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RESULTS OF A SURVEY TO MONITOR THE EU ANNEX I HABITAT CALAMINARIAN GRASSLAND, 2018

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An Roinn Cultúir,
Oidhreachta agus Gaeltachta
Department of Culture,
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Front cover, small photographs from top row:

Coastal heath, Howth Head, Co. Dublin, Maurice Eakin; **Red Squirrel** *Sciurus vulgaris*, Eddie Dunne, NPWS Image Library; **Marsh Fritillary** *Euphydryas aurinia*, Brian Nelson; **Puffin** *Fratercula arctica*, Mike Brown, NPWS Image Library; **Long Range and Upper Lake**, Killarney National Park, NPWS Image Library; **Limestone pavement**, Bricklieve Mountains, Co. Sligo, Andy Bleasdale; **Meadow Saffron** *Colchicum autumnale*, Lorcan Scott; **Barn Owl** *Tyto alba*, Mike Brown, NPWS Image Library; **A deep water fly trap anemone** *Phelliactis* sp., Yvonne Leahy; **Violet Crystalwort** *Riccia huebeneriana*, Robert Thompson

Main photograph:

Calaminarian grassland habitat beside Muckross Lake, Killarney National Park, Co. Kerry, Rory L. Hodd

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Executive Summary

Calaminarian grasslands of the *Violetalia calaminariae* (Natura code 6130) are listed on Annex I of the EU Habitats directive, obligating member states to report on the condition of this habitat at regular intervals, under Article 17 of the directive. This survey reports on the status and condition of 29 sites previously identified as containing Calaminarian grassland, and defines a monitoring methodology to be applied across these sites. Calaminarian grassland is a habitat that occurs on metalliferous substrates, in Ireland occurring only on spoil artificially derived from mining activity. Its presence in Ireland is indicated by the presence of metalliferous bryophyte (moss and liverwort) and vascular plant species, with a suite of rare bryophytes present in this habitat that are of high conservation value and are not found in other habitats. One moss species of this habitat, *Ditrichum cornubicum*, is of particular conservation importance, as it is only known worldwide to occur at three locations, one of which is in Ireland.

The results from this survey show that the Calaminarian grassland is undergoing a continuing decline, as the toxicity of the spoil exposed by mining activities decreases over time. This is leading to succession to other habitats, particularly scrub, heath and acid grassland, and the loss of Calaminarian grassland habitat and populations of the species that require this habitat to survive. As most old mine sites are considered to be marginal land, human activities are also impacting this habitat, with pollution, land reclamation and recreational and agricultural activities negatively impacting many sites. It was calculated that 6.2 ha of Calaminarian grassland occurs within the sites surveyed, which differs greatly from the previous survey of 2008, when a figure of 13.6 ha was estimated. This difference is due to more accurate methodology being used for this survey, and does not represent a dramatic decline in the habitat.

Of the 29 sites surveyed and based on their *Area*, *Structure and functions* and *Future prospects*, nine were as assessed as being in Favourable condition, 13 were as assessed as being in Unfavourable-inadequate condition and seven were as assessed as being in Unfavourable-bad condition. Two sites in particular, Shallee and Knockmahon Village, of those that are of high importance for rare bryophytes, are in poor condition and require conservation effort to maintain their importance. Two rare bryophyte species, *Ditrichum plumbicola* and *Cephaloziella integerrima*, were found to have declined at Calaminarian grassland sites, and may be in danger of extinction in Ireland. *D. plumbicola* was not refound at two sites where it previously grew, at one of which it grew in good quantity in 2008. It was refound at a third site, but in very small quantity and poor condition. *C. integerrima* was found at only one site, where it showed a marked decline due to pollution. *Ditrichum cornubicum* is also of concern, as it was only found in very small quantity at its only known site.

A range of conservation measures are required to maintain and improve Calaminarian grassland habitat in Ireland, particularly at sites that are important for rare bryophytes. Clearance of scrub at a number of sites is required to maintain the habitat there, and minimising human impacts such as trampling and dumping would be beneficial across many sites. In order to improve the quality of habitat for rare bryophytes, removal of sources of pollution at one site is required, and removal of trees that are depositing leaf litter on Calaminarian grassland may be required at other sites. A beneficial measure across a number of sites would be to disturb and scrape back the surface of the mine spoil to expose more strongly metalliferous spoil on which metalophyte bryophytes can grow. Even with conservation measures in place, a continued decline of this habitat is likely to take place over time.

Acknowledgements

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1 Introduction

1.1 Calaminarian grassland monitoring survey 2017–2018

This report describes the results from a survey of the EU Annex habitat Calaminarian grasslands of the *Violetalia calaminariae* (Natura code 6130) in Ireland, commissioned by the National Parks and Wildlife Service (NPWS) and carried out during 2018, and consists of a summary and discussion of the outcomes of the survey, and an Appendix with 29 site-specific reports. This work is required to collect data for the fulfilment of Ireland's legal obligation, under Article 17 of the EU Habitats Directive [92/43/EEC], to report on the conservation status of habitats listed on Annex I. Reporting is required for the current six-year reporting period of 2013–2018. This will assess the status of this habitat in Ireland under the parameters of *Range*, *Area*, *Structure and functions* and *Future prospects* (DG Environment, 2017). The conservation status of Calaminarian grassland was assessed as 'Inadequate' in the previous reporting period of 2007–2012 (NPWS, 2013). Under the Habitats Directive, habitats should be maintained in a favourable conservation status in each member state across their range.

1.2 Calaminarian grassland

Calaminarian grassland is a habitat which forms in areas that are rich in heavy metals, leading to the development of vegetation that is tolerant of high concentration of toxic elements such as Copper (Cu), Lead (Pb) and Zinc (Zn), in places where most species are unable to grow. In Ireland, this habitat is restricted to spoil heaps in the vicinity of old mine workings (Holyoak & Lockhart, 2011). Of particular note is a suite of rare bryophyte species which are tolerant of heavy-metal-rich conditions and are restricted to ground with high concentrations of Cu, Pb and Zn. These species include *Cephaloziella nicholsonii, C. integerrima, C. massalongi, Ditrichum cornubicum, D. plumbicola, D. lineare, Scopelophila cataractae* and *Pohlia andalusica*, all of which are listed as threatened in the Irish red data list (Lockhart *et al.*, 2012a) and five of which are protected under the Flora (Protection) Order, 2015. *C. massalongi, C. nicholsonii, D. cornubicum* and *S. cataractae* are obligate Cu bryophytes, while the only obligate *Pb* bryophyte is *D. plumbicola* (Holyoak & Lockhart, 2011). All other indicators are facultative metallophytes. *D. cornubicum* is of particularly high conservation significance, as it is only known from three sites worldwide, one of which is located in Ireland (Campbell *et al*., 2017, Lockhart *et al*., 2012b) and is listed as *Endangered* worldwide on the IUCN Red List (Bryophyte Specialist Group, 2000). As the soil toxicity declines over time, the habitat becomes less suitable for metallophyte species, particularly the obligate metallophyte species, and they will eventually be outcompeted and lost (Callaghan & Bowyer, 2011). A range of other bryophytes, vascular plant and lichen species are indicative of the presence of Calaminarian grassland, although many of these are not restricted to this habitat. Calaminarian grassland sites are located primarily in counties Wicklow and Cork, with other sites in counties Waterford, Tipperary, Kerry, Clare, Wexford, Dublin and Donegal (Figure 1). Five SACs (Special Areas of Conservation) list Calaminarian grassland as a qualifying interest. These are Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment SAC (365), East Burren Complex SAC (1926), Wicklow Mountains SAC (2122), Kenmare River SAC (2158) and Silvermines Mountains West SAC (2258).

In comparison to Britain and other parts of Europe, Ireland's area of Calaminarian grassland is of limited extent and has a small amount of variation, as it only occurs on artificial spoil derived from past mining operations (Holyoak & Lockhart, 2011). Calaminarian grassland varies in character across its range in Europe, but all stands have in common that they are characterised by the presence of specialist species tolerant of, or requiring, high concentration of heavy metals. Within the EU, Calaminarian grassland is known from Austria, Belgium, France, Germany, Ireland, the Netherlands, Slovenia and the UK, and is assessed as being 'Endangered' in the European Red List of habitats, based on a recent reduction in area of over 50% (Dengler & Janssen, 2016).

