# BRYOPHYTES AND METALLOPHYTE VEGETATION ON METALLIFEROUS MINE-WASTE IN IRELAND: REPORT TO NATIONAL PARKS AND WILDLIFE SERVICE OF A SURVEY IN 2008

**by D.T. Holyoak**

## Introduction

Mine workings and their artificial spoil heaps can support specialised plants and vegetation communities that are tolerant to high levels of toxic metals, principally Copper (Cu), Lead (Pb) or Zinc (Zn). Some stands of such vegetation in Ireland are notable for the presence of rare bryophytes such as *Cephaloziella integerrima*, *C. massalongi*, *C. nicholsonii*, *Ditrichum cornubicum*, *Scopelophila cataractae* and *Pohlia andalusica*, amongst others, as well as inland stands of the vascular plants *Silene uniflora* and lowland *Armeria maritima*, and some stands of *Minuartia verna*. Vegetation of mine waste with rare bryophytes is ascribable to the habitat 'Calaminarian grasslands of the *Violetalia calaminariae*', a habitat listed on Annex I of the E.U. Habitats Directive [92/43/EEC]. There are currently 3 candidate SACs selected for Calaminarian grassland:

- Moneen Mountain (54)
- Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment (365)
- Kenmare River (2158)

Habitats protected under Annex I of the Habitats Directive should be maintained in a favourable conservation status within their range in each member state. An initial baseline assessment of Calaminarian grassland in Ireland was undertaken by NPWS in 2007, but a more detailed appraisal of the resource, supported by field survey is required to make a more informed assessment.

This Report describes the methodology and results of a survey carried out from April to June 2008 in order to provide fuller information. The detailed objectives of this survey were as follows:

1) To establish the distribution and extent of metallophyte bryophyte communities of mine waste in Ireland;
2) To relate the distribution and extent of metallophyte bryophyte communities to that of the total Calaminarian grassland resource in Ireland;
3) To classify and describe the range of variation of metalliferous mine waste vegetation;
4) To identify, list and rank metalliferous mine waste sites of conservation interest;
5) To determine the condition and future prospects of metalliferous mine waste sites of conservation interest;
6) To propose management recommendations to ensure favourable conservation status is achieved;
7) To propose a monitoring prescription for this habitat type.

In addition, all records of rare bryophytes were to be documented in the same manner as the other records accumulated for the *Red Data Book* of Bryophytes of Ireland since 2002.

## Methods

The survey needed to locate sites with significant metallophyte bryophyte vegetation, then to record its extent and characteristics. Records of rare bryophytes needed to be documented using the standard methods of the *Red Data Book* surveys.

Initial selection of the sites to be visited posed a challenge at the start of the survey. The Geological Survey of Ireland database of 'Mine Site Workings' lists *ca* 280 sites. It would have been impossible to visit all of these and probably pointless to do so, as many will now have little or no botanical interest. It was therefore necessary to select a much smaller number of sites to visit, say 40, that nevertheless included as many as possible of those with the greatest interest for metallophyte bryophytes.

Experience in Cornwall and elsewhere in Britain (e.g. Holyoak 2000) provides background information on plants likely to be indicative of high heavy metal concentrations. Obligate Cu bryophytes are *Cephaloziella massalongi*, *C. nicholsonii*, *Ditrichum cornubicum*, *Scopelophila cataractae*; the only obligate Pb bryophyte is *Ditrichum plumbicola*; all others are facultative, those most indicative of Cu being *Cephaloziella integerrima*, *C. stellulifera*, *Gymnocolea inflata*, *Solenostoma gracillimum*, *Pohlia andalusica*, *Scapania compacta*, *Weissia controversa* var. *densifolia*; some indicative of Pb or Zn are *Bryum pallescens* and *Weissia controversa* var. *densifolia*. All vascular plants are merely facultative indicators, *Minuartia verna* (Pb and Zn) being strongest, but inland populations of lowland *Armeria* and *Plantago maritima* (Cu, Pb and Zn) are also significant. Generally, high Cu concentrations are characterised by poorly grown near-monospecific stands of *Agrostis capillaris* and *Calluna vulgaris* which are floristically very dull but easy to record; other metals are of little or no significance for the rarer metallophyte bryophytes (e.g. Fe, Mg, Sn).

Based on experience in Cornwall and elsewhere, it appeared that the best sites are likely to be:

(a) those already known to have rare metallophyte bryophytes;
(b) among those that produced highest tonnages of Cu, Pb or Zn historically, especially in relatively recent past;
(c) where extensive spoil tips have not been reclaimed or re-vegetated;
(d) sites of continuing interest to mineral collectors;
(e) sites with spoil in damp, low-lying settings but with largely unshaded fine-grained clayey spoil, rather than open sunny sites, or tree-shaded sites, or gravelly sites;
(f) if few of other criteria are met, entrances to adits or shafts may have something left.

The choice of the number of field days (30) was intended to allow visits to about 40 sites, some of which will be closely adjacent, e.g. in Co. Cork. Existing knowledge implied that only four Irish mine sites are really important for metallophyte bryophytes (Ross Island, Co Kerry; Allihies, Co Cork; NE. of Cappaghglass, Co Cork; Bunmahon, Co Waterford) all of which were to be resurveyed and documented in detail. Additional sites were then to be explored in order of priority (according to criteria noted under points (a) to (f) above) seeking to find and document additional important sites.

An initial list of sites that might be worth surveying was compiled from several sources. Phytosociological publications (Doyle 1982, Lötschert 1982) described only a few small disused lead-mines. Cole (1922) provided an extensive review of mine sites worked up to the 1920s. More recent information was obtained from mining, mining company and mining history websites. Personal contacts with mineral collectors (particularly John Fisher) added some useful pointers to exposed spoil tips rich in copper and lead minerals. Mike Wyse-Jackson pointed out several significant sites in Co. Cork and Co. Kerry. A visit to the NPWS offices in Dublin at the start of survey was used to assemble and copy relevant bits of 1:5000 and 1:10560 maps, air photos and other materials and scrutiny of these along with some notations of 'Shaft', 'Chimney' or 'Disused mine' were useful in locating sites.

From this body of information a short list of sites most likely to be worth surveying was drawn up, by applying criteria noted in points (a) to (f) above (Table 1). The sites visited were thus mainly those

regarded as high ranking in Table 1, along with a selection of lower ranked sites intended to represent different regions of Ireland or different mine types (particularly small lead mines). Sites described by Doyle (1982) and Lötschert (1982) were also revisited; a disused copper mine at Brow Head (Co. Cork) was added on the advice of Mike Wyse Jackson; a 'new' find near Knockmahon village (Co. Waterford) was added when it became clear from a field visit that it was significant. Requests to visit the large modern mine at Lisheen initially met with bureaucratic delay, but this may have been fortuitous good luck since the proposed visit was abandoned after it became clear from fieldwork that tailings dams on the similar modern mine nearby at Galmoy have very little interest.

