Definition of Favourable Conservation Status for Calaminarian grassland

Defining Favourable Conservation Status Project

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About the Defining Favourable Conservation Status project

Natural England's Defining Favourable Conservation Status (DFCS) project is defining the minimum threshold at which habitats and species in England can be considered to be thriving. Our Favourable Conservation Status (FCS) definitions are based on ecological evidence and the expertise of specialists.

We are doing this so we can say what good looks like and to set our aspiration for species and habitats in England, which will inform decision making and actions to achieve and sustain thriving wildlife.

We are publishing FCS definitions so that you, our partners and decision-makers can do your bit for nature, better.

As we publish more of our work, the format of our definitions may evolve, however the content will remain largely the same.

This definition has been prepared using current data and evidence. It represents Natural England's view of favourable conservation status based on the best available information at the time of production.

1 Introduction

1.1 Favourable Conservation Status Definition for Calaminarian grassland in England

This document sets out Natural England’s view on Favourable Conservation Status (FCS) for calaminarian grassland (generally referred to as ‘grassland on soils rich in heavy metals’) in England. Favourable conservation status is defined in terms of three parameters: natural range and distribution, area, and structure and function attributes.

Section 2 provides the summary definition of favourable conservation status in England. Section 3 covers contextual information, Section 4 the units used and Section 5 describes the evidence considered when defining favourable conservation status for each of the three parameters. Section 6 sets out the conclusions on favourable values for each of the three parameters. Annex 1 lists the references.

This document does not include any action planning, or describe actions, to achieve or maintain favourable conservation status. These will be presented separately, for example within strategy documents.

The guidance document Defining Favourable Conservation Status in England describes the Natural England approach to defining favourable conservation status.

2 Summary Favourable Conservation Status definition

2.1 Favourable Conservation Status in England

Calaminarian grassland is a scarce and highly localised habitat of high biodiversity value occurring in areas where the substrate has high levels of heavy metals. It occurs both in the lowlands and uplands and is maintained by a combination of substrate metal toxicity and grazing by livestock and rabbits. Although the evidence base is limited, there is some evidence that the extent of this type of grassland has declined significantly over the last 90 years although its overall range has remained stable. Vulnerability to climate change has not been formally assessed for this habitat but it is considered that it is probably low.

To the non-specialist, calaminarian grassland, now virtually confined to the products of former mining activity, would not appear to be a habitat of value for nature conservation. However, the areas associated with mine spoil wastes and heavy metal-enriched river shingles are surrogates for the natural examples of calaminarian grassland that would have formerly occurred on heavy metal-rich soils on naturally outcropping mineral veins which have been lost to historic mining activity. The vegetation on the artificial substrates are virtually the only remaining examples of heavy metal vegetation in England and are thus of biodiversity value as recognised by domestic and international legislation and policy.

The current area is c. 300 ha. The favourable area is set at 250 -300 ha which recognises that it will not be possible to maintain a proportion of the extant resource. This would involve restoration to favourable condition of the suite of existing sites, both SSSI and non-SSSI.

The attributes include those relating to floristic composition, particularly vascular and lower plant metallophytes, sward structure, soil heavy metal content, soil nutrient status and the need for supporting contiguous grassland habitat. In particular, to achieve favourable conservation status, the vegetation should be broadly typical of the relevant plant communities and their species composition. There should normally be high levels of bare ground, variation in sward height and the presence of rocks, pebbles, cobbles and gravel. The soils should have properties typical of the habitat notably high levels of heavy metals and low productivity. The habitat should be grazed by rabbits and/or livestock, depending on site productivity and levels of metal toxicity and specific conservation objectives. There should be at least some contiguous areas of suitable semi-natural habitat to ensure optimal grazing management.

2.2 Confidence

Favourable status will require at least 95% of the favourable area of the habitat (250-300 ha) to meet the structure and function requirements throughout its current range and distribution.

FCS parameter	Favourable status	Confidence in the parameter
Range and distribution	Maintenance of the current range – a maximum of 41 10 km grid squares. It is highly geographically restricted and found only in the North Pennines, Cumbria, Yorkshire Dales, Cornwall, Mendips and the Derbyshire White Peak in both lowland and upland landscapes where it is associated with substrates with high levels of heavy metals	**Moderate**
Area	250-300 ha	**Low**
Structure and function	At least 95% of the favourable area of the habitat should meet the structure and function requirements.	**Low**

As of **April 2021**, based on a comparison of the favourable values with the current values, **calaminarian grassland is not** in favourable conservation status in England. Note, this conclusion is based solely on the information within this document and not on a formal assessment of status nor on focussed and/or comprehensive monitoring of status.

3 Habitat definition and ecosystem context

3.1 Habitat definition

Calaminarian grassland is a short, open, sometimes very sparsely vegetated habitat characterised by the presence of metal-tolerant vascular plants, bryophytes and/or lichens. It is associated with soils and substrates containing high levels of heavy metals such as lead, zinc, cadmium and copper, and is now largely restricted to relicts of mining such as spoil heaps, tailings and metal enriched river shingles with near natural examples now virtually non-existent in England.

The Habitats Directive Annex 1 habitat H6130 Calaminarian grasslands of the *Violetalia calaminariae* is synonymous with the Section 41 Habitat of Principal Importance listed in the Natural Environment and Rural Communities (NERC) Act 2006 (Maddock 2008). The JNCC account for the habitat (Jackson & McLeod 2000) lists three principal occurrences:

- Near-natural, open vegetation of serpentine rock and mineral vein outcrops with skeletal soils;
- Stable river gravels rich in lead and zinc and that are near-natural, although the heavy metal content may be partly an artefact of past mining activity in the river catchment;
- Artificial mine workings and spoil heaps, mainly on limestone; these are numerous (several thousand UK localities) and extensive, although few sites have a high species-richness.