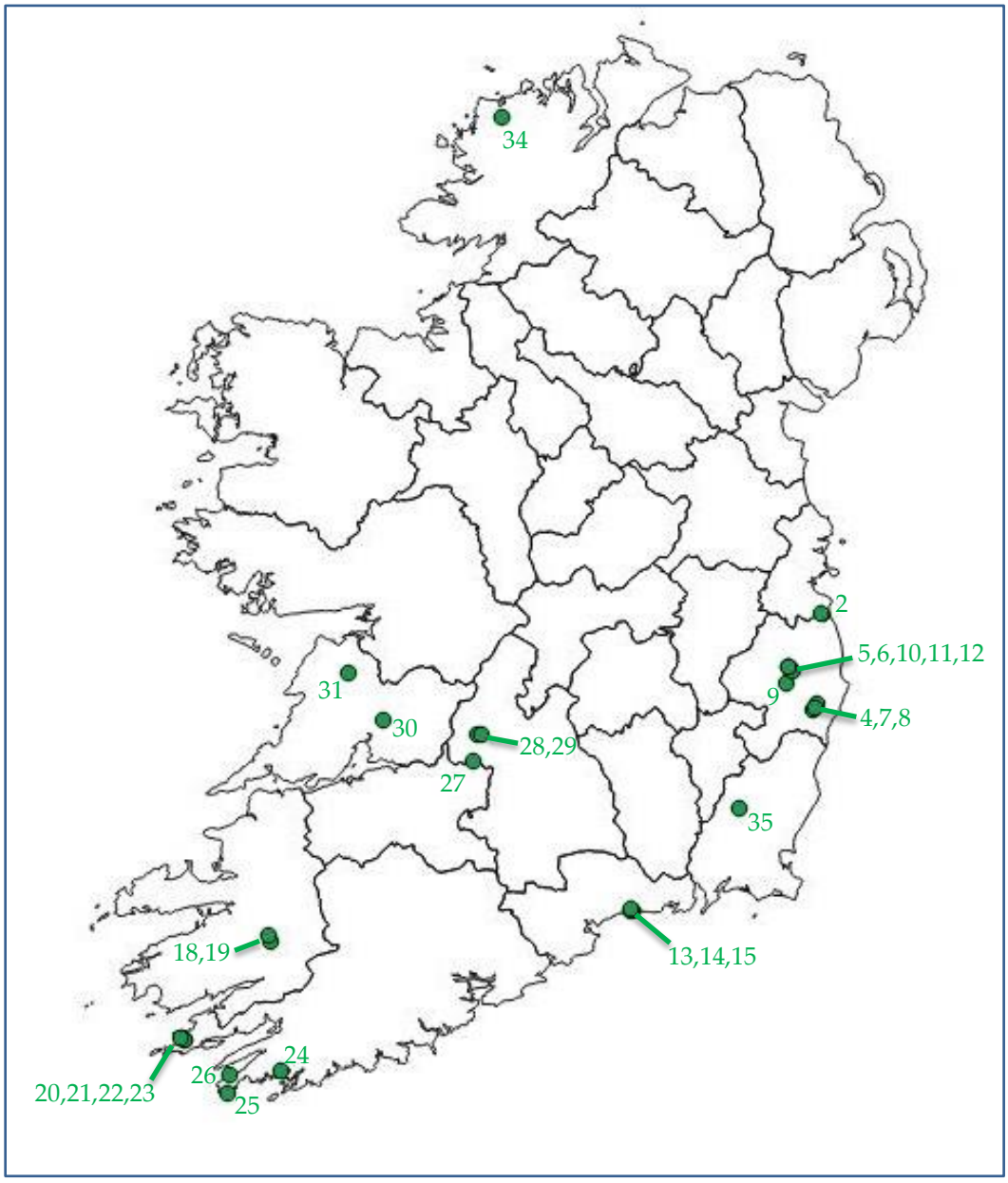

Figure 1 Map of Ireland showing the location of Calaminarian grassland sites surveyed. Site numbers as per Table 1.

In Britain, Calaminarian grassland occurs in both natural and man-made situations, covering a far larger area than in Ireland, and many stands support assemblages of rare vascular plant species such as *Thlapsi caerulescens*, *Epipactis dunensis*, *Viola lutea* and *Cochlearia pyrenaica* (JNCC, 2018; Richards & Waite, 2017). In Ireland, Holyoak (2008) identified few vascular plant indicators of Calaminarian grassland, the exception being *Minuartia verna*, which grows at one Calaminarian grassland site in Ireland, and inland, lowland stands of *Armeria maritima* and *Silene uniflora*. Prior to the work of Holyoak, bryophytes were not recognised as important components of Calaminarian grassland in Ireland. The few studies that mentioned the vegetation of mine spoil (Braun-Blanquet & Tüxen, 1952; Doyle, 1982; Lötschert, 1982) focus on the vascular vegetation, describing the vegetation of copper mines in the Killarney National Park, characterised by *Armeria maritima* and *Silene uniflora*, and the vegetation of two mine sites in the Burren (one now lost) characterised by *Minuartia verna.* In common with many old mine sites in Cornwall in southwest England, most Calaminarian grassland at Irish sites is species-poor and is defined by the presence of metallophyte bryophyte species. In addition to the rare bryophytes listed above, a number of other bryophytes, such as *Cephaloziella stellulifera*,

Weissia controversa var. *densifolia*, *Solenostoma gracillimum* and *Gymnocolea inflata*, species that are also found in a range of other habitats, are indicative of Calaminarian grassland in Ireland. Therefore, bryophytes are considered to be key indicators of the presence and quality of Calaminarian grassland in Ireland.

1.3 Previous surveys

The Article 17 assessment carried out in 2013 was informed by a national survey of Calaminarian grassland undertaken in 2008 (Holyoak, 2008), which was the first systematic survey of Calaminarian grassland undertaken in Ireland. The 2008 survey visited 35 sites that were thought to have potential for Calaminarian grassland to be present. Holyoak (2008) identified 29 sites that contained vegetation corresponding to the EU Annex I habitat 6130, Calaminarian grassland, and estimated a total national area of 13.6 ha. These 29 sites were resurveyed in 2018 and their condition was re-assessed. The 2008 survey greatly extended the known range and extent of Calaminarian grassland in Ireland and resulted in the discovery of a number of rare metallophyte species new to the country (Holyoak & Lockhart, 2009). The survey also assessed the quality of the Calaminarian grassland present in Ireland (Holyoak, 2008). However, it was not possible during the 2008 survey to establish a standard monitoring protocol that would be applicable across all sites, due to the small number of Calaminarian grassland sites and the range of variation present across the habitat in Ireland. Therefore, a suite of specialised metallophyte bryophyte species indicative of heavy metal-rich conditions were used to indicate the presence and quality of Calaminarian grassland habitat (Holyoak, 2008). Overall, the habitat was assessed as being in Unfavourable-inadequate condition, due to minor decreases in area since the Habitats Directive came into force in Ireland (in 1994) and a range of ongoing pressures, such as dumping of waste, trampling, erosion and succession (NPWS, 2013). Since the 2008 survey, Calaminarian grassland and the associated bryophytes have been surveyed in more detail in two areas – two mines at Allihies, Co. Cork (Callaghan, 2013) and a number of sites around the Avoca valley, Co. Wicklow (Callaghan, 2017). The results of these surveys were broadly similar to those presented by the 2008 survey and showed *Cephaloziella massalongi* and *C. nicholsonii* to be frequent at Allihies.

1.4 Aims of this survey

The 2018 survey was commissioned to:

- define monitoring and assessment methodologies for Calaminarian grassland in Ireland
- visit the 29 Calaminarian grassland sites present in Ireland and describe and map the Calaminarian grassland habitat present, as well as other habitats occurring on the mine spoil resource
- map the location and extent of rare metallophyte species at each site
- monitor and assess the conservation status of Calaminarian grassland present on a site by site basis, with reference to the previous survey of 2008
- provide the data collected to feed into a National Conservation Status Assessment of Calaminarian grassland for reporting under Article 17 of the EU Habitats Directive

2 Methodology

2.1 Site selection

The 29 sites selected for survey (Table 1) were based on those surveyed by Holyoak (2008). In total, 35 sites were surveyed by Holyoak (2008), but six of these were found either not to have Calaminarian grassland habitat, or were modern mines (namely at Tynagh and Galmoy) where vegetation on fine silty tailings was identified as Calaminarian grassland, but was very species-poor and ephemeral in nature and of no conservation value. The sites selected for the 2018 survey are primarily located in the south and east of Ireland (Figure 1), with a concentration of sites in Co. Wicklow (nine sites) and Co. Cork (seven sites) and an outlying site in the north of Co. Donegal. Mining ceased at the majority of these sites many decades ago, with the main minerals mined being Copper (Cu – 17 sites) and Lead (Pb – 13 sites), from which the residual toxicity supports the formation of Calaminarian grassland.

2.2 Assessment criteria

Prior to beginning the survey of Calaminarian grassland sites, it was necessary to devise a standardised set of criteria for assessing and monitoring their quality that could be applied on a site by site basis and feed into a national assessment of Calaminarian grassland in Ireland. An exhaustive review of the literature available on the monitoring and survey of Calaminarian grassland was undertaken. The outputs from the 2008 survey were studied and reviewed in detail, with particular reference to the assessment criteria and methodologies. The chosen criteria (Table 2) are used to assess each site under the three parameters: *Area*, *Structure and functions* and *Future prospects*.

