ECOLOGICAL AND NATURE CONSERVATION ASPECTS OF LAND AFFECTED BY MINING IN THE YORKSHIRE COALFIELD

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CONTENTS

Abstract

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Between 1992 and 1996, the ecology of sites affected by mining, (including former deep-mines, opencast restorations and subsidence wetlands) was investigated. The study sites were located throughout the 2500 sq.km of the Yorkshire Coalfield in northern England.
Mining impacts on nature conservation and ecological processes were examined and related to past, present and proposed land-use and restoration practices. Detrimental effects of mining included historical direct land-take of wildlife sites and ongoing indirect pollution of watercourses from iron-enriched leachate. Significant nature conservation interest at international (European), national (British), regional (county/district) and local level was identified.

On deep-mine sites (abandoned collieries and spoil-heaps) and some older opencast restorations, important features included: pioneer vegetation, grassland, heathland, woodland, vascular plants, amphibians, open ground insects and birds. On opencast wetland restorations and subsidence wetlands, key features were: aquatic and swamp vegetation, wintering wildfowl, breeding and passage birds, mammals, fish and invertebrates. Many sites were already used and valued by local people for amenity.

The associated plant communities were described. The majority corresponded to species-poor analogues of the National Vegetation Classification. Four new widely distributed pioneer communities and sub-communities were identified. Developmental trends of communities from naturally regenerated sites and failed restorations were suggested, showing the likely successional pathways for the Coal Measures region. Faunal community structure and development, including colonisation, establishment and habitat associations were explored.

Restored terrestrial sites, increasingly common after the contraction of the coal-mining industry from the mid-1980's, were found to be considerably poorer for wildlife than naturally regenerated sites, whilst wetland restorations appeared to be more variable in successfully creating wildlife habitats. Restorations followed techniques developed for amenity and agriculture. Nature conservation guidance had only been recently introduced, based on experience from traditional wildlife site management and case studies. Early successional stages and natural regeneration processes on topographically diverse landscapes were largely undervalued by restorationists in favour of large-scale intervention and fashionable habitat-types.

This work advances the knowledge and understanding of ecosystems derived from the Coal Measures of northern England and provides a comprehensive review of the nature conservation value of land affected by mining in the region.

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1. INTRODUCTION & LITERATURE REVIEW

1.1. Introduction

Traditionally, the focus of nature conservation effort in Britain has been directed towards sites of renowned wildife or earth science significance (Ratcliffe, 1977; Anon. 1994a). Nationally or internationally important sites have been awarded statutory protection via the Wildlife and Countryside Act (1981) as Sites of Special Scientific Interest (SSSI) and increasingly via European legislation such as Special Protection Areas (SPA) under the EC Directive (79/109) on the Conservation of Wild Birds, as Special Areas of Conservation (SAC) under the Habitats Directive (1992), and via international conventions such as 'Ramsar' sites (wetlands of international importance recognised under the Ramsar Convention). SSSIs have been designated under the 1981Act using rigorously defined criteria (Nature Conservancy Council 1989) such that by 1996 some 4000 sites had been designated in England alone.

Whilst the national network of SSSIs has been a success in that most of them are still remaining, there has nevertheless been a recognition that, in itself, it has not been sufficient to prevent the continuing deterioration of the total wildlife resource in England (Rowell, 1991; Juniper, 1994; Anon., 1993b). Relatively little attention has been paid to the wildlife of land outside SSSIs until perhaps the early to mid-1980's, since when increasing concern has led to progress linking nature conservation objectives to broader schemes such as Environmentally Sensitive Areas (ESA), Countryside Stewardship and the planning process in general. Local Plans now play an important role in setting the framework for local decision making which takes account of the local nature conservation heritage with robust environmentally-led policies and the inclusion of concepts such as 'second-tier sites' (i.e. sites of obvious interest but which do not quite meet the criteria for SSSI), wildlife corridors, Local Nature Reserves and nature conservation strategies such as the Leeds Nature Conservation Strategy and Sheffield Nature Conservation Strategy (Collis & Tyldesley, 1993; Bownes *et al.*, 1991; Knight, 1991).

The last decade has also seen development in the environmental field at both ends of the socio-political scale. On the one hand, world governments have joined to declare common concern for the environment reaching pioneering agreements at the Rio Summit (United Nations Conference on Environment and Development - UNCED) in 1992. Agenda 21 - the action programme agreed at UNCED, called for national sustainable development strategies to be adopted and for reports on the implementation of Agenda 21 to be made to the new UN Commission on Sustainable Development. The relevance of this to nature conservation will be realised through the Biodiversity Convention which exhorts nations to implement programmes to conserve global biodiversity. The UK government has now commited itself to a programme of action by publishing Biodiversity - the UK Action Plan (Anon., 1994a; Anon., 1995a; Anon., 1996).

On the other hand, much more attention is being given to action at the local scale with emphasis being placed on local communities being involved in understanding, appreciating and actively conserving their local environment (Rhode & Kendle, 1994; Harrison *et al.*, 1995; Smyth, 1990). The last decade in Britain, in line with other countries (particularly Europe and the USA) has seen an enormous rise in the appreciation of and commitment to conservation (e.g. the millionth member of the Royal

Society for the Protection of Birds joined in 1997), including 'urban conservation' where the conservation of quite widespread wildlife at the local level is viewed as being as important as the more traditional sites of scientific importance, because of its value to local people for education, enjoyment and appreciation (Gilbert, 1989). This has been promoted and supported by national agencies such as English Nature, the Countryside Council for Wales, and Scottish Natural Heritage. Increasingly, the incorporation of local nature conservation issues into other organisations'plans and business has also been adopted, for instance in the new national forests supported by the Countryside Commission (Watkins, 1991), and through the large estates managed by bodies such as the Forestry Commission, the Ministry of Defence, and the National Trust.

What is clear from the above, is that the field of nature conservation has changed substantially in recent years , and will continue to do so. It is still informed by its scientific discipline, ecology, but nevertheless has taken on board a wider remit. Recognition of this can be seen in the approaches of the statutory agencies in Britain. In England for example, the concept of 'Natural Areas' (broad geographical areas sharing a common identity and character e.g. the Chilterns or the Coal Measures, Appendix 26) is being promoted collaboratively by English Nature, the Countryside Commission and English Heritage to develop conservation objectives and programmes across whole landscapes and not just special sites. This will ultimately involve ecological and cultural elements (Anon., 1993c).

This new approach must be supported by sound advice. Two particular themes which have traditionally been neglected, and perhaps undervalued in established nature conservation and ecological circles, are the intrinsic value of urban, anthropogenic and post-industrial environments (Box, 1993), and the potential of land rehabilitation to contribute to the local, regional and even national nature conservation resource. Both of these themes can be effectively investigated in the Yorkshire Coalfield area since there are many sites available for study following the historical development of the mining industry in the region, and there have been significant changes to the policy framework following the collapse of the mining industry which afford opportunities for examining a variety of approaches for future land use. In addition, besides the inherent intellectual challenge, investigation of these themes may also have a very practical application by informing nature conservation objectives at local and regional level (e.g. through the 'Natural Areas' concept) as well as contributing to the development of the disciplines at national level or beyond.

1.2. Mining techniques

Two broad methods of mining can be recognised - opencasting and deep-mine.

1.2.1. Deep mining techniques.

Coal and iron have been mined in the study area from the early Middle Ages, with early references at Hipperholme (Halifax) in 1274 and numerous small concerns in the Wakefield-Pontefract-Barnsley areas (Hey, 1986). Until the late eighteenth century, extraction methods were relatively simple, the minerals being won from outcrops near to the surface and which could be accessed by shallow pits and adits. 'Bell-pits' where shafts were sunk to access the reserves and waste material raised to the surface and dumped provided a larger scale operation but still involved no machinery, though the spoil-heaps created by this method can still be dramatic, such as the Elmley and Tankersley ironstone mines (Jones, 1995).

The area was at the forefront of new winding and haulage technology from the early 1800's, when increasingly larger pits could access deeper seams of coal. The early mines tended to be in the west of the region and relatively small, but dramatic changes occurred from 1850. Then, output was about 8 million tons per annum but this had risen to over 73 million tons by 1913 (Hey, 1986), and new settlements, as well as rapid development of existing small villages, were created as 'pit-villages' to house the labour required to meet the rise in demand. Many of the larger pits in the 'concealed' coalfield were established in the twentieth century, with the last major group of pits - at Selby - receiving planning permission in 1976.

Early methods produced relatively little waste material, as the coal was immediately separated by hand on site to avoid the need to handle waste material. Modern and more efficient mechanised methods, however, raise both coal and seatearths and parts of the seam roof, and they are separated at the surface, with the waste material dumped on site. These spoilheaps can be extensive, accumulating from years of tipping and can be dramatic in terms of visual impact. Spontaneous combustion can be a problem in some older tips, but since the 1930's the separation techniques have improved greatly with the introduction of large-scale washing and settlement of tailings and slurry in lagoons (Richards, Moorhead & Laing Ltd., 1996).

Early spoil tips were not subject to any special treatment, and many have established a full vegetation cover, however many others, particularly those in active operation over the last 30-40 years, are huge and represent large areas of land with little or no vegetation cover at all. Establishing the precise vegetation history of spoil tips is also complicated by the treatment of many tips under the Tips Act 1969, when many sites were regraded for safety reasons following the Aberfan disaster where many lives were lost as a result of tip collapse.

1.2.2. Opencast mining techniques.

Opencast mining operations involve the use of heavy, earthmoving equipment to remove the strata above the coal to gain direct access to the reserves (British Coal Opencast, 1991). Those seams relatively close to the surface and generally too shallow to be worked by deep-mine methods, are worked, and the precision of modern machinery allows most of the coal to be extracted, sometimes including the pillar and stall systems left behind by old deep mines. The method is relatively new, beginning in 1942 as a wartime expedient, but has rapidly grown with the advent of new technology, especially the introduction of powerful and efficient machinery.

New sites are subject to a process of detailed planning before exploitation. Reserves are proven through the production of a geological profile based on core samples recovered by drilling and borehole logging devices. Computer models accurately assess the coal reserves as well as the amounts of other materials such as mudstones, seatearths, peat and surface deposits including sub- and top-soils which have to be moved in the process.

Screening mounds are established as a first step in the operation which progresses in a series of steps removing and storing the overburden before extracting the minerals. Restoration is normally to original ground levels and may incorporate features not present in the original landscape. Once sites have been marked by secure boundaries, stripping of topsoil and subsoil using motor scrapers and mechanical shovels begins and these are stored separately and carefully for later use. Typical sites cover an area of about 200 ha., have an average depth of 82 metres and contain 2.2 million tonnes of coal in a dozen seams of coal (British Coal Opencast, 1991). Around 40 tonnes of overburden are produced for each tonne of coal extracted. On some sites, old spoilheaps are also re-worked and material may be processed through a washery plant to yield clean coal.

Restoration proceeds by the replacement of the overburden which is compacted in layers to generate the agreed landform in the restoration plan. Subsoil placed on top of the overburden is ripped to aid drainage, and topsoil application is managed under MAFF supervision for a five year period to monitor restoration of fertility to agricultural end-uses. The majority of restorations have been agricultural, but increasingly other uses such as forestry, amenity and infrastructural development have taken place. Whilst restoration to a nature conservation end-use is now legitimate (Anon., 1993a), no such restorations were specifically encountered in this study, although the provision of some lakes and ponds were designed to incorporate wildlife requirements.

1.2.3. The regulatory framework and restoration

Many underground coal-mines pre-date planning legislation which was introduced in 1948, and progressively amended and consolidated into statutes such as the Town & Country Planning Act 1990, the Planning & Compensation Act 1991, the Coal Industry Act 1994 and the Town & Country Planning (General Permitted Development) Order 1995.

The regulatory systems include licensing of coal extraction; land use and mineral planning procedures including the monitoring of development and restoration; environmental assessment of proposals for mining, spoil disposal and major land reclamation works; regulation of surface water and groundwater quality; protection of wildlife, geological and archaeological interest; the monitoring and inspection of colliery spoil tips for safety purposes and provisions under which financial contributions or grants can be obtained (Anon., 1994c).

Recent minerals planning guidance (Anon., 1994b) has also introduced concepts of sustainable development to the process such that five objectives are now specified - to conserve minerals; to minimise production of waste; to encourage sensitive working practices; to protect areas of designated landscape or nature conservation, and to minimise impacts from transportation. It is also possible to use colliery waste and associated restoration schemes to remove adjacent dereliction.

Major programmes are now underway to reclaim and restore colliery spoil tips (as well as other similar land) and Yorkshire Forward (the Regional Development Agency, formerly English Partnerships), the Government Agency implementing policy in this area has the objective of promoting job creation, inward investment and environmental improvement through the reclamation and development of vacant, derelict and under-used or contaminated land and buildings.

Recent guidance has been produced to aid designers and practitioners involved in such schemes (Land Use Consultants & Wardell Armstrong, 1996; Richards, Moorhead &

Laing Ltd., 1996), in which there is recognition that many sites possess characteristics and features (wildlife, built heritage) which can contribute potentially to the new uses of a site.

1.2.4. Restoration

Bradshaw & Chadwick (1980) stated that "the aim of reclamation must be to restore the original qualities of the environment to ..... a normally functioning ecosystem.' The key to improvement is 'upgrading all activities of the soil component.' Six main uses of land restored from coal-mining were recognised by Chadwick *et al.* (1987) - agriculture, forestry, recreation, water use, construction sites, and wildlife. Yet the goal of biological reclamation was to "restore fertility and biological productivity", a goal which would not sit neatly with some ecosystems of nature conservation significance which are inherently infertile. Fox (1984) identified the important uses for the rehabilitation of mined lands as urban usage, cropping and recreation. Nature conservation was not mentioned. Bradshaw (1989) stated that "the aim of the restorationist is to accelerate succession", a notion which might conflict with a wildlife use in which some stages in the succession were the most valuable, however nature conservation was recognised as an important end-use.

The contribution of naturally developed nature conservation interest to the overall nature conservation significance of ex-colliery sites has not been addressed. Certain types of industrial and post-industrial site can develop unusual, rare and interesting wildlife, but no evaluative work has been done on Yorkshire Coalfield sites and no synthesis undertaken. Further, recognition of this type of interest does not appear to have been recognised widely and certainly not by the major authorities overseeing restoration programmes in the region.

In Britain, the recognition of nature conservation as a legitimate use of "derelict land" was made in 1989 when the Department of the Environment reviewed its derelict land policy (Mabey, 1991). A review of the extent and nature of the information and guidance available on the reclamation of mineral workings to amenity after-uses, and guidance on planning controls, restoration techniques and short- and long-term management requirements to achieve satisfactory standards of reclamation, has been made by the Department of the Environment (Anon., 1993a). However, whilst including some references to to habitat reconstruction and geological features, no overall theory or guidelines on the aims, policy and practice of restoration for nature conservation are included.

Traditional restorations often aim to establish visually acceptable vegetation as quickly as possible (Bradshaw & Chadwick, 1980), and whilst the two methods of deep-mining and opencasting are radically different, they do converge in the matter of restoration. In many Districts in the coalfields, there are now programmes of restoring despoiled land to more visually and culturally acceptable environments for local communities, e.g. in Wakefield, an initial audit of sites was undertaken and a prioritised programme of restorations identified which incorporated designs initially prepared by professional staff for amenity areas or recycled industrial land, and which were then offered to the local community for consultation. Finalised plans were then implemented on a rolling programme dependent on finance and manpower (City of Wakefield, 1991). For opencasting, the same cultural and social demands have linked with more rigorous procedures to allow environmental impacts to be taken account of (e.g. the Environmental Impact Assessment procedures).

Coupled with a diminution of pressure to restore land to agriculture (hitherto the predominant restoration) because of the removal of the over-riding necessity to maximise food production (Stoate, 1996), there has been increasing recognition of other restoration options. Some of these may also be cheaper than traditional methods (Welsh Development Agency, 1982; Anon., 1989; Anon.,1993a, Mabey, 1991).

Whilst agricultural and 'do-nothing' approaches have hitherto been the predominant forces for land restoration, changing priorities have recently been recognised (Couzens, 1992a, 1992b; Anon., 1989, 1991, 1993a, 1994b; Gemmell, 1992) such that nature conservation is now a valid end-product of restoration, and there is currently much interest and effort going into the creation of new environments e.g. gravel-pits, tree planting schemes, pond creation (Andrews, 1990; Andrews & Kinsman, 1991; Buckley, 1989; Bradshaw, 1989; Humphries & Benyon, 1994; Land Use Consultants, 1996). However, as Jones (1990), Byrne (1990) and Parker (1995) have pointed out, much of this is being done on an experimental basis, and an assessment of both techniques and results would be desirable, particularly as claims for success are rife.

Given the novelty of the recent guidance, and coupled with the fact that little evaluative work has been carried out on the intrinsic wildlife value of these types of site, site assessment techniques for their wildlife significance must invariably use evaluative judgements based on 'established' methods e.g. for SSSI's (Ratcliffe, 1977). In theory, this could lead to failure to recognise features unique to such sites, and thereby contribute to their subsequent loss.

1.2.5. Impacts of mining on ecology and nature conservation.

Since much of the development of collieries in particular pre-dates any regulation requiring an assessment of the nature conservation interest of the land, little data is available to quantify the loss of habitats or the value these may have had in a modern protected wildlife site system. Examination of historical maps, however, can provide anecdotal evidence for the loss of some wildlife habitats currently valued, such as ancient woodlands. In the study area, examples include New Park Spring, Grimethorpe, and Gawber Wood, Barnsley, both of which were known for the presence of rare species such as Herb Paris *(Paris quadrifolia)*, and Nightingales *(Luscinia megarhynchos)* last century. Other marshland and wetland habitats have also been lost, such as along the River Aire wetlands (Brook, 1976).

Contemporary opencast proposals generally include a survey of existing wildlife features through the Environmental Impact Assessment (EIA) process required before proceeding, such that some data are now available for a small number of cases. EIA is a formalised process for assessing impacts of a development on human welfare and the environment, and is a statutory requirement for developments of a particular size or importance. Permissions and authorisations are also secured (Anon., 1994b) following this process and the agreement of detailed restoration plans.

Two other major impacts of mining on local ecology and sites of nature conservation interest are i) the effects of minewater discharges from old and abandoned collieries and tips into watercourses, and ii) the effects of subsidence.

Water enters most mines in Britain and is normally actively removed through pumping. The chemical nature of these waters is variable but many, including those within the study area, contain reduced iron minerals which on contact with air, oxidise and precipitate out ferruginous deposits. Strata containing up to 10 % iron pyrites (ferrous sulphide), can dissolve on contact with air produced by the pumping, to produce sulphuric acid which in turn leaches other metals such as cadmium, copper and zinc. Rates of oxidisation can also be increased by the catalytic activity of bacteria such as *Thiobacillus* (National Rivers Authority, 1994). Waters can also be saline due to the presence of chloride and sulphate salts.

At working mines, waters such as these are treated by neutralisation and the settlement of solids before regulated discharge to watercourses, and can be of good quality, however long abandoned mines can still produce polluting discharges and around such 100 discharges affecting 198 km of watercourses were estimated by the National Rivers Authority in 1994 (National Rivers Authority, 1994), with some of the most damaging occurring in the study area e.g. Sheephouse Wood (grid reference SK1499 and Bullhouse Colliery SE2102 on the upper stretches of the Rivers Don and Little Don). Effluents here have levels of iron up to 75 mg/l, and in conjunction with the large volumes of discharge, produce a covering of ferric oxide deposits for around 4 km downstream of these rivers resulting in reductions of the macro-invertebrate populations and very low fish populations.

In general terms, the ecological impacts of these waters can include the depletion of numbers of sensitive organisms; reduction in biodiversity; depletion in numbers and biodiversity of the macro-invertebrate community; loss of spawning gravels for fish reproduction and nursery streams; and fish mortalities.

Subsidence of land surfaces occurs when and where deep-mines operate. Once the coal horizons are taken out, the worked areas left behind are allowed to collapse, causing a drop in the overlying land surface above. The amount of estimated subsidence can be calculated, and patterns are predictable with maximum levels immediately above the working seams, declining in a diminishing 'zone of influence' to zero. Maps of predicted subsidence can be prepared showing isopachytes, or subsidence contours.

Effects can be considerable, particularly on hydrology, and one of the features of large mines in the Yorkshire coalfield is the creation of new wetlands caused by inundation of subsided areas. Often these are in the floodplains of rivers, and some historical changes have been documented e.g. in the Aire valley (Brook, 1976). Traditionally, many of the floodplains next to the major rivers draining the study area were normally periodically flooded, giving rise to the Norse term 'Ings', and were agriculturally managed as such, possibly as hay meadow systems which can still be found along other Yorkshire rivers e.g. the Derwent Ings. A consequence of mining has been to create additional and often permanent flooding with consequential development of wetland ecosystems e.g. Fairburn Ings, Mickletown Ings, Broomhill Ings, Catcliffe Flash, Denaby Ings.

1.3. Existing studies of mined sites

Ecological and nature conservation issues are presently considered very seriously in the context of land restoration following mining activities (Anon., 1994b). These considerations will continue to be given careful attention in the future. This is both in terms of public demand for improved environmental conditions (including nature conservation) and for alternatives to traditional restorations. The mining industry also has its part to play in meeting legislative obligations which increasingly include environmental elements. More recently, the global perspectives on sustainable development, sustainability and biodiversity initiated at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 are proving influential (Holdgate, 1996; Juniper, 1994; Anon., 1994a). The reality is that the mining industry and its legacy may have a significant part to play in the development and implementation of these concepts in certain geographical areas.

Mining sites left to develop 'naturally' may or may not be be richer in wildlife than restored sites. Some wildlife value of naturally developed sites has been recognised e.g. tin mines, (Holliday *et al*., 1979), and is now acknowledged as a factor to be considered in reclamation schemes in some technical guidance (Bradshaw, 1989; Anon., 1994b). However no comprehensive investigation has been undertaken in the Yorkshire Coalfield to demonstrate whether such wildlife interest exists, or if it does, its extent. This information could be of use to engineers and planners engaged in land restoration programmes for compliance with regulations as well as contributing to wildlife conservation. Wildlife features on mining sites may not yet be widely appreciated even by the majority of nature conservationists, although similar sites in the urban environment are valued (Smyth, 1995; Whiteley, 1988; Gilbert, 1989).

A common perception is that mining activities are inherently damaging to wildlife. Whilst this is easily understandable for sites subject to opencast coal-mining where landscapes are completely transformed, in other circumstances the effects, especially long-term, are less obvious. One of the most significant contributions that mining makes to nature conservation is the uncovering of earth science interest, and there are many examples of sites of outstanding value which are quarries, road or railway cuttings or even spoil dumps. Many such sites are afforded national status as SSSI (Joint Nature Conservation Committee 1991, *et seq*.), and increasingly sites of more regional significance are being included in registers of 'Regionally Important Geological Sites' ('RIGS') (Nature Conservancy Council 1990; Harley, 1992).

A further perception is that much mining land is despoiled and that once the industrial concerns cease to operate, the legacy of redundant infrastructure and land is of no environmental significance and is derelict. Indeed, the definition of derelict land has been given as 'land which has been so damaged by industrial or other development that it is incapable of beneficial use without treatment' (Anon., 1993a). The tendency has therefore been to use 'Derelict Land Grant' to prepare land for redevelopment and only recently have 'softer' end uses (such as nature conservation) been acceptable to the Department of the Environment.

For ecologists too, mining land has traditionally held little attraction, at least in comparison to the attention devoted to other ecosystems. Some early studies described the ecology of sites such as pit-heaps in England (Molyneux, 1953; Brierley, 1956; Hall, 1957), but it was not until the 1970's and 1980's that much more attention was given to the ecology of industrial and mining land, this being catalysed by legislative and technological problems associated with land reclamation and restoration (Dutton & Bradshaw, 1982; Bradshaw & Chadwick 1980; Elias *et al*., 1982). There is now a substantial corpus of knowledge concerning restoration ecology of wastes and degraded land around the world (see Wali, 1980; Fox, 1984; Humphries & Rowell, 1994; for reviews) e.g. in Australia (Coaldrake, 1980), Montana (Schafer & Nielsen, 1980), Iowa (Glenn-Lewin, 1980) and Canada (Watkin & Watkin, 1983).

Whilst it is clear that a substantial amount of work, effort, time and financial resources have been, and continue to be, devoted to land reclamation, it is much less appreciated that such land can develop spontaneous 'natural' plant communities and associated fauna, some of which has been noted as of conservation value (e.g. Greenwood & Gemmell, 1978; Dickson, 1990; Gemmell, 1991; Box, 1993). Given the loss and degradation of much of Britain's wildlife resource, especially over the last 50 years, (Nature Conservancy Council,1984; Rowell, 1994; Anon. 1993b), these areas assume more significance in achieving nature conservation obectives. In Britain, however, there are very few studies of the nature conservation value of land affected by mining.

