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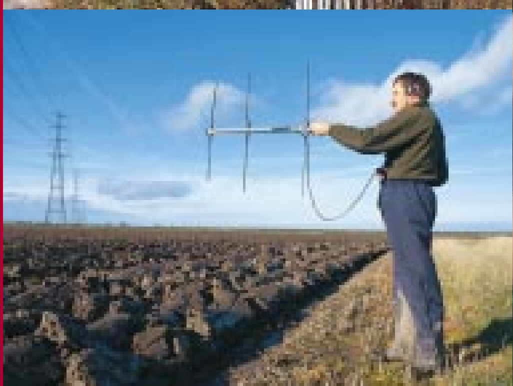
English Nature Research Reports



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Geological conservation benefits for biodiversity

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Herb-robert growing on limestone pavement, Ingleborough Site of Special Scientific Interest: Peter Wakely / English Nature

Contents

1. Introduction

Britain has a diverse geology (all periods are represented from Precambrian to recent (Nature Conservancy Council, 1990a)). The Geological Conservation Review (Ellis and others 1996) forms the framework for biological and earth science conservation in the UK. Within this framework nationally and internationally important sites and features have been given legal protection as Sites of Special Scientific Interest (SSSI). Approximately 1400 sites have been notified in England on geological or joint geological and biological grounds. There are also several hundred Regionally Important Geological/Geo-morphological Sites (RIGS) managed by local groups (Royal Society for Nature Conservation, 1999).

Some geological SSSIs are additionally protected as Special Areas of Conservation (SAC) and Special Protection Areas (SPA) for birds under the European Commission's 'Habitat' and 'Birds' Directives. The Dorset and East Devon Coast is now a World Heritage Site for its geology (inscripted by UNESCO, December 2001); this represents the only natural World Heritage Site on the UK mainland.

English Nature has set a target of 95% of all SSSIs either reaching favourable condition or being under favourable management by 2010. To achieve this some form of geological conservation work may be required. Typically, geological management aims to maintain accessible rock exposures or caves or protect the integrity of features (Nature Conservancy Council, 1990b).

The maintenance and enhancement of Britain's biodiversity (wild habitats and species) is also central to government and local authority policies and English Nature conservation strategy (HM Government, 1990). Whilst English Nature are aware that some of the geological conservation actions could potentially damage associated biodiversity, it also considers that there are likely to be wider benefits. However, the scope and opportunities are currently not well understood, hence the commissioning of this study.

The aim of this project is to examine how geological conservation techniques have the potential to benefit biodiversity, particularly BAP species. It was envisaged that the findings would be used to inform those involved in managing geological sites or combined geological and biological sites. The study comprised a desk exercise and consultation with practitioners.

2. Geological context & settings

English Nature's Earth Science Conservation Classification (ESCC) is used as the primary classification of geological SSSIs for monitoring purposes (Nature Conservancy Council, 1990a). The ESCC has a fundamental two-fold division into exposure and integrity sites, which are further categorised into different generic site types:

Exposure Sites		**Integrity Sites**	
Disused quarries, pits and cuttings	ED	Static (fossil) geo-morphological sites	IS
Active quarries and pits	EA	Active process geo-morphological sites	IA
Coastal and river cliffs	EC	Caves and Karst	IC
Foreshore exposures	EF	Unique mineral, fossil or other geological site	IM
Inland outcrops and stream sections	EO	Mine dumps	ID
Mines and tunnels	EM		

Sites can fall into more than one ESCC category. For example, a disused quarry with an extensive stratigraphic interest would be classified as ED, but localised mineral veins within the same site would also have an IM classification.

Exposure sites exhibit geological features which are relatively extensive beneath the surface; removal of material should uncover more material of the same type. Examples include active quarries, disused quarries, coastal cliffs, foreshore exposures, inland outcrops and stream sections and mines. The conservation objective at these sites is to maintain exposures of the interest features. In contrast to integrity sites, removal of material is less restrictive. In fact, removal of material by quarrying, for example, can often enhance an exposure site interest by uncovering fresh material. Similarly, continuing marine erosion is often essential for the successful geological conservation of coastal sites.

Integrity sites exhibit features which are finite and irreplaceable if destroyed. Examples include many mineral and some fossil deposits, mine dumps, karst (eg limestone pavement), caves and active and fossil geo-morphological sites. The approach to the conservation of this category is to maintain the integrity of the deposits or landforms which, usually more finite, requires closer management and restriction.

The importance of distinguishing between these two groups is that their successful management usually requires a quite different approach. As a rule, exposure sites are more robust than integrity sites and require less management intervention.

2.1 Geological conservation sites in England

A database for the statutory protected sites (SSSIs) is held on English Nature's Site Information System (ENSIS). This was interrogated to give a picture of the proportion of the different types in England and the representativeness of the consultations. However, it needs to be borne in mind that the entries represent site units rather than the whole site and may contain more than one entry per site and therefore can only be indicative.

There are some 1559 entries which are predominantly of the exposure type (77%; Table 1.1). On an England-wide basis, the quarry exposures etc (ED + EA) dominate and comprise 56% of the exposure types, coastal and river cliffs, and foreshores (EC + EF) 24%, and inland outcrops (EO) 19%. Mines and tunnels (EM) only represented about 1% of the entries. Of the integrity sites, geomorphological (IS + IA) and caves and karst (IC) co-dominate (41 & 33% respectively), 21% are unique minerals etc (IM) and 5% are mine dumps (ID).

2.2 Scope of consultation exercise

English Nature identified a representative sample of practitioners to be consulted during this study. This included English Nature's local team of geologists and conservation officers (9), English Nature Headquarters (5), RIGS groups, wildlife trusts and others (5) (Appendix 1). The consultation took the form of an initial discussion by telephone with each contact followed up by a 'questionnaire' (Appendix 2) with further discussion where appropriate.

The sample was chosen to cover the full range of exposure and integrity sites. Geographically, the sample covered the counties of Cornwall, Cumbria, Derbyshire, Devon, Gloucestershire, Kent, Lancashire, Oxfordshire, Norfolk, North Yorkshire, Somerset and

West Midlands. Discussions took place with all contacts. Views and experience were received for geological sites within parts of each of Cornwall, Cumbria, Derbyshire, Gloucestershire, Lancashire, North Yorkshire, and Somerset.

Despite the apparent small number of returns, the seven counties for which experience and views were expressed collectively accounted for about one third of the ENSIS entries. As would be expected from their geology and location, the counties differ in the range of ESCC types. However, in broad terms, the sample can be considered representative of the national picture in terms of geological types (Table 1.2).

The sites in Cornwall and Gloucester were predominantly the exposure type but contrasted in that the dominant sub-division was coastal and foreshore (EC + EF: 62%) with quarries etc being fewer (ED + EA: 17%) in the former, whereas the quarries etc accounted for 85% in the latter. The other counties have more typically a two thirds to one-third ratio of exposure to integrity sites with a more even representation of the sub-division types. The quarries etc sub-division was co-dominant with inland exposures in Cumbria, Derbyshire, Lancashire and North Yorkshire. The integrity types are apparently poorly represented in Gloucestershire. Caves and karst was the most frequent integrity type in Cumbria, Derbyshire and Somerset. In North Yorkshire the caves and karst (IC) is co-dominant with the exposure types. Geo-morphological types (IS + IA) were well represented in Cornwall, Cumbria and Derbyshire, but poorly represented in Gloucester, Lancashire and Somerset. Unique mineral etc (IM) sites were generally well represented in the sample, except in Gloucestershire. The mine dump (ID) type was only represented in the sample for Cornwall, Cumbria and Derbyshire.

Within the limits of the consultation, the proportion of those containing comment are taken to reflect the general picture in England (Table 1.3). The only exception being an under-representation of the geomorphological sites.

3. Biodiversity dependency on geological conservation types

The complex geological evolution of the UK (including recent glaciations), variations in geomorphology (from mountain ranges to low-lying land) and fluctuating weather and climate gradients, have resulted in a variety of soils, watercourses and waterbodies at the landscape and local scales (Clayden & Hollis, 1984; Haslam, 1987; Wright and others 2000). These in turn support their own range of flora and fauna (Tansley, 1949; Ratcliffe, 1977).