Although H6130 includes a compendium of different forms of grassland over heavy metal-rich soils, only one calaminarian community is recognised in the NVC, the OV37 *Festuca ovina – Minuartia verna* community, which is restricted to contaminated sites over mostly calcareous bedrock. Other forms of calaminarian grassland represented in the UK Special Area of Conservation (SAC) series include inland rock vegetation with a prominence of maritime species such as *Armeria maritima* and *Silene maritima* or metal-tolerant ecotypes, and swards characterised solely by distinctive assemblages of bryophytes or lichens, including metallophyte cryptogams such as *Ditrichum plumbicola* and certain lichens including species of *Cladonia, Peltigera, Porpidia* and *Lecanora* (Simkin in press).

The wider definition is adopted for the purpose of the FCS definition, although it should be noted that there are virtually no near-natural examples of the habitat or examples on serpentine rocks in England. Vegetation on metal-enriched soils that has an ericaceous component but supports one or more vascular plant metallophyte species is though included.

As far as the EUNIS classification is concerned, OV37 and related metallophyte vegetation conforms to E1. B Heavy-metal grassland in Western and Central Europe. In European phytosociology the calaminarian grasslands are referable to the *Thlaspion-Calaminariae* alliance, which includes all natural and anthropogenic heavy metal swards in Europe.

Calaminarian grassland varies considerably in its species–richness, ranging from quite species-poor (< 10 species/4m2) to species-rich (> 40 species/4m2). This is influenced by a range of factors, particularly the nature of the substrate, including heavy metal concentrations and pH, but also the age and stability of the particular artificial substrate and the extent to which the surrounding area supports a potential colonising species pool. Examples contain a sparse growth of metal tolerant ecotypes of species including spring sandwort (*Subulina verna*), alpine pennycress (*Noccaea caerulescens*), pyrenean scurvy-grass (*Cochlearia pyrenaica*), mountain pansy (*Viola lutea*), thrift (*Armeria maritima*), sea campion (*Silene uniflora*), moonwort (*Botrychium lunaria*) and bryophytes such as pale thread-moss (*Bryum pallens*), green-tufted stubble-moss (*Weissia controversa* including *var. densifolia*), threadworts (*Cephaloziella nicholsonii* and *C. massalongi*), tongue-leaf copper-moss (*Scopelophila cataractae*), copper moss (*Grimmia atrata*) and lead-moss (*Ditrichum plumbicola*).

Most of these are metal-tolerant ecotypes (facultative metallophytes) rather than obligate metallophytes, and there are also metal-tolerant ecotypes of more widespread species such as sheep's fescue (*Festuca ovina*), common bent (*Agrostis capillaris*), harebell (*Campanula rotundifolia*), wild thyme (*Thymus polytrichus*), yarrow (*Achillea millefolium*), bird's foot trefoil (*Lotus corniculatus*) and ribwort plantain (*Plantago lanceolata*). The first two named grasses are constant species for the OV37 NVC type (Rodwell 2000).

Where the habitat remains open but has been stable and undisturbed for some time there may be extensive and diverse populations of lichens. Some of these are part of the soil crust, such as *Baeomyces rufus*, *Vezdaea* spp., and *Sarcosagium campestre*. Larger species include many species of *Cladonia* and *Peltigera*, particularly *P. neckeri*, *P. venosa* and *P. leucophlebia*, *Cetraria aculeata* and *C. muricata*, *Thelocarpon*, *Stereocaulon* and *Lecanora* and *Ochrolechia frigida* (Forster-Brown 2017; Simkin 2007).

Where the sward becomes grassier as surface metal toxicity reduces, some species of *Cladonia* and *Peltigera* may be able to persist in the sward.

Sources: Baker & Proctor 1990; Baker and others 2010; Callaghan 2011; Forster-Brown & Chambers 2017; Jackson & McLeod 2000; Jefferson and others 2014; Maddock 2008; Robertson & Jefferson 2000; Rodwell 2000; Rodwell and others 2007; Sellars & Baker 1988; Simkin 2007; Simkin 2011; Simkin in press.

3.2 Habitat status

Calaminarian grassland is listed in Section 41 of the NERC Act 2006 as a Habitat of Principal Importance in England, reflecting its high conservation value. The habitat also supports a number of threatened species - see section 5.1 for further details.

The recently published European Red List of Habitats (Janssen and others 2016) classified the EUNIS types – E1. B Heavy-metal grassland in Western and Central Europe

– as Endangered (EN), primarily due to very substantial declines in quantity and quality suffered over the last 50 years. Specifically, this means ≥ 50% but < 80% decline over the last 50 years; a likely future decline ≥ 50% but < 80% and historic losses since c. 1750 of ≥ 70% but < 90%.

The British calaminarian vegetation is very similar to that described from western Europe that falls within the core association known as the *Minuartio-Thlaspietum*.

Sources: Janssen and others 2016; JNCC Priority habitats definition; Jefferson and others 2014; Rodwell 2000; Rodwell and others 2007.

