd. Yna dylid dadansoddi'r canlyniadau hyn gan gyfeirio at newidiadau yn yr hinsawdd gyffredinol. Dylid cynnal arolygon a monitro pellach o systemau tyfiannau montane yn Eryri, gan mai dim ond cyfran fach o'r rhain a samplodd y prosiect hwn. Dylid ymchwilio i statws *Scapania paludosa* yn Eryri, a dylid chwilio amdano ar ei unig safle Cymreig hysbys ym mhen gorllewinol y Glyderau, lle cafodd ei weld ddiwethaf ym 1981.

2. Executive Summary

This report provides the results of monitoring of bryophytes of snowbed habitats at two sites in Eryri, Ffynnon Llyffant on Carnedd Llewelyn in the Carneddau and Pant Ifan on Glyder Fawr in the Glyderau. These sites were selected for survey as they were found by previous surveys to be the most important sites for snowbed bryophytes in Wales. Wales has a small snowbed bryophyte flora in comparison with Scotland, due to its more southerly location, with less high ground. Six snowbed bryophytes (*Marsupella stableri*, *Schistochilopsis opacifolia*, *Pohlia ludwigii*, *Kiaeria falcata*, *Scapania paludosa* and *Conostomum tetragonum*) have been identified as occurring in Wales, two of which have not been seen recently and may be extinct in Wales. Due to the fragile and limited nature of the habitat occupied by these species, it is thought that they are especially vulnerable to climate change, and it is imperative that long-term monitoring of changes in these populations is implemented.

The two survey sites were visited between the 30th of May and 2nd of June 2023. A route was taken through each site to firstly, re-find previously recorded populations of the target species and, secondly, to investigate areas where further populations of these species are likely to occur, particularly where snow is known to lie late in the year. At each population of target species located, precise grid references were recorded, photos were taken and notes were made on their ecology, abundance and general health. Monitoring plots were recorded at a subset of populations to enable future detection of changes in the abundance and habitat of these species. Three further rare species of montane flushes (*Bryum weigeli*, *Philonotis seriata* and *Scapania uliginosa*) were also recorded in detail, as their habitat was also seen to be highly vulnerable.

Populations of four snowbed specialist bryophyte species (*Marsupella stableri*, *Schistochilopsis opacifolia*, *Pohlia ludwigii* and *Kiaeria falcata*) were recorded across the two sites, with multiple new populations found for each species.

These species were found not to be forming a snowbed community in association with each other, but were growing as limited patches in most cases. Multiple sites were also found for the montane flush species, particularly at Ffynnon Llyffant. At Ffynnon Llyffant the main threat to these species is poaching and trampling by livestock, with numerous hoofmarks in flushes, burst springheads and pulled up bryophyte cushions, with consequent loss and damage of the species of these flushes. This damage may be exacerbated by increased extreme precipitation events, resulting from climate change. At Pant Ifan, the main threat detected is erosion due to trampling by hillwalkers aiming for the summit of Glyder Fawr, with numerous paths present through the highly fragile and unstable habitat. In both cases, exclusion of trampling would be beneficial to the rare bryophytes present.

The species reports, photographs and monitoring plots included with this report should be used in the future to monitor changes in these populations at regular intervals. These results should then be analysed with reference to changes in the overall climate. Further surveys and monitoring should be carried out of montane flush systems in Eryri, as this project only sampled a small proportion of these. The status of *Scapania paludosa* in Eryri should be investigated, and it should be searched for at its only known Welsh site at the western end of the Glyderau, where it was last seen in 1981.

3. Background

In Britain, snowbed vegetation occurs mainly in the higher peaks of Scotland, where climatic conditions allow snow to lie late, leading to the occurrence of bryophyte-dominated vegetation. This vegetation is characterised by a range of specialised species, which are restricted almost exclusively to this habitat (Averis et al., 2004). Due to its southerly location within Britain, and relatively limited area of high-altitude ground, Eryri has very few places where snow lies late in the year and consequently has few specialised snowbed bryophyte species. However, six species that are generally considered to be snowbed specialists in Scotland have been previously recorded in Wales (Table 1), alongside a range of other species of high montane habitats that often grow in association with snowbeds.