**Table 1. Initial short-list of mine sites to be surveyed.**

| Visit | Rank | Name | V.C. | 1:50k | Grid Ref. | Metal | Ore tonnage | Years | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Y | 004 | Ross Island | H02 | 78 | V944880 | Cu | ">4,749" | 1804-1810 | Cole pp. 39-40 |
| Y | medium | Annagh | H02 | 71 | Q8303 | Pb | >409 | 1788-1828 | Cole p. 126 |
| N | low | Coosheen/Skull Bay | H03 | 88 | V939311 | Cu | ">1,957" | 1840-1878 | Cole p. 54 |
| Y | 001 | Allihies/Mountain | H03 | 84 | V589457 | Cu | ">206,574" | 1813-1918 | Cole pp. 45-8 |
| Y | low-med. | Ballycummisk | H03 | 88 | V977322 | Cu | >809 | 1814-1877 | Cole pp. 50-51 |
| Y | low | Ballydehob | H03 | 88 | V9935 | Cu[Pb] | 636 | 1817-1860 | Cole pp. 51-2 |
| Y | 002 | Cappaghglass | H03 | 88 | V990324 | Cu | "1,133" | 1819-1873 | Cole p. 53 |
| Y | low | Polleenateada | H03 | 88 | V780306 | Cu | ?? | ?? | on 1:50 k sheet |
| Y | 003 | Bunmahon etc. | H06 | 82 | X4498 | Cu | ">80,000" | 1730-1907 | Cole pp. 41-3 |
| Y | high | Lisheen | H07 | 66,74 | R9730 | Zn,Pb | "160,000 p.a." | 2001-2008 | Mining Life website |
| N | very low | Ballyvergin | H09 | 58 | R4281 | Pb | 119 | 1859-1861 | Cole pp. 117-8 |
| N | low | Carrahin/Carrahan | H09 | 58 | R4380 | Pb | 444 | 1863-1880 | Cole p. 118 |
| N | very low | Milltown | H09 | 58 | R4680 | Pb | 54 | 1826-1864 | Cole p. 118 |
| N | low | Kilbreckan/Monanoe | H09 | 58 | R3776 | Pb | >236 | 1834-1855 | Cole pp. 119-20 |
| Y | mod | Ballyhickey | H09 | 58 | R4276 | Pb | 3182 | 1836-1846 | Cole p. 119 |
| N | very low | Killeen | H10 | 59 | R8062 | Cu | 182 | 1905-1909 | Cole pp. 38-9 |
| N | low | Hollyford | H10 | 66 | R9253 | Cu | >565 | 1837-1862 | Cole p. 39 |
| Y | medium | Lackamore | H10 | 59 | R8060 | Cu | "2,848" | 1819-1859 | Cole p. 38 |
| Y | medium | Shallee W./E. | H10 | 59 | R7970 | Pb | >678 | 1847-1874 | Cole pp. 122-3 |
| Y | medium | Gorteenadiha etc. | H10 | 59 | R8271 | Pb,Zn,Cu | Pb->218,Zn-9,541 | 1819-1872 | Cole pp. 123, 146 |
| Y | high | Galmoy | H11 | 60 | S2971 | Zn,Pb | "650,000 p.a." | post1986-2008 | Mining Life website |
| Y | medium | Caim etc. | H12 | 68 | S8840 | Pb [Cu] | ">1,245" | 1815-1855 | Cole p. 125 |
| Y | medium | Barrystown | H12 | 77 | S8612 | Pb | 573 | 1777-1847 | Cole pp. 125-6 |
| Y | medium+ | Tynagh (N. of) | H15 | 53 | M754133 | Cu | ?? | -2004 | visit by DTH |
| Y | high | Connary | H20 | 62 | T1984 | Cu | "15,206" | 1832-1885 | Cole pp. 33, 144 |
| Y | high | Cronebane | H20 | 62 | T2083 | Cu | "38,909" | 1720-1912 | Cole pp. 33-4 |
| Y | high | Tigrony | H20 | 62 | T2082 | Cu | "26,390" | 1822-1854 | Cole p. 34 |
| Y | medium | Ballygahan | H20 | 62 | T2081 | Cu | ">6,809" | 1828-1879 | Cole p. 35 |
| Y | high | Ballymurtagh | H20 | 62 | T1981 | Cu | ">52,111" | 1755-1879 | Cole pp. 35-6 |
| Y | high | Glendasan etc. | H20 | 56 | O1097 | Pb | ">12,900" | 1807-1900 | Cole pp. 110-3 |
| Y | medium | Glenmalur etc. | H20 | 56 | O0892 | Pb | >1395 | 1797-1864 | Cole pp. 113-4 |
| Y | medium? | Ballycorus | H21 | 50 | O2221 | Pb | productive | 1807-1865 | Cole pp. 107-8 |
| Y | high | Tara (Navan) | H22 | 42 | N8471 | Zn,Pb | ">2,000,000" | 1977-2008 | Mining Life website |
| N | low | Beauparc | H30 | 43 | N9471 | Cu | "1,001" | 1818-1914 | Cole p. 28 |
| N | very low | Coolartrargh/Bond | H32 | 28 | H8421 | Pb | 124 | 1845-1864 | Cole p. 97 |
| N | low | Tassan | H32 | 28 | H8421 | Pb | >165 | 1853-1865 | Cole pp. 97-8 |
| N | very low | Hope Mines etc. | H32 | 28 | H8421 | Pb | 142 | 1852-1869 | Cole pp. 100-101 |
| N | low | Annaglogh | H32? | 28 | H8421 | Pb | >310 | 1852-1859 | Cole p. 99 |
| Y | medium | Glentogher | H34 | 03 | C4737 | Pb | 1800 | "1780, 1905-6" | Cole p. 91 |
| Y | medium | Keeldrum | H35 | 01 | B9027 | Pb | 1229 | 1826-1862 | Cole pp. 91-2 |

In the end, several mine sites were visited that had no (remaining) metallophyte bryophyte interest whatever (e.g. Ballycummisk, Ballydehob, Barrystown), even some high ranked sites had very little or no interest (notably Connary, Cronebane, Galmoy), but a few of the small sites selected proved to be significant new finds from a botanical viewpoint (notably Caim and Ballyhighland, Glenmalur and Shallee). There are doubtless other unsurveyed small sites that are of significant interest for bryophytes, but it seems that only chance finds or a really exhaustive survey are likely to reveal their whereabouts!