The vegetation of disused chalk quarries on the Yorkshire Wolds has been studied by Jefferson (1984) and Jefferson & Usher (1986) and significant interest has been found on spoil heaps in Scotland (Dickson, 1990; Martin, 1992), whilst more wide ranging studies of the vegetation of derelict land has been examined in Greater Manchester (Gemmell, 1982), Nottingham (Shepherd, 1995), and Sheffield (Gilbert, 1989). Few of these refer specifically to the types of land present in the Yorkshire Coalfield study area although Day (1979) has looked at similar colliery sites in North Wales.

Faunal studies are also scarce. Birds have been surveyed in the South Wales coalfield (Tyler & Geach, 1989; Anon., 1990), but the most extensive data on derelict sites is for invertebrates. In Yorkshire some uncommon insects have been recorded on colliery sites (Coldwell, 1991a; Coldwell, 1995a; Crossley, 1977) as well as unusual brackish inland freshwater Crustacea (Fryer 1978). Some parallels with abandoned arable land and urban sites may be drawn due to the starting point of bare land.

Arthropod succession on abandoned arable land has shown that diversity of Heteroptera and adult Coleoptera also increases with vegetation succession (Southwood, 1979), and both taxonomic and trophic diversity of insects can increase with successional age (including Orthoptera, Dermaptera, Dictyoptera, Psocoptera, Homoptera and Thysanoptera (Brown & Southwood, 1983).

Davis (1982) distinguished three categories of invertebrates in urban areas - widespread eurytopic species; those that only survive in less disturbed situations because of their specialised requirements; and those that thrive especially in man-made habitats. The fact that recording effort alone can demonstrate a huge diversity of invertebrates at urban sites is seen in Owen (1991) who listed large numbers of species at a garden in Leicester, many of which are listed as as rare or notable. This may perhaps indicate a lack of specialised knowledge when recording at other sites. The fact that urban sites can have a high diversity and abundance of species of interest to entomologists and conservationists because of judgements of rarity or diversity, is increasingly recognised. Sheffield, for instance, boasts a number of studies of the invertebrates of brick rubble sites, derelict and demolition sites and industrial land (Coleoptera - Lazenby, 1988, Arachnida - Roberts & Roberts, 1988, Syrphidae and other Diptera - Whiteley, 1988a, Sphecidae - Whiteley, 1988b). All of these studies highlighted the interest which has developed 'naturally' on disturbed land, and comments made on the 'desertification' of these sites through traditional landscaping. Further studies of the insects of urban habitats and greenspace include Frankie & Ehler, 1978, Hawkins & Cross, 1982 and Kirby, 1984.

The fauna of mining subsidence pools has been studied in Northumberland (Adams & Robbins, 1990) where 12 pools were examined and 91 taxa identified including new county records of Crustacea, Hirudinea and Turbellaria. Species diversity was highly significantly correlated with pool size and less significantly with pool age. The sequence of colonisation by Hemiptera matched that known of older surveys of more natural habitats e.g. Shropshire Meres (Savage & Pratt, 1976) and evidence was presented that the fauna of subsidence pools was comparable to older sites in the area. A further examination of 118 sites of Hemiptera colonisation refined the above study, concluding that the number of species increased with pond age (Williams, 1993). However caution was highlighted since the data for Trichoptera found no such relationship (Williams, 1990). Merritt (1996) has studied the aquatic coleopteran fauna of sites on the Rother valley, Yorkshire.

The deep-mine coal industry has very recently contracted substantially (e.g. the last active coal-mine in Barnsley, once the centre of the coal industry, closed in 1993), and there is a substantial legacy of redundant collieries, coal-stocking ground and spoil-heaps. Much effort, especially over the last decade, has been directed at 'restoring' this type of land (e.g. City of Wakefield, 1991), backed by a substantial regulatory framework and financial incentives, including the establishment of a specific agency, English Partnerships (now incorporated into the Regional Development Agency), as facilitator (Richards, Moorhead & Laing Ltd., 1996).

The contraction of the deep-mine industry has also been parallelled by an increase in the winning of coal by opencast methods (Hudson & Sadler, 1990). The environmental impacts of such methods are immense, since the dramatic technique consists of the complete removal of vegetation, soils and bedrock and its eventual replacement, on restoration, by a completely new landform, new landscape and vegetation communities (British Coal Opencast, 1991a, 1991b). Ironically, this extraction is often justified because it cleans up surface dereliction and can create amenity and industrial sites, eg Rother Valley Park, Sheffield, and Sheffield Airport at Tinsley (Thompson & Lawton, 1980; Hunter & Stott, 1991).

1.4 Aims of the study

It is suggested that some land affected by mining has already developed ecosystems of significant nature conservation interest and that this interest is threatened by contemporary land restoration schemes. These ecosystems are generally poorly described and whilst there is anecdotal evidence to demonstrate some interest, there has been no systematic work undertaken placing these areas into the context of the overall wildlife resource or 'environmental capital' of the region.

It is also suggested that whilst much effort, time and resources are being devoted to land restoration in the study area, the nature conservation element of this work has been poorly integrated into the philosophy, aims, planning and execution of these programmes. There are few published evaluations of this effort (especially in the Yorkshire Coalfield), and no examination of their success or failure. Further, there are no guidelines available which would optimise the nature conservation element of land restoration specific to the Yorkshire Coalfield. Defining aims and philosophy, identifying the most worthwhile, practical and achievable options and providing supporting technical guidance would supplement the more general aspects of land restoration already available (Land Use Consultants, 1996).

Further, the examination of trends in populations and communities on land affected by mining, can give important insights into ecological processes such as the colonisation of land and water, and succession of habitat-types and communities. This in turn can inform decision makers involved with the planning and land-use of such areas.

2. METHODOLOGY

2.1. Field studies

2.1.1. The Yorkshire Coalfield Study Area

The study area comprises around 2500 sq. km in the county of Yorkshire in northern England, stretching from Leeds in the north to Sheffield in the south, and from Halifax in the west to Thorne and Selby in the east (Figure 1). There is a reduction in altitude from east to west from about 320 metres above sea level (on the foothills of the Pennines) to zero.

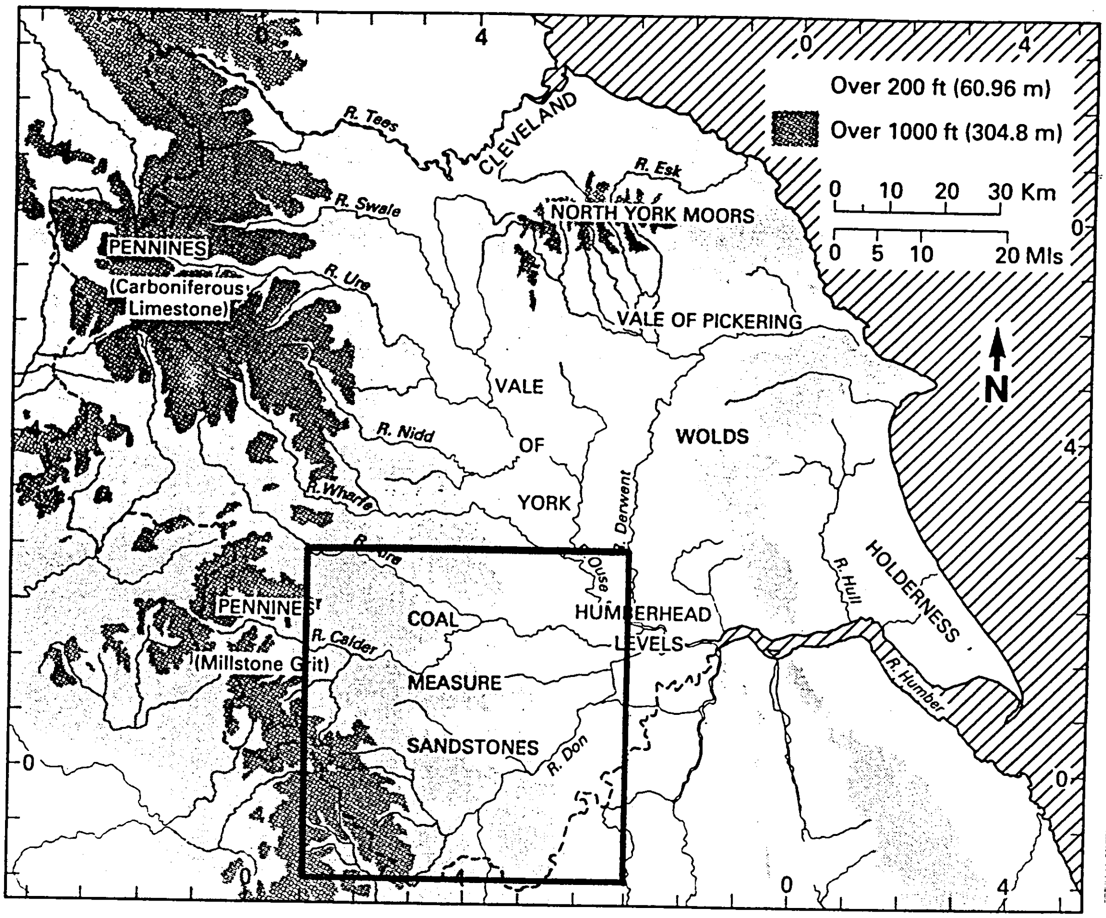


Figure 1.
Location of study area within Yorkshire, northern England.

Much of the study area is well-populated, with around 5 million people living in the various conurbations dominated by the cities of Leeds, Bradford and Sheffield. Much of the historical wealth of the region was derived from the extraction of the mineral resources of coal, ironstone and water. The exploitation of these resources, coupled with urbanisation, has led to a landscape dominated by cities, towns and villages, interspersed with remaining areas of countryside.

The region is dominated, in geological terms, by one of Britain's most important coalfields (Edwards & Trotter, 1954, Figure 2). In the west there are exposures of the older Millstone Grit formation, upon which the Upper Carboniferous Coal Measures rest conformably. The Upper and Lower Coal Measures strata dominate the study area, being partly exposed in the west and partly concealed in the east, but the character of the deposits is largely the same showing rhythmic sedimentation of sandstones, shales and mudstones laid down in shallow water. Sandstones are thinner and finer-grained than the Millstone Grits, but land conditions produced the beds of coals and seatearths, with occasional incursions of the sea producing marine bands. There are numerous beds of workable coals in the 1200 metres or so of these beds which later were uplifted and folded producing the undulating landscape known today.

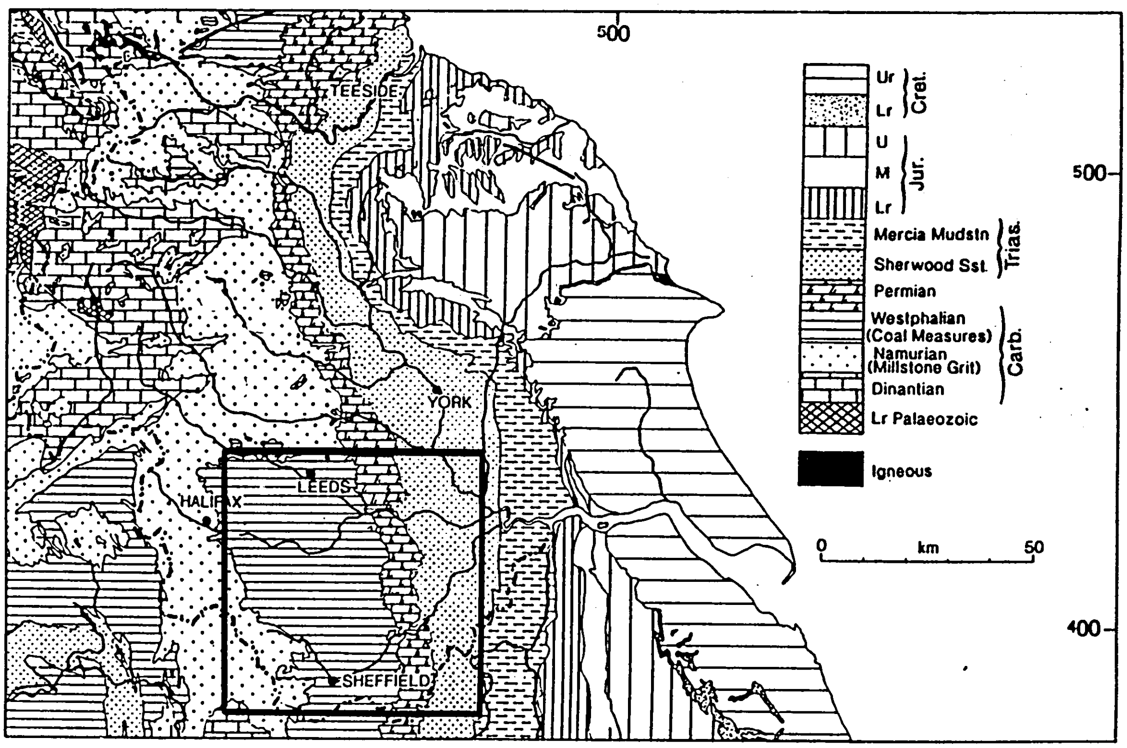


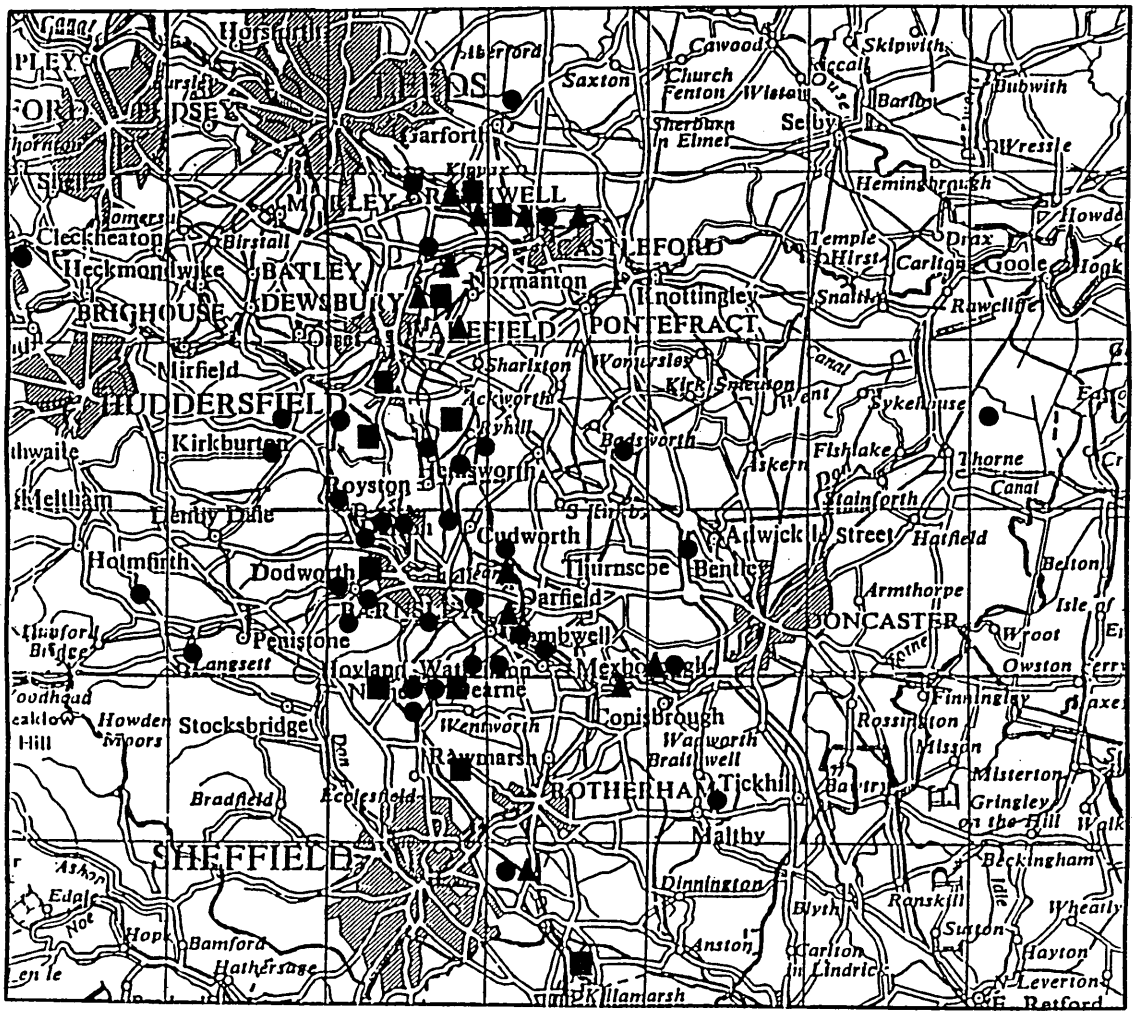
Figure 2.
Geology of study area, Yorkshire, northern England.

To the east is a band of Permian rocks - the Magnesian Limestone - and further to the east the coalfield is overlain by Triassic sediments such as the Sherwood Sandstones and Mercia Mudstones. Boulder clays, glacial sands, gravels and deposits such as alluvium of river flood plains rest on all the older rocks in this part of the region and constitute the 'Drift' deposits of the Quaternary Ice Age.

The Yorkshire Coalfield has supported, and continues to support, a range of mining activities. At various times, the land within the coalfield has been worked for fireclay, ganister, pottery clay, lead, ironstone, mudstones and shales for brick manufacture, stone (building materials, flags, grindstones). On the Permian and Triassic strata (which overlie the Coal Measures - the 'concealed coalfield'), lime, building sand and gypsum have been mined, and there are some minor records for the discovery of barytes and oil. Silica has been used for glassmaking, and gravel has also been worked (Mitchell & Bromehead, 1947). However, all of these mining activities have been minor compared with the massive impact of mining for coal on the area.

2.1.2 Selection of sites

The study area comprises the whole of the Yorkshire Coalfield in northern England (Figure 3).



Key:

- ● Deep-mine sites
- ■ Opencast sites
- ▲ Subsidence wetlands

Figure 3.
Location map of study sites, Yorkshire Coalfield. (n=70).

Three broad site categories were chosen for investigation, reflecting the principle types of mining impact:

1. Deep-mine sites.
   Includes abandoned collieries comprising derelict buildings, roads, yards, building rubble, rail trackways etc., stocking areas, spoilheaps, tail washing lagoons and small water features.

2. Opencast sites.
   Includes land restored to agriculture or amenity, aquatic and terrestrial, after opencasting operations but not land currently being mined.

3. Subsidence wetlands.

Includes surface land which has subsided due to deep-mine activities, and has subsequently become inundated.

Following the identification of the three broad categories of site (opencast, deep mine terrestrial and deep mine subsidence), an historical search was made to identify the spatial distribution and locations of collieries across the coalfield using 1:10000 and 1:2500 Ordnance Survey maps of the Yorkshire Coalfield, mining maps and other documentation (Mitchell & Bromehead, 1947, Institution of Mining & Metallurgy, 1990).

Selection of examples in each category was made to give a full geographical spread across the study area, and to include representation of other variables (altitude, aspect, size, isolation/proximity to semi-natural habitats, age). An attempt was made to try and identify dates of abandonment of sites, as this would give a start date for the initiation of natural regeneration, however these were difficult to find and poorly documented. Examination of sites also revealed that intra-site conditions were very variable, in that natural regeneration can begin almost immediately after areas begin to operate, and only detailed historical investigations on an individual site basis could provide the necessary data. However, data on colliery openings were collated as this information was available (Wilcockson, 1950) with a view to testing temporal assumptions about succession.

Once selected, sites were visited and information collected using standard methodologies for surveying (see below) on recording sheets. The bulk of data collected this way related to broad physical and vegetational characteristics. Information was collected to cover the following parameters :

1. Locational & geographical information - grid ref., name, District, surrounding context
2. Topographical information - altitude, aspect, gradient
3. Soils - wetness/dryness, compaction
4. Vegetation - habitats, plant communities & plant species lists
5. Fauna - vertebrates and invertebrates
6. Cultural and social context

2.1.3. Survey methodology

2.1.3.1. Habitat-types.

Habitat-types were recorded using the national standard Phase 1 survey (Nature Conservancy Council, 1990b). This is a technique for environmental audit based on standard definitions for different broad classifications of habitat recorded on 1:10000 Ordnance Survey maps as hierarchical alphanumeric reference codes and mapping colour codes.

2.1.3.2. Plant communities.

The National Vegetation Classification or NVC (Rodwell, 1991 *et seq.*) was chosen as a basis for producing a classification of vegetation types found on the sites surveyed. This recently devised system provides a national standard against which all sites and samples can be tested and the methodology allows rigorous comparative analysis.

For the NVC samples, stands of homogenous vegetation were located by eye after a rapid reconnaisance of the whole site, and usually five quadrats in each stand were recorded using the NVC methodology (Rodwell 1991 *et seq.*). Quadrat sizes were chosen according to the broad habitat type following NVC standards although the shape of the quadrat was varied in some instances.

On opencast sites and mining subsidence wetlands, no NVC samples were taken. However the majority of sites were already recognised as statutory or local sites of wildlife significance based on the criteria used in this study, and a judgement was taken that the description given on the published citations for these sites, based on previous survey, reflected the plant communities found there. Inferences were therefore made using these data on the types of community found, supplemented by broad habitat survey on site visits.

2.1.3.3. Plants.

Records of vascular plant species other than those which occurred in the vegetation samples were also collected. This provided a fuller picture of the flora of sites, and records of significant species, either through rarity and/or abundance could then be used in the evaluation by comparison with national and local floras. Random sampling would not necessarily pick up all such species which by definition would be rare or scarce on the sites. Plants were identified using standard texts (Clapham *et al.*, 1973; Stace,1991) and referred to local specialists for confirmation where necessary.

Samples of other taxa considered to be significant, especially lichens and bryophytes, were also taken and referred to experts for identification.

2.1.3.4. Vertebrates

Faunal information was more difficult to collect in a way which allowed statistical analysis without investment of considerably more time and resources than was available for this study. However data on birds, mammals and other vertebrates was collected in a consistent way.

Registrations of breeding birds were made using a modified version of the 'Common Birds Census' (CBC) technique (the national standard)(Bibby, 1992), which involved walking over the whole site at a constant pace such that recording effort was consistent, and between 09.00 hrs and 17.00 hrs to avoid periods of peak activity for birds. Due to time constraints, only one visit per site was made during the period April to July. This method is therefore not as rigorous as the more labour-intensive CBC method which requires 6 visits, or other constant-time methods such as upland bird survey (Brown & Shepherd, 1993) which require two visits. Despite the inherent limitations to the method which would not eliminate passage and non-breeding birds from the results, nor account for seasonal trends, as a rapid method it does provide relative data from similar sites and does indicate site usage. It cannot, however, provide accurate data on populations.

Records were also made of species, numbers and location of other animals such as mammals, reptiles and amphibians. Amphibian counts were made at a relevant locations using standard methodology (Griffiths & Raper, 1994).

Information was also obtained from the Wetland Bird Survey (Waters *et al.*,1996), particularly for the lakes, flashes and Ings sites. This is a national system operated by the British Trust for Ornithology on behalf of the statutory nature conservation agencies and the Royal Society for the Protection of Birds, and comprises nationally coordinated monthly winter counts of waterfowl (wildfowl and waders) at participating sites. These include all significant waters in the study area.

In summary, survey data on breeding birds, mammals and other vertebrates was collected by the author. Winter wildfowl counts generated by volunteers were obtained from the BTO.

2.1.3.5. Invertebrates.

Data were collected on invertebrate groups familiar to the author (butterflies and Odonata) using the same method as the other fauna.

The national Invertebrate Site Register (Ball, 1986) was searched for records, as well as papers published in local journals. Further records were also collected from local naturalists to supplement the overall picture of each site. This was particularly useful at three sites where a local specialist gave access to extensive unpublished data.

2.1.3.6. Soils.

Soils were classified according to Hollis (1992) which describes a system for classifying soils in urban areas as a development of the national standard for soil classification in England and Wales (Avery, 1980). Within this system, one of the eleven major soil groups, **made ground soils**, was used for deep-mine sites (opencast and subsidence sites were not surveyed). This is defined as soils being formed in at least 80 cm of mechanically placed material, or at least 30 cm of mechanically placed material that directly overlies a truncated soil or geological substrate, or at least 30 cm of any 'special' man-made substrate, or a consolidated man-made substrate that has at least a 50% vegetative cover. The major soil group is further differentiated into seven soil groups differentiated according to the presence of significant amounts of superficial organic matter, and broad physical characteristics (dense, dense seasonally wet, permeable seasonally wet, raw, raw-toxic, shallow, and well aerated). Most of the substrates encountered matched the 'special man-made substrate category (9.2), which is characterised by the type of anthropogenic substrate e.g. copper ore tailings, china clay waste, and is also split into base-rich and base-poor categories.