Table 1 Species of specialist snowbed bryophyte recorded in Eryri, date of last record in Eryri, number of hectads from which recorded in Wales (from Blockeel et al., 2014, except in the case of *Schistochilopsis opacifolia* which was not discovered in Wales until 2015), British Red List status (Callaghan, 2022) and Nationally Rare or Scarce status (Pescott, 2016)

Species	Last record	No. hectads	British Red List	Rare/Scarce
<i>Kiaeria falcata</i>	2015	2	Near Threatened	Nationally Scarce
<i>Schistochilopsis opacifolia</i>	2017	2	Least Concern	Nationally Scarce
<i>Marsupella stableri</i>	2015	2	Near Threatened	Nationally Scarce
<i>Pohlia ludwigii</i>	2015	3	Near Threatened	Nationally Scarce
<i>Scapania paludosa</i>	1981	1	Near Threatened	Nationally Scarce
<i>Conostomum tetragonum</i>	1920	1	Near Threatened	Nationally Scarce

Of these six species, two, *Conostomum tetragonum* and *Scapania paludosa*, have not been seen recently in Wales. *C. tetragonum* is thought to be extinct, having last been seen in Eryri, on the Glyderau, in 1920. *S. paludosa* has only been observed once in Wales, towards the western end of the Glyderau, in 1981. The other four species were all recorded during a meeting of the British Bryological Society in 2015 (Bosanquet and British Bryological Society, 2015), with *Schistochilopsis* (formerly *Lophozia*) *opacifolia* recorded for the first time in Wales, at a number of sites, during the course of that meeting. The four species score sufficient points to qualify as a Snowbed Bryophyte Assemblage feature of Eryri SSSI according to the criteria of Bosanquet *et al.* (2018).

As these species are at the southern edge of their range in Wales, and with only a small area of suitable habitat for their growth, they are likely to be vulnerable to climate change. Snow cover extent and duration has declined across Britain and is likely to continue to decline (Kay, 2016) in the future, further reducing an already restricted niche and putting pressure on the future survival of these species. This impact combines with other pressures including overgrazing, Nitrogen deposition and recreational activities to create an uncertain future for the survival of these specialised species in Eryri and Wales as a whole.

In order to quantify the long-term impact of these threats, detailed survey and monitoring of these species is required. In recent years, there had been few bryophyte surveys carried out in most montane areas of Eryri, until the detailed surveys of the British Bryological Society meeting in 2015 (Bosanquet and British Bryological Society, 2015), which focused on two of the three main massifs of Eryri, the Carneddau and the Glyderau. Particular efforts were made to visit sites where records of rare montane species were previously made, with detailed grid references and photos taken when rare species were encountered. Two sites, in particular, were identified during the course of the meeting that are important for snowbed bryophytes: Ffynnon Llyffant, on the northeastern side of Carnedd Llewelyn in the Carneddau, and Pant Ifan, below the summit of Glyder Fawr in the Glyderau.

4. Methods

4.1. Taxonomy

Taxonomy follows Blockeel *et al.* (2021) for bryophytes and Stace (2019) for vascular plants.

4.2. Survey sites

Two sites were chosen for survey, as identified by Bosanquet and British Bryological Society (2015) as being the most important sites for snowbed bryophytes in Wales. The first of these, the cwm above Ffynnon Llyffant, is located in the Carneddau on the northern side of Carnedd Llewelyn (1064m). The snowbed species *Schistochilopsis opacifolia* and *Pohlia ludwigii* have been previously recorded from this cwm, with *Kiaeria falcata* recorded nearby from rocks on the summit of Carnedd Llewelyn. Other species often associated with snowbeds, that occur in this cwm include *Philonotis seriata*, *Scapania uliginosa* and *Bryum weigelii*. All of the above species, except *Pohlia ludwigii*, were recorded during the British Bryological Society survey in 2015. The second survey site, Pant Ifan, is located above Cwm Idwal, on the northern slopes of Glyder Fawr (1001m). Target species recorded from this site previously are *Kiaeria falcata*, *Schistochilopsis opacifolia*, *Marsupella stableri* and *Pohlia ludwigii*, all of which were seen during the 2015 survey. *Conostomum tetragonum* was previously recorded in the general area in 1910, but is thought to now be extinct in Wales.