2.2.1 *Area*

The area of a site is assessed as being in Favourable condition if there is no sign of loss of area or if a very small area (< 2%) has been lost, with no overall impact on the quality of a site is evident. If a moderate decrease (2–15%) in area is detected, so that the integrity of the site is still intact, but it is clearly in decline, a site is considered as Unfavourable-inadequate. If the site has shown a major decrease (> 15%) since the last survey, or if all Calaminarian grassland habitat has been lost, it will be assessed as in Unfavourable-bad condition.

Table 1 List and details of sites selected for survey in 2018, based on the survey of Holyoak (2008).

Site no.	Site	County	Irish Grid ref.	Metal(s)	Bedrock	Recorder	Date	Rare bryophytes present 2008	Rare bryophytes confirmed 2018	Spoil area (ha) 2018	6130 area (ha) 2018
02	Ballycorus	Dublin	O225208	Pb	mica-schist	Rory Hodd	15/02/2018	*Cephaloziella massalongi*, *Ditrichum plumbicola*	*Ditrichum plumbicola*	0.174	0.106
04	Nr. Connary Hall	Wicklow	T211838	Cu	shale, etc.	Rory Hodd	27/07/2018			3.063	0.613
05	Glendasan	Wicklow	T098981	Pb	granite, schist	Rory Hodd	22/02/2018	*Cephaloziella massalongi*, *Cephaloziella nicholsonii*, *Ditrichum plumbicola*	*Cephaloziella nicholsonii*	2.315	1.268
06	Foxrock Mine	Wicklow	T104982	Pb	granite, schist	Rory Hodd	13/03/2018			1.989	0.273
07	Ballymurtagh	Wicklow	T192815	Cu, S, Fe	schistose	Rory Hodd	27/07/2018			4.279	0.004
08	Tigroney West	Wicklow	T199822	Cu, S, Fe	schistose	Rory Hodd	27/07/2018	*Cephaloziella nicholsonii*		0.891	0.003
09	Ballinafunshoge	Wicklow	T082925	Pb	schistose	Rory Hodd	12/03/2018			1.916	0.127
10	Vale of Glendasan	Wicklow	T108977	Pb	schistose	Rory Hodd	13/03/2018			3.124	0.519
11	Brockagh	Wicklow	T093992	Pb	schistose	Rory Hodd	16/02/2018			0.779	0.109
12	E. of L. Nahanagan	Wicklow	T092988	Pb	schistose	Rory Hodd	16/02/2018			0.205	0.035
13	Bunmahon	Waterford	X444986	Cu	slate	Nick Hodgetts	14/02/2018	*Cephaloziella massalongi*, *Pohlia andalusica*	*Cephaloziella massalongi*, *Pohlia andalusica*	0.307	0.061
14	Tankardstown	Waterford	X451986	Cu	slate	Nick Hodgetts	14/02/2018			0.316	0.006

Site no.	Site	County	Irish Grid ref.	Metal(s)	Bedrock	Recorder	Date	Rare bryophytes present 2008	Rare bryophytes confirmed 2018	Spoil area (ha) 2018	6130 area (ha) 2018
15	Knockmahon village	Waterford	X438990	Cu	metamorphic	Nick Hodgetts	15/02/2018	*Cephaloziella integerrima, C. nicholsonii, Pohlia andalusica*	*Cephaloziella integerrima, C. massalongi, C. nicholsonii, Pohlia andalusica*	0.620	0.279
18	Muckross Lake	Kerry	V948859	Cu	limestone	Rory Hodd	07/03/2018	*Cephaloziella massalongi*		0.043	0.027
19	Ross Island	Kerry	V945880	Cu, Pb	limestone	Rory Hodd	07/03/2018	*Cephaloziella massalongi*	*Cephaloziella massalongi*	0.145	0.055
20	Allihies (Mountain)	Cork	V590458	Cu	sandstone	Rory Hodd	02/04/2018	*Cephaloziella integerrima, C. massalongi, C. nicholsonii, Ditrichum cornubicum, D. lineare, Pohlia andalusica, Scopelophila cataractae*	*Cephaloziella massalongi, Ditrichum cornubicum*	4.850	1.316
21	N. of Caminches	Cork	V594455	Cu	sandstone	Rory Hodd	31/03/2018	*Pohlia andalusica*		0.259	0.026
22	NE. of Caminches	Cork	V597455	Cu	sandstone	Rory Hodd	31/03/2018			0.133	0.007
23	Dooneen	Cork	V577459	Cu	sandstone	Rory Hodd	31/03/2018	*Cephaloziella massalongi*		0.881	0.226
24	Cappagh	Cork	V990324	Cu	sandstone	Rory Hodd	06/04/2018	*Cephaloziella nicholsonii, Pohlia andalusica, Scopelophila cataractae*	*Cephaloziella massalongi, Pohlia andalusica*	0.088	0.063
25	Brow Head	Cork	V771235	Cu	sandstone	Rory Hodd	07/04/2018			0.196	0.007
26	Polleenateada	Cork	V780306	Cu	sandstone	Rory Hodd	06/04/2018			0.292	0.143
27	Lackamore	Tipperary	R788602	Cu	shale	Nick Hodgetts	16/02/2018			0	0
28	Shallee	Tipperary	R806712	Pb	shale	Nick Hodgetts	19/02/2018	*Cephaloziella nicholsonii, Ditrichum plumbicola*	*Cephaloziella nicholsonii*	2.357	0.472
29	Garryard West	Tipperary	R826710	Pb, ?Zn	calc. shale	Nick Hodgetts	16/02/2018			0.133	0.040

Site no.	Site	County	Irish Grid ref.	Metal(s)	Bedrock	Recorder	Date	Rare bryophytes present 2008	Rare bryophytes confirmed 2018	Spoil area (ha) 2018	6130 area (ha) 2018
30	Ballyhickey	Clare	R417768	Pb	limestone	Nick Hodgetts	18/02/2018			0.056	0.011
31	Sheshodonnell East	Clare	R268969	Pb	limestone	Nick Hodgetts	18/02/2018			0.030	0.009
34	Keeldrum	Donegal	B903262	Pb	quartzite, etc.	Rory Hodd	16/03/2018			0.136	0.013
35	Caim Ballyhighland	Wexford	S885409	Cu	metamorphic	Nick Hodgetts	13/02/2018	*Cephaloziella nicholsonii, Scopelophila cataractae*	*Cephaloziella nicholsonii, Scopelophila cataractae*	0.700	0.350

Table 2 Assessment criteria to be applied on a site by site basis.

Parameter	Criterion	Result		Assessment
Area	Annual change in area	No or minor decrease		Favourable
		Moderate decrease		Unfavourable-inadequate
		Major decrease or complete loss		Unfavourable-bad
Structure and functions	No. of criteria passed	3		Favourable
		1–2		Unfavourable-inadequate
		0		Unfavourable-bad
	Number indicator spp.	≥1	Pass	
	Scrub encroachment	≤20%	Pass	
	Negative human impact	≤20%	Pass	
Future prospects				Favourable
				Unfavourable-inadequate
				Unfavourable-bad
Overall Assessment	All favourable			Favourable
	One or more Unfavourable-inadequate			Unfavourable-inadequate
	One or more Unfavourable-bad			Unfavourable-bad

2.2.2 *Structure and functions*

Due to variations in the characteristics and composition of Calaminarian grassland within and between sites, devising meaningful and robust criteria for *Structure and functions* was not a straightforward task. The primary criterion identified was the number of indicator species. The species used were those identified by Holyoak (2008) as indicative of Calaminarian grassland (Table 3). These consist primarily of bryophyte species that are only present on the site due to the presence of Calaminarian grassland habitat. Some of these are rare species that are restricted to metalliferous spoil (obligate metallophytes) and others are more widespread species that show an affinity to metalliferous mine spoil and would not otherwise be expected to occur at a site in the absence of such toxic substrate. The rare specialist bryophytes were not used as the sole indicators, as many of the monitoring sites do not, and have never had, any of these rare species present and could not pass this criterion regardless of the actual condition of the site. Therefore, the rare species can be considered as indicators of added value of a site, and a measure of the overall conservation value of a site, as opposed to indicators of the condition of a site, and have little bearing on whether a site passes or fails the assessment (in any site where rare metallophytes are present, there are also a number of more common indicators present). A number of vascular plant indicators were also included as indicators, primarily species that are usually found in coastal habitats, but are found growing inland on metalliferous spoil. These species were not considered as indicators in coastal sites, so the only effective vascular plant indicator species in coastal sites is *Minuartia verna*.

As Calaminarian grassland by its nature is species-poor, the presence of only one indicator species is required to pass the assessment on this criterion. The other criteria for *Structure and functions* are based on physical attributes of the habitat, namely the amount of scrub encroachment present and the percentage of the Calaminarian grassland vegetation impacted negatively by human activities. The threshold for both of these was set at 20% of the habitat affected, as anything beyond this would be indicative of a serious degradation of the habitat. In order for the *Structure and functions* to be assessed as Favourable, it is necessary for all three criteria to be passed.