2.2. Data storage and handling

Data were collected and stored using a Toshiba T1910 Personal Computer equipped with Vespan II, Match, Quattro Pro spreadsheet and Wordperfect 6.1 programs.

2.2.1. VESPAN II.

1. Programs to handle multivariate vegetation data (or similar data structures).

These programs were designed to process the vast quantity of data accumulated by the National Vegetation Classification project. They are built around two analytical techniques, TWINSPAN and DECORANA: the former being a polythetic divisive method of cluster analysis, the latter an ordination technique. The programs comprise a complete system of data entry, preparation, analysis and display in tabular and map form.

Data structure

One of the problems of dealing with sample data collected in the field is the number of species encountered. In the NVC, some 4500 species, subspecies and growth forms of vascular plants, bryophytes and lichens are recognised. The raw data are stored as a series of records of variable size. Each record (sample) is identified by a unique number and contains information of eachspecies present and a measure of its quantity. In addition, up to 100 special variables (non-species data such as altitude, grid-ref., pH, date) can be accommodated. For each record (sample) a total of about 2000 species with their quantitative values can be entered. The package works in such a way that the structure of the data system need never to be known, nor how species are coded, though both structures are easily accessible (stored as ASCII files) should it be necessary to use them.

Other programs available in the VESPAN II package.

RECORD is used to enter new data into a databank, using either abbreviations of species names or by code numbers, checking the data as far as possible for accuracy, and allowing facilities to correct errors. Use of abbreviated names copes with a variety of different ways of abbreviating the names and has facilities for coping with spelling errors, some synonyms and potential confusions.

SELECT allows the selection of subsets of data from the databank, using a variety of procedures by:

1. Selection by sample number
2. Selection by presence, absence or combination of one or more attributes (species or special variables) in the samples
3. selection by the quantitative values of one or more attributes within the samples
4. selection by grid reference
5. selection by indicator species (Hill, 1979a)

These procedures may be combined in a variety of ways to allow quite complex selection strategies.

PREPARE converts data from the standard VESPAN format into a condensed format suitable for use in the programs TWINSPAN and DECORANA.

TWINSPAN or Two-way Indicator Species Analysis (Hill, 1979a) is a polythetic divisive technique for clustering multivariate data.

DECORANA or Detrended Correspondence Analysis (Hill, 1979b) is an efficient technique for producing ordinations of multivariate data.

TABLE produces tables of vegetation data and derived statistics where sample and species orders are controlled by the user or from the results of a TWINSPAN analysis (after pre-processing by TWINTAB). TABLE also produces summary data in a form suitable for entry into MATCH.

2. Species distribution programs.

This part of the package stores, extracts and maps distributions of plants. Each record is identified by a grid reference and consists of a list of the species found at that location (e.g. a 2km by 2km grid square) defined either by the National Grid of Great Britain or by an X, Y co-ordinate system. Up to 3000 species can be entered into each record. There are two main programs.

FILESPP is responsible for data entry, checking and incorporation into the database. It can use abbreviated species names or codes (if known) in a similar manner to the RECORD program mentioned earlier.

SELECTSPP is used to interrogate the database for a variety of information.

1. Compilation of lists of grid units in which a particular species occurs.
2. Compilation of a list of grid units in which a given combination of species occurs.
3. Compilation of a list of grid units which contain a total number of species between given limits (e.g. all units with a total of 200- 250 species).
4. Compilation of a list of species in a given grid unit or combination of grid units.
5. Compilation of a list of species found in a given number of grid units (e.g. for rare species, those species found in no more than 10 grid units).
6. Compilation of a list of the number of occurrences of each species in the data as a whole.
7. Compilation of a list of the total number of species found in each grid unit in the database.

The information can be presented in a number of ways, to the screen, to a printer, to file or in a form for display as maps using the GINMAP program.

2.2.2. MATCH

The National Vegetation Classification, published as British Plant Communities (Rodwell, 1991 *et seq.*) has produced a classification of British vegetation which describes a series of communities and sub-communities reflecting the variation of vegetation in Britain. Each of these units is characterised by the inter-stand frequency of the component species giving a unique constancy profile. Most British vegetation can be assigned to an appropriate unit by comparing the constancy of the constituent species found in a group of samples with the characteristic profile shown in the diagnostic list for the particular unit. The program MATCH is designed to aid this process by mathematically comparing the collected data with the diagnostic data held in file on the computer. Coefficients of similarity are calculated and a list of the diagnoses that are most similar to the collected data are displayed, together with the value of the coefficient and, optionally details of the major departures of the collected data from the diagnostic data. This enables the user to draw up a shortlist of possible communities which can be considered in more detail before a final identification is made.

The program works by finding the ten best matches against community diagnoses as a first step. Since these communities may each have a series of sub-communities, the program then compares the submitted data with the sub-community diagnostics for all sub-communities within the ten best communities. The ten best matches (whether of communities or sub-communities) is then presented.

The program can also supply further details of the ten best matches. There are two further options: the full option lists all the species found in an individual diagnosis together with their constancy class and maximum cover-abundance value. Against these data are listed the same values for the submitted data. Major discrepancies between the two sets of data are indicated if:
1. the constancy classes for a given species differ by two or more,
2. the maximum cover-abundance value of a species in the submitted data exceeds that of the diagnostic data.
Additionally, a list of species found in the submitted data but not in the diagnostic data is given. The abbreviated option merely lists the discrepancies as described above, together with any species found in the submitted data but not in the diagnostic data and any species of higher constancy in the diagnostic data that are not found in the submitted data.

2.3. Evaluation methods

2.3.1. Nature conservation criteria - general considerations.

Various systems for the comparative evaluation of nature conservation sites exist (reviewed by Usher, 1986). Most involve the assessment of features found on site against key attributes, which in Britain were originally described by Ratcliffe (1977) as size, diversity, naturalness, rarity, fragility and typicalness as primary criteria, and recorded history, position in an ecological/geographical unit, potential value and intrinsic appeal as secondary criteria. These are still used as the basis for the selection of the national series of statutory nature conservation sites - Sites of Special Scientific Interest (SSSI). Their application is complex and is subject of detailed guidance ((Nature Conservancy Council, 1989), but is made against a background framework of reference which describes the range of variation, communities and species across Britain which the SSSI series is intended to conserve. This includes national classifications such as the National Vegetation Classification (originally sponsored by the NCC), national population estimates such as the winter wildfowl counts, results of national surveys (e.g. Great Crested Newts (Swan & Oldham, 1993)) and knowledge of distribution based on the recording tradition of amateur naturalists, and professional ecologists and geologists.

At a local government level, either County or District, other important sites - 'second-tier sites' - occur which do not merit SSSI status, The criteria used for developing local evaluation systems for these is largely based on the Ratcliffe criteria (Tyldesley, 1986), however additional and important social criteria relating to the value of the site to local people are often included and given equal weighting to the more scientific criteria usually used e.g. Hawkswell, 1994.

In addition to the national and local systems of designation (SSSI and second-tier sites), other evaluation systems have been introduced with the advent of European directives related to wildlife, the Council Directive of 2 April 1979 on the Conservation of Wild Birds (79/409/EEC) (the 'Birds Directive (1979)'), and the Council Directive on the

Conservation of Natural Habitats and Wild Fauna and Flora (92/43/EEC) also termed the 'Habitats Directive (1992)'. These are aimed at securing the best European sites for nature conservation through designation of a series of Special Protection Areas (SPA) and Special Areas of Conservation (SAC) which will collectively form a European protected sites network or 'Natura 2000' sites when agreed by the European Commission. In practice in Britain, these reflect a suite of SSSI's which support habitats and species of European importance as defined by the Directive, but they are afforded more stringent protection through statute (The Conservation (Natural Habitats &c.) Regulations, 1994). Selection of these sites is based on European criteria such as the contribution those sites make as representative examples of habitat-types or biotopes, or the proportion of populations of species which contribute to the network. In reality all such sites are also SSSI's.

In addition to any evaluation on a site-by-site basis, as above, priorities for conservation action can be undertaken at a species level, whereby the status and distribution of a range of species can be compared to identify those in need of greater effort if their conservation is to be secured. For instance, the Lady's Slipper Orchid *(Cypripedium calceolus)* with only one extant native population in Britain, can be deemed to warrant higher priority than say, Fragrant Orchid *(Gymnadenia conopsea)*, which whilst still uncommon, has many extant populations. Such evaluations rely on data concerning population sizes, geographical distribution and autecology and use criteria of endemism, rarity, size, and vulnerability/threat. For some taxa, e.g. birds, where detailed population data are available over a period of time, it is also possible to use criteria such as range contractions or population declines to add to the evaluation (Marchant *et al.*, 1990), and indeed this has been done to identify 36 species of high priority ('red' list species) and 110 species of moderate priority ('amber' list species) in Britain (Gibbons *et al.*, 1996) based on data over the last 25 years.

For all species and habitat-types, evaluations have been carried out at national level, informed by the methods outlined above, but incorporating assessments across the European Union, to produce the UK Biodiversity Action Plan (Anon; 1994a, 1995a, 1996). This has cross-sectoral support from government, the voluntary conservation organisations, the statutory and academic sectors, and lists habitats and species warranting conservation action in the UK and its Dependent Territories which contribute to the conservation of biodiversity across the globe. The initiative, arising out of the Earth Summit in Rio de Janeiro in 1992 (Holdgate, 1996), focuses a rolling programme of conservation action on habitats and species, the first list of priorities including 117 species and 13 habitat types (Anon., 1995a). Species and habitat types on these lists can be used in the evaluation of sites to supplement the other methods, since the presence of such a feature, especially if notable and not ephemeral, can be seen to be potentially contributing to conservation action in a UK or European context.

A further consideration of nature conservation importance recognises that even with the plethora of designated sites, it still would not be possible to ensure the conservation of habitats and species into the future just by these sites, since their survival also depends upon the maintenance of ecosystems across a wider scale e.g. Tubbs, 1997. A holistic approach is required in which healthy ecosystems are essential and the contribution of many small populations and fragments of habitat add to the more significant designated sites, thus contributing to the overall robustness of survival of populations (Kirby, 1995). What happens in the 'wider countryside' is therefore relevant, and there has been much development of the furtherance of nature conservation objectives in this context through policy incentives and schemes e.g. Ministry of Agriculture, Fisheries and Food (MAFF) environment support schemes such as Environmentally Sensitive Areas (ESA) and Countryside Stewardship. Provision of free advice to farmers and other private landowners through the Farming and Rural Conservation Service (FRCA) and the Farming and Wildlife Advisory Group (FWAG) has also been promoted. Some have added to the '*corpus*' of nature sites through the setting up of private nature reserves or managing their estates in a wildlife-friendly way (e.g. National Trust, Ministry of Defence estate, Wildlife Trust nature reserves that are not statutory sites).

An approach in England which attempts to bring both the designated site and 'wider countryside' strands together has been recently developed which uses as its basis an eco-geographical division of the country - the Natural Areas approach (English Nature, 1995). Here, some 114 terrestrial and 21 maritime areas of the country have been identified on the basis of ecological similarity, and where common agreed policy objectives and implementation plans can take place which address the key characteristics of each Natural Area, with full participation of the human communities which live there. The inter-relationship of designated sites to their ecogeographical context is therefore addressed.

The Coal Measures Natural Area (Hirst, 1997, Appendix 26)comprises a large part of the study area, and the evaluation of the study sites can be assessed against the nature conservation objectives thus identified. It should be noted, however, that, some of the study sites in the concealed coalfield are located in other Natural Areas, notably the Southern Magnesian Limestone, and the Humberhead Levels.

The study sites were evaluated using an initial application of the basic criteria outlined below for habitat types and species, followed by a further assessment against the established systems for European, SSSI, second-tier sites, and Biodiversity Action Plan priorities which place the mining sites in a much wider context. It is assumed that the evaluation systems for the latter are robust, as it would be impossible to analyse the study sites without comparable data for all sites across regional, national and international frameworks.

2.3.1.1. Evaluation of habitat-types.

The primary attributes considered were;

Size - given that the intrinsic quality of the habitat-type is acceptable, then larger sites would be more viable and have less edge-effects.
Naturalness - whilst truly natural environments i.e. not modified by human activity, are rare in Britain, sites which satisfy a level of quality marked by a lack of gross modification are usually scored higher in any judgement. Ironically, most of the natural colonisation of many former deep-mine sites is entirely natural and represents a unique feature in the landscape where there has been no obvious further human intervention.
Rarity - this is an important aspect, since the more rare the habitat-type, the more likely it will require conservation to ensure its future in a particular geographical area. However, difficult and often subjective judgements need to be made. Should small fragments that are more common and well-distributed elsewhere, or habitat-types which are genuinely rare and for which the region holds a significant area, be classified as important?

Diversity - this tends to be valued more positively as it increases (but caution needs to be made to discount non-target attributes, for instance the presence of a weed flora when assessing a woodland). It can operate at coarse habitat-type, plant community or individual species level.
Representativeness - the selection of examples of habitat-types can also be made on the basis that not all examples can be chosen for conservation action and therefore those which are representative of the total sample are preferred (rather than only the exceptional examples).

A number of secondary attributes can also contribute to the evaluation such as fragility, spatial context (or position in an ecological unit, with sites near to or linking other sites of interest deemed to be of more significance), intrinsic appeal, and recorded history.

2.3.1.2. Plant communities.

Plant communities were assigned to NVC types in the case of deep-mine sites. Quality of these stands in terms of the representativeness criterion could be judged by reference to the published NVC (Rodwell, 1991 *et seq.*), particularly by comparing the extent of cover and abundance of the diagnostic species, notably the community constants and preferentials, giving a weighting for representativeness, however the other criteria used in assessment of habitat types such as size (=area of the community), presence of rarities and diversity were taken into account.

2.3.1.3. Plants

The presence and abundance of rare and scarce species (Franklyn & Farrell, 1983; Stewart *et al.*, 1994) was noted, with significant species or large populations rating higher.

2.3.1.4. Vertebrates

Methods for evaluating populations of vertebrates are not as advanced as for habitats. The SSSI methodology, for instance, recognises that site designation is difficult to apply to wide-ranging species such as Otters or raptors. Site based evaluations are most useful where concentrations of animals occur persistently e.g. waterfowl on wetlands, bat hibernacula, or amphibian spawning sites. National monitoring schemes can also highlight national population trends for widely distributed species and if downward trends are detected, then policy action can be implemented, rather than site based designations, for instance birds of arable farmland. For some groups, standard survey methods have been refined to provide reliable data. Further consideration was also given to the prioritised lists of species in the UK Biodiversity Action Plan (Anon; 1994a, 1996) and statutorily protected species.

2.3.1.4.1. Birds

For deep-mine sites, frequencies and abundances on sites was tabulated (Figure 10, Appendix 20), and the presence of nationally scarce or locally scarce species noted. Consideration was also given to the more sophisticated lists of birds of conservation concern in the United Kingdom (Gibbons *et al.*, 1996). This is a prioritised list of all species categorised into red (globally threatened or in rapid decline) and amber (moderate decline, rare, localised, internationally important or of an unfavourable conservation status in Europe) lists. These latter gave greater weighting to the evaluation since the sites generally supported typical assemblages (Fuller, 1982).

For opencast and subsidence wetlands, the use of winter wildfowl counts provided the most useful source of information, especially as the data could then reveal the percentages of national or international populations that the site supported. Further use of breeding bird data, extracted from local bird reports, was also used to provide scores based on a typical species assemblage for openwaters and their margins, and lowland grasslands to enable comparisons with the national thresholds for such assemblages used for the selection of bird SSSI's (NCC, 1989). In addition, the red and amber lists (Gibbons *et al.*, 1996) and the Red Data Book (Batten *et al.*, 1990) provided further background for analysis.

2.3.1.4.2. Mammals

The presence of statutorily protected mammals was recognised in the evaluation (e.g. Badger setts). Further consideration was also given to the presence of species highlighted by the UK Biodiversity Action Plan as warranting conservation attention.

2.3.1.4.3. Reptiles and amphibians

Use of local status accounts was used to evaluate reptiles. For amphibians, a scoring system was used whereby the presence of small, medium and large populations of each species scored 1, 2 or 3, with additional points for 3, 4, or 5 species present commanding 1, 2 or 3 extra points (NCC, 1989).

2.3.1.5. Invertebrates

For butterflies and dragonflies, the numbers and populations found on the deep-mine sites were used to compare assemblages, with extra significance given to the presence of rare species as determined by reference to local and national species accounts.

For other groups, the presence of Red Data Book, Nationally Notable (a and b) and Regionally Notable species was used to indicate importance (Ball, 1986), with attention also being given to narrative accounts of the assemblages found.

2.3.1.6. Earth science features

Reference was made to the SSSI series and to the RIGS (Regionally Important Geological Sites) series to determine if any of the study sites had already been recognised for geological interest, the methodology for which is radically different from biological site evaluation (Ellis *et al.*, 1996). Incidental records of dramatic exposures or fossils were noted in the survey.

3. RESULTS

3.1. General

Information was collated through survey and other sources from seventy sites in the Yorkshire Coalfield (Location map, Figure 3; full inventory, Appendix 18), of which 46 were collieries/spoilheaps, 12 opencast sites and 12 subsidence wetlands (Figure 4).

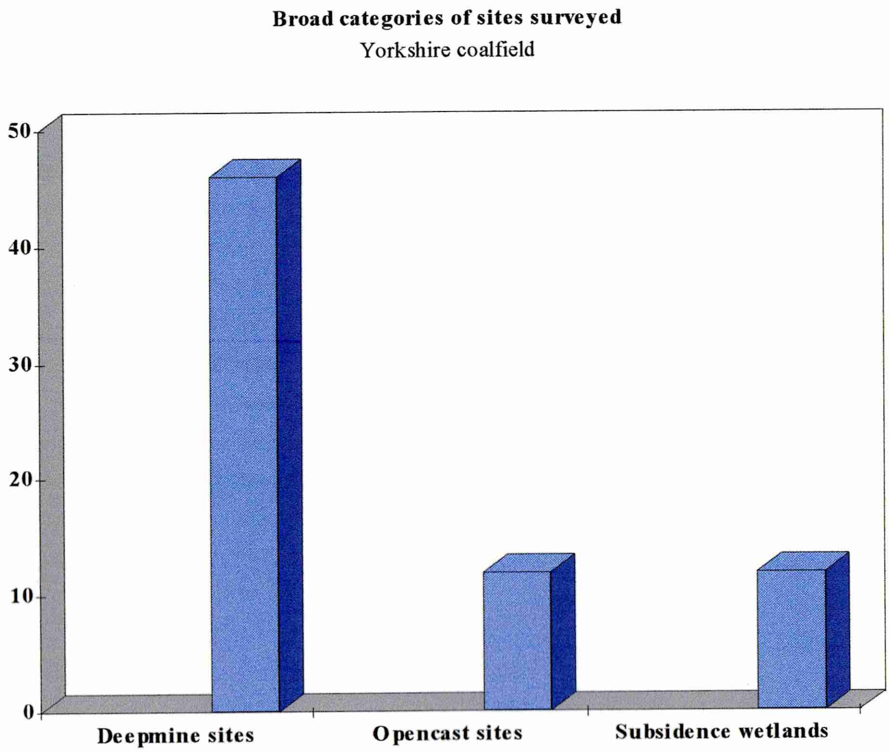


Figure 4.
Broad categories of sites surveyed, Yorkshire coalfield.

Of the 46 collieries/spoilheaps, 3 included some relatively large-scale lakes (two of these newly engineered and the other an area of impeded drainage on a spoilheap), and limited information on these was included in the analysis. Of the 12 opencast sites, 5 were terrestrial reclamations - 2 to agriculture, 2 engineered restorations with wildlife objectives, and one naturally regenerated site. The rest were terrestrial/wetland restorations, with varying degrees (ranging from nil to full) attention to wildlife features. All the 12 subsidence sites were wetlands.

Phase 1 methodology was used to categorise the frequency and abundance of habitats encountered on sites which are shown in Figure 5. Wetlands (especially open water as created features), and pioneer communities are dominant, with grassland communities also common (whether naturally developed or created). Woodlands are relatively scarce, reflecting the immaturity of most sites, and heathlands are almost absent.

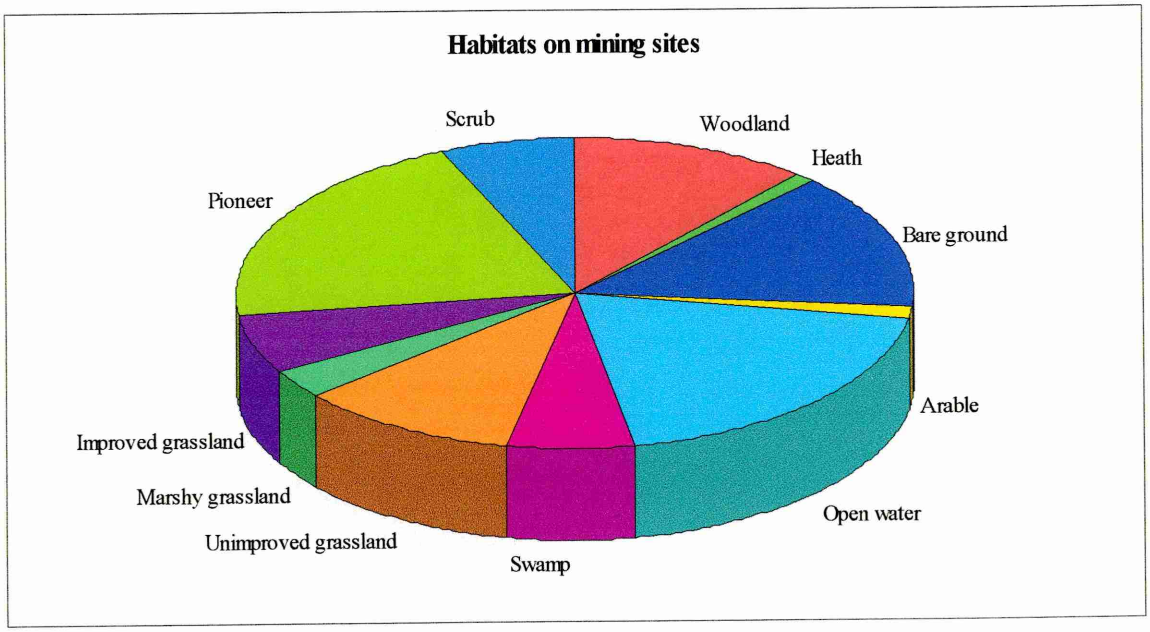


Figure 5.
Habitat-types on mining sites, Yorkshire (n=70).

3.2. Deep-mine sites

3.2.1. Habitat-types.

Habitat-types ranged from almost bare spoil to mature woodland; wetlands were scarce. Figure 6 shows the broad range encountered, with an indication of frequency and undance. The most frequent habitat-types were pioneer, grassland, woodland and bare ground (often being dominant). Small wetlands were less frequent on the sites. Heathlands were scarce.

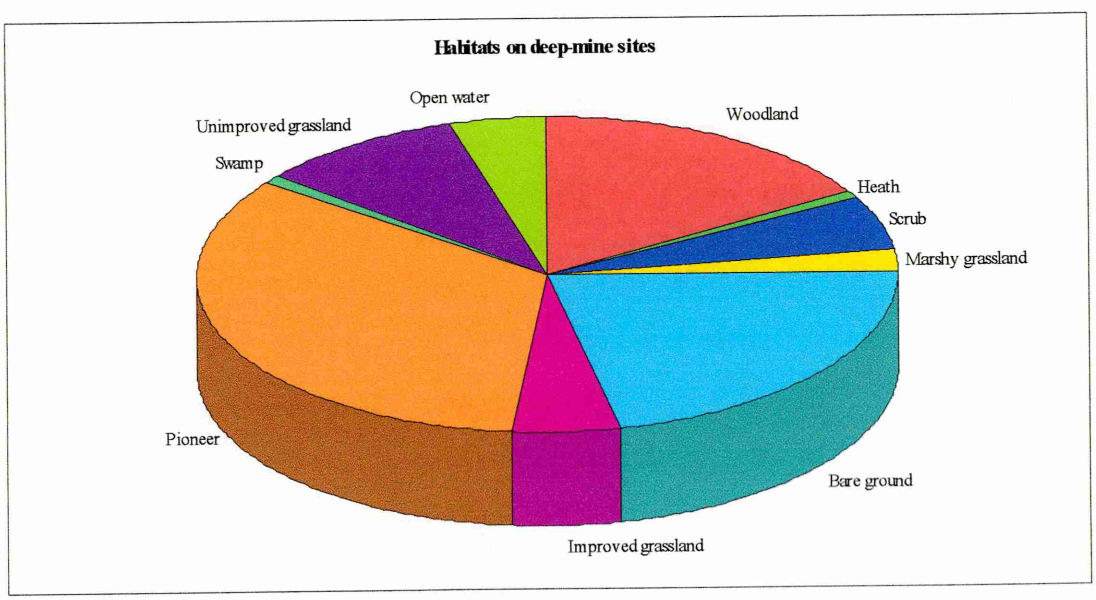


Figure 6.
Habitat-types on deep-mine sites (n=46).