3.3 Ecosystem context

Distribution, geology, soils and management

The main concentrations of calaminarian grassland occur in the North Pennines, Cumbria and the Derbyshire White Peak with more limited examples in the Mendips and in Cornwall, in both lowland and upland landscapes. It is grazed by livestock or ungrazed. The majority of calaminarian grassland in England now occurs on artificial waste from former metal mining activity and on metal-enriched river shingle originating from mining in the catchments. Metal mining in Britain goes back to the Bronze Age, initially for gold, tin and copper but by Roman and medieval times also for lead, zinc and silver. Lead mining peaked in the 18-19th centuries but had ended in most areas by 1890, with zinc mining lasting only about a further 40 years until 1920. The supply of metal-contaminated material to rivers significantly decreased in the late 19th Century once the impact on agriculture and river wildlife was recognised (for example, by the Rivers Pollution Commissioners in 1874) and there were restrictions on the disposal of mining wastes into rivers. A few mines continued to operate until very recently but were regulated so that new calaminarian habitats would not be created. The calaminarian grassland sites are thus artificial examples of the type, but they clearly occur within the same area as the original ore veins or in the same catchment. Natural rock outcrops of this type were always geologically scarce within the UK and continental Europe and have been largely eliminated by mining activity. It seems likely that far more metal-rich habitat was created by mining than was likely to have been present naturally and including outside its natural range. This has yet to be assessed.

The occurrence, composition and structure of the vegetation is strongly influenced by the mineralogy of the metal-rich substrate or parent material.

Mosaics with other vegetation

Calaminarian grasslands are usually distinctive and easily partitioned from other forms of grassland by the prominence of metallophyte species. However, transitions to and mosaics with other dry grassland types do occur, especially calcareous, acid or neutral grasslands and dwarf shrub heath. Such mosaics are controlled primarily by edaphic factors. However, where surface toxicity has declined due to ecological succession and surface leaching of metals, this may result in the development of grassland, scrub or woodland vegetation over time which may form a mosaic with areas of metallophyte vegetation in patches with remaining high levels of heavy metals in the surface soil or substrate.

Microhabitats associated with calaminarian grassland include extensive often rocky bare ground and small grass tussocks and moss cushions.

Vascular plants

As mentioned in section 3.1, the habitat can support a range of vascular plants depending on the nature of the substrate, its age and stability and the landscape context. These factors also strongly influence the richness and diversity of the flora.

Calaminarian grasslands and associated rock outcrops also provide a habitat for a number of rare or geographically restricted vascular plants (see section 5.1).

Bryophytes and lichens

As mentioned in section 3.1, the habitat can support a wide range of lichens and bryophytes. This includes some rare and threatened species – see section 5.1. Ecologically coherent assemblages of specialist lichens of high conservation value can qualify for selection as SSSI and a scoring system has been developed to aid SSSI selection in the UK (Sanderson and others 2018).

Fungi

The value of metal-rich sites for fungi does not appear to be high but they have been poorly studied. It is possible that further survey may show that non-lichenised fungal species/communities of this habitat could prove to be important for conservation.

Fauna

The value of calaminarian grasslands for invertebrates has been recognised (Spalding 2005) although there appear to be no examples of invertebrate or higher fauna that are entirely restricted to calaminarian grassland in England. The habitat provides niches for a range of species, notably those reliant on areas of bare or partially vegetated ground such as mining Hymenoptera. In Cornwall, calaminarian grassland is considered to provide a significant proportion of the habitat resource for Grayling *Hipparchia semele* (Spalding 2005).

Sources: Baker & Proctor 1990; Baker and others 2010; Mainstone and others 2018; Preston and others 2002; Rodwell 2000; Rodwell and others 2007; Sanderson and others 2018; Simkin in press; Spalding 2005.

4 Units and attributes

4.1 Natural range and distribution

10 km square

The appropriate metric given the relatively wide distribution of the habitat across England

4.2 Area

Hectare

4.3 Structure and function attributes

Structure attributes

• Vegetation community and species composition especially presence of metallophyte species

• Low cover of undesirable species including coarse grasses and shrub /tree species

• A high cover of bare ground

• The presence of rocks, pebbles, cobbles, gravel, bare soil etc especially in relation to bryophytes and lichens

• Sward height and structure

Function attributes

• Maintenance of low productivity soils with high levels of heavy metals

• Supporting off-site habitat – to ensure optimal management of the habitat

• Concentrations and deposition of air pollutants at or below the site-relevant Critical Load or Level values.

• Grazing management where required

The rationale for the selection of each attribute is provided in section 6.3.

Sources: Crofts & Jefferson 1999; Robertson & Jefferson 2000; Richards 2017; Rodwell 2000; Simkin 2007; Stevens and others 2011.

5 Evidence

5.1 Current situation

Natural range and distribution

The habitat is restricted in its occurrence to areas of former metal mining activity and in England is confined to the North Pennines, Cumbria, the Derbyshire White Peak, the Mendips and Cornwall. Figure 1 shows the distribution by 10 km square (Rodwell and others 2007).

