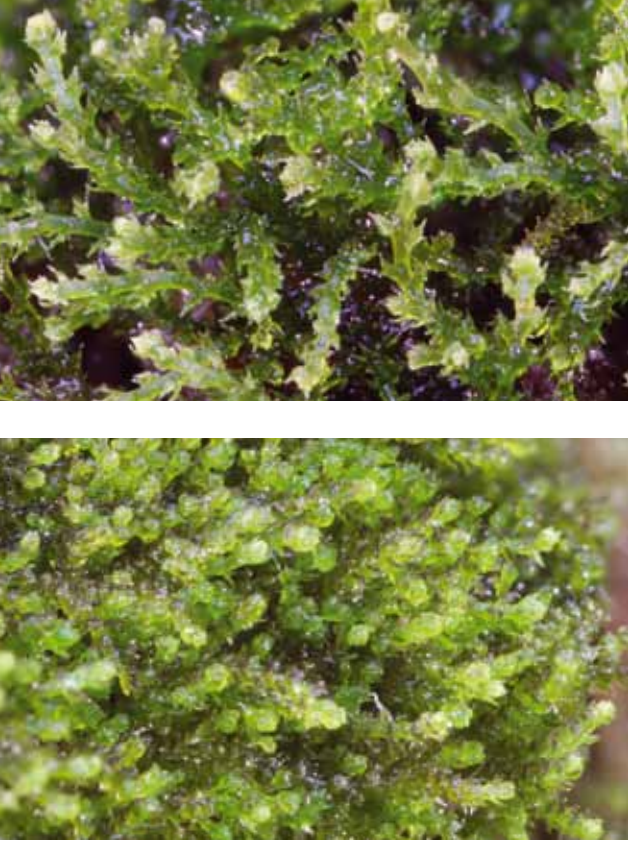
Notes on *Cephaloziella massalongi* and *C. nicholsonii* in Snowdonia

Complementing his detailed study published recently in *Journal of Bryology*, **Des Callaghan** reports on the status of two rare *Cephaloziella* species in the copper mines of north-west Wales.

Cephaloziella massalongi (Spruce) Müll.Frib. (Fig. 1) is a tiny, metallophytic liverwort that has been reported from many European countries, including Austria, Bulgaria, Corsica, Croatia, Finland, France, Germany, Iceland, Ireland, Italy, Norway, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland and the UK (Söderström *et al.*, 2002, 2007). Elsewhere in the Palaearctic, the plant is known only from Japan (Yamada & Iwatsuki, 2006) and Nepal (Ohashi, 1975), while in the Nearctic it occurs in Canada (Damsholt, 2002) and the USA (Schuster, 1980). Despite the widespread distribution, *C. massalongi* is invariably rare within the countries where it occurs and is included on many national Red Lists (Söderström *et al.*, 2002, 2007). This is not simply due to a small plant being consistently under-recorded, but is the product of its narrow habitat requirements and a general restriction to humid locations that are rich in heavy metals, especially copper. In the UK, the plant is nationally rare (Preston, 2010) and is treated as 'Vulnerable' in the national Red List of bryophytes (Hodgetts, 2011).

Cephaloziella nicholsonii Douin & Schiffn. (Fig. 1) is closely related to *C. massalongi* and occupies a very similar niche, though it seems to have the ability to tolerate more exposed microhabitats (Paton, 1984; pers. obs.). Globally, *C. nicholsonii* is much rarer, with one old (1936) record from Germany (Meinunger & Schröder, 2007), an unconfirmed record from Spain, and recent sightings only in Ireland (Holyoak, 2009) and the UK (Paton, 1999). It will be included in the forthcoming Irish Red List as 'Vulnerable' (N. Lockhart, pers. comm.) and is similarly categorized in the current UK Red List (Hodgetts, 2011). It is not included on the global IUCN Red List (IUCN, 2010), but probably deserves inclusion under the 'Data Deficient' category, pending the results of species-specific surveys in countries where it may occur. Under the UK Biodiversity Action Plan, *C. nicholsonii* is considered to be a national priority for conservation (Anon., 2007), while in England and Wales the species is of principal



△ Fig. 1. *C. massalongi* (top) and *C. nicholsonii* (bottom). Note that the images are not at the same scale (*C. massalongi* is the smaller of the two species). *D. Callaghan*

importance for the purpose of conserving biodiversity under the Natural Environment and Rural Communities Act 2006.