Table 3 List of positive indicator species of Calaminarian grassland in Ireland (following Holyoak (2008)). These are used in the *Structure and functions* criterion 'Number of Indicator spp.'

Positive indicators:	
Obligate metallophytes:	*Cephaloziella massalongi*
	Cephaloziella nicholsonii
	Ditrichum cornubicum
	Ditrichum plumbicola
	Scopelophila cataractae
Other bryophytes:	*Bryum pallescens*
	Cephaloziella integerrima
	Cephaloziella stellulifera
	Ditrichum lineare
	Gymnocolea inflata
	Solenostoma gracillimum
	Pohlia andalusica
	Scapania compacta
	Weissia controversa var *densifolia*
Vascular plants:	*Minuartia verna*
	*Armeria maritima**
	*Plantago maritima**
	*Silene uniflora**

*in inland, lowland sites only

There are a number of reasons why it would be inadvisable for the presence or absence of rare species to have a direct bearing on the assessment of a site. Identifiable specimens of these species can be very difficult to find, particularly *Cephaloziella* species, with weather conditions and time of year influencing how easy they are to locate and whether or not fertile plants suitable for identification can be located. The taxonomy of *Cephaloziella* species is complex and uncertain, and there seems to be much variation within species, with material collected from the same location being identified as different species by different bryologists. Therefore, whether or not any species of *Cephaloziella* has been identified from a site cannot be used as a reliable indicator of site condition, and the absence of confirmed specimens of any particular *Cephaloziella* species from a site should not be taken as a sign that the site is in poor condition. If there is a genuine loss of a species, it is likely that this will be

accompanied by an associated loss of habitat or clear impact, which will be accounted for elsewhere in the assessment.

Due to lying snow in early 2018, many of the bryophytes present were in poor condition and formed indistinct, mostly non-fertile mats during most of the survey, making identification of some species difficult and the locating of good material for collection virtually impossible.

2.2.3 *Future prospects*

Future prospects were determined with respect to the other assessment criteria, based on the threats and pressures currently present, and how these and other threats and pressures are likely to impact the site in the future, both between now and the next monitoring period, and in the longer term. These site-based assessments will feed into the overall national assessment of Calaminarian grassland in Ireland.

2.3 Site packs

Site packs were prepared for all 29 sites to aid survey in the field. These consisted of a recording sheet to record all data required for the individual site reports and assessments. Aerial photographs of each site were prepared, overlain with the location of relevés from the 2008 surveys, to enable comparison between the 2008 and 2018 surveys. A copy of each site report and associated maps from 2008 was also included in each site pack. Before entering the field, a risk assessment was completed for the entire project and a risk assessment form was filled in each day before entering the field to account for hazards, and to mitigate against them at each site. As this project required lone working, a strict check-in protocol was employed. A licence under Section 21 of the Wildlife Act to collect species protected under the Flora (Protection) Order, 2015 was obtained and local and regional NPWS staff were liaised with to obtain permission for access to sites.

2.4 Field survey

As winter is the best time for undertaking survey of this habitat, when bryophytes are normally most easily located and identified, the majority of sites were surveyed between February and April 2018. The extent of the mine spoil resource was mapped at each site. The percentage of each habitat (following Fossitt (2000)) on the mine spoil area was obtained, with particular attention paid to the amount of Calaminarian grassland habitat present. As the habitats present at most sites occur in an intimate mosaic, and the areas of Calaminarian grassland are generally patchy and rarely form a large unbroken extent, it was necessary to map the vegetation at each site as a mosaic. It was not feasible to individually map patches of habitat. However, if there were significant variations in vegetation between areas of a site, multiple polygons were created. Mapping was carried out using a combination of handheld GPS and annotation on field maps.

A general description of both the site and the Calaminarian grassland habitat was made, noting the composition, structure and cover of the habitat, with reference to data recorded during the 2008 survey. Any apparent changes since the 2008 survey were recorded. A list of key species of bryophytes, lichens and vascular plants was made at each site, with the grid reference (10-figure) of populations of notable metalliferous species recorded. In addition to taking the GPS coordinates of populations of metalliferous bryophyte species, their extent was recorded and notes on their occurrence were made. The species for which detailed information was recorded were *Cephaloziella integerrima, C. massalongi, C. nicholsonii, Ditrichum cornubicum, D. plumbicola, Scopelophila cataractae* and *Pohlia andalusica*. Specimens of critical species were collected for later verification. Photographs were taken of overall site, habitat, vegetation and species, as well as other features that were impacting the site, or may impact the site in the future.

Land use and other physical impacts on the site were noted and all pressures and threats acting on sites were listed and ranked, following Ssymank (2011), and later cross referenced with the 2018 EU standard list of impact codes (Version 2.4 - Updated final version 07/05/2018, file named Pressures_Threats_Final_20180507.xls). Any conservation measures needed for the Calaminarian grassland habitat and metallophyte species at each site were noted.

2.5 Report writing and data processing

At the conclusion of fieldwork, all data collected were collated and converted to digital format. Based on this data, site reports were generated for each of the 29 sites. Nomenclature in this report follows Hill *et al.* (2008) for bryophytes, Smith *et al.* (2009) for lichens and Stace (2010) for vascular plants. Each site report (Appendix I, contained within a separate file) contains site and vegetation descriptions, species lists, notes on threats and pressures and conservation measures and a site-specific assessment of the Calaminarian grassland habitat. Any differences detected between 2008 and present were highlighted and discussed. Using Q-GIS, shapefiles were created for each of the 29 survey sites, showing the extent of the mine spoil resource and the locations of rare metallophyte species. These were overlaid on OSI Discovery Series maps, 1:5000 OSI maps and 2005 OSI aerial photographs and integrated into the site reports. Photographs were also integrated into the site reports and labelled and catalogued following the standard NPWS format.

All specimens collected were checked and identified using Paton (1999) for liverworts and Smith (2004) for mosses. All specimens of metallophyte species were lodged in the National Botanic Gardens, Glasnevin. Details for all populations of metallophyte species were entered into an Excel spreadsheet template, suitable for entry into Recorder 6.

3 Results

3.1 Summary of results

Full reports for all 29 sites are included in Appendix I (contained within a separate file). Overall, the survey highlighted the precarious position of Calaminarian grassland in Ireland, as it is a habitat in continual decline, with many threats and pressures acting on it. At least a small area of Calaminarian grassland was found at all but one site surveyed, with a range of types of Calaminarian grassland present. The most widespread type of Calaminarian grassland encountered was characterised by the presence of low, dense bryophyte mats, most usually dominated by *Cephaloziella* spp. or *Solenostoma gracillima*, with other species sometimes abundant including *Dicranella varia, Weissia controversa, Scapania compacta* and *Gymnocolea inflata*. The most frequent vascular plant in Calaminarian grassland habitat was found to be *Agrostis capillaris*, which sometimes forms almost monospecific stands on toxic spoil, most extensively on alluvial spoil in the Vale of Glendasan. *Armeria maritima* forms a significant component of the vegetation at a number of sites, mostly coastal, but is only indicative of Calaminarian grassland at one site, at Ross Island in Co. Kerry, as this is an inland site. Similarly, *Silene uniflora* is present at a number of sites, mostly coastal, but is only indicative of Calaminarian grassland at the inland sites of Ross Island and Muckross in Co. Kerry. The other vascular plant indicator, *Minuartia verna*, was recorded from one site, Sheshodonnell East in Co. Clare. Rare metallophyte bryophytes were reliably identified at nine sites, in varying condition and abundance. Generally, the most important sites for rare metallophyte species were the same as those identified by Holyoak (2008), although smaller populations of metallophyte species were found at Allihies and Glendasan, most likely due to adverse weather conditions than to a genuine decline. One site at which rare bryophytes have genuinely declined is Shallee, and this site can now be considered as being of less importance for bryophytes than it was in 2008.

A range of habitats were found to occur on spoil (Table 4); a mean of 27% of spoil at each site was covered by Calaminarian grassland, and a further 28% was covered by bare spoil (ED2 as per Fossit (2000)). The remainder was covered by a range of habitats, the most frequent of which were dry-humid acid grassland (GS3), dry heath (HH1) and scrub (WS1), occurring on spoil at 20, 16 and 15 sites respectively. These habitats have a high cover on some spoil areas, of up to 80%, illustrating the loss of toxicity from many spoil areas. Mixed woodland grows on spoil at two sites, and is likely to expand in the future. A significant portion of the mine spoil at a number of sites consisted of loose siliceous or calcareous rock, with no toxicity. Apart from Calaminarian grassland, few other Annex I habitats were found on spoil areas, the most widespread being Dry heath (Natura code 4030), which was recorded on spoil from sixteen sites. Although this heath is mostly species-poor and of low quality, all dry heath recorded from these sites corresponds to the Annex I habitat. Wet heath (Natura code 4010) was recorded, in small quantity, from three sites. Similarly, although it is not of high quality, all wet heath recorded from these sites corresponds to Annex I habitat.