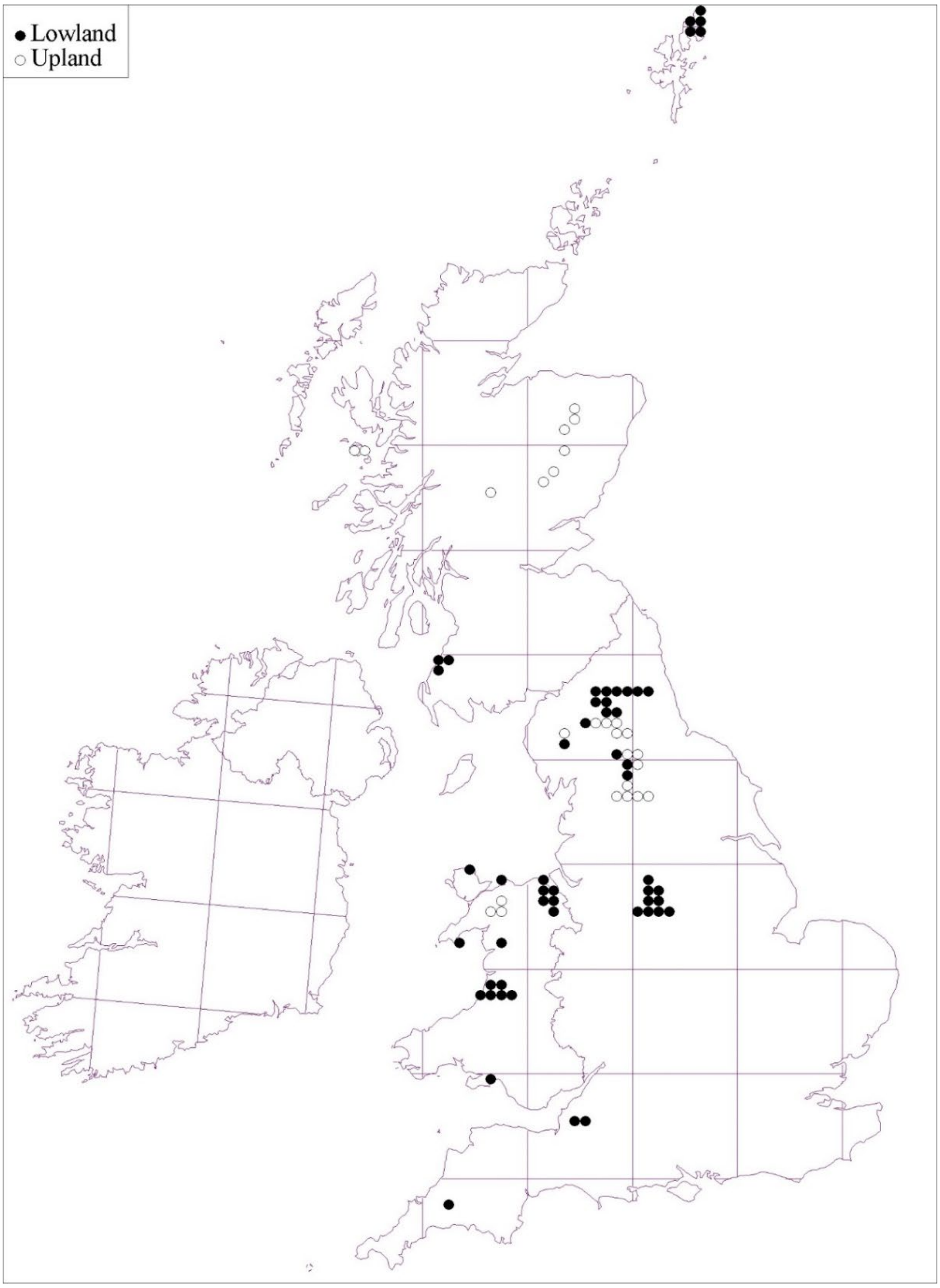

Figure 1: distribution by 10 km square © JNCC 2007. Reproduced with permission.

Area

There are two estimates for the extent of the habitat in England, the first is < 200ha – this was the figure used for the first two rounds of Article 17 reporting (JNCC Article 17 Habitats Directive Report 2019). An estimate produced for the 2017 report however was 300 ha. Around 56% of this resource is within the SSSI series. The latter area estimate was based on data from the SSSI and agri-environment databases and the Priority Habitat Inventories. It is proposed to use the latter area figure for the purpose of this definition while acknowledging that this is only a rough estimate as there has never been a comprehensive England-wide ecological survey of the habitat.

Patch size

Data on median patch size and the range of patch sizes of the habitat is unavailable. However, an analysis of CMSi data shows that the size of SSSI units containing calaminarian grassland range from 0.9 ha to 2032 ha. The larger units are part of large upland SSSIs where the calaminarian grassland habitat has not been individually mapped and is likely to only occupy a small fraction of the total unit area. In the lowland calaminarian grassland SSSIs, the data indicates that the extent or patch size of the habitat as derived from the size of the units containing the habitat is small to moderate, ranging from around 0.1 ha to 150 ha.

Quality of habitat patches

Information on the state of the structure and function attributes comes from the monitoring of those calaminarian grassland sites that are SSSI and SAC. The most recent data based on Common Standards Monitoring shows that 51% of the resource within SSSIs is determined to be in favourable condition, falling to 39% within SACs. Analysis of the site-based data reveals this is due to the unfavourable condition of certain key river shingle SACs where the metallophyte vegetation is being gradually replaced by coarse grasses and herbaceous species because of an amelioration of surface toxicity. This is due to successional processes caused in part by a reduction in the influx of metal-rich sediments since the late 19th century and the very slow natural decrease in metal concentrations in mine water discharges since the mines closed. Mine water treatment schemes proposed by Government to clean up polluted rivers are intended to significantly decrease metal concentrations in the water column, but this is unlikely to measurably impact replenishment of particulate metals to calaminarian habitats although the evidence base is deficient. Measures controlling mobilisation of metals from diffuse sources (mine wastes and in-river sediments) will lower the overall flux of metals but this is considered unlikely to substantially accelerate the existing succession rate.