3.2.2. Plant communities

Vegetation was sampled on 36 sites, with 357 samples of NVC data collected. Many of the samples of homogenous vegetation corresponded to recognised NVC types. The pioneer vegetation types, however, were particularly novel. The results of the first TWINSPAN analysis contained 14 end-groups of which 8 corresponded to published NVC accounts (Table 1). The other end-groups were subsequently subjected to further analysis.

1st analysis	2nd analysis	NVC fit and comments
1. (37)		W16 *Quercus-Betula-Deschampsia flexuosa* woodland
2. (28)		U2 *Deschampsia flexuosa* grassland
3. (47)		U1 *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland
4. (39)		
	1. (10)	MG9 *Holcus lanatus-Deschampsia cespitosa* grassland
	2. (25)	MG9-type
	3. (14)	MG1 *Arrhenatherum elatius* grassland
5. (110)		No NVC equivalent - described as *Agrostis stolonifera-Holcus lanatus* pioneer vegetation
	1. (57)	*Agrostis stolonifera* sub-community
	2. (36)	*Tussilago farfara* sub-community
	3. (17)	*Hypochoeris radicata* sub-community
6. (68)		No NVC equivalent
	1. (9)	MG12 *Festuca arundinacea* coarse grassland
	2. (5)	CG 3d *Bromus erectus* grassland
	3. (20)	No NVC equivalent -described as *Vulpia bromoides-Arenaria serpyllifolia* pioneer vegetation
	4. (10)	No NVC equivalent- *Anthyllis vulneraria* lawns
	5. (24)	Unassigned (5 groups)
7. (16)		
	1. (6)	MG7 *Lolium perenne* grassland
	2. (10)	No NVC equivalent but plantations over sown grassland
8. (2)		S12 *Typha latifolia* swamp
9-12 (6)		S19 *Eleocharis palustris* swamp
13. (1)		No NVC equivalent - single sample of *Calamagrostis epipejos*
14. (4)		No NVC equivalent - woodland

Table 1.

Initial TWINSPAN analysis of vegetation samples, deep-mine sites (n=357).

The largest end-group from the first analysis contained 110 samples and could be readily distinguished as a distinct community which corresponded to field descriptions and is described as *Agrostis stolonifera-Holcus lanatus* pioneer vegetation. Of the 17 end-groups produced by the second TWINSPAN analysis of this group, only two (36 and 17 samples respectively) produced any constant species other than the two community descriptors. These end-groups were removed from the whole data set, evaluated independently by table and reference to field descriptions and were considered to be sub-communities. The remaining end-groups were so small as to make further analysis meaningless, and so were treated as one set.

The second large sample from the first TWINSPAN analysis containing 68 samples had no such distinctiveness. Of the 13 end-groups produced by the second analysis, three could be readily further assigned to NVC communities (Table 1). These were removed from the data set. For the rest of the end-groups, the original samples and descriptions were consulted to see if any patterns could be detected. 20 samples comprising four of the end-groups were distinctive and could be described as a pioneer *Vulpia bromoides-Arenaria serpyllifolia* community - one readily identifiable in the field from many locations.

Another end-group of 10 samples from this group comprised a highly unusual series of species rich samples dominated by *Anthyllis vulneraria* from different locations on a single site. General inference of a widespread community would clearly be unwarranted from this single site, however extensive the vegetation.

The remaining end-groups in this large sample could not be clearly differentiated and represented samples subjected to the effects of management as well as samples intermediate between some of the more distinct communities.

All the other end-groups from the first analysis were also subjected to further examination, revealing 7 further groups which corresponded to recognised NVC types. End-groups were reassembled into similar groups by reference to the original sample descriptions and a full summary is given in Table 2.

Detailed accounts of all the NVC community or sub-community equivalents and the 5 'new'communities and subcommunities are described below and in Appendices 1-17.

Plant communities on deep-mine sites	**No. of samples**
Agrostis stolonifera-Holcus lanatus pioneer vegetation	
Agrostis stolonifera sub-community	57
Tussilago farfara sub-community	36
Hypochoeris radicata sub-community	17
Vulpia bromoides-Arenaria serpyllifolia pioneer vegetation	20
U1 *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland	47
U2 *Deschampsia flexuosa* grassland	28
H9 *Calluna vulgaris-Deschampsia flexuosa* heath	1
MG1 *Arrhenatherum elatius* grassland	14
MG7 *Lolium perenne* grassland	9
MG9 *Holcus lanatus-Deschampsia cespitosa* grassland	21
MG10 *Holcus lanatus-Juncus effusus* rush pasture	7
MG12 *Festuca arundinacea* coarse grassland	9
CG 3d *Bromus erectus* grassland	5
Anthyllis vulneraria lawns	10
Festuca rubra-Lotus corniculatus grassland	19
S12 *Typha latifolia* swamp	2
S19 *Eleocharis palustris* swamp	6
W10 *Quercus-Pteridium aquilinum-Rubus fruticosus* woodland	12
W16 *Quercus spp.-Betula spp.-Deschampsia flexuosa* woodland	18
Calamagrostis epipejos sample	1
Plantation scrub/woodland	18
TOTAL	357

Table 2.
Final summary of vegetation samples, deep-mine sites. (N=357).

1. *Agrostis stolonifera-Holcus lanatus* pioneer community (Appendix 1).

Constant species
Agrostis stolonifera, Holcus lanatus

Rare species
Corrigiola litoralis

Physiognomy
The community is naturally developed and has a varied character ranging from fragmentary colonising vegetation on bare ground (which can account for over 80% of the sample) to almost complete cover in which the grass *Agrostis stolonifera* predominates (Plate 1).

Plate 1.
Pioneer vegetation on colliery site. *Agrostis stolonifera-Holcus lanatus community,* typical sub-community, Methley Colliery tip, July 1995.

Agrostis stolonifera and *Holcus lanatus* are constant although the latter characteristically only occurs at low cover. Other grasses never achieve the frequency or cover of the two constants, but *Poa pratensis* and *Agrostis capillaris* can be frequent, the latter prevalent in more closed stands. Some caution may be required in the identification of *Agrostis*, since some samples were difficult to identify, being intermediate between *A.stolonifera* and *A.capillaris* and may well have been the hybrid *A.*x *murbekii* Fouill.ex P.Fourn. (Stace, 1991). Of note is the almost complete absence of grasses which are generally common in the surrounding landscape, and are more typical of 'unimproved' or partly 'improved' grasslands such as *Festuca rubra, F. ovina, Trisetum flavescens, Briza media, Alopecurus pratensis* and *Phleum pratense*. Grasses typical of improved agricultural grasslands such as *Lolium perenne* and *Dactylis glomerata* are also virtually absent.

A large range of small herbs is associated with the community, almost all at very low frequency, but only *Hypochoeris radicata* and *Tussilago farfara* achieve constancy in some stands and these are assigned to different sub-communities. There can, however, be an apparent patchy dominance of some species such as *Reseda luteola, Hypericum perforatum* and *Elytrigia repens* on particular sites where their tall and prominent growth stands out against the bare ground.

Sub-communities

***Agrostis stolonifera* sub-community**

This is the typical sub-community and has the two constants but a very variable set of associates. In some stands, particular associates can be visually prominent, either throughout as with the tall *Reseda luteola* (Plate 2), or in patches such as with the grass *Elytrigia repens.*

Plate 2.
Pioneer vegetation on colliery site. Agrostis stolonifera-Holcus lanatus community. Typical sub-community showing variant character with tall herbs *Reseda luteola, Artemisia, Leucanthemum* prominent. Wath Main Colliery tip, July 1993.

Invasion by birches *Betula pendula* and *B. pubescens* and by other trees and shrubs such as *Quercus petraea* and *Salix cinerea* can give a scrubby look to some stands and an indication of successional trends. A long list of open ground species reflecting the very open nature of the sub-community and the adaptability of urban, agricultural and coastal pioneers such as *Senecio squalidus* and *S. viscosus, Poa annua* and *Polygonum aviculare, Anagallis arvensis* and *Bromus hordeaceus hordeaceus,* and *Spergularia rubra* and *Arenaria serpyllifolia* is distinctive in a broad sense. As with the other sub-communities, some unusual species can be present such as the Red Data Book

Corrigiola litoralis (Perring & Farrell, 1983), and the locally scarce *Poa compressa* (Lavin & Wilmore, 1994).
Associates can be restricted to one or a handful of sites, but can sometimes be frequent and can give the vegetation a distinct look, as with large stands of vegetation sprinkled with *Oenothera glazoviana* (Plate 3) or *Reseda luteola*.

Plate 3.
Agrostis stolonifera-Holcus lanatus pioneer vegetation. Typical sub-community with *Oenothera glazoviana*. Manvers Colliery tip. July 1993.

***Tussilago farfara* sub-community**

Here, *Tussilago farfara* also occurs as a constant and can appear to dominate the vegetation with its large leaves in summer (Plate 4). The grass *Deschampsia cespitosa* is preferential and can be abundant but few of the other associates achieve distinctive prominence. The introduced moss *Campylopus introflexus* and *Hieracium sabaudum* group can be frequent in some stands.

***Hypochoeris radicata* sub-community**

In this case, *Hypochoeris radicata* also occurs as a constant in a grassier and more closed sward but whilst never dominating the vegetation can appear prominent either through its rosettes or flowers. *Agrostis capillaris* is preferential and can be more abundant than *A.stolonifera*, as also is a suite of species characteristic of mesotrophic grasslands such as *Trifolium pratense, T.repens* and *Medicago lupulina*. Also preferential is the striking *Centaurium erythraea*, which along with a group of associates such as *Linum catharticum, Anthyllis vulneraria, Crepis capillaris, Carex flacca, Geranium molle* and *Vulpia bromoides* reflects the more species-rich nature of this vegetation (Plate 5).

Plate 4.
Pioneer vegetation on colliery site. *Agrostis stolonifera-Holcus lanatus* community, *Tussilago farfara* sub-community. Falthwaite Colliery tip, July 1994.

Plate 5.
Pioneer vegetation on colliery site. *Agrostis stolonifera-Holcus lanatus* community, *Hypochoeris radicata* sub-community showing more species-rich character, here by *Centaurium erythraea*. Methley Colliery tip. July 1995.

Habitat
The *Agrostis stolonifera-Holcus lanatus* community is the typical and almost ubiquitous naturally pioneering vegetation of spoilheaps and abandoned collieries in the lowlands of the Yorkshire coalfield.

The spoil substrate is a reflection of the Coal Measures Series horizons with a varied mixture of mudstones, siltstones, sandstones, grits and seatearths (varying from fireclay to ganisters) as well as the coals themselves (Edwards & Trotter, 1954). Some marine and shell band horizons are also likely to form part of the spoil and further variation is introduced by surface tipping of industrial process wastes such as coke, coal washings, concrete and brick rubble. Chemical changes can also occur when the spoil is exposed to air and rainfall, leading to a highly variable chemical environment which may be considered to be toxic and acidic in those sites where a high proportion of iron pyrites oxidises to sulphuric acid, but contrastingly may also be circumneutral and calcareous in parts. The substrate however, is largely inert with no organic matter and can be further modified by compaction from heavy vehicles associated with spoil heap management and restoration. Temperature ranges can be extreme, with summer conditions hot and dry on the grey-black surface due to absorption of heat, whilst in winter the exposed surface offers little shelter to biota at ground level. However, it may be that these conditions help to modify the surface layers to enable colonisation.

There is generally no management of this community, although some nutrient build-up and soil development is likely as the vegetation matures. Localised contributions to this are made by Rabbits - the most common mammal occurring on these sites (see Section 4.2.4.2.)

Zonation and succession
The *Agrostis stolonifera-Holcus lanatus* community varies in character from the typical sub-community found in the barer, exposed situations through to the slightly wetter conditions supporting the *Tussilago farfara* sub-community and the more closed, grassier swards of the *Hypochoeris radicata* sub-community.

Other grassland and woodland communities also occur on these sites, and zonations and gradations between these are frequent. On damper ground MG9 *Holcus lanatus-Deschampsia cespitosa* grassland becomes frequent, reflecting a gradual change of frequency between *Agrostis stolonifera* and *D. cespitosa*. The other mesotrophic grassland communities MG1 *Arrhenatherum elatius* coarse grassland and MG12 *Festuca arundinacea* coarse grassland also occur and may represent developments of the community. In contrast, other pioneering vegetation can also occur in close proximity reflecting subtle environmental variation.

Plate 6.
Direct colonisation of colliery tips by Birch *Betula,* Manvers Colliery tip, July 1993.

Perhaps the most striking indicator of succession is the colonisation by trees and shrubs, particularly *Betula pendula, B. pubescens* and *Quercus petraea* which occur as seedlings or saplings in all sub-communities and may even colonise directly onto the bare ground in the absence of any other vegetation (Plate 6). This can develop into types of birch/oak woodland - either W10 *Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland, or analogues of W16 *Betula- Quercus-Deschampsia flexuosa* woodland occur, although it is unclear whether this is through the development of this community or also the U2 *Deschampsia flexuosa* grassland which also occurs on abandoned collieries. Other woody species may also colonise and the development of a type of W1*Salix cinerea-Galium palustre* woodland may take place. At the higher altitudes which occur towards the Pennine uplands, this vegetation on spoil tips is partly replaced by forms of U1 *Festuca ovina-Agrostis capillaris-Galium saxatile* grassland.

Distribution
Samples of this vegetation were taken from all around the Yorkshire coalfield but particularly on the flatter and lower-lying ground.

2. *Vulpia bromoides-Arenaria serpyllifolia* pioneer community (Appendix 2)

Constant species
Vulpia bromoides

Physiognomy
This naturally developed community has a distinctive and readily identifiable character in which the annual grass *Vulpia bromoides* dominates in a low and sparse sward on 20-80% open ground. *Vulpia bromoides* is constant and no other species reaches this

frequency, although in some stands, patches of other species such as *Sedum acre, Vulpia myuros* and *Lotus corniculatus* achieve local prominence and can give the vegetation a rich and colourful look (Plate 7). Indeed, 'islands' or patches of vegetation dominated by *Sedum acre* growing on weathered concrete spoil can appear dramatic (Plate 8).

Plate 7.
Pioneer vegetation on colliery site. *Vulpia bromoides-Arenaria serpyllifolia* community. Tankersley Colliery . May 1993.

Of greater significance is the presence of a range of diminutive annuals or ephemerals growing in the sparse sward, the most frequent and diagnostic being *Arenaria serpyllifolia*, but often accompanied with species more typically associated with coastal or inland sand dunes and thin, parched soils such as *Sagina apetala apetala, Spergularia rubra, Erodium cicutarium, Myosotis discolor, Anthyllis vulneraria* and *Ononis repens*. Other grasses are infrequent, but a wide range of species can occur with no clear pattern. *Holcus lanatus* is the most frequent grass, but typically with low cover. Species more typical of mesotrophic grasslands or even woodlands such as *Dactylis glomerata* and *Holcus mollis* can occur with equal regularity to those of walls, screes and open ground such as *Aira praecox, A. caryophyllea* and the locally rare *Catapodium rigidum*.

In addition to the few species occurring at low frequency, a feature of this community is the very wide range of species which occur casually at very low frequency and cover. These include many species typical of waste ground such as *Reseda luteola, Cirsium arvense, Plantago major, Senecio* spp., but also include a range of other therophytes and annuals such as *Erophila verna, Cerastium glomeratum,* and *Rumex acetosella*. Indeed, an even wider range of species is certain with further sampling, and other similar species noted in the community (but not in the samples) included *Cerastium semidecandrum, Sedum album* and *Filago vulgaris.*

Plate 8.
Pioneer vegetation on colliery site. *Vulpia bromoides-Arenaria seryllifolia* community - *Sedum acre* islands. Upton Colliery. May 1993.

Habitat

The *Vulpia bromoides* pioneer community typically occurs on abandoned colliery sites in areas where mixing of substrates has occurred. It is not present on the raw material freshly dumped from the mine workings themselves - the shales, sandstones and seat-earths, but occurs where other wastes, particularly processed materials such as cinders, finings, coke or slag have been dumped or mixed with the raw wastes. These processed materials have also been chemically modified and have been shown to be less acidic than raw spoil. As very little nitrogen is available in colliery spoils, and potassium is not usually deficient, it is the availability of phosphorus which is variable, being higher in neutral/basic conditions (Taylor, 1984). These substrates are therefore less acidic and possess more available phosphorus than colliery spoil *per se*. Some calcium may also be available, particularly in the early stages of weathering before substantial leaching has occurred.

The substrate tends to be fine grained, of a thin, sandy texture, and therefore well drained. Being largely grey, it also absorbs heat and therefore dries out quickly and becomes hot. The annuals and ephemerals which dominate this community must therefore capitalise on only a brief growing season in spring and early summer, by which time water shortage is a limiting factor.

These chemical and physical factors are thus significantly different to the raw spoils of the majority of colliery waste which support the more ubiquitous *Agrostis stolonifera-Holcus lanatus* pioneering vegetation. Many of the colliery site locations supporting this community appear to be associated with rail trackways (used for transporting coal, slag, cinders etc.) and the basic materials are often mixed with imported ballast, including in some instances limestone.

This is an entirely naturally developed community, with no obvious management. Some very localised rabbit grazing may occur, but by early summer the vegetation is parched and brown, with many of the ephemerals and annuals over.

Zonation and succession

The *Vulpia bromoides* pioneer community usually occurs in stands with other pioneering and grassy swards on open ground such as *Agrostis stolonifera-Holcus lanatus* pioneer vegetation, MG1 *Arrhenatherum elatius* grassland, MG10 *Festuca arundinacea* grassland and as islands in more acidic locations which support U1 *Festuca ovina-Rumex acetosella* grassland.

In some stands where the more robust and taller *Vulpia myuros* predominates, it may be difficult to assign samples to either this community or the *Agrostis stolonifera-Holcus lanatus* community, and indeed further sampling may reveal whether vegetation in which *V.myuros* is physiognomically dominant warrants either sub-community or community status. The patches in which this latter species occurs nevertheless tend to be more closed, particularly when the taller, arching stems bend over, leaving less open ground underneath in which the suite of ephemeral species so typical of the *Vulpia bromoides* community can flourish. In the colliery site samples, *Vulpia myuros* vegetation is very patchy and samples have been included in both this type of vegetation and the *Agrostis stolonifera-Holcus lanatus* pioneer community.

This type of vegetation recalls the pioneering vegetation of coastal sand-dunes such as SD7 *Ammophila arenaria-Festuca rubra* semi-fixed dune community (although lacking the constants here) and the open U1 *Festuca ovina-Agrostis capillaris-Rumex acetosella* grasslands more typical of inland southern summer parched soils such as found in the Brecks of East Anglia. In the Yorkshire coalfield, this latter community is also well represented on old spoil-heaps as a species poor variant of *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland in which the annual grass *Aira praecox* is abundant and can give stands a distinct orange hue in early summer (see below).

3. U1 *Festuca ovina - Agrostis capillaris - Rumex acetosella* grassland (Appendix 3).

47 samples corresponded to the recognised NVC community U1 *Festuca ovina-Agrostis capillaris Rumex acetosella* grassland, in which an open short grassy sward is dominated by the grass *F.ovina* with only *R.acetosella* reaching any constancy. Both the mean number of species (6.4 vs 16) and the range of species per sample (2-11 vs 6-35) were significantly poorer than the published accounts. The samples corresponded most closely to the typical sub-community (U1b). *Plantago lanceolata* was less constant than expected (I vs III), but *Hypochoeris radicata* was more constant than expected (III vs I). The latter species was also more abundant than expected (5 vs 3), as was *Aira praecox* (8 vs 6), this annual grass being a distinctive feature of these sparse grasslands which invariably were found on the steep slopes of bell-pits (Plate 9).

Plate 9.
U1 *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland on old bell-pit abandoned late 19th century. Tankersley golf course. July 1994.

The hawkweed *Hieracium sabaudum* group was recorded at frequency III (3), and is not recorded from the NVC. A number of species which should be found at frequency II or more were missing from the samples - the mosses *Dicranum scoparium, Bracythecium rutabulum,* and *Erodium cicutarium, Anthoxanthum odoratum, Koeleria macrantha, Taraxacum* and *Poa annua.*

A feature of the community is the degree of bare ground and the long list of associates occasionally found in the sward, some such as *Pilosella officinarum, Hypocheoeris radicata* and *Lotus corniculatus,* occasionally occurring in large patches giving the community a pleasing look when in flower. The bare ground too can show early signs of the bryophyte and lichen colonisation typical of the community elsewhere, and although not all recorded in the samples, the lichens *Peltigera canina, Cladonia fimbriata* were recorded.

4. U2 *Deschampsia flexuosa* grassland (Appendix 4).

28 samples corresponded to the typical NVC sub-community dominated by the grass *Deschampsia flexuosa*. Both the mean and range of species 5.9 (2-11) was significantly poorer than the published accounts 9 (3-16).

Three species were significantly less constant; *Calluna vulgaris* II vs. IV in the NVC; *Galium saxatile* I vs.III, and *Potentilla erecta* I vs.III. Four species - *Calluna vulgaris, Agrostis capillaris, Festuca ovina* and *Nardus stricta* were found at higher quantitative levels in the samples. The moss *Campylopus introflexus*, abundant in the samples, is not recorded in the NVC. A number of species recorded at frequency II or more in the NVC were not found in the samples - *Pteridium aquilinum, Empetrum nigrum, Polytrichum piliferum, Dicranum scoparium* and *Pleurozium schreberi,* although sampling of mosses was perhaps not as thorough (through inexperience) as it could have been.

Plate 10.
U2 *Deschampsia flexuosa* grassland with colonisation of H9 *Calluna vulgaris-D. flexuosa* heath. Tankersley golf course. July 1995.

Five of the samples containing abundant *Calluna* were re-examined, and can be separated into a heathland community. These corresponded to H9 *Calluna vulgaris-Deschampsia flexuosa* heath but with some significant differences, notably the reduced frequency of *D. flexuosa* and the higher frequency and abundance of the grasses *Agrostis capillaris* and *Festuca ovina*. All these samples were from a single site at 320 m. high on the Pennine fringes and the presence of moorland species such as *Vaccinium myrtillus* and *Nardus stricta* reflects the abundance of these species in the surrounding landscape.

Overall the samples show a relatively impoverished version of the *Deschampsia flexuosa* grassland, with a higher frequency and abundance of other grasses, and a lower incidence of some diagnostic herbs. There is a clear progression to patchy heath - tending towards H9 *Calluna vulgaris-D.flexuosa* heath (Plate 10). The majority of samples were found on slopes of tips, although some patches were found on flat ground in mosaics with other vegetation.

5. MG1 *Arrhenatherum elatius* grassland (Appendix 5).

14 samples corresponded to the recognised NVC community MG1 *Arrhenatherum elatius* grassland in which the community is dominated by this tall, coarse grass (Plate 11). Both the mean number of species (8 vs.14) and the diversity of species (3-11 vs. 3-30) was significantly poorer than the published accounts.

Less constant than expected were *Dactylis glomerata, Heracleum sphondylium, Urtica dioica* and *Achillea millefolium*, perhaps reflecting an impoverishment of soil nitrogen. *Holcus lanatus,* on the other hand, was significantly more frequent (in fact a constant), possibly indicating development from the *Agrostis stolonifera-Holcus lanatus* pioneer grassland, and two species - *Carex flacca* (II(2)) and *Senecio aquaticus* (II(2)) were recorded in the samples but are not recorded in the published accounts.

A wider range of species normally expected in the NVC at frequency II or more were missing from the samples, including *Anthyllis vulneraria, Galium aparine, G. verum, Festuca rubra, Poa trivialis, Rumex acetosa, Elymus repens, Rubus fruticosus, Taraxacum, Vicia sativa* and *Brachythecium rutabulum.*

Although the sub-community most resembling the sample data was MG 1a - the *Festuca rubra* sub-community, the absence of this species makes assignment to a particular sub-community impossible.

Plate 11.
M1 *Arrhenatherum elatius* grassland developing on Rothwell Colliery tip. Sept. 1995.

6. MG7 *Lolium perenne* grassland (Appendix 6).

Nine samples corresponded to the recognised NVC community MG7 *Lolium perenne* grassland, and in particular the MG7a sub-community *Lolium perenne-Trifolium repens* leys. These were all agricultural grasslands newly created with sowings of the productive grasses *Lolium perenne* and *Dactylis glomerata*, together with the nitrogen fixing clover *Trifolium repens*, over a prepared topsoil over the colliery spoil substrate (Plate 12). Here, the two grasses form the bulk of the vegetation, with other herbs less frequent, and mostly provided by legumes also included in the seed mix. Some slight differences between the samples and the published NVC were noted, such as the increased frequency of *D. glomerata* and *Vicia sepium*; slightly higher than expected quantitative value of *L. perenne* and *L. multiflora* and absence of some species such as *Phleum pratense, Taraxacum* spp., and *Ranunculus repens*. The majority of these differences can be accounted for by the deliberate choice in seed mix.

