The importance of the oil-shale Bings of West Lothian, Scotland, to local and national biodiversity

The Importance of the Oil-Shale Bings of West Lothian, Scotland, to Local and National Biodiversity

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Summary

The oil-shale bings of West Lothian, Scotland, are a group of post-industrial waste sites, unique in Britain and Western Europe. The industrial exploitation of oil-bearing rocks has created a habitat with its own distinctive flora and fauna. The floral diversity of individual sites has been documented as species lists in several studies. A comprehensive list of more than 350 plant species, with supplementary information on animal species, was compiled from an extensive literature review of these studies. From these data it was possible to determine the extent of species variation within and between bings, identify locally and nationally rare species, and thus to determine the importance of the oil-shale bing habitat at a local and national scale. The results will go some way to allay concerns about the loss of local biodiversity, generally throughout the countryside, due to changes in agricultural practices and increased urbanisation. Findings from the bings and evidence from other types of derelict land suggest that species are not lost, they have moved to new habitats.

Key words: oil-shale bing, plant species diversity, Red Data Species.

Introduction

Plant species on shale bing sites in Scotland have been documented in research of the vegetation carried out over more than 35 years (Russell, 1971; Martin, 1992; Maka, 1995; Harvie, 2005a). There are also records from the North Addiewell Nature Reserve of the Scottish Wildlife Trust (Collinson & McLean, 1997) and from the bing at Faucheldean sites that are protected from development and which support several plant species not found elsewhere in West Lothian county (Sheldon, 1997). The oil-shale bings are noted as a valuable lichen habitat (Coppins, 2002). Five Sisters and Greendykes, both scheduled national monuments, provide habitats for a wide range of locally threatened species of the flora and fauna (Harvie, 2005b). In addition the bings are home to many common plants and animals that are becoming increasingly marginalised by demands for more land for new housing and changes in farming methods (Sheldon, 1997; Harvie, 2005b). Diversity of species in the county still abounds although the individual species are not necessarily in the habitats where they once were.

The aims of this paper are to quantify the biodiversity of species on the oil-shale bing habitat both within and between bing sites; to discuss the importance of plant diversity at a local (West Lothian) and national (United Kingdom) scale and to briefly describe some of the possible causes of this diversity. The objective is to raise awareness of the contribution of the oil-shale bings of West Lothian to biodiversity at a local and national level.

Throughout this paper 'West Lothian' is the political county of West Lothian

whose boundary includes most of the botanical vice county of West Lothian (Watsonian VC 84), and a large section of the botanical vice county of Midlothian (Watsonian VC 83).

Site description

The oil-shale bings of West Lothian are unique spoil heaps formed from the waste material created during an industrial process to retort crude oil, in the form of paraffin, from deep mined oil-bearing shale. The substrate was heated to over 500 °C during the process and was completely sterile of all life when the spoil was deposited. The resulting mounds of spoil can be low lying over a large area or steep sided, single or multiple peaked. Height above the surrounding landscape ranges from 9 m to 95 m (summit altitude above sea level from 100 m to 240 m). The vegetation that has developed over the 50 or more years since the cessation of dumping is species rich and varied in comparison with the immediately surrounding agricultural and urban landscape. The chemical and physical properties of the bing material are very different from the surrounding countryside, which is low lying and has slightly acidic soils.

The bing substrate

When the blaes (burnt shale) is dumped after retorting it rapidly weathers into smaller pieces as a result of wind, rain and frost breaking down the laminar structure of the shale. The weathered substrate has a large particle size and a lower water holding capacity than coal spoil, making it free-draining. The shale particles are also more cohesive than coal increasing the stability of the bing surface and the slopes are less likely to be eroded by rainfall and runoff. Oxidation of the shale causes the colour to change from its initial blue-grey to the characteristic red associated with the bings.

The substrate is more basic than the surrounding agricultural land, pH 5.72 - 8.17, and has an extremely low nitrogen content, <0.47 ppm (Harvie, 2005a). Although there is considerable variation in the amounts of Na, Mg, K, P, and Ca, both within and between bing sites, there is no evidence of heavy metal pollution, and the sites are not toxic (Harvie, 2005a).

The physical and chemical structure of the substrate is amenable to seed germination and seedling development, offering a good rooting medium; however, lack of existing vegetation can result in rapid, short-term, surface desiccation from sun and wind, making conditions difficult for early colonisers and seedling establishment.