Standard information was recorded at each mine site that was visited where either significant metallophyte vegetation or rare metallophyte bryophytes were found. This information comprised a Site Survey Card (Table 2) and, where quadrat data were recorded, a Relevé Card (Table 3). Large numbers of digital photos were taken using a Nikon Coolpix 4500 to show the general character of each site, with emphasis on metallophyte vegetation and locations with rare bryophytes. All relevé were also photographed. All of the photos are given serial numbers prefaced with NPW08- and all are on a CD that accompanies the site files (held at NPWS, 7 Ely Place, Dublin).

Following initial widespread searching and inspection of the vegetation at each mine site, relevé (quadrats) were routinely selected as representative samples chosen to document well defined examples of the different types of metallophyte vegetation encountered. Vegetation types that did not have strong evidence of metalliferous influence were mainly ignored during this sampling and recording process, although some 'weakly metalliferous' relevés were recorded. There was some deliberate bias in selection of sites for relevé towards selection of small patches of habitat with rare metallophyte bryophytes, but this was to some extent countered by occasional recording of near-monospecific stands of *Agrostis* grassland on obviously toxic spoil.

Prior to the fieldwork, a decision was required regarding the size of quadrat to be used in recording relevé data. The 'standard' 2 x 2 metres used in grassland survey was clearly too large for recording small bryophytes, since accurate recording of each quadrat could take several hours. On the other hand, the 0.50 x 0.25 m adopted as a standard for bryophyte survey by BRECOG (the British Bryological Society's 'Bryophyte Ecology Group') seems rather small when vascular plants are also being recorded. Quadrats of 0.5 x 0.5 m were therefore chosen as a compromise and this size worked well in the field. A square frame (4 thin tent pegs joined by thin string stretched taut: Photo 1) was always used when recording data.

Voucher specimens for microscopic identification were routinely collected from relevé. This sampling and subsequent curation of material was carried out as part of the programme of work recording threatened bryophytes for the *Red Data Book*. Details of the methods involved and the standard Species-Site data form are included in a separate Report to NPWS (Holyoak 2008).

## Table 2. Site Survey Card - Survey of vegetation on Irish metalliferous mines

| Site name: | Time spent on site | Date |
|---|---|---|

| | | |
|---|---|---|
| Townland name<br>County | Site Area<br>Extent of coverage<br>Alt range (m) | |
| Grid ref.<br>Discovery Map no<br>1:5000 sheet<br>6" sheet<br>Air photo ID & year | Bedrock type<br>Mineral type (Cu, Pb, Zn, etc.)<br>Soil type<br>Soil moisture regime<br>Seasonal flooding (y/n) | |
| NPWS Region<br>NHA code<br>SAC code<br>SPA code | HC Habitats (% cover) | EU 2<br>ED 2<br>ED 3<br>Other |
| Ownership | HD Habitats (% cover) | 6130<br>Other |

Site geography & landscape setting

Site history & management

Significance of site for bryophytes

Development of metallophyte plant communities

Assessment of conservation value

Threats/recommendations for conservation

Species list

| Liverworts | Mosses | Vascular plants |
|---|---|---|
| *Gymnocolea inflata* | *Ceratodon purpureus* | Grasses indet |
| *Cephaloziella stellulifera* | *Polytrichum juniperinum* | Dicot seedlings |
| *Cephaloziella sp* | *Dicranella varia* | *Agrostis capillaris* |
| | *Pohlia annotina* | *Agrostis stolonifera* |
| *Scapania compacta* | *Ditrichum cornubicum* | *Armeria maritima* |
| *Nardia scalaris* | *Ditrichum lineare* | *Calluna vulgaris* |
| *Cephaloziella massalongi* | *Pohlia andalusica* | *Erica cinerea* |
| *Cephaloziella nicholsonii* | *Scopelophila cataractae* | *Plantago coronopus* |
| *Cephaloziella integerrima* | *Weissia controversa* var *densifolia* | *Plantago maritima* |
| | | *Silene vulgaris* |
| | | *Ulex gallii* |
| | | *Ulex europaeus* |
| | | *Ulex sp* |

Impacting Activities (NATURA list codes)

## Table 3. Relevé Card - Survey of vegetation on Irish metalliferous mines

Site name: Date

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Releve Number | | | | | | | |
| Slope:<br>Aspect: | | | | | | | |
| Grid Ref:<br>Altitude:<br>Substrate type:<br>Description: | | | | | | | |
| Herb height (cm) | | | | | | | |
| Photo ID | | | | | | | |

**DOMIN scale**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| General | Bare soil | | | | | | | |
| | Rock | | | | | | | |
| | Surface water | | | | | | | |
| | Litter | | | | | | | |
| | Vegetation | | | | | | | |
| | Vascular plant | | | | | | | |
| | Bryophyte | | | | | | | |
| | Lichen | | | | | | | |
| | Algae | | | | | | | |
| | | | | | | | | |
| Liverworts | *Gymnocolea inflata* | | | | | | | |
| | *Cephaloziella stellulifera* | | | | | | | |
| | *Cephaloziella sp* | | | | | | | |
| | *Diplophyllum albicans* | | | | | | | |
| | *Scapania compacta* | | | | | | | |
| | *Nardia scalaris* | | | | | | | |
| | | | | | | | | |
| | *Cephaloziella massalongi* | | | | | | | |
| | *Cephaloziella nicholsonii* | | | | | | | |
| | *Cephaloziella integerrima* | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Mosses | *Ceratodon purpureus* | | | | | | | |
| | *Polytrichum juniperinum* | | | | | | | |
| | *Dicranella varia* | | | | | | | |
| | *Pohlia annotina* | | | | | | | |
| | | | | | | | | |
| | *Ditrichum cornubicum* | | | | | | | |
| | *Ditrichum lineare* | | | | | | | |
| | *Pohlia andalusica* | | | | | | | |
| | *Scopelophila cataractae* | | | | | | | |
| | *Weissia controversa* var *densifolia* | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Vascular plants | Grasses indet | | | | | | | |
| | Dicot seedlings | | | | | | | |
| | | | | | | | | |
| | *Agrostis capillaris* | | | | | | | |
| | *Agrostis stolonifera* | | | | | | | |
| | *Armeria maritima* | | | | | | | |
| | *Calluna vulgaris* | | | | | | | |
| | *Erica cinerea* | | | | | | | |
| | *Plantago coronopus* | | | | | | | |
| | *Plantago maritima* | | | | | | | |
| | *Silene vulgaris* | | | | | | | |
| | *Ulex gallii* | | | | | | | |
| | *Ulex europaeus* | | | | | | | |
| | *Ulex sp* | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## Results

About 50 mine sites were visited during the fieldwork, which took place from 12th April to 5th June 2008, a diary of the work being appended to the Report by Holyoak (2008). Early spring was deliberately chosen as the best seasonal timing for the fieldwork, since many metallophyte bryophytes are tiny plants that make most of their growth during the winter and become very difficult to find in summer. Fortunately the weather during April and May 2008 was ideal, with frequent rain that kept bryophytes hydrated, but not so much rain that fieldwork was hampered.