Table 4 Area of spoil and percentage of spoil covered by 6130 Calaminarian grassland, and habitat (as per Fossitt, 2000). ED2 - Spoil and bare ground, GS3 - Dry-humid acid grassland, GA1 - Improved agricultural grassland, HH1 - Dry siliceous heath, ED3 - Recolonising bare ground, WS1 - Scrub, ER2 - Exposed calcareous rock, WD2 - Mixed broadleaved/conifer woodland, GS1 - Dry calcareous and neutral grassland , ER4 - Calcareous scree and loose rock, ER1 - Exposed siliceous rock.

Site	Spoil area (ha)	% 6130	% ED2	% GS3	% GA1	% HH1	% ED3	% WS1	% ER2	% WD2	% GS1	% ER4	% ER1
02 Ballycorus	0.174	61	15	20	0	0	0	1	0	0	0	0	3
04 nr Connarry Hall	3.063	20	25	10	0	35	0	5	0	0	0	0	0
05 Glendasan	2.315	54.8	4	3	0	22	0	0	0	0	0	0	2
06 Foxrock Mine	1.989	13.7	54	1	0	9	0	0	0	0	0	0	0
07 Ballymurtagh	4.279	0.1	75	0	0	10	1	10	0	3	0	0	0
08 Tigroney West	0.891	0.3	1	5	0	0	49	15	0	30	0	0	0
09 Ballinafunshoge	1.916	6.6	70	1	0	14	0	5	0	0	0	0	0
10 Vale of Glendasan	3.124	16.6	45	16	0	0	0	4	0	0	0	0	0
11 Brockagh	0.779	14	10	20	0	50	0	0	0	0	0	0	0
12 E. of L. Nahanagan	0.205	16.9	59	4	0	20	0	0	0	0	0	0	0
13 Bunmahon	0.307	20	5	50	0	15	0	0	0	0	0	0	0
14 Tankardstown	0.316	2	3	80	0	15	0	0	0	0	0	0	0
15 Knockmahon Village	0.620	45	20	5	0	0	0	23	0	0	0	0	0
18 Muckross Lake	0.043	62	5	0	0	0	0	20	3	0	0	10	0
19 Ross Island	0.145	37.6	25	0	0	0	0	2	0	11	0	21	0
20 Allihies	4.850	27.1	5	3	0	50	0	0	0	0	0	0	4
21 N. of Caminches	0.259	10	30	0	0	15	0	0	0	0	0	0	20
22 NE. of Caminches	0.133	5	82	5	0	3	0	0	0	0	0	0	1
23 Dooneen	0.881	25.6	15	23	2	27	0	1	0	0	0	0	0
24 Cappagh	0.088	71.8	13	4	0	9	0	0	0	0	0	0	3
25 Brow Head	0.196	3.6	56	13	0	24	0	0	0	0	0	0	0
26 Polleenateada	0.292	49	30	15	0	1	0	1	0	0	0	0	1
28 Shallee	2.357	20	37.5	0	0	1	0	40	0	0	0	0	0
29 Garryard West	0.133	30	30	0	0	0	0	40	0	0	0	0	0
30 Ballyhickey	0.056	20	15	0	65	0	0	0	0	0	0	0	0
31 Sheshodonnell East	0.030	30	15	0	0	0	0	0	30	0	25	0	0
34 Keeldrum	0.136	9.9	11	48	0	0	0	12	0	0	0	0	0
35 Caim Ballyhighland	0.700	50	35	10	0	0	0	5	0	0	0	0	0

3.2 *Area*

The total area of Calaminarian grassland across the sites surveyed was calculated as 6.17 ha (Table 5), which is significantly lower than that calculated by Holyoak (2008), at 13.58 ha. This is mainly due to the more accurate use of GIS for this survey to calculate exact figures, whereas Holyoak's calculations were estimated by eye from paper maps. In addition to Calaminarian grassland sites recorded, Holyoak also estimated that there was approximately a further 2 ha of the habitat present at Pb mines in Co. Wicklow, in the upper Glendasan valley, Glendalough and Glemalure, that had not been surveyed, but this was not included in the figure of 13.58 ha. There are also mines on a number of islands in Roaringwater Bay in West Cork with potential areas of Calaminarian grassland (C. Heardman, NPWS, pers. comm.). Therefore, the figure of 6.17 ha should be taken as a minimum area, rather than as an absolute area, although the total area of Calaminarian grassland in Ireland, including those sites mentioned above, is likely to be less than 10 ha. The two largest areas of Calaminarian grassland occur at Allihies, Co. Cork (1.32 ha) and Glendasan, Co. Wicklow (1.27 ha), which were also noted as the largest sites by Holyoak.

Although the difference in total area of Calaminarian grassland between 2008 and 2018 is mostly accounted for by the difference in methodology, a genuine decline has also taken place. One site, at Lackamore in Co. Tipperary, has been lost completely, with open spoil replaced by improved pasture, leading to the loss of all Calaminarian grassland. Significant declines in the area of Calaminarian grassland were apparent at a number of other sites, including Tankardstown, Co. Waterford, Shallee, Co. Tipperary and Muckross Lake, Co. Kerry. The area of the majority of sites including the largest and more important sites at Allihies, Co. Cork and Glendasan, Co. Wicklow seems to be relatively stable. An increase in area was recorded at one site, Keeldrum, Co. Donegal, due to the scraping back of soil with a digger, but the spoil exposed is weakly metalliferous and of little conservation value. Of the total area of Calaminarian grassland, 76% was deemed to be in good condition, while 24% was considered to be in bad condition.

Table 5 Area of 6130 Calaminarian grassland present at each site surveyed, trend in area (positive (+), neutral (0) or negative (-)) and area of habitat in good, not-good and unknown condition.

Site	6130 Area (ha)	Trend	Area (ha) in good condition	Area (ha) in not- good condition	Area (ha) unknown condition
02 Ballycorus	0.106	(-)	0.032	0.074	0
04 nr Connarry Hall	0.613	0	0.613	0	0
05 Glendasan	1.268	0	1.141	0.127	0
06 Foxrock Mine	0.273	0	0.273	0	0
07 Ballymurtagh	0.004	-	0.004	0	0
08 Tigroney West	0.003	(-)	0.003	0	0
09 Ballinafunshoge	0.127	0	0.051	0.076	0
10 Vale of Glendasan	0.519	0	0.519	0	0
11 Brockagh	0.109	0	0.022	0.087	0
12 E. of L Nahanagan	0.035	0	0.035	0	0
13 Bunmahon	0.061	0	0.041	0.020	0
14 Tankardstown	0.006	-	0.002	0.004	0
15 Knockmahon Village	0.279	-	0.139	0.139	0
18 Muckross Lake	0.027	-	0.022	0.005	0
19 Ross Island	0.055	0	0.017	0.038	0
20 Allihies	1.316	0	1.250	0.066	0
21 N. of Caminches	0.026	0	0.021	0.005	0
22 NE. of Caminches	0.007	-	0.003	0.003	0
23 Dooneen	0.226	0	0.124	0.102	0
24 Cappagh	0.063	(-)	0.051	0.013	0
25 Brow Head	0.007	(-)	0.007	0	0
26 Polleenateada	0.143	0	0.143	0	0
27 Lackamore	0	-	0	0	0
28 Shallee	0.472	-	0.047	0.425	0
29 Garryard West	0.040	-	0.028	0.012	0
30 Ballyhickey	0.011	0	0	0.011	0
31 Sheshodonnell East	0.009	0	0.002	0.007	0
34 Keeldrum	0.013	+	0	0.013	0
35 Caim Ballyhighland	0.350	0	0.105	0.245	0
Total area	**6.167**		**4.695**	**1.472**	

3.3 *Structure and functions*

Although this survey was carried out at what would usually be the optimal time for locating and identifying rare metallophyte bryophytes, it was hampered by an unusually cold late winter/early spring with significant snowfall that drifted and lay at some sites for weeks. Finding suitable material of rare bryophytes in adequate condition for identification was a challenge at many sites. As mentioned above, this was especially the case for *Cephaloziella massalongi* and *C. nicholsonii*, which were not located, or found only in small quantity, from sites at which they are known to be frequent, most notably at Allihies, where extensive surface water flowing over the mats of *Cephaloziella* posed an additional challenge. *Cephaloziella* species often present taxonomic difficulties, so a definitive identification cannot always be reached. Therefore, in most cases, failure to find a species at a site was not taken to be a sign of a decline in quality, unless other signs of degradation were identified. All of the rare metallophyte species were confirmed from at least one site, although *Ditrichum plumbicola* was only found in very small quantity, and in poor condition at one site, Ballycorus, and, despite intensive searching, could not be found at two further sites, including Shallee in Co. Tipperary, where it occurred in good quantity in 2008. *Cephaloziella nicholsonii* was refound at Shallee, but only in very small quantity and poor condition, and it was apparent that algal mats had become prevalent, swamping the bryophytes at this site, possibly due to atmospheric pollution. One site for *D. plumbicola*, at Van Diemen's Mine in Glendalough, Co. Wicklow (Denyer, 2013), was not included in this survey, so the status of that population is not known. A small population of the rarest of the metallophyte bryophytes, *Ditrichum cornubicum*, was refound at Allihies at one of only three sites for this species worldwide, from where it had been feared lost, as it had not been seen in a number of years.