For the unexposed English geology, the landscape has been formally classified into 120 Natural Areas. At this scale there is a clear link between biodiversity and the underlying solid and drift geology as manifest in the diversity of soils and water bodies. Vegetation types and communities, and their associated fauna, are characteristic of the soils and water as determined by the type of rock or drift. This is a manifestation of the relative pH (hydrogen ion concentration) and its effect on the availability of the plant nutrients (eg phosphate and nitrogen) and phyto-toxic elements (eg aluminium, manganese, heavy metal).

For example, the thin calcareous soils of the North Downs of Kent on Cretaceous Chalk, the mesotrophic alluvial floodplains of the Trent valley in Nottinghamshire, and the acidic soils of the Carboniferous Millstone Grits of the Dark Peak in Derbyshire (English Nature 1997a & b, 1998) differ subtly in the range of habitats and species supported. At this level, numerically, most of England's biodiversity (ie number of species) is associated with the variety of the derived soils and waterbodies. In this context, the maintenance and enhancement of biodiversity of unexposed geological features is part of English Nature's biological conservation programme and the responsibility of the biological Local Team Officers.

In addition to this countrywide link with geology, there is a special link between biodiversity and exposed geological surfaces and features. There is often a marked association with rare plant (vascular (higher plants and ferns) and non-vascular (eg lichens, bryophytes)) species, or unusual 'mixtures' or species rich assemblages with certain geological features or formations. This occurs particularly with base-rich rocks (eg limestone and chalk, base rich igneous serpentine and gabbro rocks, metamorphosed schists and hydro-thermal altered igneous and sedimentary rocks) (Hopkins, 1994; Hopkins unpublished manuscript; Church and others 2001; etc).

The plant species are usually physiologically adapted to extreme conditions of exposure, low nutrient availability and periodic drought conditions etc., and are notably slow growing in open habitats (either exposed to sunlight or in shade). Consequently, they are poor competitors with more common species of derived soils. Examples include the Teesdale sandwort *Minuartia stricta* on the 'marblised' limestone of Teesdale in Durham, Cornish heath (*Erica vagans*) and upright clover *Trifolium strictum* on the serpentine of the Lizard in Cornwall and alpine pennycress *Thlapsi caerulescens* and forked spleenwort *Asplenium septentrionale* on metaliferous and fluorspar outcrops of the Carboniferous Limestone throughout the Pennines.

Whilst the plant species are typically specific, the fauna of geological exposures (mainly birds and invertebrates) tend to be more catholic and reflect the provision of open habitat with appropriate physical characteristics (eg bare ground, thermal characteristics (Key, 1993, 2000)). However, there are examples which require open conditions and certain geological substrates (eg. the rare mollusc *Truncatellina callicratus* associated with calcareous rocks on the Dorset coast (Bratton, 1991)). It is within the context of geological sites (exposed and integrity types) that there is scope for integration of the conservation efforts and programmes of the geological and biological conservation officers and teams.

4. Biodiversity Action Plans

Biodiversity Action Plans (BAPs) are the UK's response to Her Majesty's Government obligation as a signatory to the Convention on Biological Diversity, Rio de Janeiro 1992. Through a series of committees and consultations, wild species and habitats requiring protection and recovery measures were identified (HM Government, 1994; UK Steering Group, 1995; UK Biodiversity Group 2000). These lists and targets are set out as BAPs at the national (UK BAP) and also at the local (county) level (LBAPs); the latter being the level of implementation. Within this framework geological conservation sites already contribute significantly to the UK's biodiversity in terms of habitat and species capital at both the national and local (county) level. The examples described below for England are taken from the current published UK BAP documents and web site (www.ukbap.org.uk) and some examples of Local Biodiversity Action Plans.

Whilst the BAPs concentrate on the rarer habitats and species, they are also concerned with the wider countryside. Geological sites are associated with a wide range of common plants and animals, but are notable for the occurrence of rare and specialist species of which several are on the BAP list (Appendix 3). It is within this context that the benefit of geological conservation for biodiversity is explored further.

4.1 Habitats

UKBAP

Some of the exposure and integrity geological sites are included in the national biodiversity action plan (UK BAP) because of their associated flora and fauna. Karst features (IC), as limestone pavements, are large integrity sites of national importance for both their earth science interest and biodiversity. Many examples are also SSSIs, with the Ashby, Craven Limestone, Ingleborough Complexes and the Morecombe Bay Pavements being of international importance and **priority** Special Areas of Conservation (SAC) under the 'Habitats' Directive (Brown and others 1997). Their biodiversity encompasses a number of rare plant species, unusual assemblages of woodland and woodland edge species with a rich lower plant flora (lichens and bryophytes), and probably local genotypes too.

Coastline cliffs (EC) and carbonate foreshores (EF) are two types of exposure sites of national importance for their geological and habitat biodiversity. Several examples (Flamborough Head, Portland to Studland Cliffs, The Lizard, Clovelly Coast and South Wight Maritime) are also of international importance as SACs under the Habitats Directive. Coastline cliffs are of biodiversity interest for their higher plants, specialist bryophytes and lichens flora, distinctive invertebrate fauna, as well as birds and seals. Carbonate (chalk) foreshores and cliff sections are important for their alga and invertebrate communities.

Although not included within the UK BAP priority action plans, scree habitats of rock fragments on mountain summits or accumulating on slopes below or beneath cliffs are also internationally important inland (EO) geological habitats. The Helvellyn and Fairfield complex of siliceous scree in north-west England support restricted communities and rare plants (eg stone bramble *Rubus saxatilis*, parsley fern *Cryptogramma crispa*) and is also an SAC. Similarly, Moor House – Upper Teesdale is an SAC for its eutric base rich scree with contrasting elements of northern and southern flora. The Helvellyn – Fairfield complex and the Wasdale Screes are also SACs on account of rock fissure (chasmophytic) vegetation (eg alpine lady's mantle *Alchemilla alpina*, starry saxifrage *Saxifraga stellaris*, forked spleenwort *Asplenium septenionale*).

Also not included in the action plans are the internationally important metaliferous plant communities of the calaminarian grassland type. These grasslands occur on soils with high levels of heavy metals such as lead, chromium and copper which are toxic to most plants. The majority of sites are associated with past mining (ID), but natural outcrops include serpentine rocks (EO) and river gravels. Notable species include alpine penny-cress *Thlapsi caerulescens* and spring sand wort *Minuartia verna* at the Gang Mine SAC in northern England. The Tyne and Allen River SAC includes fossil river channels (IS) with gravels with abundant lichens and rare plant species such as Young's helleborine *Epipactis youngiana*.

LBAPs

Where the above UK BAP habitats occur at the local (regional/county) level they are usually included in the LBAPs. For example, limestone pavements (IC) are included in the Cumbria, Lancashire, Gloucestershire and Mid-Derbyshire BAPs for their lower and higher plant flora, and lower plant ferns.

The Devon BAP (Devon Biodiversity Partnership, 1998) includes coastal cliffs and slopes (EC) for birds, invertebrates, lower plants (including fungi) and rocky foreshore (EF) for birds and wide range of invertebrate fauna. The Devon and Mid-Derbyshire (Derbyshire Wildlife Trust, 1998) BAPs include geological exposures in quarries, pits and cuttings (ED) for exposed geological deposits and eroded material (scree etc) because of associated lower plants (lichens, mosses & liverworts), birds, invertebrates and bats. Similarly, inland rock exposures (EO) are represented in the Mid-Derbyshire BAP for their lower plants and invertebrates. Mines (EM) are also included in the Devon and Mid-Derbyshire BAP for lower plants (including ferns), invertebrates and bats. Mine dumps (ID) are included in the Cornwall (http://www.ukbap.org.uk/lbap.aspx?id=465) BAP particularly for their lower plant lichen and bryophyte assemblages.