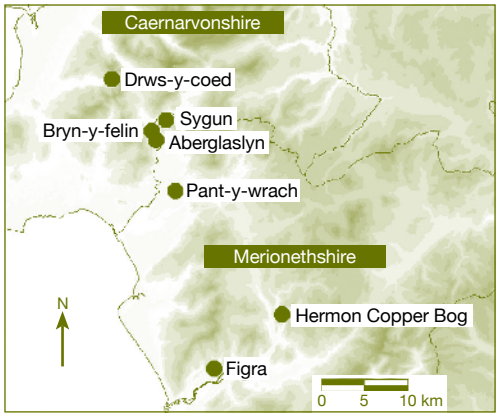
Both *C. massalongi* and *C. nicholsonii* occur in the old copper-mining regions of south-west England and north-west Wales. Within the former area, the distributions of the plants are relatively well known as a result of much survey activity in recent decades, in particular by D.T. Holyoak and J.A. Paton. In Wales, however, their current status is less well understood; there are few modern records and it may be that many old copper mines have never been searched for these plants. The aim of the present article is to present the results of recent surveys for the two species undertaken at seven old copper mines in Snowdonia, north-west Wales. Taxonomy follows Hill *et al.* (2008).

Method

Surveys of the mines (Fig. 2, Table 1) were made during January and February 2011, targeting mineral-rich veins of rock around mine adits and shafts, areas of old mine spoil and the banks of any water channels ('leats') that were associated with the former mining operations. Once a colony was found, information was collected on location, habitat, substrate, abundance, threats and management needs. In addition, a soil sample (approximately 200 cm^3) was taken immediately adjacent to those colonies growing on soil, which was subsequently dried, sieved and analysed to determine the chemical composition by X-ray fluorescence spectrometry using an Olympus Innov-X Omega Xpress meter, as described by Callaghan & Bowyer (2011). Light

Table 1. Sites of former copper mines surveyed during the present study

Site	Grid reference	Vice-county	SSSI	Survey coverage
Aberglaslyn	SH594463	Caernarvonshire	Coedydd Beddgelert a Cheunant Aberglaslyn	Good
Bryn-y-felin	SH591470	Caernarvonshire	Coedydd Beddgelert a Cheunant Aberglaslyn	Good
Drws-y-coed	SH546534	Caernarvonshire	Glynllifon	Moderate
Figra	SH662191	Merionethshire	–	Poor
Hermon Copper Bog	SH740255	Merionethshire	Hermon Copper Bog	Very good
Pant-y-wrach	SH616402	Caernarvonshire	Mwyngloddiau Llanfrothen	Good
Sygun	SH606482	Merionethshire	–	Good



△ Fig. 2. Locations of former copper mines visited during the present study. *D. Callaghan*

levels were measured at the surface of colonies and under the nearby open sky with a Lutron LX-1108 light meter, recording the minimum and maximum lux readings during a 1 minute sampling period. The relative light (RL) at each colony was then calculated by expressing the mean lux level at the colony as a percentage of the mean open sky lux.

Results and discussion

Survey constraints

The main constraint encountered was the inability to survey significant areas of metal-rich rock around open mine shafts (Fig. 3), where populations of the two liverworts may have gone undetected. This was a problem at all sites surveyed except Hermon Copper Bog.

Aberglaslyn

The mine is located within a mixed forest plantation (Coed Aberglaslyn). Frequent shafts (Fig. 3) and adits associated with the mine stretch from the roadside north of Pont Aberglaslyn (at SH59434630) southwards over the hillside to the Afon Goch (at SH59264608). There is one

△ Fig. 3. Inaccessible, metal-rich rock faces at the entrance to a deep old mine shaft at Aberglaslyn, providing potential habitat for metallophytes. *D. Callaghan*

△ Fig. 4. Location of *C. massalongi* colony at Aberglaslyn, on the bank of an old mine leat. *D. Callaghan*

previous record of *C. massalongi* from this site ('near Pont Aber Glaslyn, 1916, P.G.M. Rhodes') and during the present survey the plant was found in two locations (Fig. 4; Table 2). There are no previous records of *C. nicholsonii*, and this species was not seen during the present survey. Records of other notable bryophytes included the nationally scarce *Fissidens polyphyllus*, which was locally abundant from SH5943046302 to SH5924746133 on rocks and soil banks beside several old mine shafts and along a small stream through the woodland.