A range of impacts were found to be acting on these sites, in most cases having a negative impact (Table 6). The most widespread impact was natural erosion, which was recorded as an impact at seventeen sites. This was a negative impact in most instances, at medium intensity. This is a particularly significant impact at coastal sites, with spoil at a number of sites, including Dooneen and Polleenateada, eroding into the sea. Another widespread negative impact was natural succession, which was noted at fourteen sites and this is likely to accelerate as the toxicity of the mine spoil continues to decrease. Scrub encroachment is a particular problem at three sites; Muckross, Shallee and Garryard West, and may become an issue at a further number of sites in the future. Activities associated with tourism and recreation are also an issue at a number of sites, particularly those located within the Killarney (Ross Island, Muckross) and Wicklow (Glendasan) National Parks, where walking routes pass through or close to the areas of Calaminarian grassland and information boards are in place to draw visitors to the abandoned mine sites. Although evidence that grazing is taking place was seen at a number of sites, it is not a significant impact in most cases, and at low to moderate levels may be beneficial to the habitat as it assists in keeping the spoil open and disturbs the surface. At one site, at Brockagh in the Wicklow Mountains National Park, grazing is having a significant negative impact, as a ring feeder for sheep has been placed on the Calaminarian grassland. This has resulted in much eutrophication, trampling and churning by tractor tyres. Other negative impacting activities recorded include: dumping of waste, removal and excavation of spoil and pollution from agricultural and urban sources. Urban pollution is a significant and pressing threat at Knockmahon Village, an important site that supports populations of four rare metallophyte species, and which is also showing signs of encroachment by gorse scrub. The *Structure and functions* of 15 of the 29 sites were assessed as Unfavourable-inadequate (Table 7).

Table 6 Impacts recorded as acting on Calaminarian grassland habitat, with the EU standard list of pressures and impacts codes (Version 2.4 - Updated final version 07/05/2018, file named Pressures_Threats_Final_20180507.xls), the number of sites impacted, type of impact recorded ((positive (+), neutral (0) or negative (-)) and the intensity of the recorded impact (High (H), Medium (M) or Low (L)).

Impact code (2018)	Description	Number of sites impacted	Type of impact	Impact intensity
L01	abiotic natural processes	17	- to 0	L to H
L02	natural succession	14	-	L to H
F07	sports, tourism and leisure activities	13	- to 0	L to H
A10	extensive grazing	11	- to 0	L to H
F09	deposition of waste	10	-	L to H
C01	extraction of minerals	6	- to +	M to H
H06	restrictive access to site	4	- to +	L to M
A06	abandonment of grassland management	3	-	H
A09	intensive grazing by livestock	2	-	M
J03	air pollution	2	-	M to H
A01	conversion into agricultural land	1	-	H
A25	agricultural activities generating point source pollution to surface waters	1	-	M
A26	agricultural activities generating diffuse pollution to surface or ground waters	1	-	M
A36	other agricultural activities	1	-	L
F11	pollution to surface or ground water due to urban run-offs	1	-	H
L03	accumulation of organic material	1	-	M

Table 7 Assessment of the *Structure and functions* of all sites (see Table 1 for site names corresponding to numbers) on each of three criteria. In all cases, Unfavourable sites are Unfavourable-inadequate.

Site number	Number indicator spp.	Result	% scrub encroachment	Result	% -ve human impact	Result	Assessment
02	3	Pass	1	Pass	45	Fail	Unfavourable
04	2	Pass	5	Pass	0	Pass	Favourable
05	7	Pass	0	Pass	10	Pass	Favourable
06	3	Pass	0	Pass	0	Pass	Favourable
07	1	Pass	0	Pass	10	Pass	Favourable
08	2	Pass	0	Pass	0	Pass	Favourable
09	2	Pass	10	Pass	50	Fail	Unfavourable
10	1	Pass	10	Pass	0	Pass	Favourable
11	5	Pass	0	Pass	80	Fail	Unfavourable
12	2	Pass	0	Pass	0	Pass	Favourable
13	5	Pass	0	Pass	33	Fail	Unfavourable
14	1	Pass	0	Pass	66	Fail	Unfavourable
15	7	Pass	15	Pass	50	Fail	Unfavourable
18	2	Pass	20	Fail	5	Pass	Unfavourable
19	4	Pass	2.5	Pass	30	Fail	Unfavourable
20	7	Pass	0	Pass	5	Pass	Favourable
21	1	Pass	0	Pass	5	Pass	Favourable
22	2	Pass	0	Pass	50	Fail	Unfavourable
23	3	Pass	0	Pass	45	Fail	Unfavourable
24	5	Pass	15	Pass	10	Pass	Favourable
25	5	Pass	0	Pass	0	Pass	Favourable
26	3	Pass	0	Pass	0	Pass	Favourable
27	0	Fail	0	Pass	100	Fail	Unfavourable
28	5	Pass	50	Fail	90	Fail	Unfavourable
29	3	Pass	40	Fail	30	Fail	Unfavourable
30	0	Fail	0	Pass	100	Fail	Unfavourable
31	4	Pass	0	Pass	80	Fail	Unfavourable
34	2	Pass	10	Pass	10	Pass	Favourable
35	5	Pass	15	Pass	10	Pass	Favourable

3.4 *Future prospects*

The *Future prospects* of most sites surveyed are not Favourable in the long-term (Table 8). It is clear that this habitat is in continuous decline as it is not a natural habitat and occurs as a result of disturbance, so, without intervention, succession to other habitats is inevitable in the medium to long-term. Additionally, many of the impacts mentioned above act as threats and pressures and are accelerating the decline of Calaminarian grassland at these sites. A total of seven sites were assessed as having bad *Future prospects*. All Calaminarian grassland habitat may be lost from at least four sites in the near future, having been lost from one site, Lackamore, already. Even the sites that currently are in Favourable condition may quickly become unfavourable if small changes in the activities taking place on the land occur.

Table 8 Summary of *Future prospects* of the survey sites.

Site no.	Site	*Future prospects*
02	Ballycorus	Unfavourable-inadequate
04	Nr. Connary Hall	Favourable
05	Glendasan	Favourable
06	Foxrock Mine	Favourable
07	Ballymurtagh	Unfavourable-inadequate
08	Tigroney West	Unfavourable-inadequate
09	Ballinafunshoge	Unfavourable-inadequate
10	Vale of Glendasan	Favourable
11	Brockagh	Unfavourable-bad
12	E. of L. Nahanagan	Favourable
13	Bunmahon	Unfavourable-inadequate
14	Tankardstown	Unfavourable-bad
15	Knockmahon village	Unfavourable-inadequate
18	Muckross Lake	Unfavourable-inadequate
19	Ross Island	Unfavourable-inadequate
20	Allihies (Mountain)	Favourable
21	N. of Caminches	Favourable
22	NE. of Caminches	Unfavourable-inadequate
23	Dooneen	Unfavourable-inadequate
24	Cappagh	Unfavourable-inadequate
25	Brow Head	Unfavourable-inadequate
26	Polleenateada	Favourable
27	Lackamore	Unfavourable-bad
28	Shallee	Unfavourable-bad
29	Garryard West	Unfavourable-bad
30	Ballyhickey	Unfavourable-bad
31	Sheshodonnell East	Unfavourable-inadequate
34	Keeldrum	Unfavourable-bad
35	Caim Ballyhighland	Favourable

3.5 Overall assessment of sites

Of the 29 sites surveyed, nine were assessed as being in Favourable overall condition, 13 as in Unfavourable-inadequate condition and seven as in Unfavourable-bad condition (Table 9). Of those assessed as Favourable, three sites are of importance for rare metallophyte bryophytes: the two largest and most important sites, Allihies and Glendasan; and Caim Ballyhighland, which contains the largest population of *Scopelophila cataractae* in Ireland. The other six Favourable sites are of limited conservation value, but do contain some good-quality Calaminarian grassland habitat, albeit without any of the rare species. A number of the sites in Unfavourable-inadequate condition are of importance for metallophyte bryophytes, such as Knockmahon Village, Ballycorus, Cappagh and Ross Island, and would be priorities for undertaking conservation work to return them to good condition. The majority of sites assessed as Unfavourable-bad are of low significance for metallophyte bryophytes, with the exception of Shallee, where the habitat quality appears to have declined dramatically since 2008.