Methods

Species and environmental data were collected in an extensive survey of eight of the oil-shale bings of West Lothian (Harvie, 2005a). From this survey species lists of vascular plant species and macro cryptogams were produced for each bing site. Shared species and species unique to each site were identified. The lists from this study were then combined with additional vascular plant species that had been recorded in surveys of other bing sites (Russell, 1971; Martin, 1992; Maka, 1995; Collinson & McLean, 1997). Further species recorded on the bings were established from reviewing local floras and species checklists (McKean, 1989;

Muscott, 1989; Smith *et al.*, 2002). This resulted in a single compilation list of species recorded on the bings derived from all available sources. Rare species and species of local importance were identified from frequency and abundance information in the literature (McKean, 1989; Muscott, 1989; Smith *et al.*, 2002), and also from national Red Data Book lists (Church *et al.*, 1996; 2001). Plant names follow Stace (1997).

Results

Plant species diversity

The survey by Harvie (2005a) resulted in 211 plant species being recorded over eight bing sites. The numbers of species recorded between sites differed considerably and each bing had a particular cohort of 'unique' species (Table 1). The highest number of species recorded on a single bing site was 101 at Addiewell south and the lowest was 49 at Drumshoreland south. The highest number of unique species (20) was recorded at Addiewell north and the lowest numbers of unique species (2) were recorded at Drumshoreland north and Drumshoreland south.

The combination of the individual lists and the addition of species data from other sources resulted in a compilation list of 357 species recorded in the bing habitat (species list available in Harvie, 2005b). Only five of these species are common to all bing sites: *Holcus lanatus*, *Salix caprea*, *Trifolium repens*, *Tussilago farfara* and *Urtica dioica*.

Locally rare plant species and habitats

Thirty-two species (Table 2) that are rare within, or important to, West Lothian were identified from comparison of species lists with the local checklists and floras. Five of these are also recognised as indicators of important local habitats (Sheldon, 1997). *Lycopodium clavatum* is not only rare in the county (Fig. 1) but the bing records are outwith the usual montane habitat for this species. *Anthyllis vulneraria*, also locally rare, is associated with coastal habitats apart from the record from Mid Breich bing (Fig. 2).

Table 1. Species numbers and unique species on eight bings in West Lothian, Scotland.

Name of bing	OS grid reference	Total number of species*	Number of unique species
Addiewell north	NT 002 631	99	20
Addiewell south	NT 005 627	101	8
Clapperton	NT 079 697	92	13
Drumshoreland north	NT 075 700	60	2
Drumshoreland south	NT 078 695	49	2
Greendykes	NT 087 736	86	4
Mid Breich	NT 009 646	92	13
Oakbank	NT 076 664	84	11

* Species includes vascular plant species and cryptogams (adapted from Harvie, 2005a).

Table 2. Rare and locally important plant species on bing sites in West Lothian, Scotland.

Species name	Common name
Anthyllis vulneraria	Kidney vetch
Artemisia absinthium	Wormwood
Atropa belladonna	Deadly nightshade
*Betula pubescens**	Downy birch
*Briza media**	Quaking grass
Centaurea scabiosa	Greater knapweed
Chaenorhinum minus	Small toadflax
Chrysanthemum segetum	Corn marigold
Cirsium heterophyllum	Melancholy thistle
Cichorium intybus	Chicory
Diphasiastrum alpinum	Alpine clubmoss
Empetrum nigrum	Crowberry
Epipactis helleborine	Broad helleborine
Epipactis youngiana	Young's helleborine
Gnaphalium sylvaticum	Heath cudweed
*Hyacinthoides non-scriptus**	Wild hyacinth (bluebell)
Listera ovata	Common twayblade
*Lotus corniculatus**	Bird's-foot trefoil
Lycopodium clavatum	Stag's-horn clubmoss
Melilotus altissima	Tall melilot
Orchis mascula	Early purple orchid
Plantago media	Hoary plantain
Platanthera chlorantha	Great butterfly orchid
Pyrola minor	Common wintergreen
Rhinanathus minor	Yellow rattle
Sagina nodosa	Knotted pearlwort
Sanguisorba minor	Salad burnet
Sedum acre	Bitter stonecrop
Senecio viscosus	Sticky groundsel
Tragopogon pratensis	Jack go-to-bed-at-noon
Trifolium striatum	Knotted clover
Veronica polita	Grey field-speedwell

List compiled from all available records and literature; nomenclature follows Stace (1997).
* denotes species that are key indicators of Local Biodiversity Plan habitats (Sheldon, 1997).