4.2 Species

UKBAP

Several moss, lichen, liverwort and vascular plant species are associated with geological features or formations such as stable or unstable acid or base rich coastal cliffs, serpentine rocks, inland limestone outcrops and quarries, metal ores and waste dumps. For example:

Species	Common Name	Status (Red Data Book)	Geological site
Caloplaca aractina	Lichen	Critically endangered	Acidic coastal cliffs or serpentine rocks in Cornwall (EC)
Aucaulon triquetrum	Triangular pygmy-moss	Endangered	Calcareous unstable cliffs (EC)
Tortula freibergii	Freiberg's screw-moss	Near threatened	Acidic outcrops on Yorkshire coast (EC)
Brachythecium appleyardiae	Appleyard's feather moss	Near threatened	Limestone inland outcrops (EO)
Belonia calicicola	Lichen	Data deficient	Limestone inland outcrops (EO)
Zygodon gracilis	Nowell's limestone moss	Endangered	Carboniferous limestone
Desmatodon cernuus	Flamingo moss	Endangered	Magnesian limestone quarries (ED) in Nottinghamshire and Yorkshire
Asparagus officinalis ssp. prostratus	Wild asparagus	Vulnerable	Coastal cliffs (EC)
Thlaspi perfoliatum	Cotswold pennycress	Vulnerable	Oolitic limestone in Cotswold quarries (ED)
Cephalozialla nocholsonii	Greater copperwort	Vulnerable	Only found on copper enriched substrates, particularly mine spoil sites (ID) in Cornwall and Devon
Ditrichum plumbicola	Lead moss	Near threatened	Lead spoils (ID)

Examples of invertebrates include the rare tiger beetle *Cicindela germanica* is associated with coastal cliffs (EC), the mason bee (eg *Osmia xanthomelana*) with inland cliffs (EO), the scarce moth *Hypena rostttralis* (buttoned snout) with caves (IC), and *Aricia artaxerxes* (northern brown argus-butterfly) with limestone quarries (ID) and limestone pavements (IC).

Several bat species are notably associated with caves (IC) or mines or tunnels (EM) (lesser horsehoe bat *Rhinolophus hipposideros* and Barbastelle bat *Barbastella barbastellus*). While birds of geological sites are not UK BAP species, many are associated with the geological conservation features, have special protection under Schedule 1 of the Wildlife & Countryside Act (1981 as amended), are listed under RSPB lists for birds of conservation concern (Anon, 1996) or are known as Red Data Birds (Batten and others 1990). As a consequence, geological sites are of significant conservation importance for them. Examples are given below:

Species	**Common Name**	**Status**	**Geological Site**
Puffinus puffinus	Manx Shearwater	RSPB Amber List Red Data Book	Coastal Cliffs (EC)
Morus bassanus	Gannet	RSPB Amber List Red Data Book	Coastal Cliffs (EC)
Haematopus ostralegus	Oystercatcher	RSPB Amber List Red Data Book	Coastal Cliffs (EC)
Larus argentatus	Herring Gull	RSPB Amber List	Coastal Cliffs (EC)
Uria aalge	Guillemot	RSPB Amber List Red Data Book	Coastal Cliffs (EC)
Alca torda	Razorbill	RSPB Amber List Red Data Book	Coastal Cliffs (EC)
Phyrrhocorax phyrrhocorax	Chough	W&CA Schedule 1 RSPB Amber List Red Data Book	Coastal Cliffs (EC)
Podiceps nigricollis	Black-necked grebe	W&CA Schedule 1 RSPB Amber List Red Data Book	Gravel pits (ED)
Anas clypeata	Shoveler	RSPB Amber List Red Data Book	Gravel pits (ED)
Aythya ferina	Pochard	RSPB Amber List Red Data Book	Gravel pits (ED)
Falco perrigrinus	Peregrine	W&CA Schedule 1 RSPB Amber List Red Data Book	Inland outcrops and quarry faces (EA/ED & EO)
Riparia riparia	Sand Martin	RSPB Amber List	Sand and gravel in quarries (EA/ED)
Calidris maritima	Purple Sandpiper	W&CA Schedule 1 RSPB Amber List Red Data Book	Rocky foreshores (EF)
Arenaria interpres	Turnstone	RSPB Amber List Red Data Book	Rocky foreshores (EF)
Turdus torquatus	Ring Ouzel	RSPB Amber List	Rock outcrops, quarries and mine shafts (EO/ED/EM)

LBAP

At the local (regional/county) level some of the above UKBAP species, along with more common occurring species are included, for example, the northern brown argus-butterfly *Articia artaxerxes* is in the Lancashire BAP (http://www.ukbap.org.uk/lbap.aspx?ID=439).

Several bird species (eg razorbill, guilemot, kittiwake *Rissa tridactyla*, rock pipit *Anthus petrosus*, peregrine, puffin *Fratercula artica*, herring gull *Larus argentatus*, fulmar *Fulmarus glacialis*, cirl bunting *Emberiza cirlus*, dartford warbler *Sylvia undata*, stonechat *Saxicola torquata*), moths (eg rustic, whitespot, thrift clearwing), lichens (eg *Romalina siliquosa*, *Heterodermia leucmelos*), mosses *Weissa multicapsularis* and fungi (eg *Sirobasidium brefeldianna*, *Lepidomyles subcalceus*) are cited for the coastal cliff habitat (EC) in the Devon BAP. The golden hair lichen *Teloschistes flavicans* on coastal cliffs (EC) is included in the Devon BAP, and the early gentian *Gentianella anglica* on chalk cliff tops (EC) in the Kent BAP (Kent Action Plan Steering Group, 1997). Coastal cliffs are highlighted in the Kent BAP for the rare plants (wild cabbage *Brassica oleracea*, Nottingham catchfly *Silene nutans*, early spider orchid *Ophrys sphegodes*) and hard cliffs for several birds (peregrine, kittiwake, fulmar), whereas digger wasps (*Eclemnius ruficornis* and *Alysson lunicornis*) and sand and house martins are both listed for soft cliffs. Chalk foreshores (EF) in Kent are important for algae species. In the Devon BAP the oyster *Ostrae edulis*, the honeycomb worm (*Scabellana alveolata*), the gold and scarlet coral *Balanopyllia regia*, the trumpet anemone *Aiptasia mutabilis*, and turnstone and purple sandpiper are listed for rocky foreshores.

Caves (IC) and mines (EM) in the Mid-Derbyshire plan support invertebrates such as the millipede *Nanogona polydesmoides*, and a range of bat species (natterers, noctule, brown long-eared). The caves and mines (IC/EM) of Devon host the largest population of greater horseshoe bats in Britain. Caves and mines also host specialist flora and fauna (the cave shrimp *Nipargus glenniei*, the water beetle *Hydrochus nitidicollis*, and the luminous moss *Shistostega pennata*.

Natural outcrops (EO) are identified in the Mid-Derbyshire BAP as important for lichens *Lecanora campestris*, liverworts *Trichoclea tomentella* and mosses *Fissidens rivulans*. In the Devon BAP several lichens are listed (eg *Acarospera sinopica*, *Lecanora soralifera*) and ferns (eg the Tunbridge filmy fern, *Hymenophyllum tunbridgense*).

Disused quarries (ED) are particularly important in the Kent and Devon BAPs for bats, birds (peregrine, kestrel, sand martin), great crested newt *Triturus cristatus*, damselflies, as well as plants such as bee orchid *Ophrys apifera*, autumn lady's tresses *Spiranthes spiralis*, carline thistle *Carlina vulgaris*, ivy broomrape *Orobanche hederae*.

5. Threats to biodiversity & benefit of conservation management

The potential threats to the integrity of geological sites are set out in the Nature Conservancy Council's Earth Science Strategy (Nature Conservancy Council, 1990a) and equally apply to the associated biodiversity interest. Consideration of these is outside the scope of this study.

However, natural processes of denudation (weathering and erosion) of the geological feature and vegetation development are particular threats to the accessibility or integrity of the geological features (Nature Conservancy Council, 1990b). They may also be a threat to the inherent biodiversity interest of the geological feature.

5.1 Weathering & erosion

Geological features are susceptible to natural processes of weathering and erosion (Table 2). Weathering is the mechanical degradation or chemical breakdown of *in situ* rock and erosion is the subsequent removal of the mass of weathered material; processes of weathering and erosion operate simultaneously. In some instance, such as an eroding coastline, the failure of a cliff may not necessarily have detrimental consequences for the biodiversity of that particular site. This may serve to protect the site (for example the Holderness and Norfolk Coastline) where the mass of accumulated debris at the toe of the cliff can significantly arrest the rate of coastal erosion. Similarly, the deposition of large amounts of tufa (calcium carbonate which has been dissolved then subsequently re-deposited by groundwaters) can enhance geological features (for example, Janet's Foss and Gordale Scar in the Yorkshire Dales National Park). To determine if weathering and erosion has a detrimental or positive effect on biodiversity, it is necessary to recognise the process of weathering and erosion which may be operating at any one site.