Site Survey Cards were completed for 35 mine sites that had at least some slight metallophyte interest, although several of these were of little real importance for metallophyte vegetation or metallophyte bryophytes. The bulk of the present Report consists of these Site Survey Cards, accompanied in most cases by Relevé Cards and marked maps, and often also by marked air-photos and other documentation. These are held at NPWS, 7 Ely Place, Dublin.

A short paper has been prepared to publish new distributional records of metallophyte bryophytes from this survey, along with the more significant metallophyte records obtained from other surveys over the past few years (*Journal of Bryology*, in press). In brief, the most notable results of the present survey are as follows:

- *Ditrichum plumbicola* new to Ireland, at sites in Co. Dublin and Co. Galway;
- *Cephaloziella nicholsonii* at additional sites (new to Co. Galway, Co. Waterford, Co. Wicklow, Co. Wexford);
- *Cephaloziella massalongi* at additional sites (new to Co. Dublin, Co. Wicklow);
- *Cephaloziella integerrima* at additional sites;
- *Scopelophila cataractae* at a third Irish site (new to Co. Wexford).

A second paper is in preparation to summarise phytosociological data and observations from this survey. The main conclusion from this is that existing literature deals very incompletely with metallophyte vegetation in Ireland (and indeed in the British Isles or Europe as a whole). Several vegetation types composed of single bryophyte species or very few species occur on copper-mine spoil, all of them lacking formal names as syntaxa. Coining new names for such 'Associations' consisting of a single species seems illogical, so the temptation to do so is resisted. On less toxic substrata these monospecific or species-poor stands grade into several heathland and grassland vegetation types, resulting in complexity that existing phytosociological classification as *'Violetalia calaminariae'* does not adequately cover.

Much of the detailed material and discussion from these two papers is not repeated here. Hence, the remainder of the present report is mainly devoted to: (i) a consideration of the extent and distribution of the Calaminarian Grassland (6130) habitat in Ireland, and (ii) discussion of priorities and practicalities in conservation of metallophyte vegetation and rare metallophyte species in Ireland.

### (i) Extent and distribution of Calaminarian Grassland (6130) habitat inIreland

For the purposes of the present survey, Calaminarian Grassland was regarded as a syntaxon including *all* vegetation types showing very strong influence of heavy metals (Cu, Pb, Zn) in the substrata, whether grasses are evident or not. English Nature adopted this position in its decision to protect vegetation as

Sites of Special Scientific Interest at eight disused copper mine sites in Cornwall under the umbrella category of EC habitat type 6130, since there was no other appropriate category under which this rare and vulnerable habitat could be protected. As noted above, presence of indicator species was taken as the strongest evidence that these distinctive vegetation types are present. Thus:

(a) Obligate Cu bryophytes are *Cephaloziella massalongi*, *C. nicholsonii*, *Ditrichum cornubicum*, *Scopelophila cataractae*; the only obligate Pb bryophyte is *Ditrichum plumbicola*.

(b) All others are facultative metallophytes, those most indicative of high [Cu] being *Cephaloziella integerrima*, *C. stellulifera*, *Gymnocolea inflata*, *Solenostoma gracillimum*, *Pohlia andalusica*, *Scapania compacta*, *Weissia controversa* var. *densifolia*; some indicative of Pb or Zn are *Bryum pallescens* and *Weissia controversa* var. *densifolia*.

(c) All vascular plants are merely facultative indicators, *Minuartia verna* (Pb and Zn) being strongest, but inland populations of *Armeria* (in the lowlands) and *Plantago maritima* (Cu, Pb and Zn) are also significant. Generally, high Cu concentrations are characterised by poorly grown near-monospecific stands of *Agrostis capillaris* and *Calluna* which are floristically very dull.

(d) These conclusions about indicator species are supported by a body of analytical data from Cornwall on available heavy metal contents of substrata on which the plants occur (Clements 1996, Rouen 2000, Walsh 2001). Such data are important to confirm that restriction of particular plant species to mine areas is due to the presence there of metal residues and not to other factors such as disturbance, minimal soil development, or low nutrient levels.

Ground with high levels of heavy metals generally has species-poor vegetation, with only a few of the species from adjoining grassland or heathland growing well. However, other factors beside metal toxicity can produce species-poor communities, particularly recent disturbance, extreme acidity or alkalinity, extreme poverty in nutrients, other toxic substances (e.g. arsenic, certain organic compounds, selective herbicides), drought, or combinations of these. During this survey extremely species-poor and sparse vegetation at some mines in the Avoca Valley of Co. Wicklow (notably Cronebane and Connary) appeared to result from strongly acidic substrate reactions associated with high Sulphur levels in the bedrock, rather than from high metal levels. Hence little use was made of low species numbers as indicators of metallophyte vegetation in the absence of evidence from the indicator species listed above. It is quite likely therefore that the extent of 6130 habitat has been somewhat underestimated, but correspondingly unlikely that much of what has been recognised is misidentified.

In order to estimate the total area of metallophyte vegetation in Ireland, many scattered occurrences of the *Weissia controversa* var. *densifolia-Bryum pallescens* community away from mine-sites in places enriched with zinc were ignored. These occurrences are widespread under edges of galvanised-iron roofs, crash barriers, fences and gates. They are doubtless still greatly under-recorded, they appear to be increasing at least under roadside crash-barriers, they involve no metallophyte species other than the two character species, and hence they are of no conservation concern.

Table 5 ranks mine sites according to the extent of 6130 vegetation recorded. Only four sites have more than 1.0 ha of 6130 habitat (three Cu mines: Allihies (Mountain) 3.1 ha, Tynagh 2.5, near Connary Hall 2.2; one Pb mine: Glendasan (Old Works) 3.6, although two other Pb mines approach this amount, at Vale of Glendasan 0.97, Shallee 0.9 ha). These few relatively rich sites contribute a large proportion of the total resource of 16.8 ha of type 6130 accumulated in Table 5.