Table 9 Overall assessment of the condition of the 29 surveyed, based on *Area*, *Structure and functions* and *Future prospects*. Sites are assessed as Favourable if all parameters are assessed as Favourable, as Unfavourable-inadequate if one or more parameters are assessed as Unfavourable-inadequate and as Unfavourable-bad if one or more parameters are assessed as Unfavourable-bad.

Site no.	Site	*Area*	*Structure and functions*	*Future prospects*	*Overall assessment*
02	Ballycorus	Favourable	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
04	Nr. Connary Hall	Favourable	Favourable	Favourable	Favourable
05	Glendasan	Favourable	Favourable	Favourable	Favourable
06	Foxrock Mine	Favourable	Favourable	Favourable	Favourable
07	Ballymurtagh	Unfavourable-inadequate	Favourable	Unfavourable-inadequate	Unfavourable-inadequate
08	Tigroney West	Favourable	Favourable	Unfavourable-inadequate	Unfavourable-inadequate
09	Ballinafunshoge	Favourable	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
10	Vale of Glendasan	Favourable	Favourable	Favourable	Favourable
11	Brockagh	Favourable	Unfavourable-inadequate	Unfavourable-bad	Unfavourable-bad
12	E. of L. Nahanagan	Favourable	Favourable	Favourable	Favourable
13	Bunmahon	Favourable	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
14	Tankardstown	Unfavourable-bad	Unfavourable-inadequate	Unfavourable-bad	Unfavourable-bad
15	Knockmahon village	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
18	Muckross Lake	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
19	Ross Island	Favourable	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
20	Allihies (Mountain)	Favourable	Favourable	Favourable	Favourable
21	N. of Caminches	Favourable	Favourable	Favourable	Favourable
22	NE. of Caminches	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
23	Dooneen	Favourable	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
24	Cappagh	Favourable	Favourable	Unfavourable-inadequate	Unfavourable-inadequate
25	Brow Head	Favourable	Favourable	Unfavourable-inadequate	Unfavourable-inadequate

Site no.	Site	*Area*	*Structure and functions*	*Future prospects*	*Overall assessment*
26	Polleenateada	Favourable	Favourable	Favourable	Favourable
27	Lackamore	Unfavourable-bad	Unfavourable-inadequate	Unfavourable-bad	Unfavourable-bad
28	Shallee	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-bad	Unfavourable-bad
29	Garryard West	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-bad	Unfavourable-bad
30	Ballyhickey	Favourable	Unfavourable-inadequate	Unfavourable-bad	Unfavourable-bad
31	Sheshodonnell East	Favourable	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
34	Keeldrum	Favourable	Favourable	Unfavourable-bad	Unfavourable-bad
35	Caim Ballyhighland	Favourable	Favourable	Favourable	Favourable

3.6 Conservation measures

A range of conservation measures were identified as being required to restore sites to good condition, or to maintain them in good condition (Table 10). By far the most widespread conservation measure required is management of habitats to stop succession from Calaminarian grassland to other habitats, as toxicity at surface of the spoil decreases. This was identified as being required at eighteen sites and would be particularly worthwhile at sites where rare metallophyte bryophytes occur in order to maintain optimum conditions for their growth. A conservation measure that was identified as being required at five sites was to reduce the impact of recreational activities, mainly trampling by visitors and damage by scrambler bikes and off-road vehicles. Other measures identified that are integral for the conservation of Calaminarian grassland habitat at certain sites include reduction or increase in grazing, halting pollution from domestic and agricultural sources and ceasing removal of spoil.

Table 10 Conservation measures required at the survey sites, ranked by the number of sites where these measures are required.

Conservation measure	Description	Number of sites
CL01	Management of habitats (others than agriculture and forest) to slow, stop or reverse natural processes	18
CF03	Reduce impact of outdoor sports, leisure and recreational activities	5
CH03	Reduce impact of other specific human actions	3
CA04	Reinstate appropriate agricultural practices to address abandonment, including mowing, grazing or equivalent measures	3
CF04	Reduce/eliminate point pollution to surface or ground waters from residential areas and activities	2
CC01	Adapt/manage extraction of non-energy resources	2
CA05	Adapt mowing, grazing and other equivalent agricultural activities	2
CA10	Reduce/eliminate point pollution to surface or ground waters from agricultural activities	1

4 Discussion

This survey highlights the continuing decline of Calaminarian grassland in Ireland, and elucidates many of the reasons for this decline. The primary cause is natural succession, as the toxicity derived from mining operations begins to leach out of the soil and its influence lessens, allowing previously inhibited plants to recolonise the spoil at the expense of Calaminarian grassland habitat. This will continue over time and become more apparent across all sites, even though some of the best sites still have strongly toxic substrates. As Calaminarian grassland is generally considered to be marginal land and of little use or value, it is also vulnerable to a range of human impacts, including dumping, activities related to grazing, excavation, pollution and trampling by tourists and walkers. Also, as many of these sites are on non-protected land, sites may be lost or damaged through reclamation, building work or conversion to productive agricultural land, as has happened at Lackamore, and undoubtedly at other sites prior to the 2008 survey.

It might be argued that the habitat of Calaminarian grassland is not worthy of conservation in its own right, as it is man-made, species-poor, of little value for most wildlife, contains toxic minerals, is often unsightly and covers land which could be put to better use. However, these sites have value as a cultural landscape, and an ecologically distinctive and novel plant community has developed. Calaminarian grassland that supports rare metallophyte bryophytes is undoubtedly worthy of conservation efforts. The sites at which the rare species *Cephaloziella nicholsonii, C. integerrima, C. massalongi, Ditrichum cornubicum, D. plumbicola, Scopelophila cataractae* and *Pohlia andalusica* occur should be conserved in best possible condition. Rare metallophyte species have been recorded from 13 sites between 2008 and present, of which seven are located in SACs, with three additionally within National Parks (Table 11). The remaining sites are located outside of SACs, but should at the very least be considered for designation as Natural Heritage Areas (NHAs) in recognition of their important bryophyte assemblages (Campbell & Lockhart, 2017), in particular Knockmahon Village, Co. Waterford and Caim Ballyhighland, Co. Wexford, that both have significant populations of metallophyte species.

A description of the conservation measures that could be carried out at each site containing metallophyte species is included in Table 11. Conservation measures recommended for all other sites that do not contain rare metallophytes, can be found in the individual site reports in Appendix I (contained within a separate file). The two most extensive and important sites, Allihies and Glendasan, are in relatively good condition. At Allihies, removal of construction waste and fencing dumped on Calaminarian grassland would be beneficial and scraping back of vegetation and topsoil in the vicinity of the location of *Ditrichum cornubicum* may be necessary. Removal of topsoil to encourage the growth of *Ditrichum cornubicum* has been carried out with great success at sites for this species in Cornwall, and has led to a large increase in the population there, as the rhizoidal tubers of this species remain dormant in the soil (Callaghan, 2018). The population of *D. cornubicum* found during this survey was extremely small, consisting of one patch containing *c*. 30 stems, and a number of searches since 2008 failed to find any plants (Campbell *et al*., 2017), suggesting that its occurrence at this site is sporadic and it is possibly in decline. Holyoak & Lockhart (2011) surmised that *D. cornubicum* at Allihies may be a very recent introduction, transported from Cornwall when the Man Engine House was being restored. However, the work of Campbell *et al*. (2017) showed that this population is genetically distinct from those in Cornwall, which therefore makes the conservation of this population of this globally endangered species of utmost importance.

At Glendasan, the most pressing issue to be addressed is trampling of the Calaminarian grassland by visitors, as there is easy access from the adjacent carpark, and an information board draws visitors to the site. The installation of a marked trail around the site would draw trampling away from the Calaminarian grassland and focus it on the path. Trampling is also an issue on Ross Island, but the location of the large population of *Cephaloziella massalongi* is in an inaccessible area that is not impacted by trampling. Knockmahon Village is host to four species of rare metallophyte bryophyte, but is not in good condition, due to pollution resulting from runoff from residential properties

upslope of the site. A priority would be to halt this runoff, as it is clearly having a major impact on the rare species present. Encroachment of scrub is also an issue at this site, and at a further number of sites.

Like *Ditrichum cornubicum*, *D. plumbicola* appears to be in a very precarious position in Ireland. However, there are few obvious answers for how to halt its decline. It was only found at one site during this survey, Ballycorus, Co. Dublin, where a very small, alga-covered patch was located after much searching. It is unlikely that it will survive at this site in the long-term. The algal cover is probably due to the dense needle litter shed from the mature *Pinus sylvestris* trees at the edge of the spoil area. Removal of these trees and disturbance of the spoil surface may result in a revival of this population of *D. plumbicola*. A detailed search was carried out for this species at Glendasan in the vicinity of the precise location where it was previously recorded, but *D. plumbicola* was not found. This site is still in good condition, so it may be rediscovered here in the future. The most concerning loss of this species is from Shallee in Co. Tipperary, where it occurred in good quantity in 2008 (Holyoak & Lockhart, 2009) but is now almost certainly not present. An extensive search revealed no sign of *D. plumbicola* and found that the habitat was covered in an algal mat, possibly due to atmospheric pollution. *Cephaloziella nicholsonii* was found at this site, but only in very small quantity. The fourth site for *D. plumbicola*, in Glendalough, was not visited, so its current status there is unknown, but the findings at the three other sites that were surveyed suggest that this species is struggling to survive in Ireland.