Weathering and erosion may result in the physical removal of the species of interest or its habitat, or their burial at places of accretion and accumulation. In both cases there would be a need for management for conservation of the geological features or access to them. This might be by using standard geo-technical methods to avoid, arrest or mitigate for these effects such as scaling of faces, rock bolting of caves (Nature Conservancy Council, 1990b). These measures would also benefit the associated biodiversity interest by maintaining the provision of relatively stable and suitable habitat (Table 2). However, in some instances, the most effective form of management to influence biodiversity, may be to leave the site alone and "do nothing".

Other natural degradation processes of weathering and erosion may add to the interest of unique mineral exposures and mine dumps. Weathering may reduce the biodiversity interest dependent on the minerals and levels of phyto-toxic agents such as heavy metals to maintain the surfaces free from more aggressive competitors; otherwise degradation may result in their eventual exclusion as more common species invade. Hence, conservation work to re-expose unweathered minerals may be required to maintain the biological interest.

5.2 Vegetation development

Vegetation development may obscure the geological exposures or landscape, or interfere with the natural processes of erosion etc which maintain them (Table 2). In these contexts vegetation removal or control is used as a standard management tool (Nature Conservancy Council, 1990b). Many of the specialist species (birds, invertebrates and lower plants) associated with the geological sites are dependent on open habitat (Appendix 3). Vegetation colonisation and development by common vascular plants pose particular threats by shading of open habitats (especially shrubs and trees) and the reduction of the extent of open ground through the encroachment of a range of vegetation. Here the approach is to remove the vegetation either wholesale or as patches or individual plants (eg trees and scrub).

6. Consultation responses

The questionnaire (Appendix 2) was used to assemble the following information:

i) examples of geological conservation sites (SSSIs/RIGS) which had a biodiversity interest,
ii) whether the sites were under conservation management and its effect on biodiversity,
iii) if not under management, whether there was a need on biodiversity grounds,
iv) where there are areas of geological or biodiversity conservation practice, understanding or knowledge which required further investigation or refinement.

The responses were as follows for each of the conservation site types.

6.1 Exposure sites

The prime geological conservation objective for this grouping of sites is to maintain access and visibility of the features. For this reason, geological conservation work would be expected.

i) **Disused Quarries, Pits & Cuttings** (ED)

Fifteen sites of this type were identified overall, but comment was only provided for five. The sites were located in Somerset, Gloucestershire, Cornwall and Lancashire (Table 1.3).

The examples tended to be relatively small-scale and specific entities but had a high biodiversity interest of lower and higher plants, and invertebrates associated with open/sparsely vegetated ground. All of these sites required periodic vegetation clearance to re-expose the geological features. Where this was scrub, it was accepted by both the geological and biological advisors that without its removal their respective interests would be lost. The vegetation clearance recreated open conditions necessary to support the intrinsic biological interest of the geological feature by providing new surfaces for colonisation. In such cases, there is generally no conflict between the geological and biodiversity conservation objectives as they are the same and use similar methods. In cases where the vegetation being cleared was of particular biodiversity interest or that the vegetation 'supported' fauna of importance, there could be a potential conflict which required careful consideration before such work should proceed.

Another geological conservation practice referred to was 'digging out' the exposure following the accumulation of '*scree/spoil'* (Nature Conservancy Council, 1990b). Reference was frequently made to potential conflicts of interest where access to remove the spoil resulted in disturbance of adjacent high quality vegetation. Also, where the 'spoil' has itself become colonised by specialist flora or fauna there may also be a potential conflict.

Overall, active geological conservation was required at this type of exposed site. The conservation work was considered particularly beneficial for the biodiversity interest of specialist flora and fauna, but the vegetation or spoil itself may be important for diversity and should be taken into account.

ii) **Active Quarries & Pits** (EA)

Conservation management of exposures in active quarries and pits appears to be rarely considered necessary or undertaken, and therefore is usually not considered further. However, specialist invertebrates as well as other fauna (eg bats, sand martins) and plants may be resident in the active quarries and need consideration.

iii) **Inland Rock Exposures** (EO)

These may be large-scale or relatively small-scale discrete features. Two large-scale examples, Lathkill Dale and Cressbrook Dale in the Derbyshire Peak District, were commented upon. The conservation officers considered that generally no geological conservation management was required due to the extensiveness of such exposures at these and similar sites. Therefore the view was there was little scope for biodiversity benefit through geological conservation. However, in Lathkill Dale some outcrops were important for cliff nesting birds and lower plant assemblages. Here, scrub clearance was undertaken to maintain the biological interest and part of the biological conservation programme, but not primarily for geological reasons although it maintained the visibility of the exposure.

iv) **Mines & Tunnels** (EM)

These are generally small-scale specific entities. Two tunnel and mine sites in Cornwall were commented upon. Both sites were important bat roosts, which appears to be the principal biodiversity interest of this type of geological feature. Little geological conservation work is usually necessary and there are few conflicts with the biological interest. One had a grid erected across the entrance to protect the bats from disturbance, and the other required no conservation action. Provided that the access for bats is not impeded and work does not disturb or harm these legally protected species there is no biodiversity issue.

v) **Coastal Foreshores** (EF)

Two marine foreshore sites (Aire Point to Carrick Du, Cornwall and Blue Anchor to Lilstock Coast, Somerset) were commented upon. Neither of these was considered to require geological management to maintain the exposures and therefore there was no potential biodiversity issue or scope arising.

vi) **Coastal & River Cliffs** (EC)

The coastal sites (eg in Aire Point to Carrick Du Cornwall) are large-scale features. These types of exposures are associated with high biodiversity interest of birds, lower and higher plants and invertebrates associated with open/sparsely vegetated ground, and unique coastal vegetation.

Because of the scale of this type of site and natural processes of erosion and instability, management is not usually required for geological purposes. The coastal vegetation was however prone to scrub development at some sites, and whilst its removal was beneficial to maintain the biodiversity interest it was not necessary for access to the geological exposure.

6.2 Integrity sites

The prime geological conservation objective for this grouping of sites is to maintain the integrity of the site.

i) **Mine Dumps** (ID)

Mine dumps are typically small-scale entities. Here, scrub clearance is typically necessary to maintain the lower plant biodiversity interest. At Penberthy Croft in Cornwall this comprised 54 moss and 9 liverwort taxa with two nationally rare and two nationally scarce species.

From a geological perspective, scrub clearance may not normally be required for this type of site. Where the interest is metalophytes, it was considered necessary to disturb the dumps to expose less weathered minerals to raise metal toxicity, in addition to clearance of scrub or other competing vegetation for the metal tolerant vegetation to persist. In this context, there is similarity of the scope and issues concerning the ED exposure type of site.

ii) **Geomorphological Sites** (IA & IS)

These can be both extensive and small-scale specific features. Normally, other than the maintenance of natural processes, no geological conservation work would be expected necessary for this type of site. 'Fossil' sites (IS) were identified, although no comment made, but no active sites (IA) were referred to.

iii) **Unique Fossil/Mineral Feature** (IM)

These are small-scale specific sites. An example was identified in Lancashire, but no comment was made.

iv) **Caves & Karst** (IC)

'IC' sites comprise both limestone karst and caves. The karst features (including pavements) are large-scale features. The caves can be both large under-ground features and small-scale entities. For the karst landscape three sites were identified: two in Cumbria and one in the Peak District of Derbyshire; one cave was identified in Derbyshire.

Hutton Roof in Cumbria is an example of a karst feature. Here the issue was the invasion and exclusion of the typical pavement flora by an alien plant species (cotoneaster). As the invasion was not affecting the geological integrity of the feature, the removal of the cotoneaster was a biological conservation issue. On the other hand, the removal of conifer plantation from the pavement at Whitbarrow is an example of geological conservation on the landscape scale at an Integrity site. Removal of the plantation was also of biological value, as it would facilitate recolonisation of pavement flora (Webb, 2001).