Nationally rare plant species

Eight species with Nationally Scarce status in Great Britain (Church *et al.*, 1996; 2001) were recorded on the oil-shale bing habitat (Table 3). All of these were lichens or mosses and they are recorded nowhere else in West Lothian.

Discussion

The distance of the summits of the bings from the most immediate seed sources in the surrounding vegetation, combined with the alkaline habitat (in stark contrast to the surrounding acid soils), results in the successful colonisation, particularly of the peaks and plateaux of the bings, with plant species that are best

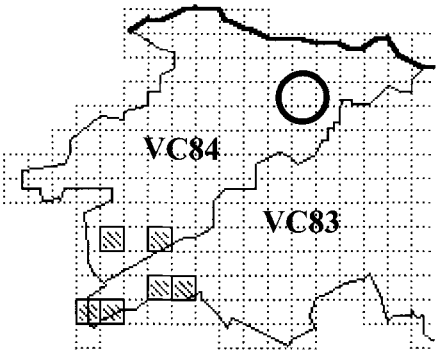

Fig. 1. Distribution of *Lycopodium clavatum* in BSBI vice counties 83 and 84 within West Lothian, Scotland. Records are illustrated by shaded squares (2 km × 2 km). Circle highlights position of Faucheldean but no record is shown for this square. Map adapted from Smith *et al.* (2002).

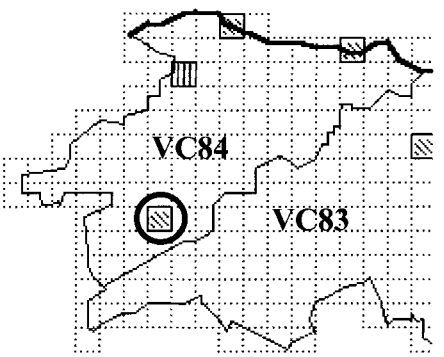

Fig. 2. Distribution of *Anthyllis vulneraria* in BSBI vice counties 83 and 84 within West Lothian, Scotland. Records are illustrated by shaded squares 2 km × 2 km). Circle highlights Mid Breich record. Map adapted from Smith *et al.* (2002).

suited to this substrate and that also have mechanisms for long-range dispersal from similar habitats. A high proportion of species recorded at the tops and plateaux of bings are associated with high pH habitats like calcareous grassland or sand dunes, or have wind or animal dispersed seeds (Harvie, 2005a). Man-made sites like the oil-shale bings provide a receptive substrate for seed rain that is very different in physical and chemical structure from the surrounding land. Seeds that would otherwise be unsuited to local soil conditions find refuge in these sites and add to the local biodiversity (Zhang *et al.*, 2001).

Habitats within the bings vary from almost bare substrate to semi-natural grassland, heather scrub and pioneering birch woodland. Differences in the age and size of the bings, how they have been managed, available seed sources, substrate type and soil chemistry all contribute to the habitats and their vegetation.

Table 3. Nationally rare species found on bing sites in West Lothian, Scotland.

Species name	Common name
Bacidia viridescens (A.Massel) Norman	A lichen
Buxbaumia aphylla Hedw.	A moss
Caloplaca cerinella (Nyl.) Flagey	A lichen
Micarea lithinella (Nyl.) Hedl.	A lichen
Steinia geophana (Nyl.) Stein	A lichen
Stereocaulon leucophaeopsis (Nyl.) P.James & Purves	A lichen
Stereocaulon nanodes Tuck.	A lichen
Stereocaulon saxatale H. Magn.	A lichen

Extracted from the red Data Books of Britain and Ireland for lichens (Church *et al.* 1996) and for mosses and liverworts (Church *et al.* 2001).