The survey area at both sites was focused mainly on locations where the target species were recorded by the 2015 British Bryological Society survey, with a route planned to visit each of the populations of target species recorded by the 2015 survey. Additional areas to survey at each site were also selected based on images taken over the past 20 years by Alex Turner of the last remaining patches of snow after the winter, which are consistently in the same locations (Appendix 1). Most of the areas of late snow lie were visited by the BBS survey, but some additional areas for survey outside of those visited by the BBS were identified, most notably two deep gullies below the ridge to the northeast of the summit of Carnedd Llewelyn, although this area did not prove to be of importance for snowbed bryophytes upon investigation. On Glyder Fawr, two small additional areas outside of Pant Ifan, around the top of Cwm Cneifion, were surveyed from the ridge, where snow also lies late. The primary survey areas at Ffynnon Llyffant and Pant Ifan are shown in Appendix 2, Figures 3 and 4 respectively.

4.3. Desk preparation

Laminated paper maps were created, underlain by aerial imagery, showing the locations of target species recorded during the 2015 British Bryological Society survey at each survey site, using Q-GIS (QGIS, 2018).

Recording sheets for populations of target species were compiled and printed. These sheets were used for the purpose of recording the location of each population, the habitat, abundance, associated species, general health of the population and threats present. A methodology was devised to enable long-term monitoring of change at a subset of populations of target species at both survey sites. This was based partly on Common Standards Monitoring criteria (JNCC, 2005), incorporating criteria for niche diversity and availability in the local vicinity, as well as evidence of disturbance of the habitat. At a 1x1m scale, it was decided that cover of the target species, vegetation components and bare ground were appropriate variables to use to monitor change in the populations in the future.

4.4. Field survey

The field survey was undertaken over the course of four days between the 30th of May and the 2nd of June 2023, with two days spent at each site. As access to each site involves a long walk in and an ascent to over 900m altitude, survey time on each day was relatively short and much ground could not be surveyed at both sites. A route was followed at each site to visit all locations for the target species recorded by Bosanquet and British Bryological Society (2015). Any other area of suitable habitat for the target species encountered was also searched carefully, especially within areas identified as being where snow lies late. The locations of all populations of target species was recorded using a hand-held GPS, generally to an accuracy of 3m. A detailed target species recording sheet was recorded at the first population of each target located at each site, with notes taken on all additional populations encountered. Photographs were taken of all populations of target species to enable them to be relocated. In addition to the species listed as snowbed species in Table 1, recording sheets were used to record populations of other rare montane species encountered. The additional species recorded, *Bryum weigeli*, *Philonotis seriata* and *Scapania uliginosa*, are all species of montane flushes and are often important components of snowbed communities in Scotland.

Monitoring plots of 1x1m area were recorded at a representative sample of the locations found for each of the target species. Three plots were also recorded

at Ffynnon Llyffant containing *Scapania uliginosa*, as the montane flush habitat in which it grows is highly vulnerable to change and shows damage from overgrazing. Variables recorded at each plot were: cover of various vegetation components, bare soil and rock, disturbed ground, as well as the cover of the target species within the plot and the cover of any other notable species or of negative, non-native species. The location of each plot was recorded by GPS and two photos were taken, one from a distance and another close-up to enable the plots to be precisely relocated in the future. Where necessary to confirm the identity of a target species or an associated species within a plot, a small sample was taken for later microscopic identification. Locations of other species of note were also recorded, and specimens were taken to confirm the identification of any potentially interesting species that could not be confirmed in the field. Microscopic identification of specimens was carried out using Smith (2004) and Paton (1999) as the primary reference for mosses and liverworts, respectively.