As an example of natural caves, Lathkill Dale's caves were identified for their bats and rare aquatic invertebrates. Here, the conservation work comprised restricting access to remove the threat of disturbance.

6.3 Further investigations & comment

Further Investigations

A range of suggestions for further investigations were received. Headquarters staff considered there was a need for fundamental research on (i) why certain geological exposures were especially rich in species whereas others were not, and (ii) how the physical and chemical properties related to biodiversity. Several Local Team Conservation Officers referred to (i) the need for systematic surveys of the biodiversity resource of the geological sites and in particular the lower plant species and assemblages, (ii) the need for precise information of the location and extent of geological features, especially underground cave systems, and (iii) guidance sheets/book for the management of bare rock/geological features for biodiversity. Site practitioners referred to the need for techniques to deter the development and dominance of vegetation.

Other Comment

There was a general view that geological conservation was relatively poorly financed and that there was a poor appreciation of the significance of geological sites for biodiversity.

Specific comment was made about health and safety matters, particularly in quarries, that might affect the implementation of geological initiatives. Concern was expressed about the long-term sustainability of biodiversity features (mine dumps (ID) & river shingle (IA)) dependent on toxic substrates where leaching was reducing levels to an extent where the specialist species could no longer compete with more common invading species. Similar concern was expressed about the planning system which favours the reclamation of mineral workings and dumps, leaving fewer future ED and ID sites.

7. Geological management & benefit for biodiversity

The above consultation identified a number of cases where geological conservation had, or was likely to, benefit biodiversity.

7.1 Potential benefits of commonly used conservation methods

The effects on biodiversity of the most commonly used geological conservation methods are set out in Table 3 for the four groups of animals and plants which are special to geological conservation sites. These are the ‘lower plants’(algae, lichens, fungi, bryophytes and ferns), invertebrates, birds and bats.

The lower plant group require stable surfaces and open habitat (whether in shade or direct sunlight). Similarly, terrestrial invertebrates require open unconsolidated materials such as ‘scree’ with sparse vegetation, open stable inaccessible ledges are required for nesting birds or unconsolidated material (eg sand) for burrowing birds (sand martin, kingfisher), and deep crevices or caves for bats.

Conservation methods such as scaling of rock faces, reprofiling of faces, rock bolting, removal of vegetation (dense herbaceous vegetation, scrub) are generally beneficial for the lower plant group by increasing stability and maintaining the open habitat. Shot-blasting (using non-toxic material) is another geological conservation technique which may be used with similar benefits to reprofiling. Fencing to reduce physical disturbance by human and stock may also be beneficial, but may serve to hasten vegetation closure.

Similarly, scaling, reprofiling, use of mesh to stabilise faces and the removal of vegetation is likely to maintain open conditions and provide suitable substrates for terrestrial invertebrates. Reprofiling and removal of vegetation is usually beneficial for birds by maintaining or creating nesting sites, openness etc and fencing may also reduce disturbance. Reprofiling may create the opportunity to create hibernacular for bats and fencing or grills would reduce risks of disturbance. The practice of sequential treatment to allow re-colonisation is advisable and essential when some of these practices are employed, particularly reprofiling.

Before any works are carried out, the geological feature should be checked for rare plants or invertebrates and any dependent associates (eg host plant for invertebrates). For bats and birds there are also legal restrictions on works, and surveys must be carried out to determine their presence.

7.2 Consultation examples

A notable large-scale example is the conifer plantation removal at Whitbarrow (IC), Morcambe Bay Pavement SAC, Cumbria has restored the karst landscape and provided opportunity for restoration of the pavement flora (Webb, 2001).

On a smaller scale, scrub clearance at Penberthy Croft in Cornwall benefited bryophytes on mine dumps (ID), coastal cliff vegetation (EC) at Aire Point, Cornwall and cliff nesting sites for birds in Lathkill Dale, Derbyshire. Another example was the removal of an alien species which was threatening the limestone pavement plant communities at Hutton Roof, Cumbria.

Scrub clearance was a common conservation activity at quarry and cutting sites (ED) (eg Salthill Quarry, Lancashire, Cleave, Michampton and Selsey Commons Gloucestershire, Bruton Railway and Seavington St Mary, Somerset). At Wheal Martyn in Cornwall a general clearance of vegetation created open ground and benefited rare lower plants (lichens and bryophytes).

Measures to restrict access to caves in Lathkill Dale in Derbyshire to protect bats and aquatic invertebrates. Similarly, an erection of a grill prevented disturbance of horseshoe bat-roost by cattle and humans at South Terras Mine (EM) in Cornwall.

8. The case & scope for geo-biodiversity

It was widely accepted during the consultation with English Nature and non-government organisations that many geological conservation sites are inherently important for biodiversity. Whilst this is often manifest as species richness (ie the number of species present), the most notable feature arising from this preliminary study is the potential for specialist and endangered species, unusual assemblages and local specially adapted populations (eg McLean and others 1999). This is particularly the case for those sites with exposed rock surfaces, raw/skeletal-soils, toxic materials (eg metaliferous spoil) and other extreme environments. It is within this context of unusual genotypes that geological conservation sites stand apart from the countryside at large and biodiversity issues involving more common and widespread species. The geological conservation sites are therefore of utmost importance for the maintenance of bio- and genetic diversity and should be developed with this aim. Their conservation maintains the vital earth science link between rocks, soils, water and atmosphere (Schwartzman, 1999).

8.1 Scope

It should not be expected that all geological sites in England are equally important, nor offer the same opportunity for promotion of biodiversity through geological conservation. It is evident from this brief study that only certain types of sites are likely to provide significant opportunity for biodiversity enhancement through geological conservation work. This is not because the other sites such as coastal and river cliffs (EC) are not important (they are often of national and international importance for their flora and fauna), but because the natural processes and the scale of erosion etc are sufficient to maintain and renew suitable habitat. Other sites, such as karst pavement (IC) and inland exposures (EO), are covered by biological conservation programmes which also serve the geological conservation needs; for example the removal of conifer plantation from karst landforms (Webb, 2001). A similar situation may potentially exist for the geo-morphological sites (IS & IA) as it appears these sites do not normally require conservation management. However, in some cases vegetation removal would enhance the visibility of the geological and morphological features in the landscape, and could provide an opportunity for benefiting biodiversity.

The most promising exposure site for promoting the biodiversity benefit of geological conservation is the disused quarry-cuttings type (ED) and those parts of active quarries and pits (EA) where commercial extraction has ceased. Not only are they numerically the most abundant type, they are well distributed throughout England. These inland sites are very important for biodiversity, a fact reflected in the number of sites designated as biological SSSIs in the context of an English landscape becoming increasingly dominated by intensive agriculture and urbanisation (Bate and others 1998; Humphries and others 1999; Marren 2001). These sites are refuges for both specialist and non-specialist wildlife (Holiday & Johnson 1979; Humphries & Elkington 1980; Davis 1982; Hopkins 2003), a fact which is well recognised by English Nature and which the agency has promoted through partnering with mineral extraction company associations (English Nature and others 1999). These sites offer scope for geological conservation work to promote colonisation by specialist species or a programme of introduction, probably on a relatively large local scale, without compromising biological features. However, such sites are typically ‘young and dynamic’ in terms of soil development and surface stability and will need an active programme of conservation management owing to relatively high potential for colonisation and subsequent development by more common vegetation.

Similarly the most promising integrity site type are mine dumps (ID). Whilst the integrity of these finite resources is critical, control of invasive non-specialist vegetation is important particularly where toxicity is declining or the exposure is being ameliorated. This is becoming of concern for many metaliferous sites. Here, a programme of geological conservation to expose unweathered minerals may be necessary or a limited ‘mining’ of mineral to provide new substrate. Currently, the inventory of dumps appears to be solely metaliferous spoils due to the mineralogical interest. There may be a case to expand this to include other mineral spoils if there were to be a mineralogical interest, for example colliery wastes, which through reclamation and brown-field development schemes are becoming scarcer, but often have special biodiversity interests (Hall, 1957; Middleton, 2000; Lunn, 2001).