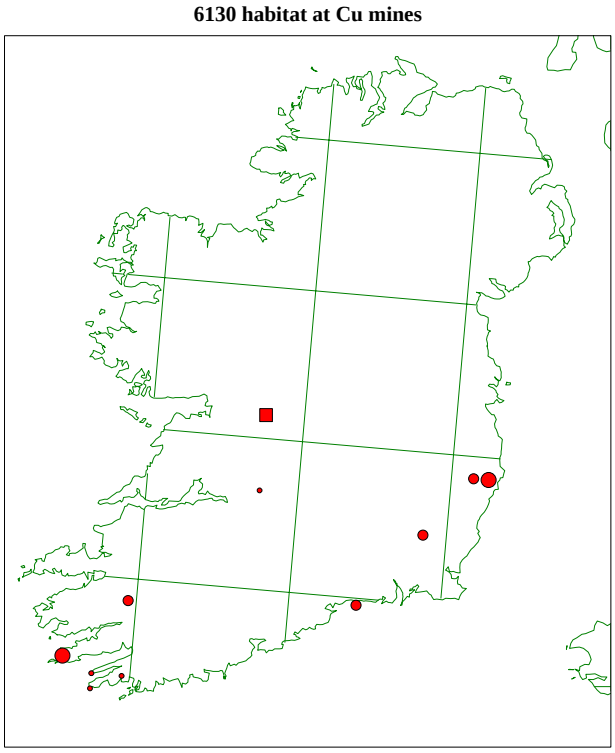
However, in calculating the total extent of 6130 vegetation in Ireland several other points need to be considered. Two modern mines have 6130 vegetation restricted to damp, flat surfaces on fine silty-clay tailings (Galmoy 0.7 ha, Tynagh 2.5 ha); the vegetation involved is extraordinarily poor in species, it

lacks rarities and it represents only a short-lived stage in vegetation succession on the sediment infilling lagoons within tailings dams. This vegetation has no conservation significance and it should therefore be discounted in arriving at figures for the total resource of the habitat. Adjustment of the totals is also necessary to take account of additional small lead mine sites that were not surveyed in detail in the County Wicklow hills (in Vale of Glendasan and around Van Diemen's Mines), where a total of perhaps 2 ha more of 6130 may exist scattered across maybe 15 small sites. Bearing in mind these corrections, the total resource of 6130 habitat in Ireland can be estimated as:

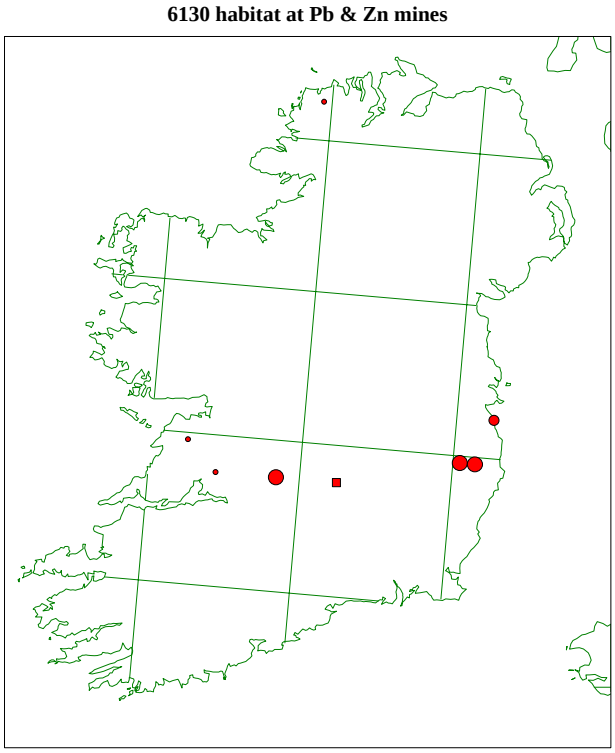
- 6.8 ha at Cu mine sites,
- 6.8 ha at Pb (and Zn) mine sites which were surveyed,
- 2.0 ha estimated at Pb mine sites in Co Wicklow hills not surveyed,
- Hence an overall total of 15.6 ha.

The habitat is widely distributed geographically (Maps 1 and 2) and it occurs on a range of bedrock types from strongly basic (Carboniferous Limestone, calcareous shales) to distinctly acidic (granitic, schist, shale and quartzite) lithologies (Table 4). The diversity of plant association types found within 6130 vegetation in Ireland doubtless relates at least partly to this variability in bedrock geology, chemistry and hydrology. It is therefore desirable to protect a range of the better examples of 6130 vegetation from different bedrock and heavy-metal types.

**Map 1. Distribution of Calaminarian Grassland (metallophyte vegetation of EU type 6130) at copper mine sites in Ireland. Large symbols > 1 ha, medium symbols 0.1-1.0 ha, small symbols < 0.1 ha; square symbols = vegetation only on modern tailings dams.**



**Map 2. Distribution of Calaminarian Grassland (metallophyte vegetation of EU type 6130) at lead and zinc mine sites in Ireland. Symbols as in Map 1.**




### (ii) Priorities and practicalities in conservation of metallophyte vegetation and rare metallophyte species in Ireland

Conservation of 6130 vegetation for its own sake has little appeal, particularly when it consists of pure stands of metal-tolerant ecotypes of the common grass *Agrostis capillaris* with or without such common herbs as *Cerastium fontanum* and *Rumex acetosa*. The artificial nature of these floristically dull habitats also discourages their conservation.

It is the presence of rare species in the metallophyte vegetation that necessitates conservation concern. Eight bryophytes from the Irish Red-list are closely associated with metalliferous sites (*Cephaloziella integerrima*, *C. massalongi*, *C. nicholsonii*, *Ditrichum cornubicum*, *D. lineare*, *D. plumbicola*, *Pohlia andalusica*, *Scopelophila cataractae*). Five of these are strict metallophytes (some populations of *C. integerrima* and *P. andalusica* and most of those of *D. lineare* occur on uncontaminated substrata). Among them, *D. cornubicum* is on the European and British Red-lists (with three extant sites known globally) and *C. integerrima*, *C. massalongi*, *C. nicholsonii*, *D. plumbicola* and *S. cataractae* are on the British Red-list. The present survey has reinforced the view that several other bryophytes found mainly at mine sites have too many records to remain on the Irish Red-list (*Bryum pallescens*, *Cephaloziella stellulifera*, *Weissia controversa* var. *densifolia*). None of the vascular plants associated with metalliferous ground in Ireland depends on this habitat alone and none is really rare, although *Minuartia verna* is local and rather scarce.

The eight rare bryophytes closely associated with metalliferous sites in Ireland are more or less closely associated with peculiar, species-poor vegetation types. This vegetation as well as the populations of rare species merit conservation.