Plate 12.
MG7 *Lolium perenne* sown grassland, Barnsley main tip, July 1993.

7. MG9 *Holcus lanatus-Deschampsia cespitosa* grassland (Appendix 7).

21 samples corresponded to MG9 *Holcus lanatus-Deschampsia cespitosa* grassland. The mean number of species and range of species was significantly less than the published accounts - 8.9 (3-19) vs 16 (7-36) (Rodwell, 1991 *et seq.*).

Less constant than expected were *Poa trivialis* (I vs III), *Dactylis glomerata* (I vs III), *Festuca rubra* (I vs III) and *Ranunculus repens* (I vs III). *Tussilago farfara* was more frequent than expected, perhaps indicating a development from stands of the *Tussilago farfara* sub-community of the *Agrostis stolonifera-Holcus lanatus* pioneer community. A number of species were also found at higher quantitative values than expected -

Senecio aquaticus (3 vs 1), *Arrhenatherum elatius* (9 vs 8), *Urtica dioica* (3 vs 2), *Lotus pedunculatus* (8 vs 4), *Lotus corniculatus* (5 vs 4) and *Achillea ptarmica* (7 vs 5). These species and some others e.g. *Juncus effusus, Carex flacca,* were often found patchily in certain stands.

A number of more mesotrophic species were missing from the samples - *Festuca pratensis, Anthoxanthum odoratum, Filipendula ulmaria, Cerastium fontanum, Alopecurus pratensis* and *Lolium perenne* (and indeed were not recorded in the wider stands), perhaps indicating the impoverished nature of the substrate.

8. MG10 *Holcus lanatus-Juncus effusus* rush pasture (Appendix 8).

Seven samples corresponded to MG10 *Holcus lanatus-Juncus effusus* rush pasture, and most closely to the typical sub-community (Plate 13).

Both the mean number of species and the range of species were significantly less than the published accounts - 6.1 (2-11) vs 12 (6-20)(Rodwell, 1991 *et seq.*). *Cirsium palustre* was more frequent than expected (III vs I), and both *Juncus effusus* (9 vs 8) and *Cirsium arvense* (2 vs 1) were slightly more abundant than expected. Three species - *Deschampsia cespitosa, Senecio jacobaea* and *Campylopus introflexus* - were found in the samples at a constancy of II or more, but are not recorded in the published accounts, perhaps reflecting the naure of the substrate.

A number of species recorded in the NVC at constancy II or more were not recorded in the samples - *Cardamine pratensis, Ranunculus acris, Trifolium repens, Lolium perenne, Rumex acetosa, Potentilla anserina, Cerastium fontanum* and *Agrostis stolonifera*. Most of these are characteristic of more enriched situations.

Plate 13.
MG10 *Holcus lanatus-Juncus effusus* rush pasture, Falthwaite Colliery tip, July 1993.

9. MG12 *Festuca arundinacea* grassland (Appendix 9).

Nine samples corresponded to MG12 *Festuca arundinacea* grassland, and most closely to the *Lolium-Holcus lanatus* sub-community (Plate 14). Both the mean number of species and the range of species was broadly similar to the published accounts (Rodwell, 1991 *et seq.*) - 11 (6-18) vs 11 (7-26).

Some significant differences from the published accounts of this community were found. *Holcus lanatus* (II vs IV) and *Elymus repens* (I vs III) were both less constant than expected, whilst some constants were completely absent - *Agrostis stolonifera* and *Lolium perenne*. *Lotus corniculatus* (IV vs II) and *Plantago lanceolata* (V vs II) were both more frequent than expected, whilst *Leucanthemum vulgare* (V), *Pilosella officinarum* (V), *Linum catharticum* (IV) and *Daucus carota* (IV) were constant in the samples, but are not recorded from the NVC. *Plantago lanceolata* was also more abundant than expected (4 vs 3).

A number of other species also occurred in the samples at constancy II or more, and are not recorded in the published accounts - *Hieracium sabaudum* group (II), *Ophrys apifera* (III), *Trisetum flavescens* (II) and *Tussilago farfara* (III).

A longer list of other species recorded at constancy II or more in the NVC were not found in the samples - *Ranunculus acris* (III), *Anthoxanthum odoratum* (II), *Juncus gerardii* (II), *Carex otrubae* (II), *Potentilla anserina* (III), *Carex distans* (II), *Vicia cracca* (II) and *Poa pratensis* (II).

Plate 14.
MG12 *Festuca arundinacea* grassland. Upton Colliery. July 1993.

The *Festuca arundinacea* community is described in the NVC as an exclusive coastal community (Rodwell 1991 *et seq.*), hence its occurrence on colliery sites inland in

Yorkshire is surprising. Halophytes were therefore not surprisingly absent from the samples, and a different set of associates present reflect the proximity of other pioneer and grassland communities, as well as some variation in the usual spoil substrate. Some of the samples occurred near to the CG3 *Bromopsis erecta* grassland described below, but at the bottom of a slope, and some influence from the Magnesian Limestone, as well as impeded drainage would have an influence.

10. *Anthyllis vulneraria* lawns (Appendix 10).

Ten samples from one site (Upton Colliery) represented some discrete areas, but overall a significantly large area of homogenous vegetation physiognomically dominated by *Anthyllis vulneraria* (Plate 15). Whilst the samples are thus very restricted geographically, the stands were sufficiently well defined to warrant a more detailed description.

This species rich vegetation (mean number of species per sample 13.2, range 10-17) occurs as herb rich medium/short luxuriant grassland in which the grasses *Festuca rubra* and *F. pratensis* dominate, but are accompanied by an abundance of herbs, overwhelmingly prominent being *Anthyllis vulneraria*, but also notably *Lotus corniculatus, Pilosella officinarum* agg., *Plantago lanceolata*, and lesser amounts of *Linum catharticum, Hypochoeris radicata, Dactylis glomerata* and *Leucanthemum vulgare* in a colourful sward. A range of other herbs is also present, some indicating the calcareous influence of the Permian Magnesian Limestone which is located nearby - *Daucus carota, Centaurium erythraea, Leontodon hispidus* and *L.saxatilis.* Other grasses are less noticable, although *Holcus lanatus* and *Deschampsia cespitosa* are frequent at low cover.

Comparison of this vegetation with the published NVC revealed the closest fit with the maritime community MC9b *Festuca rubra-Holcus lanatus* grassland, *Dactylis glomerata* sub-community. Although *F. rubra* was less frequent than expected for this community, it was partly replaced by *F. pratensis*. *Holcus lanatus* (III vs V) and *Daucus carota* (II vs IV) were also less frequent than expected, whereas *Lotus corniculatus* (V vs III), *Anthyllis vulneraria* (V vs II) and *Leucanthemum vulgare* (IV vs I) were more frequent than expected. The latter two species were also more abundant than expected.

The striking differences between the samples and the maritime community relate to the suites of species not present in either group. A number of maritime species were understandably absent - *Armeria maritima, Scilla verna, Cochlearia officinalis,* together with *Rumex acetosa, Galium verum, Silene vulgaris* and *Agrostis stolonifera;* whereas the following were present in the samples but not in the NVC - *Centaurium erythraea, Arrhenatherum elatius, Deschampsia cespitosa, Festuca pratensis, Hieracium sabaudum group, Pilosella officinarum, Campylopus introflexus* and *Linum catharticum*.

In some ways this community could be seen as an inland variant of the MC9b community, lacking the maritime constants expected on the coast, but replaced with a number of the associates becoming more abundant and frequent - *Anthyllis, Lotus, Hypochoeris, Leucanthemum*, and a range of other herbs replacing some of the expected constants, notably *Festuca pratensis,* but also *Pilosella officinarum* and *Linum catharticum*.

Plate 15.
Anthyllis vulneraria lawns, Upton colliery, July 1993.

11. *Festuca rubra - Lotus corniculatus* grassland (Appendix 11).

19 samples of grassland vegetation could be described as a *Festuca rubra - Lotus corniculatus* grassland. This is the least definitive sample group, and contains a diverse set of samples which comprise a rather coarse grassland with no particular dominant grass. *Festuca rubra* is the most constant at IV, but patches of *Dactylis glomerata, Festuca ovina, Arrhenatherum elatius* occur, sometimes abundantly, with frequent *Holcus lanatus, Agrostis stolonifera* and *Poa pratensis*.

The only other constant is *Lotus corniculatus* also at IV, but a feature of the sample group is the patchy nature of the herb associates, with many occurring abundantly in places, such as *Leucanthemum vulgare, Taraxacum* agg., *Trifolium pratense* and *T.repens, Carex flacca, Medicago lupulina, Plantago lanceolata, Anthyllis vulneraria, Sedum acre* and patches of *Cytisus scoparius* scrub.

Samples occurred on a wide range of sites, both on flat and sloping ground, areas of which sometimes had been clearly treated or prepared, and the vegetation represents both attempts to 'create' or imitate flower-rich grasslands, and their subsequent natural invasion. It is of note that the legumes are often abundant but patchy giving the first suspicion that the vegetation is anthropogenic. Treatments of the substrate were also variable, with some stands growing on a layer of imported soil above the spoil substrate, but others directly on spoil which had received some form of treatment e.g. ripping, lime and/or fertiliser application.

Comparison with the NVC revealed the closest match to be with the sand-dune community SD8a *Festuca rubra - Galium verum* fixed dune community, typical sub-community, although there were too many variations to warrant a strong link e.g. *Galium verum* was absent from the samples, as well as a longer list of other herbs. Despite this, the ecological similarities of the grassland to the SD8 community do probably have some relevance, with stands representing a development from pioneer and establishing communities to forms of more stable grassland on relatively poor soils (either inherent or via reversion after initial treatments).

12. CG3 *Bromopsis erecta* grassland (Appendix 12).

Five samples corresponded to the calcicolous grassland community CG3 *Bromopsis erecta* grassland, and were exclusively located on one site, Upton Colliery tip, which itself is located at the juncture of the Permian Magnesian Limestone and the Carboniferous Coal Measures. Here, the colliery spoil abutted a railway cutting and the spoil had been mixed with limestone soil debris. Colonisation of the spoil over an area some 100m square was influenced by the calcicolous vegetation in the cutting.

The vegetation was characterised as a coarse rank grassland dominated by the grass *Bromopsis erecta*, with a range of other constants - *Festuca rubra, Trifolium pratense, Leontodon hispidus, Pilosella officinarum, Poa pratensis* and *Campanula glomerata* - indeed the last species here giving the vegetation a spectacular look (Plate 16). Although the vegetation matched most closely the CG3d *Festuca rubra-Festuca arundinacea* sub-community, many differences were apparent, including the higher constancy and cover of the species above, and the absence of a suite of species expected in the NVC - *Sanguisorba minor, Campanula rotundifolia, Festuca arundinacea, Centaurea scabiosa, Cirsium acaule, Koeleria macrantha, Helianthemum* *nummularium*. However, the samples matched the description of the vegetation as a coarse, ungrazed grassland, and the influence of the adjacent pioneer vegetation is evident with a suite of occasional species such as *Agrostis stolonifera, Crepis capillaris* and *Erigeron acer.*

With a mean number of 13.2 species vs 13 in the NVC, and a range of species 10-15 vs 6-22, the samples were comparable to the published accounts (Rodwell, 1991 *et seq*.).

Plate 16.
CG3 *Bromopsis erectus* grassland developed on tip, Upton colliery, July 1991. (Site at junction of Carboniferous Coal Measures and Permian Magnesian Limestone).

13. S12 *Typha latifolia* reedbed (Appendix 13).

Five samples corresponded to S12 *Typha latifolia* swamp, being a distinctive reedswamp dominated by this tall species (Plate 17). The mean number of species, 5 vs 9, and the range of species, 3-7 vs 5-14, was significantly poorer than the published accounts. However, comparisons with the various sub-comunities is difficult, given the small sample size. *Juncus effusus* was present in all samples, and not expected from the NVC. *Carex disticha* was an unexpected and abundant species in one sample where a colliery lagoon had possibly originated from marshland on a river floodplain.

Samples were typically found at the margins of pools formed on the open ground of colliery tips, sometimes in the ruts made by heavy plant, where compaction resulted in local impoundment of surface water. pH at two sites was 4, indicating comparatively acidic conditions, and nutrient inputs were considered to be absent. At one site (the old lagoon referred to above), *Typha latifolia* was extensive and abundant and a wider range of swamp species was present in the wider stand, and reflected an older and more mature system than the pools found on the tips themselves.

Plate 17.
Pool at Manvers Colliery tip showing colonisation by S12 *Typha latifolia* swamp and S19 *Eleocharis palustris* swamp, July 1993.

14. S19 *Eleocharis palustris* swamp (Appendix 14).

Six samples corresponded to the S19 *Eleocharis palustris* swamp community in which the vegetation was dominated by *Eleocharis palustris*, with *Alisma plantago-aquatica* being the only other constant at low cover. Locations were similar to the *Typha latifolia* community (see also Plate 16), around the margins of pools and small ponds formed on the colliery tips.

A small range of associates was also present, the most surprising of which was probably *Eriophorum angustifolium*, a sedge more usually associated with mire communities developed on peat substrates. Both the mean number of species (3.8 vs 7) and range of species (3-6 vs 1-14) was poorer than the published accounts (Rodwell, 1991 *et seq.*).

15. W10 *Quercus robur-Pteridium-Rubus fruticosus* woodland (Appendix 15).

Twelve samples of naturally regenerated woodland could be loosely assigned to W10 *Quercus robur-Pteridium-Rubus fruticosus* woodland, although there were significant differences in the composition of this vegetation compared to the published accounts. The mean number of species (10.7 vs 10) was comparable to the published accounts, although the range (4-16 vs 1-27) was not. All samples represented woodland naturally developed on colliery sites, but some samples represent the re-invasion of earlier planted stands.

No single tree was constant in a somewhat variable canopy, but Birch *Betula pendula* was the most frequent and abundant. On other sites cover was patchily represented by

Sycamore *Acer pseudoplatanus*, Alder *Alnus glutinosa* or Beech *Fagus sylvatica*, with Ash *Fraxinus excelsior* and Sessile Oak *Quercus petraea* being occasionally frequent. Other canopy species were rare and of unknown provenance.

In the shrub layer, a small range of woody species was present, patches of *Fraxinus* and *Betula pendula* representing more substantial areas of natural regeneration, and Wych Elm *Ulmus glabra* making a first appearance.

The only constant species in the sample data was *Rubus fruticosus* agg. which was often dominant in the ground layer (and provides the most obvious link to the W10 community). Other ground flora was variable, but *Galium aparine, Holcus lanatus, Poa trivialis, Arrhenatherum elatius* could be significant in patches. A very wide range of occasionals was present, reflecting the links to the more open ground and grassland communities found on sites. For example, *Chamerion angustifolium* and *Agrostis capillaris* were both found at higher frequencies than would be normally expected for this community, and the presence of species such as *Galium aparine, Epilobium montanum, Heracleum sphondylium, Artemisia vulgaris* would not normally be found at all.

The most obvious differences between the sample data and the published NVC accounts is the complete absence of *Quercus robur*, and the much reduced frequency of *Pteridium aquilinum* (I vs V) - both expected constants. Ferns, however, were a notably rare group in the whole of the data set. *Quercus petraea* was present and could be regarded as an unsurprising substitute for *Q. robur*, especially given tendency for most woodland samples to correspond to W16 (see next section).

It must be stressed that the sample data represent early closure of the woodland canopy of the vegetation on colliery sites, and are immature types of woodland still influenced by open ground and early successional communities. Assignment to the W10 NVC community is made with this caveat.

16. W16 *Quercus spp.- Betula spp.-Deschampsia flexuosa* woodland (Appendix 16).

Eighteen samples corresponded to W16 *Quercus* spp.- *Betula* spp.- *Deschampsia flexuosa* woodland (Plate 18), in particular the *Quercus robur* sub-community, and were remarkably similar to the published accounts with a mean number of species of 9.9 vs 9, and a range of species 7-20 vs 3-26.

Both *Betula pendula* and *Quercus petraea* were constant in the canopy, with a range of other trees. Hybrid oaks, along with *Quercus robur, Acer pseudoplatanus, Betula pubescens* and *Alnus glutinosa* were patchily frequent, with occasional records for expected species such as *Castanea sativa* and *Crataegus monogyna*. The presence of some planted species such as *Robinia pseudacacia, Alnus incana* and *Pinus nigra* reflect the fact that some attempts had been made to plant in some of the stands, which had subsequently been overwhelmed by the pace of regeneration, but had persisted. Both birches *B.pendula* and *B.pubescens* were present in the shrub layer (usually the former), along with small numbers of other undershrubs.

Most striking in these stands was the dominance of *Deschampsia flexuosa* in the ground layer, with only *Chamerion angustifolium* being the other constant, and then at low cover. Patches of *Agrostis capillaris, Holcus lanatus,* and *Festuca ovina* were also present in some samples, giving the vegetation an overall grassy character.

Comparisons with the published accounts reveal a lower than expected frequency of *Pteridium aquilinum* (I vs IV), and a higher frequency of *Quercus robur* (IV vs II), *Agrostis capillaris* (III vs I) and *Chamerion angustifolium* (IV vs I), with higher quantitative values than expected for *Acer pseudoplatanus, Betula pendula, Quercus petraea* (canopy and seedling), and the grasses *D.flexuosa, F.ovina* and *A.capillaris*. *Galium aparine, Hieracium sabaudum* group and *Q.robur* were found at higher frequency than expected, with a number of species absent from the samples - *Pinus sylvestris, Ilex aquifolium, Calluna vulgaris* and *Vaccinium myrtillus*, perhaps signifying some of the more semi-natural upland stands sampled in the NVC.

Plate 18.
W16 *Quercus* spp.-*Betula* spp.-*Deschampsia flexuosa* woodland. Skiers Spring Colliery, August 1993.

17. Plantation woodlands/scrub on deep-mine sites (Appendix 17).

Twenty-five samples of plantation woodlands/scrub were taken, all representing deliberate plantings of shrubs and trees on colliery sites, and all reflecting various degrees of existing ground vegetation as well as subsequent invasion by ground flora or woody shrubs.

The long list of 'canopy' and 'shrub layer' species is somewhat arbitrary, depending on the height of the plantation (less than c. 3m. being regarded as shrubs). The plantings clearly reflect the use of a wide range of exotic species and the preference for nitrogen-fixers such as the alders *Alnus* spp. and *Robinia pseudacacia*, as well as species chosen for visual effect. However, it is also clear that native species are also significant, and indeed the invasion of many stands, and by birch in particular was evident. The success (relative frequency and abundance) of *Betula pendula* and *Crataegus monogyna* amongst the native species is notable, as is the presence of *Acer pseudoplatanus* (though the separation of natural colonisers vs plantings was not distinguished).

In the ground layer, *Holcus lanatus* was the only constant, but other grasses were also patchily dominant or frequent - *Arrhenatherum elatius, Agrostis capillaris, Festuca rubra, Deschampsia cespitosa, Festuca ovina, Agrostis stolonifera*, and a very wide range of occasional associates was also found, most typical of the open ground and grassy swards also found on colliery sites. Suites of species from both naturally developed and sown swards can be distinguished in the samples.

Comparisons with the published NVC revealed a very loose comparison with W24 *Rubus fruticosus* agg.-*Holcus lanatus* underscrub, but with the principal constant *Rubus fruticosus* being much less frequent (I vs IV). However similarities with the *Arrhenatherum elatius-Heracleum sphondylium* sub-community are evident and reflect the sequential development of scrub from grassland (here deliberate plantations), with the prominence of the grasses mentioned above being notable.

18. Other vegetation.

Some vegetation features with too few samples or which were not sampled within the NVC methodology, are of note. A single sample dominated by the grass *Calamagrostis epipejos* represented an area of homogenous vegetation overwhelmingly dominated by this species (which was found on two sites in similar circumstances). Similarly, *Phragmites australis* was also found growing on tips, often in extensive but fragmentary stands and not always in water and possibly represent a type of S4 *Phragmites australis* swamp vegetation. Some scrub vegetation characterised by *Cytisus scoparius* and *Ulex europaeus* was found as fragmentary stands on a number of sites and represents rudimentary examples of W23 *Ulex europaeus-Rubus fruticosus* agg. scrub. Open water communities were largely absent, although three water features on the colliery tips had the stonewort *Chara vulgaris* as a common early coloniser, on one site abundantly.

Conclusions

All the samples were selected from homogenous stands of vegetation and entered into a single file before analysis. They reflected a range of broad environments - pioneer areas, grassland, woodland, swamp - and also reflected major management intervention in some cases. A striking feature of the analysis is the strong correlation with the National

Vegetation Classification. 15 communities and sub-communities corresponding to the published accounts were found on abandoned collieries and spoilheaps.

Comparisons with the NVC show that many of the communities identified in this study represent species-poor examples of the published NVC communities. This may not be surprising, given the immaturity of the vegetation; the fact that ground conditions are severe, and for some of the communities at least, they appear to be located some distance from similar, more established vegetation elsewhere which could act as seed sources. This would restrict colonisation opportunities.

Two new communities which were found to be widespread over the whole of the coalfield have not been described by the NVC. The *Vulpia bromoides-Arenaria serpyllifolia* community in particular is very distinctive and has since been found by the author over a very wide geographical area and can be readily seen along both disused and active railway lines (for instance at major stations on the East Coast line from York to London). The *Agrostis stolonifera-Holcus lanatus* community forms the major pioneering vegetation of sites in the coalfield. The plantation woodland communities represent an initial attempt to describe highly artificial vegetation. Although the ground flora may be largely naturally developed and correspond to some of the other samples in this study, the tree and shrub plantings are varied and reflect the whims and designs of landscape architects and horticulturalists.

Grassland communities were variable reflecting naturally developed swards and those produced by various restoration treatments. At one end of the scale were limited agricultural grasslands of *Lolium perenne* and *Dactylis glomerata,* through more amenity-orientated *Festuca-Poa-Lolium* swards often with abundant legumes, to those at the other end of the scale comprised of naturally developed grassland communities usually dominated by *Agrostis, Deschampsia flexuosa* or more rarely *Festuca ovina.* Most of these grasslands could be readily recognised as examples of NVC community types e.g. MG7 *Lolium perenne* leys and related grasslands, U2 *Deschampsia flexuosa* grassland etc. Damper stands dominated by *Deschampsia cespitosa* reflected zonations to rush pasture and swamp communities. Some species rich stands on drier ground were unexpected and localised - particularly the CG3 and MG12 communities, but also included some stands more analagous to sand dune or maritime cliff communities published in the NVC.

Woodlands were very variable, reflecting natural mature communities on old spoilheaps (over 50 years old) to very recent plantings. Mature stands were invariably examples of W16 *Quercus* spp.-*Betula* spp.-*Deschampsia flexuosa* woodland. Older plantations demonstrated past establishment patterns, fashions and experiments with particular species. Failures were frequently invaded by both *Betula pubescens* and *B. pendula.* Whatever the initial planting mix a succession to a W16 community was likely to be the eventual outcome, although the position of W10 woodland was also a possibility, though less strongly supported by the evidence from the samples. Birch was also the most common scrub component, sometimes colonising spoil directly. On wetter sites, *Salix cinerea* and *S. caprea* were also common colonisers. Apart from elements in the W16 community, recognisable woodland ground flora was largely absent, with canopies apparently developed over pioneer or grassland communities.
Although heathlands were relatively scarce, two sites had developed fragments of H9 *Calluna vulgaris-Deschampsia flexuosa* heath. This community is largely distributed around the Pennines on both upland and lowland substrates.

3.2.3. Plants

3.2.3.1. Vascular plants.

Plate 19.
Northern Marsh Orchid *Dacylorhiza purpurella* on colliery tip. Redbrook colliery. July 1993.

In addition to plant communities, other species were noted during the surveys since scattered or clustered examples might not be captured by the NVC methods. Locally rare and scarce species were regularly recorded e.g. colonies of orchids - Bee *(Ophrys apifera)*, Northern and Southern Marsh *(Dactylorhiza purpurella* and *D. praetermissa)* (Plate 19), Spotted *(D. fuchsii)* and Pyramidal *(Anacamptis pyramidalis)*. A colony of over 2200 plants of Strapwort *(Corrigiola litoralis),* a British Red Data Book species (Perring & Farrell, 1986) scheduled under the Wildlife & Countryside Act (1981), now found only at one native station in Devon, was an unexpected find (Plate 20).

Plate 20.
Strapwort *Corrigiola litoralis* on colliery tip. Manvers Main colliery. July 1993.