More generally, ecological succession is the main reason for unfavourable condition and is sometimes compounded by lack of grazing management and even tree planting. The speed of successional change will vary from site to site and will be influenced primarily by the initial toxicity of the substrate. In addition, the local source pool of potential colonists including bryophytes, lichens and vascular plants may influence the nature and quantity of organic matter accumulation that serves to mask soil surface toxicity. A lack of grazing may in some cases be due to a reluctance by farmers and graziers to put livestock on calaminarian grassland due to concerns over toxicity effects on them (see section 6.3). Research has shown that stripping off the surface soil to remove the less toxic soil material may increase metal toxicity (see Callaghan 2018; Richards 2017; Simkin 2007, 2011) and hence conserve the range of metallophyte species. This may be a way to restore calaminarian grassland. However, this would need to be done with extreme caution due to the possibility of contaminating surrounding habitats including negative impacts on water quality and consequent pollution. Such restoration would need careful assessment using specialist advice. In addition, there is the possibility that re-instating metal toxicity may deter grazing with domestic livestock.

There are no data on the condition of the resource outside of the protected sites series. This is because the habitat was not included in the two non-statutory grassland sample surveys that took place in 2003/2004 (Hewins and others 2005) and 2017/2018 (Wheeler & Wilson in prep). There are no immediate plans in place to plug this evidence gap.

Threatened species

Calaminarian grasslands and associated rock outcrops provide a habitat for a range of rare or geographically restricted vascular plants. *Viola lutea* and *Botrychium lunaria* are Near Threatened and Vulnerable respectively in England (Stroh and others 2014). *Subulina verna*, is Near Threatened in England (but nonetheless Nationally Scarce, occurring in in 16-100 10 km grid squares), Vulnerable in Wales and Near Threatened in Great Britain (Stewart, Pearman & Preston 1994, Stroh and others 2019). All three species satisfy the criteria for inclusion as threatened grassland plants in Britain & Ireland in Stroh and others (2019). This publication has individual accounts for these threatened species. None of the threatened vascular plant species is confined to calaminarian grassland but those occurring in the habitat are likely to be metal-tolerant ecotypes.

The lichen assemblage of calaminarian grassland has long been known to include species of conservation interest. Such habitats can support a very high lichen diversity: a collective total of 626 taxa (excluding species that primarily grow on trees) has been recorded, including eight Threatened and 18 Near Threatened species. Saxicolous and terricolous species are the main interest, principally in areas of sparse vegetation. This includes a list 49 indicator species/taxa that can be used to evaluate the conservation value of sites (Annex 3). For example, the habitat supports assemblages of metal-tolerant cryptogams on mine waste, even where metallophyte higher plants are scarce or lacking. Threatened metallicolous lichens include *Peltigera venosa* (Vulnerable), *Gyalidea subscutellaris* (Near Threatened), *Lecidea inops* (Endangered), *Lecanora handelii* (Near Threatened), *Stereocaulon glareosum* (Near Threatened), *Stereocaulon symphycheilum* (Endangered) and *Rhizocarpon furfurosum* (Near Threatened) (Woods & Coppins 2012).

Similarly, there is a suite of threatened metallophyte bryophytes including the mosses *Ditrichum cornubicum* (Endangered) and *Scopelophila cataractae* (Vulnerable) and the liverworts *Cephaloziella integerrima* and *C. nicholsonii* (both Vulnerable). *Ditrichum cornubicum* is restricted to two Cornish sites (Callaghan 2018, Hodgetts 2011).

The bryophytes *Cephaloziella integerrima, C. nicholsonii, Ditichum cornubicum* and *D. plumbicola* and the lichens *Peltigera venosa, Stereocaulon symphycheilum* are Section 41 Species of Principal Importance (NERC Act 2006).

Sources: Callaghan 2018; Hodgetts 2011; Rodwell and others 2007; Sanderson and others 2018; Simkin 2011; Stroh and others 2019; Woods & Coppins 2012.

Confidence: Moderate

5.2 Historical variation in the above parameters

There is very little information on changes in the extent of calaminarian grassland during the 20th century. Evidence for a decline in the extent and quality of this habitat is drawn from data on the fate of the characteristic species of the habitat (metallophytes) and information from the monitoring and surveillance of those sites that have statutory protection or are known local wildlife sites.

Of the seven vascular plant metallophyte species listed in 3.1, six (in the case of *Cochleria pyrenaica* the aggregate species) declined between the two plant atlases (1960s to late 1990s) with negative change indices (Preston and others 2002). The change index is a measure of the relative performance of a species between the two national atlas surveys allowing for overall variation in recording effort between the two surveys and is explained more fully in Preston and others 2002.

Botrychium lunaria and *Viola lutea* in particular belonged to a group of species that showed a significant decrease over the period 1987–2004 in a re-survey of a sample of tetrads in 2003– 2004 previously surveyed in 1987–1988 (Braithwaite and others 2006). In contrast, *Noccaea caerulescens*, appears to have been broadly stable over the period (Preston and others 2000), but this does not reflect or account for the loss of local populations and concomitant reductions in patch size and numbers of localities for the habitat. It should though be borne in mind that these data refer to the total British populations of these species and not just to the status of those metal-tolerant ecotypes that occur in calaminarian grassland in Great Britain.

A range of impacts have led to losses and degradation of the habitat and its component species due to factors such as mine spoil reclamation or re-working, deposition of atmospheric nitrogen, decline in the toxicity of the surface soil leading to successional change, a cessation of or decline in grazing including by rabbits, tree planting and possibly agricultural improvement by the use of fertilisers.

Although it is clear that there have been significant historical losses in extent of this habitat, published evidence of this is rather limited and the evidence is mostly derived from unpublished sources and monitoring and surveillance of known sites.