Two mining techniques have been used extensively at modern metalliferous mines in Ireland. These are extensive quarrying (open-cast) operations, or underground mining of ore that is powdered in a mill and processed before residues (tailings) are pumped into a tailings dam. Study of modern open-cast mine sites in Ireland (Cronebane and Connary, most of Ballymurtagh and Garryard West) and those with tailings dams (Galmoy, Tara, Tynagh) has failed to disclose any rare bryophytes or any habitat suitable for them. In contrast, a wider variety of mining techniques were used at mines worked during the eighteenth, nineteenth and early twentieth centuries, some of which resulted in spillage of ore or incomplete recovery of low-grade ore. The rare metallophytes have persisted at some of those sites where metals were left behind.

It is therefore clear that the modern mines are of no interest for conservation of metallophyte bryophytes, the survival of which will depend on persistence and suitable management of relict patches of habitat that resulted from the older mining work, in many cases from the nineteenth century. These areas are often under pressure as potential development land, as untidy and potentially dangerous places that need 'landscaping' (and even attract EU grant aid for it) or they are merely lost under scrub and saplings after generations of neglect.

It is therefore important to ensure statutory protection and appropriate management of the most important of the metalliferous mine sites with rare bryophytes and the distinctive habitat types on which they depend. Table 6 ranks the mine sites according to the number of Red-list bryophyte species they contain: ten disused copper mines and three disused lead mines are involved.

The richest site is at Allihies (Mountain Mine) with seven Red-list species and this site is already protected within the Kenmare River (2158) candidate SAC. Muckross Lake, Ross Island and Glendasan are also within protected areas and the sites at the tops of scenic coastal cliffs at Bunmahon and Dooneen also appear relatively safe.

Six sites thus lack statutory protection from which they might derive real benefit. Two of these are relatively less significant than the others: Tigroney West has little of importance other than a strong patch of *Cephaloziella nicholsonii* on the river bank; Cappagh still has good populations of *C. nicholsonii* and *Pohlia andalusica* (*Scopelophila cataractae* might now be extinct) but the site is small and already fragmented by housing and roads and hence difficult to protect effectively. This leaves four sites that apparently merit notification as NHA:

(1) Knockmahon village is a copper-mine spoil site, with the largest populationsin Ireland of *Cephaloziella integerrima* and *Pohlia andalusica* (see Photo 2) and very strong populations of *Cephaloziella nicholsonii*. 6130 vegetation is well developed (0.28 ha). It is on flat and gently sloping ground and highly vulnerable to development, tipping or merely being covered over with soil.

(2) Caim and Ballyhighland is a copper-mine spoil site with the largest population extant in the British Isles of *Scopelophila cataractae* (Photo 3) a strong population of *Cephaloziella nicholsonii* and well developed 6130 vegetation (0.16ha).

(3) Shallee is an extensive old and more modern lead-mine site with much the largest of the two Irish populations of *Ditrichum plumbicola* (Photo 4) and a tiny amount of *Cephaloziella nicholsonii*. 6130 vegetation is extensive (0.9 ha) andwell developed. Threats are obvious from ongoing restoration work on an engine-house ruin, and existence of large areas of derelict land with rusting oil drums and cable and dangerous open adits and workings.

(4) Ballycorus is a historic lead-mine site close to the southern edge of Dublin, with building ruins and structures of great interest to the mining historian. It hasthe second Irish population of *Ditrichum*

*plumbicola*, *Cephaloziella massalongi* (which is unusual at lead mines) and 6130 vegetation (0.12 ha). The mine-spoil is currently disturbed by motorcycling. Although less important than sites (1)-(3) it is worthy of protection.

Besides statutory protection of additional sites, it is important to ensure appropriate habitat management to ensure favourable conservation status is achieved or maintained at these and other localities with rare metallophyte bryophytes.

Notes on threats to individual sites are given in the site accounts held at NPWS, 7 Ely Place, Dublin. However, several recurrent themes are involved.

Metallophyte bryophytes are small plants that mainly have little tolerance of shading or competition from other plants. Their toxic substrata inhibit growth of competing plants, but the toxic patches are often small and prone to accumulation of litter from nearby. Planted trees, or scrub or saplings growing up in the vicinity may be particularly harmful, causing a rain of leaf litter in addition to direct shading.

Conservation workers and others (such as well intentioned builders) usually seek open patches of ground for fires to burn arisings from scrub clearance, etc. Unfortunately, the obvious open 'bare' patches are often the habitats of greatest interest for metallophyte bryophytes, because toxicity of the substrata keeps them 'bare'. Careful instruction and supervision of conservation-management workers may therefore be needed.

Competing vegetation on open ground at mine sites is often kept trimmed by rabbits. Their needs should be considered if fencing or other obstacles are erected. Housing, public amenity or car-park development near a mine site often results in more dogs, leading to fewer rabbits in the open places and inadequate grazing pressure.

Historic mine buildings (mainly ruined engine houses) are present at several mine sites. One of these was restored in 2002-2003 and another was being restored in May 2008. If more work of this kind is carried out it is important to ensure that it does not damage populations of rare bryophytes. Access for builders' vehicles may churn track surfaces, storage and mixing of building materials may also damage habitats. The rare metallophytes are all acidophiles and hence vulnerable to calcareous dust from cement or lime-mortar, which may therefore need to be mixed off-site. Similar considerations may apply to works to cap open mine-shafts or to fence adits. At the most important bryophyte sites it may be necessary to carry out bryophyte surveys and prepare impact assessments prior to works, then arrange close supervision as work proceeds.

Particular care is needed if public access to mine areas is improved. At Tankardstown Mine all metallophyte interest in the vicinity of the restored engine house has been destroyed by landscaping work, involving covering mine-spoil with soil, building steps, erecting seats and statues and planting signboards and saplings. Survey of bryophytes and impact assessment should precede consent for any such works at other mine sites.

Off-road vehicles (motorcycles, quad bikes, sometimes even Land Rovers) regularly damage mine-spoil habitats at some sites. Fencing, new ditches or work by rangers and police may be needed to exclude such activity. Dumping of rubbish is also a problem at many sites. Besides covering mine-spoil habitat, the

material involved may be nutrient rich, resulting in damage to surrounding areas as a result of eutrophic run-off.

Important sites for bryophytes that are protected as SAC or NHA need periodic monitoring. Annual visits (at least) from conservation rangers should suffice to reveal tipping, usage by off-road vehicles, squatters, serious scrub encroachment and other obvious signs of damage. However, surveys by skilled bryologists are also necessary at longer intervals, to assess bryophyte populations and threats, and where possible to demonstrate the interest to conservation rangers. These surveys need to be carried out at appropriate times of year (usually winter or early spring) in suitably damp conditions, by workers competent to find and identify e.g. *Cephaloziella* and *Ditrichum* spp. Visits to the most important sites for this work should be at four-year intervals, or more often if habitat management or other issues arise.