Plant species diversity

Biodiversity is not only about rare and exotic species but also about the variety of common species and communities that are contributing to the quality of the landscape. All of the bings are home to many common plants and animals that are becoming increasingly marginalised by demands for more land for new housing and by changes in farming methods. The 357 plant species recorded on the oil-shale bings (186 ha) is almost half the number recorded for VC84 (800 species over nearly 300,000 ha, Muscott, 1989). The variation in diversity and numbers of unique species recorded between sites (Table 1) was neither linked to the size or age of the bing nor to management in the form of seeding or planting. The sites at Clapperton (managed) and Mid Breich (unmanaged) have the same number of species recorded (92) and the same number of unique species (13) (Table 1 and Harvie, 2005a). To some degree the variation between sites reflects variations in the vegetation of the surrounding landscape and the nearest seed sources, but they also indicate the extent of colonisation by species suited to the unusual substrate whose seeds have been dispersed great distances.

Of the 357 plant species recorded only five were recorded as present on every bing site in the combined data from all available surveys. These were all locally common, generalist, perennial species (Smith *et al.*, 2002). What is perhaps more interesting is that other, very common and abundant, ruderal species like *Taraxacum officinalis* agg., *Ranunculus repens* and *Chamerion angustifolium*, that are considered to be highly invasive, are not formally recorded on some of the bings. These and other weedy species have high nutrient requirements and are probably limited by the extremely low levels of potassium and available nitrogen recorded on the bings (Harvie, 2005a). Omission from lists, however, is not conclusive evidence that a species does not occur at a site. *Sedum acre* grows in great profusion on a single slope of Greendykes (B. Harvie, pers. obs.) but does not appear on any formal records.

The importance of the bings as refuge sites for a range of plant species is acknowledged in the publication *Plant Life of Edinburgh and the Lothians* (Chamberlain, 2002; Muscott, 2002). The extent of floral diversity can be seen on protected bings like the North Addiewell Nature Reserve of the Scottish Wildlife

Trust and Faucheldean, which support several plant species not found elsewhere in the county. Five Sisters and Greendykes are protected as industrial heritage sites but these and the unprotected bings also provide habitats for a variety of locally threatened flora and fauna and are a primary site for the common spotted orchid (*Dactylorhiza fuchsii*, the recently adopted County flower of West Lothian (Plantlife, 2006).

There are many unusual, but recurring, species associations on the bings. On several sites large areas (up to 100 m^2) are covered with *Leucanthemum vulgare* and *Fragaria vesca* with very few other species present. *Senecio viscosus* and *Reseda luteola* are the dominant species in highly disturbed areas and on steep slopes on most of the bing sites. Neither of these two combinations of species is representative of any recognised plant community type described in the National Vegetation Classification (Rodwell, 1991-2000). This may be due to the local and small scale occurrence of the bing habitat and its vegetation types, which are in various stages of seral development.

Locally rare plant species and habitats

There are many records of locally and nationally rare flora on the bings (Table 2). As a habitat they are consistently recorded as sole or main habitats for species in local floras (Muscott, 1989; McKean, 1989; Smith *et al.*, 2002). *Senecio viscosus*, *Anthyllus vulneraria* and *Artemisia absinthium* are described as rare at a local level, and *Veronica polita* and *Chaenorhinum minus*, each recorded only once in the combined studies, are recognised as very rare in West Lothian (Muscott, 1989; Sheldon, 1997).

The Faucheldean site is noted for colonies of the clubmosses *Lycopodium clavatum* and *Diphastrum alpinum*. Both species are very rare in West Lothian (Muscott, 1989: Steven & Long, 1989; Smith *et al.*, 2002) and are more usually associated with montane habitats. *Tragopogon pratensis* is an indicator of alkaline soils and, apart from on the summit of bings, is therefore only occasionally found elsewhere in the county on road verges where there is salt spray.

Some locally rare species are recorded only on a single bing: for example *Melilotus altissima* on Drumshoreland south. Greendykes is one of only two sites in the county where *Artemisia absinthium* is recorded. Addiewell north is host to *Listera ovata* and *Pyrola minor*, which despite their 'common' sobriquet are rare inhabitants of the county. Faucheldean is renowned for a diverse orchid population including *Epipactis helleborine*, *Platanthera chlorantha* and *Orchis mascula*. *Epipactis youngiana* is frequently mentioned in the literature as of particular conservation importance (Richards & Porter, 2006), and because of this it has been included in the list of rare local species recorded on the bings. Its present status, however, is that it does not appear on the current list of UK rare plants (BSBI, 2006) and is no longer considered to be a species (Bateman, in press).