5. Results

The species and plots recorded are summarised in Table 2. All species recording cards are included in Appendix 3, the monitoring stop data are presented in Appendix 5, as well as in a separate spreadsheet file as Appendix A1. Photos of all populations of target species encountered and of each monitoring stop are provided separately to this report, with labels relating them to each population and monitoring stop. Maps of species and plot locations at the two survey sites are shown in Appendix 2, Figures 5-8, and the GPS locations of populations of target species and plot locations are shown in Appendix 4, with records of the target species included in a separate spreadsheet file as Appendix A2. Records of additional bryophytes of note are also included in Appendix A2.

5.1. Ffynnon Llyffant

Two snowbed bryophyte species, *Kiaeria falcata* and *Schistochilopsis opacifolia*, were located in Ffynnon Llyffant, with three and 12 populations, respectively, recorded. A total of six monitoring stops were recorded in Ffynnon Llyffant. *K. falcata* had not previously been recorded within the cwm itself, but was recorded nearby on a rock outcrop on the summit of Carnedd Llewelyn during the 2015 BBS survey. It was located in three places on rocky outcrops on a very steep slope close to the top of the cwm wall, at the northern extent of the search area. No monitoring plots were recorded at these locations, due to the precarious terrain and time constraints. No immediate threats were noted to these populations. *S. opacifolia* was found in 12 locations across the survey area, and appears to be occasional across the site, with other populations almost certainly present. This species was growing either on bare, unstable soil,

or at the edge of rocks. It was not refound at two locations where it was recorded in 2015, but populations of this species are likely to be relatively dynamic and it may be lost in a location where conditions become unsuitable, such as by encroachment by grass, but find a suitable niche nearby, for example if a rock has been dislodged, leaving bare soil. Three monitoring plots were recorded at representative populations of *S. opacifolia*.

Table 2 Summary of snowbed species and other montane species populations recorded and monitoring plots undertaken at each survey site in 2023.

Species	Ffynon Llyffant number of populations	Ffynon Llyffant number of stops	Pant Ifan number of populations	Pant Ifan number of stops
<i>Kiaeria falcata</i>	3	0	2	2
<i>Schistochilopsis opacifolia</i>	12	3	6	2
<i>Marsupella stableri</i>	0	0	6	2
<i>Pohlia ludwigii</i>	0	0	7	3
<i>Bryum weigelii</i>	1	0	0	0
<i>Philonotis seriata</i>	5	0	0	0
<i>Scapania uliginosa</i>	6	3	1	0

Three other species were recorded in detail, all of which are characteristic of montane flushes. *Scapania uliginosa* was recorded in flushes and springheads at six locations, close to Llyn Ffynnon Llyffant and in the upper part of the cwm wall. It was abundant at some of these locations, although a number of these springheads and flushes show serious signs of erosion due to poaching by grazing livestock, as well as possibly due to extreme rainfall events. Three monitoring plots were recorded from populations of *S. uliginosa*. *Philonotis seriata* was recorded by the shores of Llyn Ffynnon Llyffant, where it was also seen in 2015, and from four new locations scattered across the northern part of the cwm. Similar to *S. uliginosa*, the lower populations showed signs of damage by livestock poaching. *Bryum weigelii* was found in one place close to the top of the wall of the cwm, in an extensive flush system. However, it was not refound in another flush nearby, where it was recorded during the 2015 survey, although the flush looked to still be suitable. *Bryum muehlenbeckii* was also observed beside Llyn Ffynnon Llyffant and *Arctoa fulvella* was observed on the upper part of the cwm wall, but full details were not recorded.

5.2. Pant Ifan

Four snowbed species were recorded in Pant Ifan and on the upper rim of the adjacent Cwm Cneifion. A total of nine monitoring stops were recorded in Pant Ifan. *Kiaeria falcata* was found at two locations, one in Pant Ifan and the other above Cwm Cneifion, on vertical rockfaces. The population above Cwm Cneifion is particularly healthy, with multiple cushions present. It was not refound at the location from which it was recorded in 2015, although the habitat

seemed unchanged. Monitoring plots were taken at both locations. *Schistochilopsis opacifolia* was relocated at both locations from which it was recorded in 2015, plus a further three locations in Pant Ifan and another location at the top of Cwm Cneifion. These populations were located mainly on loose soil amongst rocks and scree. A number of these populations are vulnerable to trampling from adjacent paths and encroachment by vegetation. *S. opacifolia* is apparently uncommon in this area, despite much suitable habitat being present. Monitoring plots were recorded at two of the six locations.