8.2 Biodiversity Action Plans & geological conservation

UK Biological Action Plans are implemented through local programmes lead by appropriate organisations such as English Nature. Whilst habitat plans involving geological sites (eg karst pavement (IC), coastal foreshores (EF) & cliffs IC) are being implemented, this is largely on account of their biological conservation. There are few plans for those involving 'specialist' species, particularly lower plants. Where there are plans, they are either in Scotland or Wales (Appendix 3). It is obvious such species have a lower public profile and appeal than others (eg birds), as well as less available expertise and fewer champions. Because of the link with geological substrates, and the likely common conservation techniques, there is scope for the adoption of plans for these species by earth science conservation. This is justified given their earth science linkage with geology, soils and atmosphere (Schwartzman, 1999). There is a similar case for the specialist invertebrates. This linkage would serve to raise the profile of both geological conservation and the less popular flora and fauna.

8.3 Common objectives, expertise & techniques

Since biodiversity is inextricably linked to geology, there is a need for integration of geological and biological conservation policies, programmes and initiatives if the biodiversity of geological sites is to be protected and opportunities for enhancement are to be realised. From discussions during the consultation, a high degree of integration appears to have taken place following English Nature implementing a 'Team' approach to its business. There is good communication and understanding between the conservation officers and liaison with the specialists, and hence there is an appreciation of the issues and opportunities at this level. This is reinforced where sites are combined geological-biological SSSIs.

Hence, there is an existing reservoir of geological and biological expertise and common objectives which can be applied to integrating and promoting biodiversity and geological opportunities.

Most of the implemented geological conservation work employs techniques also used in biological conservation, with the exception of physical protection measures against coastal erosion and rock stability (Nature Conservancy Council, 1990b). The principal and most commonly used techniques are the clearance of vegetation and exclusion of humans or livestock.

Similarly, the techniques which would be used to promote the biodiversity potential of geological sites are, in principle, the same as used on biological sites. For example, natural colonisation might be relied on for situations where the species was present locally and a good coloniser. If not, then introduction would have to be employed using various standard techniques or adaptations, such as 'seeding' or 'planting' to initiate the process. All these are currently used by English Nature in its biodiversity action programmes and its parallel species recovery programmes. Hence, methodologies are already available for application.

8.4 Funding

Funding will be necessary to realise the biodiversity potential of the geological sites. Currently, there appears to be a low priority in funding of geological conservation work and is further accentuated at the local level where grant aiding of RIGS sites is scarce.

9. What next? – surveillance & research

9.1 BAP & Surveillance Programme

It is recommended that a surveillance programme is initiated. A twin track programme should be developed. One track would be an inventory of flora and fauna associated with the geological features which should be regularly updated as appropriate to the site and the biological entity. It appears that there is little biological condition monitoring of geological sites and hence the extent of the existing biodiversity capital and occurrence of BAP species is largely unknown.

Surveillance is essential in order to prevent destruction of valuable biological resources during geological conservation work. It is also the basis to review whether practices such as 'not to intervene at certain types of sites (eg coastal (EC) and inland sites (EO))' is effective or not, and whether there should be more intervention management. Surveillance should also enable assessments of the risk of damage from geological conservation programmes. At present there is little recording making it difficult to objectively assess and quantify the benefits of geological conservation for biodiversity beyond the principles set out in this report.

The other track should be to identify suitable geological conservation sites for the introduction of BAP species (either by facilitating colonisation or by intervention), the preparation of BAP plans, and overseeing of the implementation and subsequent monitoring. It is anticipated that the programme would be involved in the conservation of the species with specific earth science connections such as the lower plants (algae, lichens, fungi and bryophytes, and ferns).

9.2 Further research

Key areas of understanding required for the introduction or facilitation of colonisation by BAP species can be summarised as:

i) what is the potential for their dispersal and colonisation, and the time-scale
ii) what types of rocks and geological features offer the potential for colonisation and introduction
ii) what are the physical and chemical conditions, and physiological requirements for establishment ((rock type (eg hardness, mineralogy) and condition (ie weathered state), maco- and micro-climate)
iii) what are their requirements and conditions for their persistence and regeneration
iv) what are their responses to and requirements for geological conservation management.

There is a vast scientific literature on the biology and ecology of the targeted groups of species or close relatives. There is a need for desk based research to collate this to provide a general overview and answers to the above questions; this should be a priority of the programme.

However, for certain species current understanding may be insufficient to answer all these completely and sufficiently for the purpose of their conservation or introduction, and this will necessitate a programme of research. To achieve the level of understanding autecological studies will be required. This is likely to comprise surveys and experimentation with selected species which may be either a major community component or a rarity.

In addition, from a practical point of view, the effects and efficacy of conservation practices in promoting the targeted species in the field also needs to be understood. It is anticipated that this would be addressed by a programme of research, survey and experimentation; particularly in relation to natural colonisation and methods of introduction or site modification. Some work has already been undertaken in the latter field to promote colonisation of rock exposures (Humphries, 1977; Courtney, 2001).

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Table 1

Table 1.1 Proportion of geological conservation site types within England (Source: ENSIS)

Type of Site	**No. Entries**	**%**
Exposure		
ED	577	37
EA	92	6
EC	164	11
EF	122	8
EO	227	15
EM	13	>1
Integrity		
IS	65	4
IA	83	5
IC	120	8
IM	77	5
ID	19	1
Total	1559	

Table 1.2 Proportion of geological conservation site types in counties sampled (Source: ENSIS)

Type of Site	No. Entries	%	Glocs	%	Lancs.	%	N Yorks.	%	Somerset	%	Derbys	%	Cumbria	%	Cornwall	%
Exposure																
ED	147	26	41	77	8	30	26	25	16	33	7	30	23	17	16	11
EA	28	5	4	8	2	7	2	2	8	16	1	2	3	2	8	6
EC	69	12	3	6	0	0	10	10	3	6	0	0	2	2	51	35
EF	54	10	3	6	0	0	9	9	1	2	0	0	1	<1	40	27
EO	93	16	0	0	7	26	17	17	1	2	14	25	52	38	2	1
EM	7	1	0	0	0	0	0	0	0	0	0	0	4	3	3	2
Integrity																
IS	18	3	0	0	0	0	1	1	2	4	2	4	7	5	6	4
IA	29	5	1	2	1	4	4	4	0	0	7	12	9	7	7	5
IC	83	15	1	2	2	7	31	30	16	33	11	19	22	16	0	0
IM	31	6	0	0	4	15	3	3	2	4	4	7	10	7	8	6
ID	9	2	0	0	0	0	0	0	0	0	1	2	3	2	5	3
Total	568		53		27		103		49		57		136		146	

Table 1.3 Proportion of Geological Conservation Site Types Responding to Questionnaire

Type of Site	No. Returns	%	No. with Comments	%
Exposure				
ED	15	48	5	30
EA	1	3	1	6
EC	1	3	1	6
EF	2	7	2	12
EO	2	7	2	12
EM	2	7	2	12
Integrity				
IS	2	7	0	0
IA	0	0	0	0
IC	3	10	3	18
IM	2	7	1	6
ID	1	3	1	6
Total	31		17	

Table 2 Commonly occurring processes of weathering & erosion of geological sites & conservation measures

Type of Site	Category	Code	Main Processes of Weathering & Erosion	Influence on Geological Conservation		Conservation / Management Method
				Positive	Negative	
Disused quarries, pits and cuttings Active quarries and pits	Exposure Sites	ED EA	Mass wasting (slides, falls, topples, flows, spreads) Oxidation and dissolution.	(*)	*	Scaling of rock faces, reprofiling, rock bolting, shotcreteing
Coastal cliffs and river cliffs Mines and tunnels Inland outcrops and stream sections	Exposure Sites	EC EM EO	Mass wasting (slides, falls, topples, flows, spreads) Oxidation, dissolution, reduction, carbonation, hydrolysis groundwater erosion, river erosion, coastal erosion, wind		*	Scaling of rock faces, reprofiling, rock bolting, shotcreteing,
Foreshore exposures	Exposure Sites	EF	Coastal, wind and river erosion. Oxidation, dissolution, reduction and hydrolysis.		*	Fencing, clearance of debris, removal of vegetation
Static geomorphological site	Integrity Sites	IS	Mass wasting (slides, falls, topples, flows, spreads). Oxidation and dissolution.	(*)	*	Scaling of rock faces, reprofiling, rock bolting, shotcreteing Fencing, clearance of debris, removal of vegetation
Active geomorphological sites	Integrity Sites	IA	Mass wasting (slides, falls, topples, flows, spreads), Wind, river, ice, hydration, solution, oxidation, hydrolysis, reduction, carbonation, chelation and fixation	(*)	*	Scaling of rock faces, reprofiling, rock bolting, shotcreteing. Fencing, clearance of debris, removal of vegetation
Caves and Karst	Integrity Sites	IC	Mass wasting (slides, falls, topples, flows, spreads), solution and dissolution		*	Fencing, clearance of debris, removal of vegetation and loose rock
Unique mineral or fossil sites	Integrity Sites	IM	Wind, river, ice, hydration, solution, oxidation, hydrolysis, reduction, carbonation, chelation and fixation		*	Fencing, clearance of debris, removal of vegetation and loose rock
Mine dumps	Integrity Sites	ID	Wind, river, ice,groundwater hydration, solution, oxidation, reduction, carbonation, hydrolysis, chelation and fixation		*	Fencing, clearance of debris, removal of vegetation and loose rock