However, losses are well documented for the lead rakes of the Derbyshire Peak District (Barnatt and Penny 2004). In the Peak District, an estimated 50% of lead mining remains have been entirely lost and another 25% significantly damaged (Barnatt and Penny 2004), and losses (of unknown magnitude) are continuing here and elsewhere. Simkin (2011) reports that since the 1970s, at least 60% of the calaminarian grassland in the north Pennines has been lost, and many of the remaining sites have lost some or all of their conservation interest.

Increasing fragmentation and isolation of sites has and is an ongoing threat, with many calaminarian grassland sites now small in extent (see section 5.1).

Although the rate of decline since 1994 is not precisely documented, assessments made for Article 17 reporting between 2007-2017 each concluded that the extent of the habitat was decreasing albeit at rates thought to be less than 1% a year.

Loss and fragmentation

Island biogeography theory predicts that the decreasing extent and fragmentation of semi-natural grasslands more generally over the last 50-100 years will ultimately result in losses of species from remaining areas of grassland habitat. Long transient times in response to decreasing habitat area and increasing isolation due to fragmentation may cause the present plant (and animal) species distribution to reflect the historical rather than the present landscape configuration. Hence, current species populations are possibly not yet in equilibrium with the current landscape configuration, but rather reflect that of the past.

Although the reality of such 'extinction debt' has not been demonstrated for grasslands in England/UK, the principles outlined in Lawton and others (2010) of 'better, bigger, more and joined' should be applied if they are to be conserved effectively. However, for calaminarian grassland, only the first of these apply as it is not usually practicable or permissible to create additional areas of the habitat without major effort such as by spreading metal-rich material or translocation of soil or turf (see section 5.4).

Also, practically, at an individual site level, species populations on small or isolated patches are undoubtedly at a greater risk of extinction for a number of reasons: increased ratio of edge to area increases their susceptibility to external factors such as fertiliser drift; increased probability that stochastic events such as drought and fire will cause extinction across the entire site; tendency to be at greater risk of deterioration in habitat quality over time; and their dependence on migrants from larger habitat patches to maintain viable populations.

There is ecological evidence of the negative effects of fragmentation and isolation on the populations of some of the characteristic vascular plants of this and other semi-natural grassland habitats through, for example, genetic erosion (e.g. see Matthies and others 2004).

Impact of these changes:

Natural range and distribution

The natural range of calaminarian grassland is ultimately dependent on the availability of suitable metal-rich substrates. It has probably not radically changed over the last 100 years. However, within the range, the distribution, extent and size of individual sites has markedly changed over the last 50-100 years as detailed below.

Area

Significant areas of calaminarian grassland have been lost during the last 60 years or more, though it is rarely possible to provide accurate figures (see above).

Patch size

There is no data on change in patch size of the habitat over time. However, in addition to an overall likely reduction in extent, there has probably also been a decline in the size of remaining patches.

Quality of habitat patches

Data on patch quality (such as site condition assessments) is only available for a limited period (last 15-20 years) and only for SSSIs (see section 5.1).

However, the quality of habitat patches is likely to have declined both at the individual patch level and at the landscape scale over the last 50-100 years, although no detailed studies are available. This assessment is based on what is known of the likely cumulative impacts of declining soil metal toxicity over time and successional change, mine spoil reclamation or re-working, deposition of atmospheric nitrogen, a cessation of or decline in grazing including by rabbits and agricultural improvement.

Threatened species

As detailed in sections 5.1 and above, a number of the vascular and lower plant metallophytes are now classified as threatened using IUCN criteria, indicating that loss and fragmentation of the calaminarian grassland habitat (and their other habitats) has had a negative impact on the populations of these species.

Sources: JNCC Article 17 Reports 2007-2017; Barnatt & Penny 2004; Braithwaite and others 2006; Hodgetts 2011; Lawton and others 2010; Matthies and others 2004; Preston and others 2002; Rodwell and others 2007; Simkin 2011; Stroh and others 2019; Woods & Coppins 2012.

Confidence: Moderate

5.3 Future maintenance of biological diversity and variation in the habitat

Current pressures and threats

The main pressures and threats are a decline in the toxicity of the surface soil leading to successional change, mine spoil reclamation or re-working, deposition of atmospheric nitrogen, a cessation of or decline in grazing including by rabbits, and potentially tree planting.

Although the evidence base is deficient, there remains a possibility that reduction of metals in the water column due to capping of mine discharges may also be a driver for decline in calaminarian river shingle sites due to less scope for re-charge of metal toxicity via sediment for those sites that flood. Other localised pressures that may be due to them being perceived by some as waste ground include tipping, storage of timber, scrap metal and imported stone and use for motor sports.

Vulnerability to climate change has not been assessed for this habitat but it is considered that it is probably low as for other lowland dry grasslands (calcareous and acid) (Natural England & RSPB 2020). However, increased flooding from higher rainfall and more frequent extreme weather events can remobilise heavy metal deposits originally released during historic mining activity and now trapped within soils and sediments in metal mining catchments. While this represents a challenge from a pollution control perspective, it is likely to provide a potential benefit to the maintenance of calaminarian grassland sites, particular in channel river gravels. Conversely, it could conceivably enhance run-off and more leaching of heavy metals resulting in their depletion from calaminarian soils.

Natural range and distribution

The range and distribution of calaminarian grassland is determined by the extent of former metal-mining activity that has created the artificial substrates on which the habitat now depends. While this range and general distribution is unlikely to change in the future there may be changes in the detailed distribution of the habitat and its component species due to the impacts identified above.

Area

Although it would be theoretically possible to create new calaminarian grassland habitat (see section 5.4) it is not proposed to set any national targets for the creation of new calaminarian grassland habitat. The rationale for this approach is firstly that calaminarian grassland is not now a naturally occurring habitat in England and secondly creation is mostly impractical and may lead to negative impacts on the environment, including compromising the health of people and livestock.