Marsupella stableri was also relocated at all locations from which it was recorded in 2015, as well as in an additional four places in Pant Ifan, on intermittently flushed rocks. These populations are all healthy, with the largest population over a 5x2m area. No pressing threats were detected to these populations. Monitoring stops were recorded at two of these locations. *Pohlia ludwigii* was recorded at six locations in Pant Ifan and at one location at the top of Easy Gully in Cwm Cneifion. It was not relocated at one of the places where it was found in 2015, although there were no obvious changes in habitat, so it may be due to an incorrect grid reference. It was refound at the other two locations where it was recorded in 2015. At most of these locations, it occurs as patches or scattered shoots in crevices, but one large, almost pure cushion was found in the open on a flushed grassy slope in the upper part of Pant Ifan, measuring 1m x 40cm across. Monitoring plots were recorded at three of these populations. Additionally, *Scapania uliginosa* was recorded at one location in a springhead in the lower part of Pant Ifan. This species was not recorded at this site in 2015. Other species noted in Pant Ifan and above Cwm Cneifion, but for which full details were not recorded are *Hymenoloma crispulum*, *Brachydontium trichodes* and *Grimmia incurva*.

6. Discussion

Overall, the populations of snowbed bryophytes surveyed currently appear to be stable and persisting, with more populations of the target species found than during the 2015 British Bryological Society survey. Although a few populations recorded in 2015 were not refound, this is likely to be either due to natural dynamics leading to loss of small populations or to not finding the precise location of a small patch of the target species in a landscape with many possible niches. All populations not refound were balanced with newly discovered populations in the local vicinity. This is not likely to reflect a general increase in these species at these sites, but is likely due to a longer search over the course of two days at each site, target specifically on a small number of species. There are undoubtedly further populations of the target species awaiting discovery, as large areas of habitat were not explored, due to time limitations and the inaccessibility of some areas of steep ground.

The most visible threat to snowbed bryophytes, and montane bryophytes in general, at these sites is due to poaching by livestock at Ffynnon Llyffant and trampling and disturbance by walkers at Pant Ifan. At Ffynnon Llyffant, the main impact was not to the target snowbed bryophytes, but to montane flushes and springheads containing *Scapania uliginosa* and *Philonotis seriata*. Particularly on the lower slopes of the corrie wall, ponies and sheep have walked through the flushes, leaving deep hoofprints and uprooting bryophytes. A number of springheads have also been washed out, likely as a result of the interaction of poaching and extreme rainfall events. Occasional washing out of springhead vegetation like this may occur naturally from time to time, but the intensity and frequency observed in these springs was greater than would be expected. Reduction of livestock numbers on these slopes would be beneficial to the bryophyte communities and allow the montane flushes to recover and repair. Temporarily excluding access for livestock to the area around the flushes using fencing may also be beneficial, although long-term cessation of grazing may have a negative impact through build-up of rank vegetation and colonisation by more vigorous species. The invasive non-native *Epilobium brunnescens* was noted in some flushes, and was abundant in some instances. Although the presence of this species is not desirable, there was no evidence that it was significantly negatively impacting the bryophyte species present.

At Pant Ifan, populations of both *Schistochilopsis opacifolia* and *Marsupella stableri* are located close to loose, unstable paths, created by walkers to reach the summit of Glyder Fawr. As the main path to the summit of Glyder Fawr from the top of Cwm Idwal is in poor condition, traversing loose and dangerous scree and eroded soil, numerous alternative paths have developed through the sensitive environment of Pant Ifan. If the main path to the summit of Glyder Fawr were restored and made safe, this would divert most walkers away from Pant Ifan, reducing erosion and allowing the scree slopes to partially stabilise.