(*) time related benefit

Table 3 Effect of geological conservation methods on habitat suitability for specialist BAP species

Conservation Method	Specialist Biodiversity Groups	Effect on Suitability of Habitat		Comment & Recommendations
		Positive	**Negative**	
Scaling Rock Faces (eg hard rock)	Lower Plants (algae, fungi lichens, bryo-phytes) & ferns	Maintains open areas & stable surfaces	Disturbs & possibly removes plants	Treat only portions of the feature and leave to recover before treating rest: avoid removal of key species and colonised areas
	Invertebrates	May result in accretion of fine materials and debris		
	Bats			Probably not applicable: check bats not using crevices, illegal to disturb
	Birds	May maintain open areas for rock face nesting birds		If birds nesting or attempting to nest, scaling to be undertaken outside breeding season (approx September to January), illegal to disturb or prevent from nesting
Reprofiling Faces (eg soft rock)	Lower Plants & Ferns	Provides new surfaces for colonisation	Disturbs & possibly removes plants	Treat only portions of the feature and leave to recover before treating rest: avoid removal of key species and colonised areas
	Invertebrates	May provide loose material	May remove suitable friable and accreted material	Treat only portions of the feature and leave to recover before treating rest: avoid removal of key species and colonised areas
	Bats	May provide opportunity to create caves/crevices		Probably not applicable: check bats not using crevices, illegal to disturb
	Birds	May provide new surfaces for nest sites	May remove nest sites (eg sand martin burrows)	Treat only portions of the feature and leave to recolonise before treating rest: avoid removal of key species and colonised areas: if birds nesting or attempting to nest, reprofiling to be undertaken outside breeding season (approx September to January), illegal to disturb or prevent from nesting
Rock Mesh & Rock Bolti ng	Lower Plants & ferns	Maintains stability of surfaces: mesh provides microclimate		

Conservation Method	Specialist Biodiversity Groups	Effect on Suitability of Habitat		Comment & Recommendations
		Positive	**Negative**	
	Invertebrates	Maintains stability of surfaces: mesh provides microclimate		
	Bats		Mesh may interfere with bat access to crevices:	Illegal to disturb and prevent access of bats to roosts: check bats not using crevices before erecting mesh or bolting
	Birds		Mesh may interfere with access to nest sites	If birds nesting or attempting to nest, mesh or bolting to be undertaken outside breeding season (approx September to January), illegal to disturb or prevent from nesting
Fencing (to prevent access & for safety)	Lower Plants & Ferns	Reduces physical disturbance		
	Invertebrates		May result in reduced open ground	
	Bats	Reduces physical disturbance		Illegal to disturb and prevent access of bats to roosts
	Birds	Reduces physical disturbance		If birds nesting or attempting to nest, fencing to be undertaken outside breeding season (approx September to January), illegal to disturb or prevent from nesting
Shot-blasting (using non-toxic material)	Lower Plants & Ferns		Likely to remove plants	Treat only portions of the feature and leave to recover before treating rest: avoid removal of key species and colonised areas
	Invertebrates			
	Bats			Illegal to disturb and harm bats
	Birds			If birds nesting or attempting to nest shot-blasting to be undertaken outside breeding season (approx September to January), illegal to disturb or prevent from nesting
Clearance of mounds of accumulated/fall	Lower Plants & Ferns	Maintains open areas		
	Invertebrates		Likely to remove suitable material	
	Bats			N/A

Conservation Method	Specialist Biodiversity Groups	Effect on Suitability of Habitat		Comment & Recommendations
		Positive	**Negative**	
	Birds			If birds nesting or attempting to nest, clearing to be undertaken outside breeding season (approx September to January), illegal to disturb or prevent from nesting
Removal of vegetation	Lower Plants & Ferns	Maintains open areas		Treat only portions of the feature and leave to recover before treating rest: avoid removal of key species and colonised areas
	Invertebrates	Maintains open areas		Treat only portions of the feature and leave to recover before treating rest: avoid removal of key species and colonised areas
	Bats			N/A
	Birds	Maintains open areas		If birds nesting or attempting to nest, removal to be undertaken outside breeding season (approx September to January), illegal to disturb or prevent from nesting

Appendix 1 – List of consultees

English Nature Headquarters

Dr J Larwood
Dr M Murphy
Dr J Hopkins
Dr K Porter
Dr R Jefferson

English Nature Local Teams

P Evans (North Yorkshire)
S Webb (Cumbria)
M Edgington (Somerset)
K Paige (Devon)
A Mcdouall (Cornwall)
B Le Bas (Derbyshire)
B Corns (Somerset)
P Lambley (Norfolk)
W Smyth (Cornwall)

Non-Government organisations & others

M Campbell (Gloucestershire RIGS & Wildlife Trust)
A Connah (Dudley Metropolitan Borough Council)
P Allen (Bedfordshire, Berkshire & Oxfordshire Wildlife Trust)
A Gorman (Kent County Council)
J Lamb (Lancashire Wildlife Trust)

Appendix 2 – Copy of questionnaire

Geological Conservation & Biodiversity

Client: English Nature, Contract EIT31-02-16

Contractor: Humphries Rowell Associates, Project D8084

Date

Enquiry to:

From:
Neil Humphries
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Subject: **Geological Conservation & Biodiversity: Experience, Information & Comment**

The aim of English Nature's project is to examine how Geological Conservation techniques have the potential to benefit biodiversity, in particular in relation to UK/LBAP species and habitats, and the wider countryside.

Please could you help us with the following (please expand/append as you wish);

1 Do you know of/or have Geological Conservation Sites (SSSIs/RIGs) of biodiversity interest/importance in your control/area/region?

Please give details (site, geological and biodiversity interest, etc) or other contacts.

2 Those under management;

2a Are any of the sites being managed for Geological Conservation?

Please give details (type of management, extent, frequency etc) or other contacts.

2b Is the biodiversity (habitat or species) being directly or indirectly benefited or adversely affected?

Please give details or other contacts.

3 Those not under management;

3a Are any of these sites in need of management for Geological Conservation?

Please give details (type of management, extent, frequency etc) or other contacts.

3b What biodiversity (habitat or species) would directly or indirectly benefit or be adversely affected?

Please give details or other contacts.

4 Are there areas of practice, understanding or knowledge which require further investigation or refinement?

Please give details or other contacts.