Bryn-y-felin

The former mining site in the south-east of this area (at SH59124703) now comprises rough grazing with little indication of former mining and no open shafts, adits or mine spoil.

The main mining took place in the north-west (around SH58914723), where much of the mine is now within mature mixed woodland. There is a complex of deep, open shafts, old mine buildings and areas of exposed spoil. Much of the old mine spoil has become overgrown and that which remains open largely comprises coarse rocky material. There were no previous records of *C. massalongi* or *C. nicholsonii* from Bryn-y-felin and neither was found during the present survey. Scattered, small colonies of the nationally scarce *F. polyphyllus* were noticed on the banks of a small stream through rough pasture close to the mine (at SH5910847036).

Drws-y-coed

The former mining area covers an extensive area, spread across the north-facing hillside behind the village of Drws-y-coed. Both *C. massalongi* (Fig. 5) and *C. nicholsonii* were found during

Table 2. Details of colonies of *C. massalongi* and *C. nicholsonii*

Site	Species	Colony	Altitude (m)	Habitat	RL (%)*	Colony size (cm²)	Close associates
Aberglaslyn	*C. massalongi*	1	60	On old mine spoil of leat bank of disused copper mine in mixed woodland	5.0	1,000	*Diplophyllum albicans*, *Nardia scalaris*, *Solenostoma gracillimum*
Aberglaslyn	*C. massalongi*	2	70	On thin soil in crevice of metal-rich rock in disused copper mine shaft in mixed woodland	6.6	5	Nil
Drws-y-coed	*C. massalongi*	1	150	In crevice of metal-rich rock of disused copper mine adit on moorland slope	0.2	3	*Diplophyllum albicans*, *Pseudotaxiphyllum elegans*
Drws-y-coed	*C. nicholsonii*	1	160	On old copper mine spoil on north-facing moorland slope	NR†	Moderate	*Cephaloziella stellulifera*
Figra	*C. massalongi*	1	230	On metal-rich rock and thin soil over rock at entrance of disused copper mine adit	NR†	Large	NR†
Hermon Copper Bog	*C. massalongi*	1	120	On soil deep under overhang of stream bank	4.4	70	*Pogonatum aloides*, *Solenostoma gracillimum*
Hermon Copper Bog	*C. massalongi*	2	120	On face of eroding, peaty stream bank	23.1	50	Nil
Hermon Copper Bog	*C. massalongi*	3	130	On soil and thin silt over rocks under overhangs of stream bank	0.8	1,100‡	*Pogonatum aloides*
Hermon Copper Bog	*C. massalongi*	4	150	On thin humic matter in rocky crevices of small seasonal stream	NR†	200	Nil
Hermon Copper Bog	*C. massalongi*	5	145	On spoil between crevices of stonework of old mine building	NR†	150	Nil
Hermon Copper Bog	*C. massalongi*	6	145	On clayey spoil under overhangs of stream bank	7.6	1,500‡	*Solenostoma gracillimum*
Pant-y-wrach	*C. massalongi*	1	40	On spoil, stream bank and bases of building ruins at disused copper mine in mixed woodland	15.3	Very large	*Diplophyllum albicans*, *Cephaloziella rubella*, *Nardia scalaris*, *Solenostoma gracillimum*

*RL, Relative light; †NR, not recorded; ‡approximate total of scattered subcolonies.

the survey, but in small amounts (Table 2). The former was recorded here previously, by C.V.B. Marquand in 1921, while the latter was not known. In addition, moderate-sized colonies of the nationally scarce *C. stellulifera* were noted on old mine spoil at SH5448753389 and SH5447353393 (outside the SSSI). A small colony of the nationally scarce *Pohlia flexuosa* was also noticed at SH5463053375, on thin silt in a vertical crevice of metal-rich rock in the deep shade of a disused mine adit beside the B4418 (also outside the SSSI).

Figra

Only a very brief visit was made to Figra, where the old mine is located high on a hillside and now partly within a conifer plantation. A record of *C. nicholsonii* from 'Bontddu' by D.A. Jones in 1921 may refer to this site, while D.T. Holyoak recorded *C. massalongi* in 1999. Spoil around the mine was searched briefly, but neither species was found, though a small population of *C. stellulifera* was present. Only one old mine adit was visited, where a large population of *C. massalongi* was present (Table 2). A thorough search of the site would be worthwhile to determine the extent of the *C. massalongi* population and to assess the continued presence of *C. nicholsonii*. It is notable that the site is not protected within a SSSI.