In addition, maintaining the existing areas of habitat in favourable condition is challenging due to the need to artificially maintain metal toxicity that declines over time as increasing organic matter from plant remains and leaching of metals leads to less contaminated conditions and successional vegetation change.

The habitat extent and populations of the metallophyte species may decline if sustainable management cannot be achieved. It is however expected to be relatively robust to the direct threats posed by climate change. The aim is to maintain the existing area of the habitat in favourable condition whilst accepting that there may be some decline in extent especially in relation to the river shingle examples.

Patch size

Little is known on what constitutes a viable patch size for this habitat but seemingly, provided management is appropriate, patches of 0.5 ha or smaller may be viable in the long-term. The minimum size for qualification as SSSI is normally 0.5 ha (Jefferson and others 2014).

Quality of habitat patches

Although the evidence base is limited, there is a likelihood that patch quality and species diversity of calaminarian grassland sites has declined over the last 90 years, due to a range of impacts including decline in surface soil metal toxicity, nutrient enrichment and management changes (see 5.2). The lack of available data on these changes makes it challenging to decide on what constitutes an appropriate baseline.

Should the CSM favourable condition baseline plus species richness and species composition variables from the National Vegetation Classification (Rodwell 2000) and other vegetation and lichen and fungal data (Sanderson and others 2018, Simkin 2007) be used as measures of quality and diversity then, assuming the pressures of declining soil metal toxicity, nutrient enrichment and lack of management are addressed over time, quality and diversity of patches could be maintained.

Threatened species

Maintenance and restoration of favourable condition of the existing area of calaminarian grassland will help to ensure viable populations of the threatened species associated with the habitat (section 5.1).

Sources: Jefferson and others 2014; Natural England & RSPB 2020; Rodwell 2000; Simkin 2007.

Confidence: Moderate

5.4 Constraints to expansion or restoration

As far as is known, no natural calaminarian grassland sites remain in England and there are no places in the landscape where new near-natural calaminarian grassland could be created as naturally occurring ore veins have been eliminated by mining.

However, it would be theoretically possible to create new calaminarian grassland habitat by spreading heavy metal-contaminated waste over an area with no intrinsic conservation value, mixing it with stone to create the necessary free drainage and sheltered microhabitats. The contamination levels would need to include at least one heavy metal at phytotoxic levels (Pb >10,000 mg kg-1, Zn >2,000 mg kg-1, Cd >15mg kg-1). However, it is very unlikely that such an approach would ever be adopted very widely due to concerns over heavy metal pollution of soil and surface and groundwater resources. There may however be very limited opportunities for creating new habitat if a risk assessment shows it will not cause water pollution (primarily to rivers) not least since it may be a useful way to use highly metal contaminated sediments captured using in-river check weirs and smaller (ditch scale) sediment traps, and preferable to taking to landfill. There would though be waste regulatory legislative protocols to address.

However, the focus of favourable conservation status is on restoration and maintenance of the condition of the existing resource of calaminarian grassland where practically possible.

As previously mentioned, even conserving and restoring existing examples at or to a favourable condition is challenging due to the successional changes that are occurring on some sites due to a decline in soil surface metal toxicity and these will require interventionist management by soil perturbation or removal. The most recent research (Simkin, 2007 & 2011, Simkin in press) has shown that attempts to reverse this succession by surface soil removal can be successful but only if followed by ongoing scrub control and grazing. Habitat restoration schemes are often jeopardised by the lack of this follow up. However, there is a need for further practical trials and research to test soil stripping as a method for restoring the habitat and if it is successful, to upscale this over larger areas of the habitat that is in unfavourable condition.

Sustaining the calaminarian grasslands of the river shingle sites in the north and south Tyne catchments, will be particularly challenging, due to general surface toxicity decline. For those sites that still flood, heavy metal content in the river is likely to further decline due to the implementation of measures to reduce metal pollution in the rivers draining former mining areas. There is, however, some uncertainty as to whether or not this will impact the supply of metal-rich materials to calaminarian sites. Thus, for these sites no further input of metal-rich sediment can be anticipated longer term and perturbation of the substrate may be discouraged due to pollution concerns. The future prospects for a proportion of the extant calaminarian grassland resource is therefore uncertain and some sites ultimately will no longer support the habitat due to successional changes. It may be that the successional vegetation may still be of biodiversity value but possibly not in all cases. For those sites that are SSSI, this will require a reappraisal of the site conservation objectives, site boundaries and the specified interest features.

Existing sites may also be in poor condition due to other factors such as excessive inputs of nutrients from atmospheric nitrogen deposition. A critical load level has not been formally allocated to this habitat, so the critical load for calcareous grassland (15-25 kg N/ha/year) was adopted in 2007. Air pollution (N deposition) is also known to detrimentally affect calcareous and other dry grasslands (Stevens and others 2004, 2011).

Sources: Bobbink and others 1998; Rodwell and others 2007; Simkin 2007; Simkin 2011, Simkin in press; Stevens and others 2004.

Confidence: Moderate

6 Conclusions

6.1 Favourable range and distribution

The current range (see section 5.1) is likely to be favourable for future maintenance of the existing habitat. The favourable area will fall within the current range (including historic and current occurrences). The range could be monitored using a combination of climate, topographical and soil/substrate parameters.

6.2 Favourable area

The favourable area is set at 250-300 ha with the latter figure being the approximate current area. This would involve restoration to favourable condition of the suite of existing sites, both SSSI and non-SSSI. This would be achieved through a combination of grazing, removal of shrubs and trees and soil stripping. On sites where soil stripping is used, care will be required to avoid negative environmental impacts such as water pollution.