**Table 4. Summary of data on mine sites surveyed.**

| Site | VC (H:) | Grid ref. | Metal(s) | Bedrock | 6130 area (ha) | Rare bryophytes |
|---|---|---|---|---|---|---|
| 01 Tara | 22 | N858716 | Zn, Pb | shale/slate | 0 | - |
| 02 Ballycorus | 21 | O225208 | Pb | mica-schist | 0.12 | Cep mas, Dit plu |
| 03 Cronebane | 20 | T208831 | Cu, S, etc. | shale, schist | 0 | - |
| 04 nr Connary Hall | 20 | T211838 | Cu | shale, etc. | 2.2 | - |
| 05 Glendasan | 20 | T098981 | Pb | granite, schist | 3.6 | C. mas, C. nic |
| 06 Foxrock Mine | 20 | T104982 | Pb | granite, schist | 0.6 | - |
| 07 Ballymurtagh | 20 | T192815 | Cu, S, Fe | schistose | 0.11 | - |
| 08 Tigroney West | 20 | T199822 | Cu, Fe, S | schistose | 0.03 | Cep nic |
| 09 Ballinafunshoge | 20 | T082925 | Pb | schistose | 0.10 | - |
| 10 Vale of Glendasan | 20 | T108977 | Pb | schistose | 0.97 | - |
| 11 Brockagh | 20 | T093992 | Pb | schistose | 0.20 | - |
| 12 E. of L. Nahanagan | 20 | T092988 | Pb | schistose | 0.10 | - |
| 13 Bunmahon | 06 | X444986 | Cu | slate | 0.02 | Cep mas, Poh and |
| 14 Tankardstown | 06 | X451986 | Cu | slate | 0.006 | - |
| 15 Knockmahon village | 06 | X438990 | Cu | metamorphic | 0.28 | Cep int, C. nic, Poh and |
| 16 Galmoy (Trial Cells) | 11 | S274722 | Zn, Pb | carbonates | 0.01 | - |
| 17 Galmoy (Dam) | 11 | S271724 | Zn, Pb | carbonates | 0.7 | - |
| 18 Muckross Lake | 02 | V948859 | Cu | limestone | 0.16 | Cep mas |
| 19 Ross Island | 02 | V945880 | Cu, Pb | limestone | 0.15 | Cep mas |
| 20 Allihies (Mountain) | 03 | V590458 | Cu | sandstone | 3.1 | Cep int, C. mas, C. nic, Dit cor, Dit lin, Poh and, Sco cat |
| 21 N. of Caminches | 03 | V594455 | Cu | sandstone | 0.01 | Poh and |
| 22 NE. of Caminches | 03 | V597455 | Cu | sandstone | 0.006 | - |
| 23 Dooneen | 03 | V577459 | Cu | sandstone | 0.34 | Cep mas (?) |
| 24 Cappagh | 03 | V990324 | Cu | sandstone | 0.08 | Cep nic, Poh and, Sco cat (?) |
| 25 Brow Head | 03 | V771235 | Cu | sandstone | 0.07 | - |
| 26 Polleenateada | 03 | V780306 | Cu | sandstone | 0.015 | - |
| 27 Lackamore | 10 | R788602 | Cu | shale | 0.07 | - |
| 28 Shallee | 10 | R806712 | Pb | shale | 0.9 | Cep nic, Dit plu |
| 29 Garryard West | 10 | R826710 | Pb, ?Zn | calc. shale | 0.19 | - |
| 30 Ballyhickey | 09 | R417768 | Pb | limestone | 0.009 | - |
| 31 Sheshodonnell East | 09 | R268969 | Pb | limestone | 0.014 | - |
| 32 Mogouhy | 09 | R274983 | Pb | limestone | 0 | - |
| 33 Tynagh | 15 | M753133 | Cu | limestone | 2.5 | - |
| 34 Keeldrum | 35 | B903262 | Pb | quartzite, etc. | 0.0009 | - |
| 35 Caim & Ballyhighland | 12 | S885409 | Cu | metamorphic | 0.16 | Cep nic, Sco cat |

**Table 5. Analysis of data on mine sites surveyed.**

**(a) Ranking of sites by extent of 6130 vegetation (area in ha)**

* = only on silty-clay tailings at modern mines

**Copper Mines**

| | | | |
|---|---|---|---|
| Allihies (Mountain) | 3.1 | Cappagh | 0.08 |
| Tynagh | 2.5* | Brow Head | 0.07 |
| near Connary Hall | 2.2 | Lackamore | 0.07 |
| Dooneen | 0.34 | Tigroney West | 0.03 |
| Knockmahon village | 0.28 | Bunmahon | 0.02 |
| Caim & Ballyhighland | 0.16 | Polleenateada | 0.015 |
| Muckross Lake | 0.16 | N. of Caminches | 0.01 |
| Ross Island | 0.15 | NE. of Caminches | 0.006 |
| Ballymurtagh | 0.11 | Tankardstown | 0.006 |
| | | TOTAL | 9.307 ha |

**Lead or Zinc Mines**

| | | | |
|---|---|---|---|
| Glendasan (Old Works) | 3.6 | Ballinafunshoge | 0.1 |
| Vale of Glendasan | 0.97 | E. of L. Nahanagan | 0.1 |
| Shallee | 0.9 | Sheshodonnell East | 0.014 |
| Galmoy (Dam) | 0.7* | Galmoy (Trial Cells) | 0.01* |
| Foxrock Mine | 0.6 | Ballyhickey | 0.009 |
| Brockagh | 0.20 | Keeldrum | 0.0009 |
| Garryard West | 0.19 | | |
| Ballycorus | 0.12 | | |
| | | TOTAL | 7.5139 ha |

**Table 6. Analysis of data on mine sites surveyed.**

**(b) Ranking of sites by occurrence of rare bryophytes**

(?) = doubt exists about whether populations found in 2006 have become extinct.