In addition to the rare species there are also rare habitats found on the bings. The Addiewell site supports a diverse range of vegetation types from established woodland, both natural and planted, to almost bare scree slopes. On the flat summit of Greendykes, above the bare steep sides of the bing, a species poor

calcareous grassland has established from self-seeding species. Pioneering birch woodland has developed naturally at the base of the tiny bing at Mid Breich, complete with many of the associated ground flora and bryophyte species of long established native woodlands. Old elder trees growing on many of the bings are also a key habitat for epiphytic lichen and mosses (Harvie, 2005a,b).

Nationally rare species

The recording of eight cryptogam species with Nationally Scarce status in Great Britain, that are recorded nowhere else in West Lothian, highlights the importance of the oil shale bings as a key habitat (Table 3). Coppins (2002) describes a small population of the montane lichen *Stereocaulon saxatile* on Addiewell and extensive colonies of three species (*S. leucophaeopsis*, *S. nanodes* and *S. pileatum*) on Philpstoun that are otherwise exceedingly rare locally. Almost half of all the bryophytes that are recorded in Britain are present in the Lothians and among the many habitats in the three counties the shale bing habits are identified as important to the bryophyte flora by Chamberlain (2002). *Buxbaumia aphylla* is a rare moss in Britain that has been recorded in sizeable populations only on bing debris in central Scotland (Steven & Long, 1989). Its persistence at Addiewell for more than 35 years is remarkable for a species that is usually considered to be ephemeral in natural habitats (Crum, 1973). The destruction and landscaping of the bings is a severe threat to these species nationally.

Locally rare fauna

The bings and their vegetation are also important to the faunal diversity of West Lothian. Locally rare insects (*Aphantopus hyperantus* L. and *Adalia decempunctata* L. on the Addiewell site, Collinson & McLean, 1997), birds (*Alauda arvensis* L., *Carduelis cannabina* L., *Anthus pratensis* L. and *Emberiza citronella* L. at Addiewell and Faucheldean, Collinson & McLean, 1997; Maka, 1995) and mammals (*Lepus europaeus* Pallas on Greendykes and Clapperton and *Meles meles* L. on Oakbank, Harvie, 2005a) add to the biodiversity of the oil-shale bing habitat and emphasise the importance of the bings as refuges to local populations that are increasingly marginalised by human requirements for housing, industry and agriculture.

Ecology of the bing species

The substrate of the bings is suitable for plants that thrive in dry conditions on nutrient poor alkaline soils. This eliminates many weedy species and ruderals, which have high nutrient requirements. Successful species include transitory species that reproduce and are well adapted to the initial conditions of the new environment but are less able to compete with new invaders. Examples are *Senecio viscosus* and *Reseda luteola* that are limited to areas of the bings where continuous disturbance or steep slopes maintain conditions similar to those found in early succession. These are species of 'no fixed abode' that survive by 'island hopping' from one disturbed site to the next.

There are also exotics in the form of garden escapes that are well established

on many bing sites. *Papaver somniferum* grows in profusion on more than one bing. Industrial wasteland, such as the oil-shale bings, was described as 'a battle-ground for aliens and casuals' by Tansley (1911).

Several other species recorded on the bings are also of dubious origin. *Matricaria matricarioides* was first recorded in Britain in 1871 only becoming widespread after the invention of the patterned tread of motor tyres (Lousley, 1953). *Veronica persica* was first recorded *circa* 1820 and extended throughout Britain within 50 years despite its large seed size (Preston *et al.*, 2002). *Senecio viscosus* is possibly only native as far north as Belgium on the European continent and was first recorded in Britain in 1660 (Preston *et al.*, 2002). *Acer pseudoplatanus* is a naturalised introduction that is perceived to be displacing native woodland species in Scotland (Peterken, 2001), as is *Fagus sylvatica*.

Sixteen percent of the species recorded on the bings are non-native. Exotics (aliens and casuals) often pose a major dilemma for botanists, ecologists and land managers. Convention deems that they be treated as undesirables and removed for fear that they spread uncontrollably throughout the surrounding landscape. Control and eradication of aliens were among the most frequent management suggestions in the consultation document prepared for the Convention of the Conservation of European Wildlife and Natural Habitats (Genovesi & Shine, 2003). Smith (2003) disagrees, and points out that 'Some plant species are genuinely native only in human-created habitats, having originated there; they can scarcely be alien or introduced'. This view must hold true for the exotics on post-industrial sites such as the bings where such species can be a key component of plant assemblages that then form established and recognisable communities. These species also add to the overall biodiversity of the oil-shale bing habitat and to the county of West Lothian. For these reasons they should probably be defended as integral to the development of new vegetation types.