A full inventory of plant species recorded on deep-mine sites is given at Appendix 19. This is based on the quadrat samples taken, supplemented by other records which were located in the vegetation stands, but not in the quadrats. It is presented as an archive but was not used as a tool in the evaluation process.

3.2.3.2. Mosses.

Although mosses were not systematically recorded, and in general were rare on the colliery sites, a number of species were identified (Table 3). The most frequent and abundant species was *Campylopus introflexus,* which at some locations was sufficiently abundant to be a significant contributor to the vegetation.

Species	No. of sites
Aulacomnium androgynum	1
Barbula tophacea	1
Barbula unguiculata	1
Brachythecium spp.	1
Brachythecium rutabulum	1
Bryum spp.	1
Bryum argenteum	1
Ceratodon purpureus	2
Campylopus introflexus	20
Dicranella heteromalla	1
Dicranoweisia cirrata	1
Drepanocladus fluitans	1
Eurynchium praelongum	2
Funaria hygrometrica	1
Hypnum cupressiforme	2
Mnium hornum	2
Polytrichum commune	1
Polytrichum juniperum	1
Sphagnum fimbriatum	1

Table 3.
Mosses recorded at deep-mine sites.

3.2.3.3. Lichens.

Records of lichens incidentally made are shown in Table 4. Although more widespread than the table appears, lichens were encountered colonising openground in the pioneer vegetation communities, particularly the *Agrostis stolonifera-Holcus lanatus* community and the sparse grasslands dominated by *Festuca ovina* and *Deschampsia flexuosa*. Many of the *Cladonia* specimens could not be recorded to species.

Species	No. of sites
Cladonia spp.	6
Cladonia chlorophaea	1
Cladonia coniocraca	1
Cladonia fimbriata	4
Cladonia furcata	1
Cladonia squamosa	1
Peltigera didactyla	1

Table 4.
Lichens at deep-mine sites.

3.2.4. Vertebrates

3.2.4.1. Birds

60 species were recorded through original survey from the 32 deep-mine sites out of the total 46 sites (Appendix 20). The most frequent 10 species is shown in Figure 7.

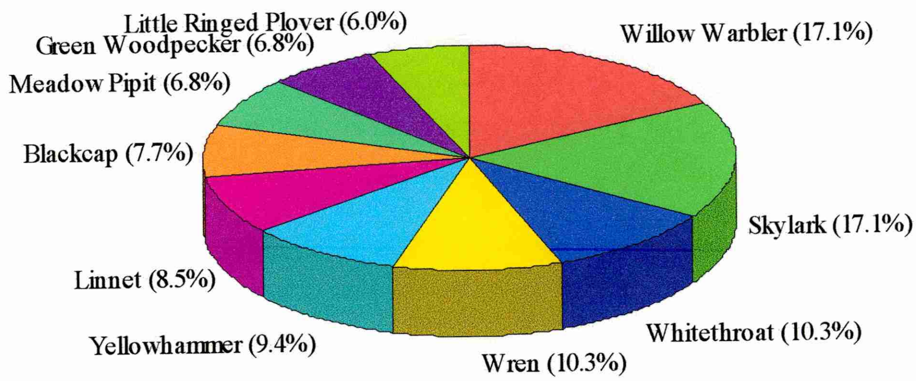


Figure 7.
Bird diversity and frequency on deep-mine sites (number of sites with top 10 species).

Most bird diversity and abundance reflected habitat. Mosaics of scrub and grassland were the most productive, supporting typical assemblages of passerines, particularly finches, buntings and warblers. Willow Warbler (*Phylloscopus trochilus*) and Skylark (*Alauda arvensis*) were the most frequently encountered species, followed by Wren (*Troglodytes troglodytes*) and Whitethroat (*Sylvia communis*), and then Yellowhammer (*Emberiza citrinella*) and Linnet (*Carduelis acanthis*). Small wetlands supported local species such as Reed and Sedge warblers (*Acrocephalus scirpaceus*) and (*A. schoenobaenus*), and roosting flocks of passerines in autumn and winter - notably up to 3000 hirundines - Swallow (*Hirundo rustica*), Sand (*Riparia riparia*) and House (*Delichon urbica*) martins in a *Typha* bed, and a mixed bunting roost in two *Phragmites* beds, including significant numbers of Corn Buntings (*Miliaria calandra*). These beds and adjacent scrub were also used for ringing purposes and a wide diversity of species had been captured through this activity, with the habitats being used by autumn and winter passage migrants, especially warblers and thrushes. Two sites with developing sparse marshland/inundated grassland also recorded the scarce winter migrant Jack Snipe (*Lymnocryptes minimus*), including regular large counts of up to 12.

The open ground was also notable for other birds. Green Woodpeckers (*Picus viridis*) were recorded at 8 sites - much more frequently than expected for this locally scarce species and were often flushed from the ground. Young broods of game-birds were also regularly noted - all 7 records of Grey Partridge (*Perdix perdix*) and Red-legged Partridge (*Alectoris rufa*) being of family parties, probably attracted to the invertebrate food sources on the richer areas. Two records of Quail (*Coturnix coturnix*) were also noted, this being a rare summer visitor usually associated with traditional grasslands, but again the flower-rich but sparse grasslands may have reflected the species' Mediterranean habitat more closely than the intensive grasslands normally found.

However, of most interest was the frequency of breeding waders, especially the Little Ringed Plovers (*Charadrius dubius),* recorded from 11 out of 46 sites and with an estimated 21 pairs (Plate 21). This species has a British population of around 600 pairs (Parrinder, 1989), and is specially protected under the Wildlife & Countryside Act (1981). The bare and sparsely vegetated ground on the study sites probably suitably imitates the species' natural nesting conditions of river shingle. 3 sites also supported Ringed Plover (*Charadrius hiaticula)*, this normally being a coastal breeding species.

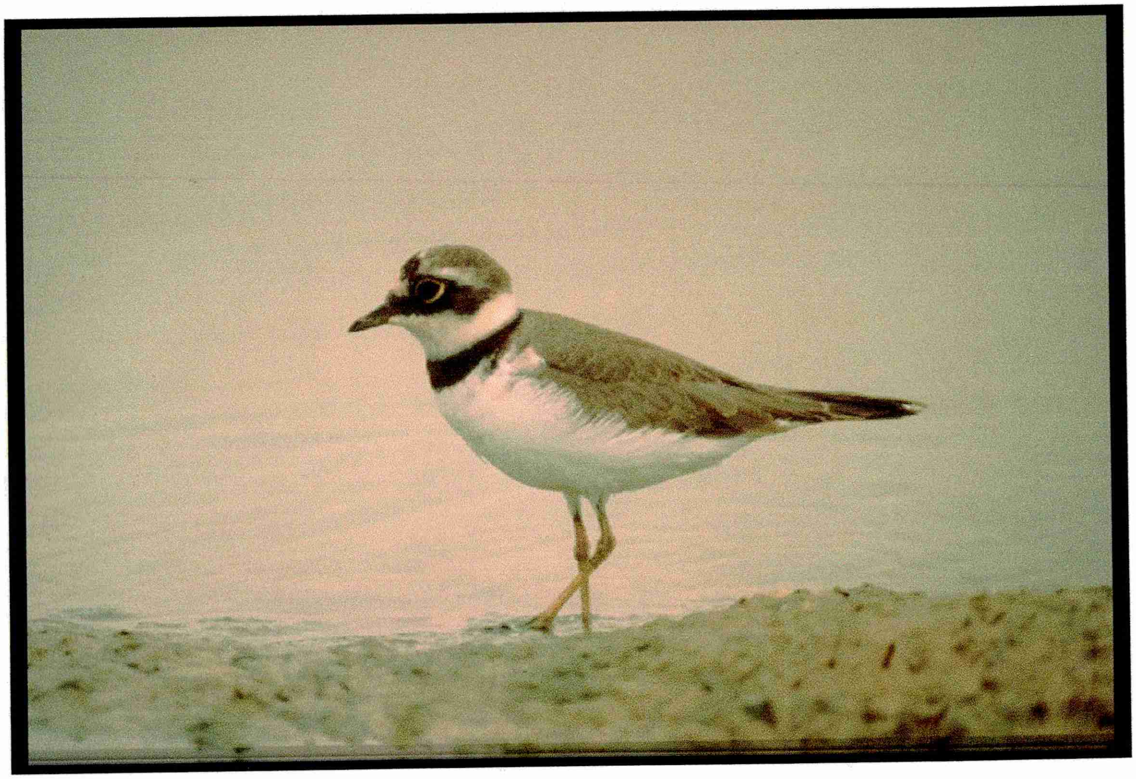


Plate 21.
Little Ringed Plover (*Charadrius dubius*). (David Cottridge)

3.2.4.2. Mammals

Five species of mammal were recorded on the survey from 32 sites (Figure 8). The most frequent was Rabbit (*Oryctolagus cuniculus)* from 15 sites. Fox (*Vulpes vulpes*) was recorded at 5, with Brown Hare (*Lepus capensis*) and Badger (*Meles meles)* setts recorded at three, all the latter being in old adits and galleries associated with older mines (two woodlands and one quarry). Small mammal populations were not studied, but predatory birds such as Kestrel (*Falco tinnunculus)* were regularly recorded, indicating that such mammals would be present. Water Voles *(Arvicola terrestris*) were recorded at one site.

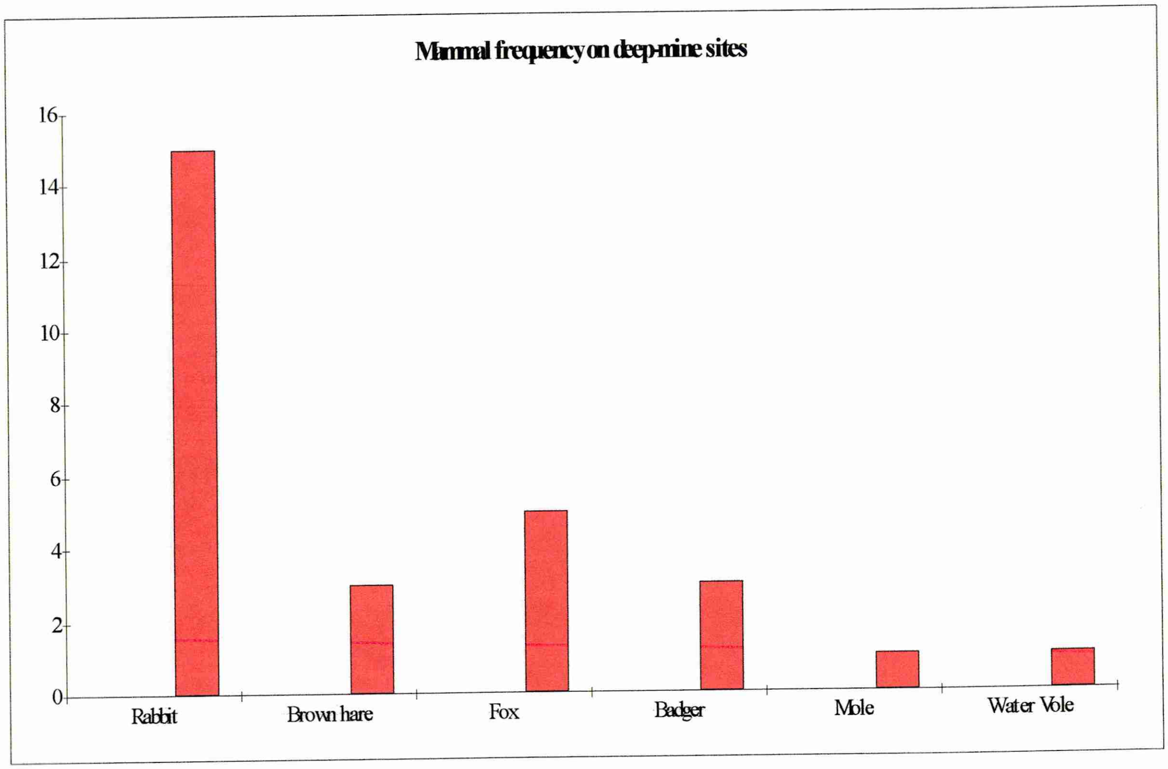


Figure 8.
Mammal frequency on former deep-mine sites (number of sites where recorded).

3.2.4.3. Reptiles and amphibians

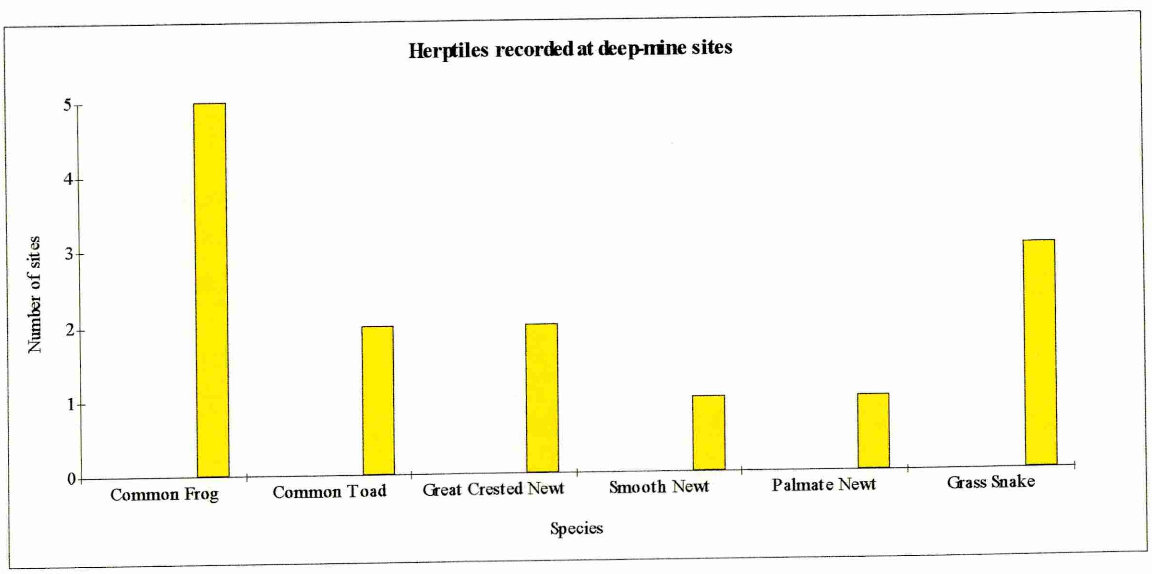


Figure 9.
Herptiles recorded at former deep-mine sites.

Six species (one reptile and five amphibians) were recorded on the survey from 32 sites (Figure 9). Common Frog (*Rana temporaria*) was the most frequent, associated with small pools of impeded drainage. By far the most significant site was a colliery lagoon adjacent to an ancient woodland which contained all five species of amphibian, including very large numbers of all newt species recorded by night counts including 623 Great Crested newts (*Triturus cristatus*), 450 Smooth (*T. vulgaris*) and 150 Palmate (*T. helveticus*). Great Crested Newts were also found at one other site.

3.2.3. Invertebrates

Comprehensive sampling of invertebrates was not possible, but abundant populations of butterflies were recorded by the author during the survey at many sites, with further data supplied by local naturalists (Figure 10).

Species	*No. of sites recorded (total n=46), data 1994*
Meadow Brown	16
Common Blue	14
Small Skipper	12
Small Heath	10
Peacock	7
Gatekeeper	6
Dingy Skipper	5
Small Tortoiseshell	5
Small Copper	4
Wall	3
Painted Lady	3
Orange Tip	3
Large Skipper	3
Small White	2
Red Admiral	2
Ringlet	2

Figure 10.
Butterflies recorded at former deep-mine sites - frequency and abundance.

The most frequently encountered species were Meadow Brown (*Maniola jurtina*), Common Blue (*Polyommatus icarus*) and Small Skipper (*Thymelicus sylvestris*). Whilst these and many other species are commonly encountered in the countryside, the populations of some were sometimes dramatic - up to 250 at a single site. Four sites supported the scarce Dingy Skipper (*Erynnis tages*), at one in significant numbers (Plate 22). Although Odonata records were made, these are treated together with the opencast and subsidence wetland sites below.

Plate 22.
Dingy Skipper (*Erynnis tages*). Falthwaite Colliery,1993 (J.D. Coldwell).

Of greater note were the presence of Red Data Book (RDB), Regionally and Nationally Notable insects recorded through more intensive sampling by other entomologists, particularly at two sites - Manvers Colliery tip and Cortonwood colliery tip, with further records fromFalthwaitecolliery (Coldwell 1991a, 1991b, 1991c, 1993, 1995a, 1995b, 1997). Significant Diptera, Hymenoptera, Coleoptera, Lepidoptera and Orthoptera were recorded. Crossley (1977) also recorded a number of noteworthy Heteroptera at Thorne colliery and J.D.Brown (*pers.comm.*) the Forester moth (*Adscita statices*)(Lepidoptera) at Falthwaite. Insects were associated with pioneer, sparse grassland and scrub habitats, at Manvers also close to the riparian habitats of the River Dearne. A summary of records is given at Appendix 21.

3.2.6. Soils.

The following categories of soils were identified (after Hollis, 1992); detailed examination of the soils was considered beyond the scope of this study. Figures refer to the Hollis classification.

9. Made ground soils

9.1. Raw-toxic made ground soils

9.12. Dense raw-toxic made ground soils

Dense raw-toxic made ground soils in shale spoil (taken as compacted shale spoil containing iron pyrites).

9.2. Raw made ground soils

9.23. Dense raw made ground soils

Dense raw made ground soils in shale spoil (taken as compacted shale spoil with no evidence of pyrites)

9.24. Well aerated raw made ground soils

Well aerated raw made ground soils in *shale spoil*. This was judged to be the dominant type on colliery spoil heaps, but was also mixed with the following other 'special man-made substrates';

Urban rubble (taken as demolished buildings and infrastructure)

Cinder and ashes (by-products of on-site coking works - these
Railway ballast (taken as the rubbly component of the trackway)
Burnt shale spoil (clearly identified as red shale)

9.25. Dense, seasonally wet raw made ground soils
Dense, seasonally wet raw made ground soils in shale spoil (frequent as compacted shale spoil, vehicle ruts and hollows where obvious inundation occurs)

9.27. Permanently wet raw made ground soils
Permanently wet raw made ground soils in shale spoil (present as obvious small permanent water bodies occurring on sites).

Further typing of soils present on sites was not undertaken, although there is clear potential for further examination and categorisation of the range of soil types found on sites.

3.3. Opencast sites

3.3.1. Habitat-types.

Figure 11 shows the broad range of Phase 1 habitat-types found through survey on the twelve opencast sites. Caution needs to be taken in interpreting these data as the sites chosen reflect the deliberate choice of the author in selecting sites for comparative purposes.

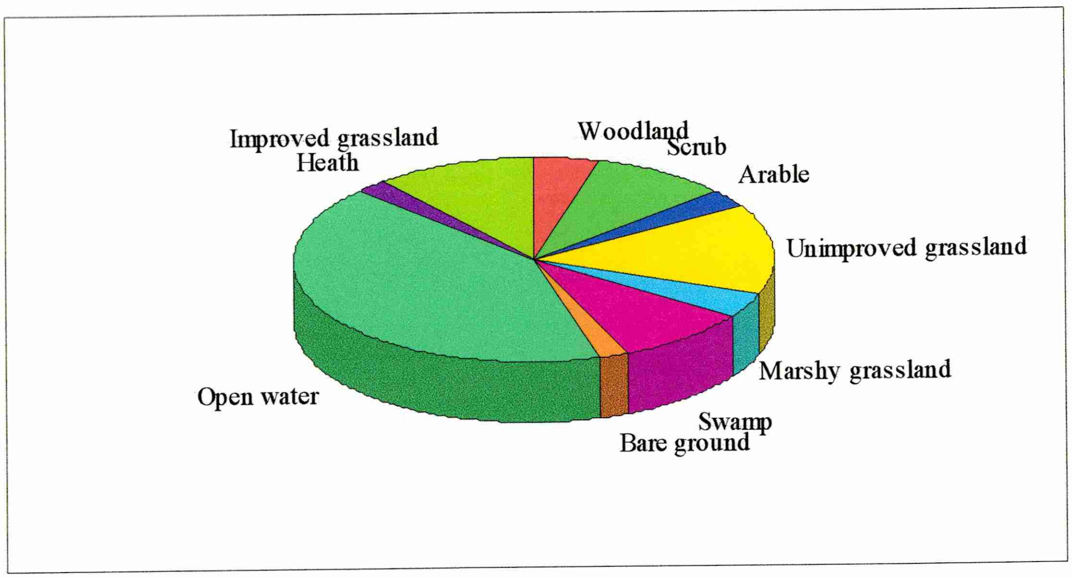


Figure 11.
Habitat-types on restored opencast sites (occurrence by %age on 12 sites).

Two sites were agricultural restorations, with the fields being entirely of crops delineated by fencing. No wildlife was recorded at these sites.

Two sites were restorations to hay meadow type grassland at Banks, Tankersley, and Scholes Common. The Banks site was recently created (early 1990's) using hay meadow seed from an established MG5 meadow SSSI at Pye Flatts, Barnsley, and although mainly grassland has included within it two newly created ponds. The Scholes Common site represents an unusual restoration of some 40 years which has not been agriculturally improved (Plate 23). The site was a former opencast coal site worked in the 1940's under the Defence Regulations, but since the late 1950's has been managed on the basis of an annual hay cut and has also been used as an informal recreation area by the local Rotherham communities of Thorpe Hesley and Kimberworth (C.Palmer, *pers. comm.*). It is likely therefore, that despite being an engineered restoration, it has escaped the agricultural improvements of many other grasslands found in the farmed landscape. Although mainly grassland, this site also had some *Salix* scrub.

Three sites had no habitat data as the interest was mainly birds. A further four sites had significant wetland interest in which open water, marsh and swamp communities were well represented, although the terrestrial elements of the sites were amenity grasslands and plantations, with some sparse ruderal vegetation.

The remaining site - Seckar Wood, was an area of lowland heath, mire and woodland opencasted in the late 1940's but which had been left to regenerate naturally and which held considerable wildlife interest (see next section).

Plate 23.
Grassland restoration on opencast site (50 years old). Scholes Common, July 1994.

3.3.2. Plant communities

Plant communities were not sampled in detail, except for 7 quadrats taken by the author at the Banks and Scholes Common sites. Here, three grassland communities were described (Appendix 22) as MG9 *Holcus lanatus-Deschampsia cespitosa* grassland and MG10 *Holcus lanatus-Juncus effusus* rush pasture, both of which had significant areas on the two sites respectively, and a poorer form of MG5 *Cynosurus cristatus-Centaurea nigra* grassland in which a wide range of grasses was present, but the stands lacked many of the associates normally expected for this type of vegetation. Seeding of the Banks site with seed of MG5 provenance gives a strong link with the samples, and further work would be of interest to describe the differences from donor to receptor site. The extent of MG9 grassland was however extensive, and may indicate impeded drainage conditions on part of the restoration, or less intensive management - the MG5 communities are cut for hay on an annual basis.

Plate 24.
Natural regeneration on opencast site. Heathland at Seckar Wood.

The area of opencasted land at Seckar Wood is now dominated by an extensive area of lowland heath comprising H9 *Calluna vulgaris-Deschampsia flexuosa* heath and mosaics with U2 *Deschampsia flexuosa* grassland (Plate 24). Some fragmentary stands of H8 *Calluna vulgaris-Ulex gallii* heath also contribute to the mosaic. A former conduit supplying a sawmill had been damaged in the coaling operations, causing seepage to occur down a slope forming a significant area of M16 *Erica tetralix-Sphagnum compactum* wet heath. Opencasting occurred in 1948-1950 as a small-scale operation, since some patches of vegetation still had oak and Bluebell *(Hyacinthoides non-scripta)* surviving in the mosaic. It is thought that the contractor went bankrupt leaving no scope for 'traditional' top-soil restoration (J.Watson, in litt.).

The wetland sites (Anglers, Pugneys, Rother Valley Country Park, Lowther North) in general form a pattern of a created water body or water bodies set into a sculpted landform of amenity grassland (MG7 *Lolium perenne* leys) and plantation woodlands (Plate 24). Management intervention can be significant with some trials at diversifying the grasslands apparent, as well as lack of management in parts. In the water bodies, fragmentary stands of swamp vegetation - mainly S12 *Typha latifolia* swamp, but also S4 *Phragmites australis* swamp, S5 *Glyceria maxima* swamp, S14 *Sparganium erectum* swamp and S19 *Eleocharis palustris* swamp can be seen, though nowhere as extensive as in the subsidence wetlands encountered elsewhere. Some aquatics have been sampled. At Lowther North, some of the stands of reedswamp and marsh were established by translocation after 1981 and have since diversified to include species such as *Lysimachia vulgaris, Lycopus europaeus, Stachys palustris* (C. Palmer, in litt.). The origin and colonisation by *Potamogeton pectinatus, Elodea nuttallii, Myriophyllum spicatum* communities are less obvious, although mature wetlands are present nearby and could act as a seed source.