**Copper Mines**

| | |
|---|---|
| Allihies (Mountain) | *Cep int, C. mas, C. nic, Dit cor, Dit lin, Poh and, Sco cat* |
| Knockmahon village | *Cep int, C. nic, Poh and* |
| Cappagh | *Cep nic, Poh and, Sco cat* (?) |
| Bunmahon | *Cep mas, Poh and* |
| Caim & Ballyhighland | *Cep nic, Sco cat* |
| Tigroney West | *Cep nic* |
| Muckross Lake | *Cep mas* |
| Ross Island | *Cep mas* |
| N. of Caminches | *Poh and* |
| Dooneen | *Cep mas* (?) |

**Lead Mines**

| | |
|---|---|
| Glendasan | *Cep mas, C. nic* |
| Shallee | *Cep nic, Dit plu* |
| Ballycorus | *Cep mas, Dit plu* |

**Acknowledgements**

This survey was funded by National Parks and Wildlife Service. Thanks are due to Dr Neil Lockhart for efficient arrangements for the work and wise counsel about its organisation and scientific content. Marie Dromey provided helpful liaison with ongoing grassland surveys. Dr Naomi Kingston designed standard recording forms (Tables 2 and 3) and a database for the survey which saved much time in data recording. John Fisher and Mike Wyse Jackson provided details of worthwhile mine sites that might otherwise have been overlooked. Maps 1 and 2 were prepared using DMAPW © Dr Alan Morton.

**References**

Clements R. 1996. *Copper tolerance in the bryophytes* Cephaloziella nicholsonii *and*

Scopelophila cataractae. Project Dissertation for BSc (Hons.) Environmental Science (EVPJ301), University of Plymouth. (unpublished, 55 pp.).

Cole, G.A.J. 1922. *Memoir of Localities of Minerals of Economic Importance and Metalliferous Mines in Ireland*. (3rd ed., reprinted 1998, Dublin: The Mining Heritage Society of Ireland; available from Geological Survey of Ireland, Dublin.

Doyle, G.J. 1982. Minuartio-Thlaspietum alpestris (Violetea calaminariae) in Ireland. *Journal of Life Sciences, Royal Dublin Society* **3**:143-146.

Holyoak, D.T. 2000. Bryophyte interest and conservation importance of former metalliferous mine sites in Cornwall. *English Nature Research Reports* **328**: 1-40.

Holyoak, D.T. 2008. *Surveys of rare and threatened bryophytes mainly in W. Cork, S. Kerry, W. Mayo, W. Donegal and Louth (Ireland). Report on work carried out during 2008 to National Parks and Wildlife Service of the Department of the Environment, Heritage and Local Government.* (Unpublished Report).

Lötschert, W. 1982. The heavy metal content of some Irish plants. *Journal of Life Sciences, Royal Dublin Society* **3**:261-266.

Rouen S. 2000. *Substrate metal contamination in relation to rare bryophyte species distribution at former metalliferous mining locations in Cornwall*. Research Project Report, submitted as part requirement for the degree of BSc (Hons) in Environmental Studies, University of Hertfordshire. (unpublished, 44 pp.).

Walsh, L. 2001. *Heavy metal concentrations in the soil substrates associated with rare bryophytes at former metalliferous mining sites in East Cornwall.* Research project report submitted as part requirement for the degree of BSc in Environmental Studies, University of Hertfordshire. (unpublished, 62 pp.).

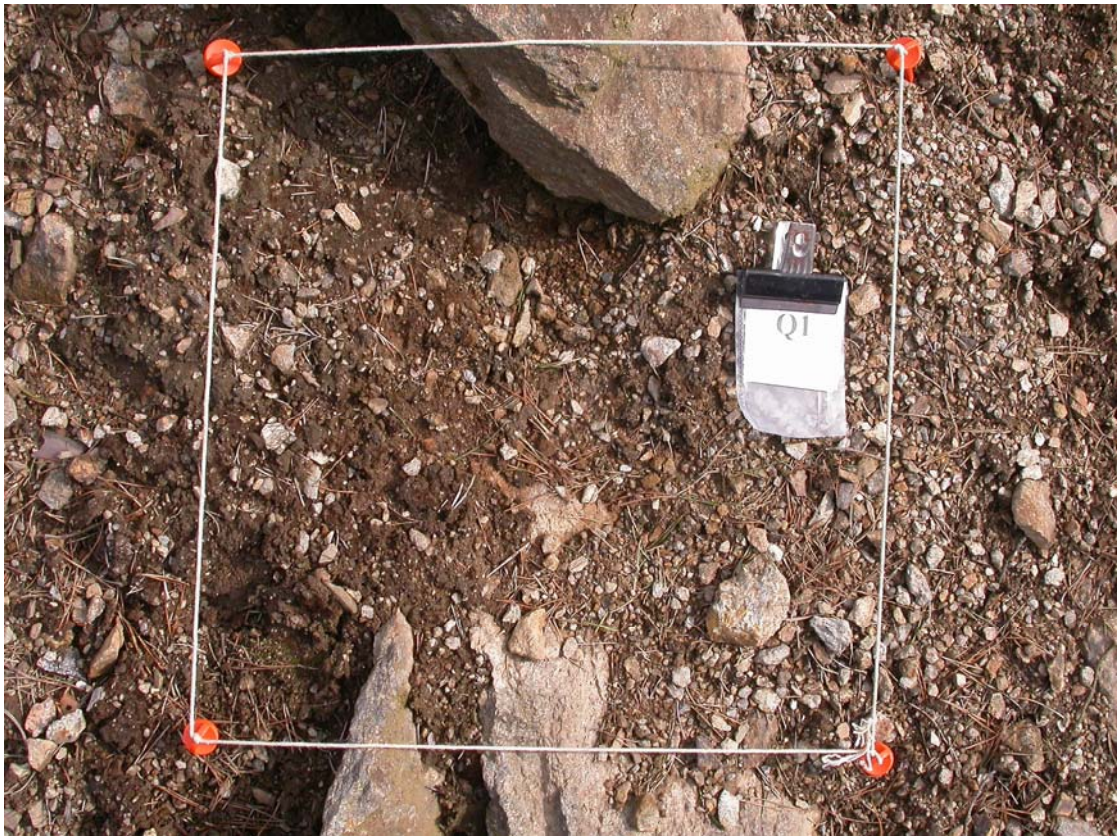



Photo 1. Relevé 1 at Ballycorus, Co. Dublin: lead-mine spoil with sparse cover of *Ditrichum plumbicola* and *Solenostoma gracillimum*.

Photo 2. Copper-mine spoil at Knockmahon village, Co. Waterford: the unprepossessing vegetation in foreground has the largest Irish populations of both *Cephaloziella integerrima* and *Pohlia andalusica*.

Photo 3. Relevé 68 at Shallee, Co. Tipperary: lead-mine spoil with sparse cover of *Ditrichum plumbicola*, *Solenostoma gracillimum* and *Agrostis capillaris*.

Photo 4. Bank of highly toxic copper-mine spoil at Caim and Ballyhighland Mine, Co. Wexford: steep spoil apparently lacks all vegetation at first sight, but close inspection reveals large patches of *Scopelophila cataractae* (e.g. by knife), forming its largest population extant in British Isles.