Hermon Copper Bog

A very thorough search of this site was undertaken, from where *C. massalongi* was first recorded in 1996 (Blackstock & Yeo, 1996), when it was '*seen in several places, characteristically on steep, moist soil banks, shaded by overhanging soil slumps, by the outflow stream running through the bog.*' A total of six colonies were found during the survey (Table 2), totalling about 3,070 cm^2. The bulk of the population is located on the eroding banks of a main ditch that runs through the centre of the site (Fig. 6).

Pant-y-wrach

The former mining area is relatively small, with a few scattered shafts and adits spread across a steep north-west-facing hillside partly within a conifer plantation (Fig. 7). A collection of records of *C. massalongi* from 1906 to 1918 and a small number made during the latter half of the last

△ Fig. 5. Location of a small colony of *C. massalongi* on the metal-rich wall of an old mine adit at Drws-y-coed, in deep shade. *D. Callaghan*

△ Fig. 6. Main ditch running through Hermon Copper Bog, where colonies of *C. massalongi* occur beneath the overhanging banks. *D. Callaghan*

△ Fig. 7. Derelict mine at Pant-y-wrach, where a large population of *C. massalongi* stretches from the roadside up the hill. *D. Callaghan*

century from 'Llanfrothen' and 'Penrhyndeudraeth' may refer to this location, though there are other old copper mine sites in the area. During the present survey, a sizeable population of *C. massalongi* was found (Table 2), probably one of the largest in Britain currently. There are no previous records of *C. nicholsonii* and this species was not seen during the present survey.

Sygun

This is an extensive area of old copper-mining activity spread over hilly, moorland terrain. Large parts of the lower slopes and gullies within the former mining area now support dense swathes of *Rhododendron*, though large-scale clearance of this invasive is being undertaken. Good survey coverage was attained and a total of 13 mine shafts, adits and associated spoil were searched for the two target species. The spoil around the adits of the site tends to be coarse, rocky material and it appears that the ore from the mines was transported to riverside locations for processing, for example beside the Afon Glaslyn at SH6043148939. This latter area was searched for old spoil habitat, but none was evident and the area has been extensively redeveloped since mining operations ceased. There are no previous records of *C. massalongi* or *C. nicholsonii* at Sygun and neither was found during the present survey.

Soil conditions

Soil analysis results are shown in Table 3. The levels of elements indicated are broadly similar to those reported from Cornish sites for *C. massalongi* and *C. nicholsonii* (Callaghan & Bowyer, 2011; Rouen, 2000). The soils typically show a very high content of iron and concentrations of various other elements well above their ambient background concentration. Several elements are often present at levels that are toxic to normal plant growth, such as arsenic and manganese. However, the most characteristic is copper, with highly elevated concentrations found in all samples and attaining an impressive 36,800 p.p.m. in a sample from Coed Pant-y-wrach (the ambient background concentration of copper in rural soils is around 17 p.p.m.).

Light conditions

Light levels sampled at eight colonies of *C. massalongi* show that they typically grow in shaded conditions, usually <10% RL (Table 2), which is characteristic of bryophytes and especially liverworts (Marschall & Proctor, 2004). An impressively low light level was found at the Drws-y-coed colony (2.5 lux; 0.2% RL), where the plant grew within an old mine adit (Fig. 4). It is perhaps not unusual for many bryophyte species to be able to tolerate such low irradiance conditions. For example, Pentecost & Zhaohui (2001) found that 14 species of moss and liverwort grew in a single limestone cave at light levels below 0.5% RL, and that *Fissidens dubius* and *Thamnobryum alopecurum* were present at 0.2% RL. Toda (1918) concluded that the optimum RL for the famously shade-tolerant *Schistostega pennata* was 0.005–0.02% RL, while Bisang (1985) reported field measurements for colonies of the epiphytic