Plate 25.
Opencast site. Amenity restoration with water features. Rother Valley Country Park. May 1993.

Some marsh communities e.g. areas dominated by MG10 *Holcus lanatus-Juncus effusus* rush pasture, can also be a feature. Small created ponds at the Banks opencast site had a range of introduced aquatic and marginal vegetation similar to the above.

3.3.3. Plants

Plants were not systematically recorded and significant species were collated through the survey by the author combined with records from published sources. The site with the most valuable information was Seckar Wood where detailed records go back to the early 1970's. Significant species here include *Genista anglica, Empetrum nigrum, Equisetum sylvaticum* and *Pyrola rotundifolia* as well as the components of the heathland communities.

3.3.4. Vertebrates

Records suitable for collation were scarce except for information on breeding birds largely derived from local reports, but supplemented by survey by the author, and wintering wildfowl at wetland restorations (BTO data). Here, significant numbers of wintering waterfowl were recorded at Rother Valley Country Park, Anglers, Pugneys and St. Aidans (Appendix 23). Roe Deer, Rabbit, Fox, Common Frog, Common Toad and Palmate Newt were recorded at Seckar Wood within the land previously opencasted (although the site adjoins a significant area of other woodland). Stocking of some of the water bodies with fish, notably Rainbow Trout *(Salmo gairdneri)* and Brown Trout *(Salmo trutta)* (Anglers), and the coarse fish Roach *(Rutilus rutilus)*, Perch *(Perca perca)*, Bream and Pike *(Esox lucius)* was noted at the other large sites.

3.3.5. Invertebrates

Detailed information was not collected.

3.4. Subsidence wetlands

3.4.1. Habitats

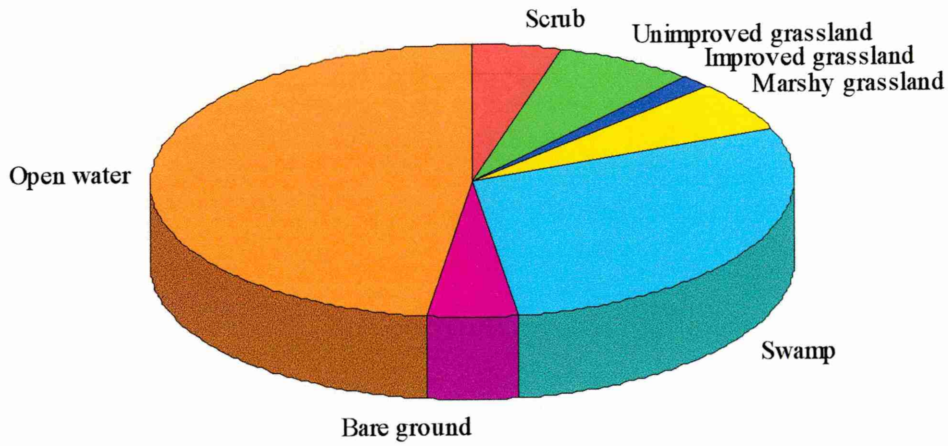


Figure 12.
Habitat-types on subsidence wetlands (%age occurrence on 12 sites).

Figure 12 shows the broad range of Phase 1 habitat types surveyed on the 12 subsidence wetlands. In general, swamp, marsh, wet grassland and open water features were much more extensive than on the opencast sites (as expected), with much less amenity grassland and plantations.

3.4.2. Plant communities

Significant areas of the following communities were recorded during the survey from the sites:

Plant communities at subsidence wetlands, Yorkshire coalfield.
S4 *Phragmites australis* swamp
S5 *Glyceria maxima* swamp
S12 *Typha latifolia* swamp
S14 *Sparganium erectum* swamp
S15 *Acorus calamus* swamp
S19 *Eleocharis palustris* swamp
S28 *Phalaris arundinacea* tall-herb fen
MG9 *Holcus lanatus-Deschampsia cespitosa* grassland
MG10 *Holcus lanatus Juncus effusus* rush pasture
MG6 *Lolium perenne-Cynosurus cristatus* pasture
A5 *Ceratophyllum demersum* aquatic community
A11 *Potamogeton pectinatus-Myriophyllum spicatum* aquatic community
A9 *Potamogeton natans* aquatic community
A10 *Polygonum amphibium* aquatic community
W1 *Salix cinerea-Galium palustre* woodland

Table 5.
Plant communities at subsidence wetlands, Yorkshire Coalfield.

In addition, small and fragmented stands of a number of other plant communities were inferred, these possibly originating from older marsh, fen and grassland communities present before subsidence occurred but which survived in a reduced form, escaping from inundation or agricultural improvement.

MG4 *Alopecurus pratensis-Sanguisorba major* flood pasture
S8 *Schoenoplectus lacustris* ssp. *lacustris* swamp

In general, plant communities were well developed and many of the major swamp stands were extensive, for instance *Glyceria maxima* beds at Denaby Ings, Wath Ings; *Typha* beds at Mickletown Ings, Fairburn Ings and Broomhill, and *Salix cinerea* carr woodland at Catcliffe Flash (Plate 26). Many of the wetlands were located in the floodplains of the rivers Aire, Calder, Don and Dearne and were historically subjected to winter flooding (the Norse word *Ings* refers to this). Effects of subsidence have been to exacerbate this flooding effect and to create standing pools and lakes, rather than a free drainage regime which would have formerly obtained.

Plate 26.
Subsidence wetlands. Open water with fringing carr woodland. Catcliffe Flash. July 1995.

3.4.3. Plants

In addition to the well-developed nature of the plant communities, many sites supported species scarce in the region (reflecting the scarcity of wetlands generally). Of particular note (derived from published records but some re-confirmed by the author through the survey) was the occurrence of brackish water species, with *Schoenoplectus lacustris* ssp *tabernaemontani* recorded at three sites, *Juncus gerardii* at two, and *Cotula coronipifolia* at two. *Potamogeton trichoides* was recorded at Broomhill Flash.

Other species scarce in West Yorkshire (Lavin & Wilmore 1994) include *Hippuris vulgaris, Hottonia palustris, Juncus compressus, Carex acuta, Ceratophyllum demersum, Thalictrum minus.*

3.4.4. Vertebrates

Extensive information was collated on breeding and wintering birds from a number of sites. Data was largely collated from local reports and BTO sources, supplemented by the author's records on breeding birds through survey. Detailed examination of these data is made in the next section. However, for breeding birds, substantial populations of wetland species were found at a number of sites, notably grebes, ducks, swans, waders and reedswamp passerines such as Reed Bunting *Emberiza schoeniclus*, Reed *Acrocephalus scirpaceus* and Sedge *A.shoenobaenus* warblers. Breeding ducks were of particular note, with regular populations of some such as Shoveler *Anas clypeata*, Garganey *A.querquedula,* Teal *A.crecca* and Gadwall *A.strepera* characteristic of productive, shallow wetlands (Cramp & Simmons, 1985). Waders of wet grasslands - Snipe *Gallinago gallinago* and Redshank *Tringa totanus*- were significant at some sites, as were Little Ringed Plovers (often associated with the colliery spoil tips causing the subsidence in the first place).

Plate 27.
Subsidence wetlands. Open water/grassland with wintering wildfowl. Broomhill Flash April, 1993.

An unusual feature of some sites was the presence of coastal species, notably Shelduck *Tadorna tadorna (*2 sites), Common Tern *Sterna hirundo*(3 sites), Great Ringed Plover *Charadrius hiaticula* (2 sites), Oystercatcher *Haematopus ostralegus* (2 sites) and Cormorant *Phalacrocorax carbo* (no sites with confirmed breeding but a large population increase in summer), all of which seem to have recently established in the study area.

Wintering wildfowl were significant,with a number of sites supporting substantial (>1000) birds of a wide range of species (Plate 27, see next section for details).

Other vertebrate records were not systematically collated, however incidental records from local reports indicating some vertebrate significance included Otter *Lutra lutra* at two sites (Fairburn 1995 and Broomhill 1996), Harvest Mouse *Micromys minutus* (Mickletown Ings), Ten-spined Stickleback *Pungitius pungitius* (Broomhill and Mickletown Ings).

3.4.5. Invertebrates

Invertebrate records were not systematically collected. A number of the sites have detailed information drawn from the efforts of local entomologists over a number of years, but a rigorous survey of indicator groups was considered beyond the scope of this study. Merritt (1996) detailed records of water beetles from the Rother Valley and noted some significant species from two of the study sites - Catcliffe Flash and Rother Valley Country Park including *Gyrinus distinctus* (RDB3 from Catcliffe Flash), the nationally Notable Na *Coelambus nigrolineatus* (RVCP), and the Notable Nb species *Hydroglyphus geminus* (both sites), *Ilybius fenestratus* (Catcliffe), *Rhantus grapii* (Catcliffe), *R.suturalis* (Catcliffe), *Laccobius sinuatus* (RVCP), and *Enochrus melanocephalus* (RVCP). Records of Odonata were collected by the author from a number of sites when available, and have been used in the next section.

However, of particular note are a series of records from Mickletown Ings (Brook, 1976, Fryer, 1978, Ruttner-Kolisko, 1979) for Insecta, Crustacea and Rotifera indicating the brackish nature of the waters at this site which originates from the saline run-off from the adjacent Savile Colliery tip (Nature Conservancy Council, *verbally*). Insect species well established include *Macroplea mutica* (Coleoptera, RDB3, also known in the region from Spurn), *Porpyrops antennata* (Diptera, Notable N. England, also known from Spurn), *Spilogona biseriata* (Diptera, RDB3, also known from Spurn), *Cercyon marinus* (Coleoptera, usually coastal). Six crustacean species included *Gammarus duebeni* (Amphipoda), the ostracods *Cypridopsis aculeata* and *Heterocypris saline* and the copepods *Thersitina gasterostei, Acanthocyclops bicuspidatus lubbocki*, and *Eurytema velox*. Four rotifer species with an affinity for highly saline waters include *Brachionus plicatilis, Colurella adriatica, Testudinella patina and Cephalodella catellina*. Further work has also revealed brackish water diatoms (Belcher *et al.* 1980).

4. DISCUSSION

4.1. Nature conservation evaluation.

4.1.1. Habitat types

The study site data reveal a wide range of habitat types both naturally developed and 'created', including pioneer vegetation, grassland, swamp, open water communities, heath, woodland and scrub.

Good examples of each of these categories can be identified using the criteria of size, rarity, typicalness and diversity (Ratcliffe, 1977), however some difficulty is found in ranking sites without knowledge of the total extent of the resource throughout the study area (NCC, 1989). The designation of a number of sites as SSSI and 'Second-tier' is however helpful since these designations are made using the same criteria and therefore a knowledge of the broad resource across the study area had already been made and was available (Nature Conservancy Council, A. Barker *verbally*). A more rigorous approach than using broad habitat types uses an analysis of plant communities to determine quality of vegetation for nature conservation purposes, which can then be supplemented by some of the broader habitat type considerations such as the value of mosaics of habitat types, or position in an ecological unit.

4.1.2. Plant communities

A very wide range of plant communities was recorded from all sites, both those sampled on deep-mine sites, and those quickly evaluated from subsidence and opencast sites (Appendices 1- 19 and Table 5). Whilst most are widely distributed (Rodwell, 1991 et seq.), a number are of some note.

Pioneer communities are not described by the NVC, except for coastal habitats, hence their evaluation for nature conservation in terms of representativeness is difficult. Though the *Agrostis stolonifera- Holcus lanatus* community is by and large species-poor and comprises common and wide-ranging species, a number of locally uncommon species were recorded within it e.g. *Dactylorhiza purpurella, Poa compressa*. Selection of these plant communities for nature conservation purposes using criteria of size, diversity and rarity is questionable because of a lack of contextual knowledge across the whole 'geographical unit' upon which assessments are made, although the selection of a typical (sub)community could be justified, especially if the site was part of a wider ecological unit or contributed to an overall wildlife mosaic, to contribute to representation of the range and diversity of plant communities in a given area (NCC 1989). The *Hypochoeris radicata* sub-community is more diverse which could weigh more significantly in an evaluation. The *Vulpia bromoides-Arenaria serpyllifolia* community is of conservation significance as it is diverse and rare in the general landscape, and supports a range of ephemeral and diminutive species only found in these harsh environments e.g. *Chaenorhinum minus, Filago vulgaris, Vulpia* spp. The *Anthyllis vulneraria* lawns and *Festuca rubra-Lotus corniculatus* stands have no recognised equivalent, and could be justified as of some nature conservation significance for their intrinsic scientific interest as unusual stands analagous to some coastal communities, as well as being diverse and rare in their own right. Further work, however would be required in the case of the latter to compare against other semi-natural stands, especially as both these communities were only found on one site.

Grasslands in general were representative of communities more widely distributed in the wider landscape. More 'traditional' nature conservation sites such as hay meadows (MG5, MG4) and calcareous grasslands (CG3) are better represented elsewhere in the lowland landscape, whilst acidic grasslands (U2) can be found more extensively in the uplands. Stands such as MG9, MG10 and MG1 are generally frequent and widespread but could contribute to the value of a wider nature conservation site, adding diversity at the plant community level. U1 is an exception, since most of the national interest in this type of grassland is found in the south east of the country e.g. the Breckland of East Anglia (Rodwell 1991 et seq.), but the stands here add to the range of variation of vegetation in the study area and have added value being extralimital to the main areas of distribution. MG12 is less clearcut, but since the stands in the study area were generally diverse and supported some locally rare species e.g. *Ophrys apifera,* some could be justified as being of significance.

Heaths were scarce and fragmented, however the opencast site with mature H8 and H9 dry heath communities, together with M16 wet heath, and supporting a range of locally rare species, was clearly of significant nature conservation interest and illustrates the quality of interest that can be developed.

Aquatic and swamp communities were diverse and well distributed. Most were well represented in the wider landscape, however some communities are recognised as being of some significance for nature conservation e.g. A5 *Ceratophyllum demersum* community, for its rarity. Such communities, are however in decline due to a gradual impoverishment of the water environment (English Nature 1997) and as many sites supported a number of these communities together, nature conservation significance on the basis of size, diversity, and rarity is justified. Those sites supporting a number of such communities would rank higher than others, and would also meet the criterion of typicalness.

Woodlands were difficult to evaluate. Most stands were immature and had yet to gain more than a superficial resemblance to established communities that might be found in ancient woodlands. Nevertheless, stands particularly of the W16 community were of some interest from a scientific/research/recorded history point of view, and as examples of woodland types more usually found in the uplands. Scrub communities were of value for general wildlife, but stands here generally lacked diversity and rarity in terms of plant community features.

Table 6 shows a comparison of samples of vegetation communities from deep-mine sites compared with the NVC. Significance was assessed using the Fischer-Behrens test for testing means with unequal population variances (Campbell, 1974). Six communities (four grasslands, two swamp) were significantly poorer in the mean number of species and range of species than found in the published NVC (Rodwell, 1991 *et seq.*). Another six communities (four grasslands, two woodlands) were not significantly different.

NVC community	Mean no spp.samples	Mean no spp. NVC	Range samples	Range NVC	Significance
U1b	6.4	16	2-11	6-35	p<0.05
U2a	5.9	9	2-11	2-16	n.s.
MG1	8	14	3-11	3-30	p<0.05
MG7a	3.2	5	2-6	2-8	n.s.
MG9b	12.1	18	6-17	11-34	p<0.05
MG10a	6.1	12	2-11	6-20	p<0.05
MG12a	11	11	6-18	7-26	n.s.
CG3	13.2	13	10-15	6-22	n.s.
S12b	5	9	3-7	5-14	p<0.05
S19	3.8	7	2-6	1-14	p<0.05
W10d	10.7	10	4-16	1-27	n.s.
W16a	9.9	9	7-20	3-26	n.s.

Table 6.
Mean no. and range of species from deep-mine samples compared with published NVC.

4.1.3. Plants

Plant species were evaluated using Red Data Book (RDB) and Nationally Scarce Species (NSS) lists (Stewart *et al.*, 1994), together with statements for local scarcity (LS) in published Flora (e.g. all recent records cited in Lavin & Wilmore, 1994 for West Yorkshire and Shaw, 1988 for Sheffield). In the absence of *Florae* for other districts, a tentative list is proposed for locally significant species- pLS- (Table 7).

The main criterion used here is that of rarity, however some consideration of abundance in addition to rarity is warranted, since larger populations are clearly more important than small populations or single occurrences. In this respect, the *Corrigiola litoralis* population is particularly significant, with *circa* 2200 plants counted in 1993, although the species is notoriously ephemeral in its occurrence at its one native site, Slapton Ley in Devon, and further data from its coalfield location is warranted. For the NSS species, both occur on one site each but with good populations. The LS species include two maritime species, reflecting the unusualness of such species inland, although in conservation terms this represents more of a value for scientific research than conservation of populations in more typical situations.

The proposed LS species are intended to reflect an evaluation at District level, rather than County, and the list contains largely open-ground and aquatic species reflecting the general scarcity of such habitat types and the fact that these are threatened by development (e.g. reclamation schemes) or deterioration (e.g. pollution).
The evaluation did not include assessment of bryophytes or lichens due to the paucity of records and the lack of a contextual basis for comparative assessment.

RDB *Corrigiola litoralis** NSS *Potamogeton trichoides* *Pyrola rotundifolia* ssp.*rotundifolia* LS *Juncus gerardii* *Orobanche minor* *Silene uniflora* *Apera interrupta* *Ranunculus hederaceus** *Ulex gallii** pLS *Aira caryophyllea* *Aira praecox* *Anthyllis vulneraria* *Arenaria serpyllifolia* *Bidens cernua* *Bidens tripartita* *Brachypodium pinnatum* *Bromopsis erecta* *Calamagrostis epigejos* *Carex acuta* *Carex disticha* *Catapodium rigidum* *Centaurium erythraea* *Ceratopyllum demersum* *Cerastium semidecandrum* *Chaenorhinum minus* *Cotula coronipifolia* *Crepis vesicaria* *Dactylorhiza fuchsii* *Dactylorhiza praetermissa* *Dactylorhiza purpurella* *Daucus carota* *Empetrum nigrum* *Erigeron acer* *Eriophorum angustifolium* *Erodium cicutarium*	*Erophila verna* agg. *Festuca arundinacea* *Genista anglica* *Genista tinctoria* *Helictotrichon pratense* *Helictotrichon pubescens* *Hippuris vulgaris* *Leontodon hispidus* *Leontodon saxatilis* *Linaria repens* *Linum catharticum* *Lycopus europaeus* *Oenothera glazioviana* *Ononis repens* *Ophioglossum vulgatum* *Ophrys apifera* *Plantago media* *Poa compressa* *Pulicaria dysenterica* *Reseda lutea* *Reseda luteola* *Sagina apetala apetala* *Sagina procumbens* *Saponaria officinalis* *Schoenoplectus lacustris* ssp.*tabernaemontani* *Sedum acre* *Senecio erucifolius* *Senecio viscosus* *Spergularia rubra* *Trifolium arvense* *Trifolium dubium* *Triglochin palustris* *Trisetum flavescens* *Verbascum thapsus* *Verbascum nigrum* *Veronica polita* *Vulpia bromoides* *Vulpia myuros*

Table 7.

Evaluation of significant vascular plants for nature conservation, mining sites, Yorkshire. *= included in Biodiversity Action Plan lists (Anon., 1996).

4.1.4. Vertebrates

Evaluation of vertebrates can be difficult because comprehensive, comparative data is rarely available, especially for wide ranging species, those that require large home ranges, and cryptic taxa which are hard to survey (NCC, 1989). Such reliable data can be collated only for a few groups where regular monitoring and recording takes place e.g. bat roosts, amphibian and reptile breeding assemblages, wintering wildfowl, and where the national status of species is known.

For the study sites, data for mammals can only suggest that such sites can provide suitable conditions for supporting a small range of species. On deep-mine sites, of most conservation significance is the regularity of sites supporting Brown Hare *Lepus capensis*, since this is a species where the national population trend is downwards (Harris *et al*., 1995), and which has been therefore included on the UK BAP list (Anon, 1994a, 1996). The presence of naturally developed habitats on some sites is likely to contribute to maintaining some aspects of the species' life cycle. Sites supporting Badgers are also of significance, as this species is legally protected and in the study area is not common, as well as being under threat (Harris *et al*. 1995). This species favours a mosaic of habitats, to which these sort of sites must contribute. Water Voles are also of current conservation concern as populations are declining, thought to be due to habitat deterioration and increased predation of depleted populations by Mink *Mustela vison* (Woodroffe, 1994), and the species has also been included on the UK BAP short list. The presence of this species on at least one deep-mine site contributes to that site's significance. The records of Otter *Lutra lutra* at two subsidence wetlands is of note given the recent recovery of populations of this species (also on the UK BAP short list) in England although in Yorkshire it is still rare with extant populations only on some of the North Yorkshire catchments (S. Jay, *pers.comm*.), and these records constitute examples of a tenuous range expansion (Jefferies, 1996). However, their presence indicates suitable conditions and must contribute to those sites' assessments. Harvest mice *Micromys minutus* are also locally uncommon in Yorkshire (Delany, 1985), and the presence of populations is of note, although in some parts of the study area they have been found to be more widespread than hitherto realised, e.g. Sheffield (Whiteley, 1996).

Small populations of herptiles were recorded at a number of sites. The outstanding nature conservation discovery of the study is probably the colliery pond supporting five species of amphibian in substantial numbers. This site scored 15 using the criteria and supports one of the best UK populations of Great Crested Newt *Triturus cristatus* as well as an outstanding assemblage (NCC, 1989). This site has since been proposed as a European Special Area of Conservation on the basis of the series of records obtained during the course of this study (A.Gent, *pers.comm*.). As Great Crested newts are of conservation concern and are included in the UK BAP short list as well a being legally protected, the other deep-mine site supporting a small population is also of conservation significance. Whilst all herptiles are afforded some limited legal protection (Wildlife & Countryside Act, 1981), populations of Common Frog *Rana temporaria*, Common Toad *Bufo bufo* and Smooth Newt *Triturus vulgaris* are generally widespread and significant populations only are of value in conservation assessments. The Palmate Newt *Triturus helveticus* is however locally uncommon and the rarest species recorded nationally (Swan & Oldham, 1993, Arnold, 1995). Reptiles are also difficult to assess, but sufficiently uncommon for their presence to contribute to a site's overall value, whilst the presence of Grass Snakes *Natrix natrix* would contribute to the site's value.
Although fish were not systematically recorded, and the modification of populations makes conservation assessments difficult except for very rare species (Maitland & Campbell, 1992), some species of no interest to anglers can be of local interest. In the study sites, the presence of Ten-spined Sticklebacks *Pungitius pungitius* at two

subsidence wetlands is of note, as this species is uncommon in the region (Bunting et al., 1974).

A summary of the key mammal, herptile and fish species of conservation value is given in Table 8.

Species	*Conservation criteria*	*Assessment*
Brown Hare	UK BAP short list	presence contributes to site value
Badger	Badger Act	presence contributes to site value
Otter	UK BAP short list W & CA (1981)	presence contributes to site value
Water Vole	UK BAP short list	presence contributes to site value
Harvest Mouse	locally significant	presence contributes to site value
Great Crested Newt	UK BAP short list W & CA (1981)	sites are important in own right
Amphibian assemblages		sites are important in own right
Palmate Newt	locally significant	presence contributes to site value
Grass Snake	locally significant	presence contributes to site value
Ten-spined Stickleback	locally significant	presence contributes to site value

Table 8.
Conservation assessment of mammals, herptiles and fish found on study sites.

4.1.4.1. Birds

The most significant bird conservation feature of mining sites is the numbers of wintering wildfowl occurring on some of the subsidence wetlands and opencast restorations. Some 16744 waterfowl occurred at peak periods during the study period at 19 sites, with 7 sites supporting 81% of this population, and each of these with over 1000 waterfowl individually (WeBS counts, winters 1992/93-1994/95 , via British Trust for Ornithology). The key sites are given in Appendix 23.

Of these waterfowl populations, a number of species occurred in nationally significant numbers (>1% of the national population) at individual sites, notably Gadwall at Fairburn Ings and Swillington, and Shoveler at Fairburn (Table 9).

For nine species, Yorkshire subsidence wetlands and restored opencast wetlands support significant proportions of the GB wintering populations - Little grebe 2.4%, Whooper Swan 1.2%, Gadwall 4%, Shoveler 3.9%, Tufted Duck 3.4%, Pochard 2.0%, Goldeneye 1.1%, Goosander 1.2% and Coot 3.7%.

Populations at individual sites supporting between 0.1% and 0.99% of the national population could be regarded as regionally significant, for example at the West Yorkshire level where this criterion is used for the selection of 'second-tier sites' (A. Barker, *pers.comm.*), and certainly those sites supporting a number of species within these thresholds could be regarded as more significant than others. Some of the data, however, have to be treated with some caution, since some of the species concerned, e.g. Little Grebe, are widely dispersed on other waterbodies not counted under the national scheme and therefore the national populations are likely to be underestimated (Waters et al.,1996). Nevertheless, the data support the contention that wintering waterfowl populations at these sites, and particularly the top 7, are of substantial conservation interest.