The other rare metallophyte species appear to be in a less precarious position than the species of *Ditrichum*, although they were not seen very often during this survey. As a result of the identification problems described earlier (Section 3.3), few records of *Cephaloziella nicholsonii* and *C. massalongi* were confirmed, but there is no reason to assume that these species are in decline. Both species were found at a number of sites, and Callaghan (2013) found both species to be frequent and widespread at Allihies. *C. integerrima* may have undergone a decline, as only a small amount was found at Knockmahon Village, a site Holyoak & Lockhart (2009) previously reported as having a large population. It was not refound at Allihies, although it was only ever found in small quantity there, most recently by Callaghan (2013). There are also records of this species from non-metalliferous substrates in two locations in Ireland, so it may be undetected at additional sites. However, a close eye should be kept on the status of this species. Healthy populations of *Pohlia andalusica* were found at two sites, Knockmahon Village and Cappagh, and although it was not found at a further two sites, there is no great cause for concern. Much indeterminate material of *Pohlia* was encountered in suitable habitat that may well be *P. andalusica*. *Scopelophila cataractae* was found to still be present in good quantity at its most important site at Caim Ballyhighland, with no pressing threats apparent. So, although it was not refound at Allihies, owing to challenging weather conditions, it can still be considered not to be imminently threatened. However, even if species currently seem to be doing well, most populations are small and in locations where they can easily be impacted, so could very quickly be lost due to development, excavation of spoil or other activities, particularly at those sites that have no protection.

Table 11 Description of conservation measures required to maintain sites, where rare metallophyte bryophytes are present, in good condition.

Site no.	Site	County	Rare bryophytes present 2008	Rare bryophytes confirmed 2018	SAC	Conservation measures needed
02	Ballycorus	Dublin	*Cephaloziella massalongi*, *Ditrichum plumbicola*	*Ditrichum plumbicola*	None	Scrambler bikes should be excluded and walkers should be diverted away from the Calaminarian grassland habitat. Removal of over-shading trees of *Pinus sylvestris*, that deposit needle litter, should be considered.
05	Glendasan	Wicklow	*Cephaloziella massalongi*, *Cephaloziella nicholsonii*, *Ditrichum plumbicola*	*Cephaloziella nicholsonii*	Wicklow Mountains SAC (2122)	Visitors should be encouraged to stick to paths to avoid trampling of Calaminarian grassland. Additional signage could be erected to highlight importance of Calaminarian grassland habitat.
08	Tigroney West	Wicklow	*Cephaloziella nicholsonii*		None	Avoid disturbance of the riverbank where *C. nicholsonii* grows.
13	Bunmahon	Waterford	*Cephaloziella massalongi*, *Pohlia andalusica*	*Cephaloziella massalongi*, *Pohlia andalusica*	None	Scraping back of encroaching grass and topsoil to create new habitat would be beneficial. Some grazing would keep the spoil open.
15	Knockmahon village	Waterford	*Cephaloziella integerrima*, *C. nicholsonii*, *Pohlia andalusica*	*Cephaloziella integerrima*, *C. massalongi*, *C. nicholsonii*, *Pohlia andalusica*	None	Pollution currently impacting the site needs to be stopped at source and encroaching gorse scrub needs to be cleared. It would be beneficial to install information boards highlighting the vegetation at this site.
18	Muckross Lake	Kerry	*Cephaloziella massalongi*		Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchement SAC (365)	Scrub that is encroaching into Calaminarian grassland should be cleared, with sensitivity for the habitat.

Site no.	Site	County	Rare bryophytes present 2008	Rare bryophytes confirmed 2018	SAC	Conservation measures needed
19	Ross Island	Kerry	*Cephaloziella massalongi*	*Cephaloziella massalongi*	Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchement SAC (365)	Prevent visitors from trampling the Calaminarian grassland. Additional signage could be erected to highlight importance of Calaminarian grassland habitat.
20	Allihies (Mountain)	Cork	*Cephaloziella integerrima*, *C. massalongi*, *C. nicholsonii*, *Ditrichum cornubicum*, *D. lineare*, *Pohlia andalusica*, *Scopelophila cataractae*	*Cephaloziella massalongi*, *Ditrichum cornubicum*	Kenmare River SAC (2158)	Scraping and disturbing of the spoil surface could be beneficial in certain parts of this site, particularly where *Ditrichum cornubicum* grows. Construction waste and old fencing dumped on Calaminarian grassland should be removed.
21	N. of Caminches	Cork	*Pohlia andalusica*		None	A horse trailer dumped adjacent to Calaminarian grassland should be removed.
23	Dooneen	Cork	*Cephaloziella massalongi*		Kenmare River SAC (2158)	Trampling by visitors that park in the adjacent parking area should be discouraged.
24	Cappagh	Cork	*Cephaloziella nicholsonii*, *Pohlia andalusica*, *Scopelophila cataractae*	*Cephaloziella massalongi*, *Pohlia andalusica*	None	The tracks where Calaminarian grassland with *Pohlia andalusica* grows should not be resurfaced. Areas of spoil where encroachment may occur should be kept clear. Development on spoil in this area should be discouraged.
28	Shallee	Tipperary	*Cephaloziella nicholsonii*, *Ditrichum plumbicola*	*Cephaloziella nicholsonii*	Silvermines Mountains West SAC (2258)	Encroaching gorse scrub needs to be controlled. However, it is difficult to address the main impact, possibly air-borne pollution, resulting in algal mats forming and swamping the metallophyte species.
35	Caim Ballyhighland	Wexford	*Cephaloziella nicholsonii*, *Scopelophila cataractae*	*Cephaloziella nicholsonii*, *Scopelophila cataractae*	None	Removal of adjacent conifers and control of scrub would be beneficial to the Calaminarian grassland at this site. Dumping of rubbish should be discouraged and pollution arising from an animal pen should be contained.

5 Recommendations

Monitoring of these sites should take place on a regular six-yearly cycle, in line with the reporting period for habitats listed on the EU Habitats Directive. A few changes should be considered for the list of sites to be monitored. All spoil and Calaminarian grassland habitat has been eradicated at Lackamore in Co. Tipperary, so this site might be excluded from future surveys. It is also questionable whether it is worthwhile to continue to monitor the sites at Keeldrum, Co. Donegal and Ballymurtagh, Co. Wicklow, as the Calaminarian grassland at these sites is of low-quality and covers a very small area and, in the case of Keeldrum, is unlikely to survive much longer. Although the area of Calaminarian grassland at Tigroney West is also very limited, it is worthwhile continuing to monitor it due to the presence of *Cephaloziella nicholsonii* in small quantity, although the long-term prospects for this site are not particularly favourable. Van Diemen's Mine in Glendalough should be included in any future surveys, as Calaminarian grassland is present and the discovery of *Ditrichum plumbicola* here in 2013 makes it an important site. A survey should be carried out of old mine sites on the islands of Roaringwater Bay in West Cork, to determine whether Calaminarian grassland habitat is present, and if so, assess the extent and quality of the habitat. Further work in the upper Glendasan Valley and Glenmalure should also be carried out, as there are numerous areas of spoil that have yet to be surveyed, some of which definitely support Calaminarian grassland habitats and may contain further populations of rare metallophyte species. Holyoak (2008) estimated that a further 2 ha of Calaminarian grassland occurred outside of those sites surveyed, but without detailed survey and an accurate area figure, this cannot be taken into account when estimating the area of Calaminarian grassland in Ireland.

Of greatest importance is implementation of conservation measures to preserve and restore the most important Calaminarian grassland sites and their characteristic species. Measures to rehabilitate the sites at Knockmahon Village and Shallee would be the top priority. All of the important species are still present at Knockmahon, so an improvement in condition would likely allow the rare species to expand, but it may be that Shallee is beyond restoration. A programme of stripping back the surface layer and disturbing the spoil would be beneficial at many sites to ensure the survival of rare metallophyte species there, particularly in the case of *Ditrichum cornubicum* at Allihies. In some areas, particularly where rare species are declining or have disappeared, such as at Shallee, this could be carried out in a heavy-handed manner using JCBs to remove the surface layer of vegetation and soil (particularly encroaching scrub). Simply maintaining areas of spoil as they currently are is unlikely to lead to the long-term survival of Calaminarian grassland vegetation and species at these sites, so large-scale restructuring would be necessary. If it were thought to be worthwhile, various other conservation measures could be undertaken across sites, as outlined in the individual site reports.

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