Strengths and weaknesses of the species data

The species lists produced during the survey of eight bing sites (Harvie, 2005a) were included in data compiled for the production of the New Atlas of the British and Irish Flora (Preston *et al.*, 2002) resulting in six new species records for Vice County 84 (West Lothian) and one for VC 83 (Mid Lothian). In addition four records were updated in VC 84 and one in VC 83. These additions to the knowledge of the local flora demonstrate the importance of the bings as a habitat. Mid Breich is by far the smallest of the remaining bing sites (West Lothian Council, undated) and has been largely ignored in favour of the study of larger better known sites. The three new and four updated records from this site reflect not only the lack of earlier surveys but also, more importantly, the impact of even a small island of novel environment to the biodiversity of the Lothians.

The greatest weakness in the floristic data available for the bings is that many of them are in the form of species lists, based on presence only. This makes it very difficult to quantify species distribution and abundance in relation to substrate chemistry or bing topography. There is also a dearth of peer reviewed literature to corroborate (or refute) the findings of Harvie (2005a).

Ecology of the sites

The topography of the sites and their unusual substrate, the resulting invasion by transitory and exotic species and anthropogenic disturbance have all contributed to the diversity of plant species on the oil-shale bings. Trampling, off-road biking, animal grazing and low nutrient availability in the substrate have resulted in the particular flora that has arisen on the bings and added to the diversity of species and habitats in West Lothian. Maximum species diversity occurs in the bing habitat when there is a small amount of disturbance; however too much of any kind of disturbance destroys both the diversity and the habitat. The lack of vegetation that is associated with some of the bings is often blamed on over enthusiasm by users and deficiencies in the substrate but is more likely to be due to isolation from similar habitats (Miles & Walton, 1993) than to either of these. The resulting vegetation is so unusual within the region that the oil-shale bings constitute one of the eight main habitats in West Lothian's Biodiversity Action Plan (Sheldon, 1997; Harvie, 2005b). The bings are recognised as 'distinctive to the area and having unique assemblages of wildlife which need more recognition and conservation ... they must now be recognised as contributing an important element of diversity' (Sheldon, 1997).

Threats to the bing environment

The concept that post-industrial sites and undeveloped land are important to biodiversity and conservation is not new and many Sites of Special Scientific Interest are quarries and mineral workings (Bradshaw & Chadwick, 1980). The future of the bings is far from secure, however, despite being recognised as an important component of the West Lothian countryside and for having a key role in the maintenance of biodiversity in the county. Individual bings are under threat from reclamation, public pressure through increased, informal recreational use, restoration with non-native species planting and insensitive habitat management.

Of the 19 bings still remaining only four have formal protected status; Addiewell north as an SWT nature reserve, Faucheldean as a local Wildlife site, and Faucheldean, Five Sisters and Greendykes as scheduled monuments. A further four have been restored and are unlikely to be under threat. The remaining 11 bings are either being extracted, have already been extracted or could be in the future.

Inclusion of the bing habitat in the West Lothian Biodiversity Action Plan is a first step toward strengthening the protected status of individual bings but current national (UK) and European designations for biologically important sites are biased against artificial landscapes (Nature Conservancy Council, 1998). The key hope for formal designation under existing legislation is that the bings are selected as a Regionally Important Geological Site (RIGS) for education and awareness raising (West Lothian Council, 2005).

Conclusion

This paper has successfully quantified the biodiversity of the oil shale habitat by combining data from a wide range of published and unpublished sources. It has demonstrated the importance of the bing habitat to locally and nationally rare species that would be unlikely to flourish in other habitats and has shown the

contribution of the oil-shale bings to plant diversity in West Lothian and the United Kingdom. More than 350 plant species, including 32 of the rarest vascular plant species in West Lothian are recorded on the bing habitat alongside eight nationally scarce lichens and mosses. The vulnerability of the sites and the problems of gaining protected status for them are also highlighted.

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