A general principle adopted by the Defining FCS project is that we should aim to conserve habitat types and species through restoring more natural ecosystem functioning as far as this is possible, since naturally functioning habitat mosaics provide the best, most comprehensive and most resilient and sustainable expressions of biodiversity (Mainstone and others 2018). The scope for restoring more naturally functioning habitat mosaics within which individual species and habitat features can thrive varies, both from place to place and from feature to feature, and such restoration generally takes time.

Calaminarian grassland is now largely confined to artificial environments and approaches to restoration particularly soil stripping is highly interventionist and does not mimic natural processes. However, it can be justified as the habitat is now virtually limited to artificial examples in England and without it, this rare habitat, together with its associated rare and threatened species, will undergo further decline.

However, even adopting this approach, given the likely threats and pressures to the habitat, it may not be possible longer term to sustain all the remaining examples in favourable condition.

Temporal changes in the area could be monitored by a combination of field-based sample based monitoring and earth observation methods. The latter are likely to become increasingly sophisticated and may, in combination with traditional field monitoring, offer a good prospect of monitoring favourable area.

6.3 Favourable structure and function attributes

Structure attributes

• Vegetation community and species composition especially presence of metallophyte species[1]

• Low cover of specified undesirable species including coarse grasses and shrub/tree species - no species/taxa more than occasional throughout the sward or singly or together more than 5% cover (Robertson & Jefferson 2000)

• A high cover of bare ground (20-90%)

• The presence of rocks, pebbles, cobbles, gravel etc, especially in relation to bryophytes and lichens

• Sward height and structure – average height 5 cm or less

Function attributes

• Maintenance of low productivity soils with high levels of heavy metals – exceed thresholds for phytotoxicity: Zinc >2,000 mg kg^{-1}; Lead >10,000 mg kg^{-1}; Cadmium >15 mg kg^{-1}. Copper no data?

• Supporting off-site habitat – e.g. contiguous grassland habitat to ensure optimal grazing management of the habitat

• Concentrations and deposition of air pollutants to at or below the site-relevant Critical Load or Level values (15-25 kg N/ha/year)

• Suitable grazing management by livestock (sheep preferred to cattle) appropriate to deliver conservation objectives where required. Note that there is a risk from lead poisoning to livestock grazing of calaminarian sites, especially where the levels of lead in soil and vegetation are very high. There are possible strategies for avoiding livestock welfare issues which might include measures such as limiting the period of exposure of individual animals and grazing in conjunction with a larger area of land that is not contaminated. A risk assessment should always be undertaken. One option that might be considered where livestock grazing is not possible is the managed re-introduction of rabbits

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[1] Annex 2 lists typical and positive indicator vascular plant species for the habitat. Annex 3 lists the 49 lichen taxa that are preferentially found in metal-rich habitats, of which 27 are saxicolous and 22 terricolous (Sanderson and others 2018).

• Presence and activity of rabbits at sustainable levels (principally creation of bare ground and short turf) to deliver habitat and species objectives at selected sites

Quality of habitat patches

At least 95% of the favourable area of the habitat meets the structure and function requirements as described above.

Threatened species

All species partially or wholly dependent on this habitat should be Least Concern, when assessed using IUCN criteria (or considered to be Least Concern if not formally assessed), as regards to this habitat.

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Annex 2: Typical and constant vascular plant species

Constant species from component National Vegetation Classification type OV37

Agrostis capillaris, Festuca ovina, ***Minuartia (Sabulina) verna****,*

Typical species indicating favourable condition (from Robertson & Jefferson 2000)

Those in bold above plus:

Armeria maritima, Cochleria pyrenaica, Minuartia verna, Noccaea caerulescens, Silene uniflora (= *Silene vulgaris* ssp *maritima*), *Viola lutea.*

Annex 3: Lichen taxa that are preferentially found in metal-rich habitats (after Sanderson and others 2018)

Saxicolous taxa	Terricolous taxa
Acarospora sinopica	*Absconditella trivialis*
Agonimia repleta	*Baeomyces placophyllus*
Catillaria stereocaulorum	*Belonia incarnata*
Gyalidea subscutellaris	*Cladonia cariosa*
Gyalideopsis crenulata	*Coppinsia minutissima*
Lecanora epanora	*Epilichen scabrosus*
Lecanora gisleriana	*Peltigera neckeri*
Lecanora handelii	*Peltigera venosa*
Lecanora subaurea	*Placynthiella hyporhoda*
Lecidea endomelaena	*Polyblastia agraria*
Lecidea inops	*Sarcosagium campestre var. campestre*
Placopsis lambii	*Sarcosagium campestre var. macrosporum*
Polycoccum squamarioides	*Steinia geophana*
Polysporina ferruginea	*Stereocaulon condensatum*
Porpidia flavicunda	*Stereocaulon glareosum*
Porpidia flavocruenta	*Taeniolella rolfii*
Porpidia melinodes	*Vezdaea acicularis*
Rhizocarpon cinereovirens	*Vezdaea aestivalis*
Rhizocarpon expallescens	*Vezdaea cobria*
Rhizocarpon furfurosum	*Vezdaea leprosa*
Rhizocarpon oederi	*Vezdaea retigera*

Stereocaulon dactylophyllum var. dactylophyllum	*Vezdaea rheocarpa*
Stereocaulon delisei	
Stereocaulon leucophaeopsis	
Stereocaulon nanodes	
Stereocaulon pileatum	
Stereocaulon vesuvianum var. nodulosum	

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