Comparing the results of this survey to those of Bosanquet and British Bryological Society (2015) suggests that there has been little measurable impact of climate change on snowbed bryophytes in Eryri within the past eight years. However, it is difficult to know the historical impact of climate change on snowbed bryophytes in Eryri and it is possible that the populations now present are relicts of more widespread snowbed communities and that gradual warming has caused these species to contract to their present small patches. These species, at present do not form a community, but generally grow as individual patches amongst scree, in flushes or on rockfaces, with no obvious correlation between their location and areas of late snow lie. On Glyder Fawr, the loss of *Conostomum tetragonum*, in particular, as well as *Scapania nimbosa*, since the early 20th century suggests that conditions in Eryri have become less montane and less suitable for the growth of snowbed bryophytes in the intervening

century. It is possible that these species previously occurred in snowbed communities that have now been lost from Wales, similar in composition to those occurring in Scotland, corresponding to NVC communities such as U13b, the *Rhytidiadelphus loreus* sub-community of *Deschampsia cespitosa*-*Galium saxatile* grassland or U12 *Salix herbacea*-*Racomitrium heterostichum* snowbed. The apparent loss of the lichen *Thamnomia vermicularis* from Eryri in the past 20 years (Turner, 2023) suggests that climate change, in interaction with other pressures, is changing the composition of montane vegetation in Eryri, and is likely to continue to do so. A further factor that may be impacting these communities is deposition of NO_x and an increase in growth of algal gunk in the niche occupied by specialist bryophytes and lichens, as has been observed in a range of habitats in Wales, including montane scree slopes (Hodd, 2018). Therefore, although the populations of snowbed bryophytes at these locations currently seem stable, this can change rapidly, and they may soon be threatened with extinction.

The montane flushes of Ffynnon Llyffant, containing *Scapania uliginosa*, *Philonotis seriata* and *Bryum weigelii*, may already be showing the impact of climate change, in interaction with inappropriately high grazing levels for the habitat. Extreme rainfall events have increased in intensity in recent decades in the UK, and are likely to continue to do so in the future (Cotterill et al., 2021). Two springheads with *Scapania uliginosa* showed signs of bursting and washing away of vegetation, as well as abundant poaching, and trampling and pulling up of mosses were observed in flushes containing *Philonotis seriata*. Photos within the report of Bosanquet and British Bryological Society (2015) do not show these signs of damage and the author does not recall having observed this damage during the survey of 2015. Therefore, this damage may have occurred primarily in the past eight years, and is likely to intensify over time.

7. Conclusions

Monitoring of these populations should be carried out at regular cycles of 5-6 years, and the monitoring plots should be repeated, to determine whether any changes have occurred. These changes should be analysed in light of changes in the overall climate and any other threats and pressures present.

Measures should be put in place to reduce the impact of poaching by livestock and trampling and erosion by walkers, in order to maximise the resilience and robustness of these populations in the face of increasing climate impacts. For these and other important sites in Eryri for montane bryophytes, a strategy should be devised to protect important species and assemblages, and conservation measures should be put in place.

Further surveys of these sites would undoubtedly reveal more populations of the target species and other rare montane bryophytes. Additionally, exploration of the upper slopes of Cwm Cneifion may be particularly worthwhile and could reveal some interesting discoveries, although the steep and precarious nature of the terrain would preclude exploration of much of the area.

This survey only sampled a small number of montane flushes, but showed that this is a very important, but vulnerable, habitat for rare montane bryophytes. Further survey and monitoring of this habitat across Eryri would be a worthwhile exercise. A survey of the only known Welsh site for *Scapania paludosa*, in Cwm Griainog at the western end of the Glyderau, where it was only seen once in 1981, to attempt to relocate this species and assess its current status and condition, should also be undertaken.

8. Acknowledgements

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10. Appendices

Appendices containing images of monitoring plots and tables of species records cannot be formatted in a way that complies with Accessibility legislation, so they have been removed from this version of the report. A full PDF version is held by the NRW Library and the national Deposit Libraries.

11. 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] Details of monitoring plots from the survey in Microsoft Excel format.
- [C] A spreadsheet of bryophyte records in Microsoft Excel format.
- [D] Labelled photographs of all populations of target species and monitoring plots in .jpg format.

The metadata for this project is held as record no 125726.

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