Table 3. Concentrations of chemical elements in soil samples

Element	ABC*	LOD†	Concentration (p.p.m.) in soil sample‡							
			Aber-glaslyn	Pant-y-wrach (A)	Pant-y-wrach (B)	Figra	Hermon (A)	Hermon (B)	Hermon (C)	Hermon (D)
Antimony (Sb)	0.6–1.5	16	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Arsenic (As)	7.1	3	5,310 (238)	437 (25.9)	210 (11.2)	1,140 (24.7)	106 (3.28)	132 (5.57)	78.2 (4.79)	35 (2.07)
Bismuth (Bi)	0.2–1.4	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cadmium (Cd)	0.3	10	16.5 (5.32)	<LOD	<LOD	8 (2.74)	<LOD	<LOD	<LOD	<LOD
Chromium (Cr)	29	10	<LOD	<LOD	92.3 (47.1)	<LOD	<LOD	<LOD	<LOD	<LOD
Cobalt (Co)	6.6–9.0	9	419 (34.1)	196 (16.1)	70 (5.28)	176 (19.9)	217 (18.7)	<LOD	137 (6.73)	123 (3.9)
Copper (Cu)	17	6	1,430 (43.6)	12,200 (631)	36,800 (5,810)	2,816 (102)	3,660 (72.8)	16,200 (647)	7,110 (261)	6,670 (805)
Gold (Au)	NM	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Iron (Fe)	NM	10	261,000 (9,130)	153,000 (6,000)	93,200 (9,420)	149,000 (3,080)	154,000 (2,840)	256,000 (9,120)	33,100 (3,050)	29,100 (3,260)
Lead (Pb)	37	3	<LOD	196 (13.4)	<LOD	245 (15.2)	16.2 (3.89)	<LOD	47.2 (2.92)	18.6 (4.65)
Manganese (Mn)	420	14	<LOD	20,200 (1,970)	40,600 (8,240)	5,510 (356)	1,190 (114)	30,700 (1,660)	169 (4.93)	334 (46.1)
Mercury (Hg)	0.1	4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Molybdenum (Mo)	0.9–1.8	2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Nickel (Ni)	16	8	<LOD	<LOD	96.5 (18.5)	<LOD	<LOD	<LOD	<LOD	<LOD
Rubidium (Rb)	7.0–40	2	<LOD	80.8 (3.5)	30.3 (5.36)	<LOD	71 (3.54)	23 (3.59)	79.2 (2.18)	71 (6.7)
Selenium (Se)	1.3–3.3	1	5.25 (1.44)	<LOD	<LOD	<LOD	<LOD	<LOD	5.6 (0.98)	<LOD
Silver (Ag)	ND–0.3	14	<LOD	<LOD	<LOD	5 (2.16)	6.6 (2.48)	<LOD	<LOD	<LOD
Strontium (Sr)	4.9–9.1	2	<LOD	<LOD	<LOD	<LOD	12.4 (3.78)	<LOD	64.8 (1.56)	69.6 (6.53)
Tin (Sn)	2	15	34.8 (12.9)	<LOD	79 (39.4)	<LOD	<LOD	<LOD	<LOD	<LOD
Titanium (Ti)	178	15	<LOD	4,240 (672)	<LOD	<LOD	13,000 (6,330)	<LOD	9,020 (3,470)	9,570 (4,020)
Tungsten (W)	ND–0.3	6	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Vanadium (V)	39	12	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Zinc (Zn)	66	3	<LOD	210 (12.4)	1,930 (304)	143 (11.1)	62 (8.13)	<LOD	44.2 (3.14)	<LOD
Zirconium (Zr)	ND–0.2	2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	82 (3.52)	78.2 (9.29)

*ABC, Ambient background concentration, defined from values for rural soils in the UK (data from Ross *et al.*, 2007). Single values are the median concentration, while ranges (minimum to maximum) are given for elements measured from only a limited set of sites. ND, Not detected; NM, not measured.

†The typical limit of detection (LOD) of each element for the Innov-X Omega Xpress operated in 'soil mode' (*Application Brief: Omega Xpress for Mining*. Woburn: Innov-X Systems Inc.). Note that LODs vary with test conditions, interfering elements and other factors, and are presented for guidance only.

‡Mean value from four subsamples of each soil sample with standard error in parentheses. <LOD, Limit of detection not exceeded for at least one subsample. Values rounded to three significant figures.

liverworts *Frullania dilatata* (2.8–20% RL), *F. tamarisci* (1.2–18.7% RL) and *F. fragilifolia* (1.1–5.3% RL). The shaded conditions in which *C. massalongi* grows may in part be the result of an evolutionary strategy that helps to escape the problems of desiccation and competition.

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