5 Please give any other comments, views and experiences.

Rnh 30/11/01

Appendix 3 - Plant/animal species linked to geological features & listed in UK Biodiversity Action Plan

Species	Common Name	UKBAP Status	Site code	Description/Behaviour	Implementation in LBAPs	Status (GB)
Vertebrates						
Barbastella barbastellus	Barbastelle bat	Priority species	IC/EM	Mainly a woodland species using old buildings and trees as summer roosts and underground sites and other suitable places such as hollow trees for hibernation Widely distributed in England and Wales – centres of population in South-west and Mid west England and Norfolk	No local implementation	Vulnerable (Red list)
Myotis bechsteinii	Bechsteins bat	Priority species	IC/EM	Rare tree dwelling bat – a few individuals are found in underground sites during hibernation but likely that most individuals roost in trees all year	No local implementation	Vulnerable (Red list)
Rhinolophus hipposideros	Lesser horseshoe bat	Priority species	IC/EM	Originally a cave roosting bat although most summer maternity colonies now use buildings. Most still hibernate in underground sites such as caves Now found only in S.W England and Wales	No local implementation	Vulnerable (Red list)

Species	Common Name	UKBAP Status	Site code	Description/Behaviour	Implementation in LBAPs	Status (GB)
Invertebrates						
Aricia artaxerxes	Northern brown argus	Species Statement	IC EC ED	Butterfly found on well drained and usually base rich sites on thin soils usually south facing and <350m alt. Primarily occurring on limestone grassland and associated with coastal valleys and quarries, limestone pavement and outcrops	Dumfries and Galloway East Lothian Fife Region Lancashire BAP LBAP for North-East Scotland Nature in the Dales	Nationally scarce (RDB)
Cerceris quadricincta *Cerceris quinque fasciata*	Solitary wasps	Priority species	ED	Favour bare sand in places exposed to sun	No local implementation	Endangered (RDB)
Cicindela germanica	A tiger beetle	Priority species	EC EF	Found on or near base of coastal cliffs/steep slopes or silt near freshwater seepages Has also been found on dry, gravelly but open situations	No local implementation	Rare (RDB)
Hypena rostralis	Buttoned snout moth	Priority species	IC EM	Adults hibernate in man-made shelters, outbuildings and in caves Moth was formerly widespread through S Britain to Lincs & S Wales	Gloucestershire BAP	Nationally scarce (RDB)
Osmia xanthomelana	A mason bee	Priority species	EC	Builds its nest cells from mud pellets which it gathers at seepage areas on cliffs and banks	No local implementation	Endangered (RDB)

Species	Common Name	UKBAP Status	Site code	Description/Behaviour	Implementation in LBAPs	Status (GB)
Vascular plants & stoneworts						
Asparagus officinalis ssp prostratus	Wild asparagus	Priority species	EC	Plant of coastal dunes/cliff tops	No local implementation	Vulnerable (RDB)
Crepis foetida	Stinking hawks-beard	Priority species	EC	Very rare in Britain-recorded on a few coastal sites in S.E England – typically on disturbed shingle/chalk	No local implementation	Endangered (RDB)
Sorbus leyana	Leys Whitebeam	Priority species	EC EO	Endemic to S.Wales : known from 2 localities on steep limestone cliffs	No local implementation	Critically Endangered (RDB)
Thlaspi perfoliatum	Cotswold pennycress	Priority species	ED	Characteristic of oolitic limestone in Cotswolds-recorded growing amongst open vegetation on pastures, screes, walls, tracks and quarries	No local implementation	Vulnerable (RDB)

Species	Common Name	UKBAP Status	Site code	Description/Behaviour	Implementation in LBAPs	Status (GB)
Lower plants and fungi						
Acaulon triquetrum	Triangular pygmy-moss	Priority species	EC	Ephemeral species generally found on south-facing slopes on coastal cliffs and banks (Usually on dry calcareous ground kept open by soil slippage) Britain is the northern edge of species range	No local implementation	Endangered (RDB)
Alectoria ochroleuca	Lichen	Priority species		Montane plateau – found in the cairngorms only	No local implementation	
Bartramia stricta	Rigid apple-moss	Priority species	EO?	Grows on thin often disturbed soil on ledges and in crevices amongst rocks Prefers sunny sheltered situations on south-facing slopes (previous records from limestone & sandstone but now only 1 remaining known population on basaltic rock in Powys)	No local implementation	Endangered (RDB)
Bellemerea alpina	Lichen	Species Statement	?	Crustose lichen last seen 1983 in Cairngorms	Local Biodiversity Plan for North-East Scotland	
Belonia calcicola	Lichen	Priority species	EC EO	Crustose lichen Restricted to limestone outcrops (possibly endemic to UK) Only known from 1 site in Cumbria	No local implementation	Data deficient (RDB)
Brachythecium appleyardiae	Appleyard's feather moss	Priority species	EC/EO IC?	Recorded in 7 sites Typical habitat is calcareous rocks in shaded valleys Endemic to England	No local implementation	Near threatened (RDB)
Cephaloziella nicholsonii	Greater copperwort (liverwort)	Priority species	ID	Found on copper-enriched substrates inclouding soil, walls, roacks and spoil found around copper mines Not recorded outside UK 22 old mine sites in Cornwall & some in Devon	No local implementation	Vulnerable (RDB)
Calicium corynellum	Lichen	Priority species	N/A	Naturally grows on siliceous rock unhangs in humid conditions Only 1 known UK site- occurring on sandstone and mortar of church tower	No local implementation	Critically endangered (RDB)

Species	Common Name	UKBAP Status	Site code	Description/Behaviour	Implementation in LBAPs	Status (GB)
Caloplaca aractina	Lichen	Priority species	EC	Crustose lichen restricted to steep, sunny, acidic rocks on coast above high water level In Cornwall found on Serpentine rocks-elsewhere on silicous rock substrates often near bird perches Now restricted to 1 site: Lizard peninsula in Cornwall	No local implementation	Critically endangered (RDB)
Desmatodon cernuus	Flamingo moss	Priority species	EO	Found on highly calcareous soils associated particularly with disused Magnesian limestone quarries Main stronghold magnesian limestone outcrop in Notts & S, W & N Yorkshire	No local implementation	Endangered (RDB)
Ditrichum plumbicola	Lead-moss	Priority species	ID	A pioneer species restricted to sparsely vegetated acid, peaty, silty or gravelly soils on old lead-mine spoil heaps	Stirling LBAP	Near threatened (RDB)
Heterodermia leucomelos	Ciliate strap-lichen	Priority species	EC	Grows on mossy rocks on sunny exposed, coastal cliff tops Found in Cornwall	No local implementation	Endangered (RDB)
Orthodontium gracile	Slender thread moss	Priority species	EC EO	In UK grows mainly on damp, vertical, shaded acid rock faces, particularly sandstones and grit stones and sometimes in rock crevices	No local implementation	Critically endangered (RDB)
Peltigera lepidophora	Ear-lobed dog lichen	Priority species	EC	Occurs on mossy rocks of calcareous old red snadstone conglomerate in a wooded river gorth (only known from 1 locality in E. Perthshire)	No local implementation	Critically Endangered (RDB)
Rhynchostegium rotunidolium	Round-leaved feathermoss	Priority species	IC? EO?	Grows on tree trunks with alkaline bark or limestone rocks Only known at 2 sites in Sussex and Gloucester	Gloucestershire Biodiversity Action Plan	Critically endangered (RDB)
Seligeria carniolica=Trochobryum carniolicum	Water rock-bristle (moss)	Priority species	EC	Grows mainly on periodically or permanently moist, shaded, calcareous rocks in or near streams in small ravines <100m alt.	No local implementation	Critically endagered (RDB)
Sematophyllum demissum	Prostrate feather-moss	Priority species	EC	Moss of shady rocks in humid places eg wooded streamsides Frequently occurs on sloping faces of acid or slightly basic gritty boulders and rock slabs where it receives intermittent seepage (Atlantic oakwoods of West Wales)	No local implementation	Endangered (RDB)

Species	Common Name	UKBAP Status	Site code	Description/Behaviour	Implementation in LBAPs	Status (GB)
Tortula freibergii	Freiberg's screw-moss	Priority species	EC	Species of acid sandstone rock outcrops and walls in sheltered to fairly exposed situations – eg sandstone on North Yorks coast	No local implementation	Near threatened (RDB)
Zygodon gracilis	Nowell's limestone moss	Priority species	IC EO EC	Mostly found on old limestone walls BUT there are also 2 records from 'natural habitat' of dry exposed rock outcrops and loose stones of Carboniferous limestone	Nature in the Dales	Endangered (RDB)

Red list: IUCN (1996) Red list of threatened animals
RDB: JNCC (various years) British Red Data Books (various species groups)

ENGLISH NATURE

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Top left: Using a home-made moth trap.
Peter Wakely/English Nature 17,396
Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
Paul Glendell/English Nature 23,020
Main: Identifying moths caught in a moth trap at Ham Wall NNR, Somerset.
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