Species															
Site	Lg	Gcg	Cm	Ms	Ws	Ga	T	Wi	Ma	Sv	Tu	Po	Gy	Gs	Co
Fairburn	0.5	0.4	0.5	0.6	0.8	**1.7**	0.3		0.2	**1.5**	0.7		0.4	0.6	0.9
Anglers		0.2				0.2		0.1			0.5	0.7	0.4	0.2	0.3
Pugneys	0.2	0.2		0.2			0.1			0.6	0.6	0.2	0.1		0.3
Rother Valley											0.2	0.3			0.3
StAidans	0.1		0.2			0.2				0.1	0.8	0.5	0.2	0.2	
Broomhill	0.1				0.3		0.2		0.1	0.3					0.1
Swill'ton	0.2				0.1	**1.1**				0.8	0.2			0.2	0.1
Mick'twn	0.7			0.1		0.3					0.1				0.2
Denaby Ings	0.1									0.1					0.2
Catcliffe											0.1	0.1			0.2
Sprotborough	0.2									0.3					0.5
Allerton Bywater	0.2										0.1				0.1
Altofts										0.2	0.1	0.2			0.5
Stanley FF	0.1														
Total	2.4	0.8	0.7	0.9	1.2	3.5	0.6	0.1	0.3	3.9	3.4	2.0	1.1	1.2	3.7

Table 9.
National percentages of wintering wildfowl at subsidence wetlands and restored opencast sites.
Nationally significant populations in bold.
Key:
Lg=LittleGrebe,Gcg=GreatCrestedGrebe,Cm=Cormorant,Co=Coot,Sv=Shoveler,Tu= Tufted Duck, Gw=Gadwall, Gs=Goosander, Gy=Goldeneye,Ms=Mute Swan, Ws=Whooper Swan, Ma=Mallard, Po=Pochard

Further bird conservation interest is apparent from breeding populations, especially of the subsidence wetlands. Using the standard criteria for SSSI evaluation for breeding bird assemblages (NCC, 1984), two sites are of particular significance for bird assemblages - Broomhill and Fairburn Ings, with a diversity of species, some in significant and regular numbers, notably of waterfowl (Table 10). Whilst the evaluation is targeted towards the selection of SSSI's at national level, it is also clear that other wetlands have breeding bird communities bordering on such status e.g. Edderthorpe, where recognition at regional level would be appropriate. Some caution needs to be taken with the data, since 5-year data sets ideally need to be used in this sort of analysis, and the figures are derived from data in local bird reports for the years 1991-1995, where some years' data are missing. Nevertheless, data from the two key sites for the years 1996-1997 reinforce the evaluation (D.Waddington *pers.comm*, Fairburn Ings Bird Reports).

Species	Score*	Fairburn	Anglers	Rother V.	St.Aidans	Broomhill	Mickletown	Denaby I.	Catcliffe	Edderthorpe
Lgrebe	2.5	2.5		2.5		2.5	2.5	2.5	2.5	2.5
GCGrebe	3	3		3	3	3	3	3	3	
Mute Swan	3	3		3		3	3	3	3	3
Shelduck	2				2	2				2
Gadwall	4	4			4	4		4		4
Teal	3	3				3		3		
Garganey	5	5				5				
Shoveler	4	4				4		4		4
Pochard	4	4					4			
Tufted Duck	3	3	3	3	3	3	3	3	3	3
Little Ringed Plover	4	4	4		4	4				4
Ringed Plover	3				3					
Curlew	2				2	2				
Snipe	2					2		2		
Redshank	2	2	2		2	2		2		2
Common Tern	3	3			3	3				
Cuckoo	2	2	2		2	2	2	2	2	2
Kingfisher	3	3			3	3				
Yellow Wagtail	1	1	1		1	1	1			1
Grey Wagtail	1									
Grasshopper Warb.	2	2		2	2	2	2	2		2
Sedge Warbler	1	1	1		1	1	1	1	1	1
Reed Warbler	2	2			2	2	2	2	2	2
Reed Bunting	1	1	1		1	1	1	1	1	1
TOTAL		52.5	14	13.5	38	54.5	24.5	34.5	17.5	33.5

*Score (NCC1984) shows evaluation for breeding bird assemblage for lowland open waters and their margins. Threshold for consideration as SSSI = 31.

Table 10.

Evaluation of breeding bird assemblage of subsidence wetlands and restored opencast sites.

In addition to the national and regional significance for waterfowl and breeding bird assemblages for open waters and their margins, all types of site have some bird significance at local level. Waterfowl sites supporting hundreds of birds are clearly of local significance, whilst some of the species in the breeding bird assemblage are also localised because of the restricted habitat availability. In addition, deep-mine sites can also be of some significance for some species (see Appendix 23 for full data).

The most important feature of deep-mine sites could be argued as those supporting Little Ringed Plovers since the total national population estimate for this species is around 600 pairs (Parrinder, 1989), and the estimated 21 pairs/territories at 11 of the 46 deep-mine sites represents 3.5% of the British population (note that Figure 7 refers to birds recorded during the survey only). In addition, 6 wetland sites also supported the species with an estimated population here of 8-12 pairs, giving a total of 29-33 pairs or 4.8-5.5% of the national population on the 70 study sites. Some caution needs to be made to the figures, since some of the wetlands were adjacent to the deep-mine sites and birds may have been double counted, and the data is based on maxima recorded during the study period. Many other deep-mine sites in the Yorkshire coalfield were not sampled in the study, however, and it is likely that the total population of this species in the study area will be higher.

The significance of other deep-mine site species can, on the one hand, be viewed as being local, in that assemblages of scrub and grassland birds occur on the more well-established sites, and contribute to local biodiversity. On the other hand, many once-common species have recently declined e.g. Tree Sparrow *Passer montanus*, Corn Bunting *Miliaria calandra* (Marchant et al., 1990), and some of these have been included in the national lists of conservation priorities (Gibbons et al. 1996, UK Biodiversity Action Plan) such that if these species occur significantly on mining sites, they could be said to be contributing to conservation at national levels.

This analysis outlined in Table 11 suggests that deep-mine sites are of conservation value for Grey Partridge, Quail, Skylark as breeding sites and foraging areas for broods, presumably because of good insect populations not affected by pesticides; for roosting Reed Buntings, Corn Buntings, Starlings, Swallows and Sand Martins in reedbeds; as foraging areas for Green Woodpeckers (found regularly on sites); for foraging Kestrels; and breeding Grasshopper Warblers. On subsidence wetlands and opencast wetland restorations for wintering wildfowl (6 species), breeding Garganey, Snipe, Curlew, Shelduck and Redshank; roosting Starling, Sand Martin, Swallow; breeding Reed Bunting, Kingfisher and Grasshopper Warbler; foraging Kestrels and wintering Lapwings and Golden Plovers. The analysis reinforces the important features derived from other methods, although the significance of the breeding Little Ringed Plover population is not highlighted in this analysis.

Species	Criteria for national listing*	Feature on mining sites
'Red list'		
Grey Partridge	BDp	DM breeds, feeding areas for broods
Quail	HD	DM breeds
Skylark	BDp	DM breeds
Reed Bunting	BDp	SW breeds, DM/SW roosts
Corn Bunting	BDp, HD	DM roosts
Song Thrush	BDp	DM but not significant
'Amber list'		
Whooper Swan	WI	SW wintering population
Shelduck	BI	SW/O small breeding population
Wigeon	WI	SW/O wintering population
Gadwall	WI, SPEC3	SW/O wintering population
Teal	WI	SW/O wintering population
Garganey	BR, SPEC3	SW small breeding population
Shoveler	WI	SW/O wintering population
Pochard	WI	SW/O wintering population
Kestrel	BDMp, SPEC3	ALL - feeds
Water Rail	BDMr	Not significant
Ringed Plover	WI	Not significant
Snipe	BDMp	SW small breeding population
Lapwing	WI	SW wintering population
Golden Plover	WI	SW wintering population
Curlew	BI, WI	O small breeding population
Redshank	SPEC2	SW breeds
Kingfisher	SPEC3	SW/O breeds
Green Woodpecker	SPEC2	DM used for feeding
Sand Martin	SPEC3	SW/DM roosts in reedbeds
Swallow	BDMp, SPEC3	SW/DM roosts in reedbeds
Blackbird	BDMp	ALL - probably not significant
Fieldfare	BR	Not relevant
Redwing	BR	Not relevant
Grasshopper Warbler	BDMr	ALL - breeds
Starling	BDMp	SW/DM roosts

Key :
BDp - > or = 50% decline in UK breeding population over last 25 years
HD - Historical population decline 1800-1995
WI - > or = 20% of NW European wildfowl non-breeding population in UK
BI > or = 20% of European breeding population in UK
BR - 5-year mean of 0.2-300 breeding pairs in UK
BDMp - Moderate (25-49%) decline in UK breeding population in last 25 years
BDMr - Moderate (25-49%) range contraction in UK breeding population over 25 years
SPEC2 and 3 - species with unfavourable conservation status, concentrated in Europe (2) or not (3).
DM - Deep-mine
O - Opencast
SW - Subsidence Wetland

Table 11.

Conservation evaluation of bird species on mining sites, Yorkshire using Gibbons *et al.*, 1996.

4.1.5. Invertebrates.

The conservation value of the study sites for invertebrates cannot be systematically addressed given the quality of the data, and only general inferences can be made, with one or two exceptions. The significance of some sites for butterflies lies with the large populations of more common species which contribute to the intrinsic appeal of sites, as well as contributing to the reservoirs of local populations. Some species e.g. Common Blue can be rare in some areas e.g. Calderdale, West Yorkshire (Sutton & Beaumont, 1989) and therefore their presence, especially in quantity contributes to sites' overall assessment, however few sites are regularly counted for numbers although this situation is changing with data published for 1996 including large counts at some of the study sites of 163 Small Skippers, and 840 Gatekeepers at Fairburn Ings, and 379 Common Blues, 150 Gatekeepers and 134 Meadow Browns at Walton Colliery (Frost & Winter, 1997). The most significant butterfly found (at 4 deep-mine sites, one in significant numbers) was Dingy Skipper, a local species thought to be declining (NCC, 1989). Its foodplant, *Lotus corniculatus* was abundant on some sites. Whilst Marbled White - a regionally scarce butterfly (Sutton & Beaumont, 1989) was also found on one site, research revealed it had been introduced (Yorkshire Wildlife Trust, *in litt.*), and therefore of limited value in conservation assessments.

For Odonata, sites supporting breeding assemblages can be compared for assessment (NCC, 1989), with threshold numbers of species being of value in different regions of the UK. Data is however rapidly increasing, with a new range of observers and assessments can be more difficult as criteria have not yet been revised (Merrit *et al.*, 1996), especially where the assemblage contains widespread species. Of the taxa recorded from the study sites, *Lestes sponsa, Libellula quadrimaculata, L.depressa, Sympetrum sanguineum, S.danae, Aeshna mixta,* and *A.cyanea* can be indicative of conservation value as they are locally scarce (Whiteley, 1981). Based on this, two deep-mine sites (Gipsy Marsh and the reclaimed Walton Colliery) stand out.

The highly unusual brackish invertebrate interest at the subsidence wetland of Mickletown Ings is of significant scientific interest, and can contribute to the site's conservation interest on the citerion of rarity.

The most significant invertebrate data from the study is apparent from Coldwell's data at the deep-mine sites of Manvers, Falthwaite and Cortonwood colliery tips, although Crossley (1977) also reported some interesting records from Thorne Colliery. Using standard assessment methods (Ball, 1986), the Manvers site scores 1740 with numerous RDB and Notable species. The threshold figure for consideration as a SSSI is 200 and whilst any assessment of a site needs to be treated with some caution to take account of the intensive recording by a specialist, it is still clear that this is an outstanding site for insects, and clearly demonstrates the value of open ground habitats. Combined assessments for 3 sites with data are given in Table 12.

Species status	Score (Ball 1986)	Manvers	No.of species Cortonwood	Falthwaite
RDB1	100	1		1
RDB2	100	2	1	
RDB3	100	2	1	1
pRDB1	50	1		
pRDB3	50	1		1
Nb	40	7		1
Nr (NE)	20	24	1	
Notable	40	7	2	
Notable (NEng)	20	5		
TOTAL		1740	350	290

Table 12.
Invertebrate evaluation from 3 deep-mine sites, Yorkshire.

4.1.6. Earth science features

No sites proposed for Regionally Important Geological Sites (RIGS) status were identified in the study, however it is recognised that certain colliery tips can prove to be valuable for nature conservation purposes such as the collection of fossils for educational purposes (Jarzembowski, 1994). At Wath Main colliery tip, molluscan fossils were found by the author on the survey, of the non-marine lamellibranch *Carbonicola* spp., in small scattered locations on top of the colliery spoil tip, but not in any great concentration. This is a characteristic taxon of marine bands in the area (Edwards & Trotter, 1954). A RIGS site demonstrating features of the Carboniferous Coal Measures and interpreting the geology of the area is located in a former stone and clay quarry at Stairfoot nearby, and a SSSI for the Top marine Band at Carlton Brickworks.

4.1.7. Conclusions

The data confirm that great wildlife interest can exist on abandoned collieries and spoilheaps, and using established methods described above can prove to have value for nature conservation. Features of international or national importance are rare, but not unknown, but of more significance is the regularity and frequency of features significant at a regional and local level e.g. some pioneer habitats, birds and invertebrates.

The study data from naturally regenerated sites clearly reveal a wide range of nature conservation interest including plant and animal communities and species, and earth science features. A summary of the key features is given in Table 13. Significance is demonstrated from the European level to local level for different attributes, however in general deep-mine sites are of value for open ground and early colonisation features (whether terrestrial or aquatic), opencast terrestrial sites for heath and grassland derived from natural regeneration, and opencast and subsidence sites for wetland plant and animal features.

In contrast, the restored terrestrial deep-mine sites hold negligible value for wildlife. Some of the restorations of tips to grassland support the BAP species Skylark, and young plantations hold local breeding bird communities, however a very significant contrast exists between these sites and the much richer naturally regenerated sites. The range and quality of significant features is much less on the restored sites.The exception here is the single deep-mine site partially restored to a wetland at Walton colliery which should be treated alongside the opencast wetland restorations. Opencast sites restored to agriculture had no interest.

Whilst this is the case for deep-mine terrestrial sites, wetland restorations - either opencast or the deep-mine - also hold considerable nature conservation significance, particularly for aquatic and swamp communities and birds. Similarly, subsidence wetlands hold considerable interest, although a difference exists between the two categories, with the opencast sites being more restricted of significant features. This is not surprising given the immaturity of the ecosystems, and the fact that many of the subsidence wetlands would by definition already be more likely to be near to existing wetlands from which new colonisation and expansion could take place.

In addition to the assessments of significance for flora, fauna and earth science features above, it is also apparent that many sites are close to settlements and so offer opportunity for amenity, recreation and conservation activities to people in local communities - the broader elements of nature conservation. These are often in disadvantaged situations with the contraction of the coal mining industry in the late 1980's and early 1990's leaving pit villages with high levels of unemployment and poor facilities (Hudson & Sadler, 1990), however many sites offer opportunities for informal recreation such as walking, and some have more formal leisure activities programmed e.g. boating on the restored wetlands at e.g. Rother Valley Country Park.

Other features are also of value in the overall assessment of sites. None of the deep-mine sites in the study had been recognised for any local history significance, although local people did remark that it would be impossible for future generations to understand the impact of mines and the associated spoil heaps on the local landscape following restoration, and that some features could be retained (P. Middleton, *verbally* (Grimethorpe)). One deep-mine restoration had symbolised the finished landscape by the placing of sculpture e.g. 'Standing stones' at Tinsley park, or half a winding gear wheel at Upton. Perhaps the most significant local history landmark, both in terms of visual impact, recorded history and current nature conservation significance is the series of 20-30 bell-pits at Tankersley (Jones, 1995). Other bell-pits at Denby Grange have already been recognised as historically significant (Hey, 1986), although the vegetation is much modified by agriculture.

Significance	Deep-mine	Opencast	Subs. wetlands
International e.g. SPA,cSAC	Great Crested Newt*		
National e.g. SSSI, BAP species	Pioneer & grassland (P2, U1) plant communities Plants - *Corrigiola litoralis** Open ground invertebrate assemblage (Dipt.,Hymenop.) Brown Hare*, Water Vole* Skylark^, Grey Partridge*, Quail, Reed Bunting*, Corn Bunting* Amphibian assemblage*	Lowland heath (H9, H8, M16)	Aquatic & swamp* plant communities Brackish invertebrates Swamp invertebrates Otter* Wintering wildfowl Breeding bird community, Reed Bunting*
Regional e.g. 2nd tier site, LNR	Pioneer & grassland comms. (P1,U2,MG1,MG9,10,12) W16 Woodland Plants - *Oro. minor, Ophrys apifera, Apera interrupta* Plants - assemblage of locally scarce plants Invertebrates of open ground Lepidoptera - Dingy Skipper, assemblages/large populations, Forester Moth*. Dragonfly assemblage^ Great Crested Newt sites* Bird roosts of reedbeds Little Ringed Plover	Grassland (MG9, MG10, 'hay meadow' Aquatic & swamp* communities Plants - *Pyrola rotundifolia, Ulex gallii* Wintering wildfowl Migratory birds esp. waders Breeding bird community Little Ringed Plover	Aquatic & swamp* communities Wet lowland grassland* Plants - *Juncus gerardii,Pot trichoides, Ran. hederaceus** Harvest Mouse Wintering wildfowl Breeding bird assemblage Migratory birds esp. waders Little Ringed Plover* Ten-spined Stickleback
Local	Badger setts Assemblages or populations of local plants & animals^, or plant communities Earth Science features		

^ - feature also found on restored deep-mine sites.
* - listed on the Biodiversity Action Plan n.b. for birds only the 'short' and 'middle' lists

Table 13.
Summary of key nature conservation features of mining sites, Yorkshire.

4.2. Ecological aspects of land affected by mining.

The 70 study sites cover a very wide range of physical and biotic features, and a comprehensive account of their ecology is beyond the aims of this study. However, some aspects of ecology can be illuminated by the investigation.

All sites show a process of seral development, both colonisation by plants and animals, and changes in these features as time progresses. The most obvious are the establishment of vegetation, and in particular vegetation communities, and the habitation of these by assemblages of animals.

Community composition

The most detailed data refer to the plant communities on deep-mine sites. Here, the majority of the samples of vegetation conform to communities already described by the NVC, with the exception of pioneer vegetation and to a lesser extent by some unique grassland samples from a single site (Upton Colliery). Many of these represent poorer versions of the NVC accounts (Table 6), but the communities do show potential routes for development, for example, the *Hypochoeris radicata* sub-community of the *Agrostis stolonifera-Holcus lanatus* pioneer vegetation clearly shows a grassier trend from the open and sparse other sub-communities. The predominance of species such as *Deschampsia cespitosa* in the *Tussilago farfara* sub-community may indicate an eventual progression to the MG9 *Deschampsia cespitosa-Holcus lanatus* grassland, or the patchiness of *Arrhenatherum elatius* in both pioneer and grassland communities a progression to MG1 *Arrhenatherum elatius* grassland.

Early studies of the ecology of pit heaps have been undertaken in Staffordshire, Somerset, Northumberland, Cumberland, Durham (Hall, 1957), South Lancashire (Molyneux, 1963), Nottinghamshire/Derbyshire (Brierley, 1955) and West Midlands (Rees, 1955). Whilst the methodology for sampling vegetation was substantially different, comparisons with this study can be made. Many of the abundant species were common to all studies, notably the abundance and frequency of pioneering vegetation dominated by grasses. Comparisons of communities are not possible, given that earlier data is presented as species lists and summary associations, however it is clear that pioneer and grassland communities are abundant, and species such as *Agrostis capillaris, A.stolonifera, Tussilago farfara, Rumex acetosella, Festuca ovina, Deschampsia flexuosa* and *Chamerion angustifolium* are common to all studies as important components of the vegetation. Regional differences are also apparent, notably the apparent greater frequency of heathland species in the south and west (also noted by J. Box, *verbally,* for the West Midlands).

Plant diversity and rarity

A wide range of plant species were recorded on the study sites. Some of these were considered to be locally rare (Table7), associated with disturbed ground. These habitats are increasingly being recognised by botanists for a rich and varied flora comparable to 'semi-natural' habitats, e.g. in the North York Moors (Sykes, 1993) and may provide the only locations for come species at the county scale e.g. for *Lepidium latifolium* in Leicestershire (Primavesi & Evans, 1988). Earlier studies of mining land have also recognised the interest, for instance on tin-mines in Cornwall where a rich assemblage of plant communities and rare species occurs (Holliday & Johnson, 1979, Holliday *et al.*, 1979). Such land has also been recognised as important for Bryophytes, where some single British locations for species such as *Ditrichum cornubicum* and *Cephaloziella nicholsonii* occur on mine waste (Holyoak, 1996). Hodgson (1986), investigating the commonness and rarity in plants with reference to the Sheffield flora, considered that rare species are now concentrated in (amongst others) less fertile sites and appear to have a narrow ecological range being restricted to 'intermediate' habitats. It is perhaps not surprising that mining sites could support a range of scarce or rare plants, given the rarity of the habitat types in comparison with those found in the mature countryside, and the relatively rapid development of the natural vegetation.

Altitudinal influences

Altitude also has an influence on the vegetation establishing on mining sites, and the notion that seed sources and edaphic and climatic conditions have an influence over the colonisation of sites by vegetation and their subsequent development is demonstrated by the sites to the west of the study area, at the higher altitudes and wetter conditions. Here, the predominance of *Festuca ovina* in the *Agrostis stolonifera* and *A.capillaris* sward is perhaps an indication of development of the common grassland community of this area - U4 *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland, further supported by the occasional presence of *Calluna vulgaris, Galium saxatile* and *Nardus stricta*. Natural colonisation of coal mine spoils at high altitude (600-200m) in Alberta (Baig, 1992) reflected nearby subalpine vegetation with invasion by *Epilobium angustifolium, Deschampsia cespitosa, Achillea millefolium* and *Phacelia heterophylla* with successional trends to dwarf shrub habitat types with *Arctostaphylos uva-ursi, Dryas* spp, *Rubus* spp and *Rosa* spp. Agronomic species used in revegetation did not survive, and the potential value in using native vegetation for restoration was strongly advised.

Plant colonisation

The absence of many species from the samples in this study, when possibly expected from comparison to the NVC, is also of significance. For the pioneer and grassland communities, a range of species commonly encountered in the general countryside are absent or rare, notably grasses such as *Lolium perenne, Phleum pratense* and even less agriculturally demanding species such as *Festuca rubra, Anthoxanthum odoratum, Cynosurus cristatus* and *Alopecurus pratensis*. These species are as likely to colonise as, say, orchid species, where the seeds are so small and wind-dispersed, so that their absence must be associated with the demanding conditions on deep-mine sites. The absence of other species may reflect the absence of other suitable seed sources nearby, or the poor colonisation characteristics of others. These observations are also apparent from examination of data in the above studies.

No attempt was made to quantify the frequency of species between sites as this would require a full species inventory for the whole study site series, and comprehensive survey of each of the 70 study sites was beyond the scope of this work. Some species, however, were much more common than others. *Holcus lanatus* was the most frequent species in the deep-mine samples (frequency band 3 - 61-80%). Difficulty was sometimes encountered with the identification of *Agrostis*, since many plants showed characters intermediate between *A.stolonifera* and *A.capillaris* and may have been immature or hybrids (Grime *et al.*, 1988), however the former was clearly the most frequent species on open ground. This clearly matches the conclusion of Clarkson & Garland, 1988, who found *A.stolonifera* to be the most frequent coloniser of urban sites in Sheffield, and which had shown the most increase in frequency on urban sites between 1972 and 1985.

Colonisation of the pioneer and early grassland communities by woody species demonstrates the development of woodland, most strongly in the establishment of W16 *Quercus-Betula-Deschampsia flexuosa* woodland, most probably via the colonisation of *Deschampsia flexuosa* grassland. However, one striking feature of the open ground vegetation on some sites is the direct colonisation by *Betula* (Plate 6) such that it is obvious that closed canopy tree cover can establish in advance of ground vegetation. It is unknown which types of ground vegetation would eventually establish in such circumstances. For the W10 type woodland community, the vegetation is much less clearly defined, with many characteristic species absent.

It is striking that vegetation establishes on the bare substrates of deep-mine sites in the way it does. For some of the communities, for instance the U1 *Festuca ovina* and U2 *Deschampsia flexuosa* community, patches of these communities could be found alongside other pioneer and less well-defined vegetation with little obvious visible changes in the quality of the shale substrate. It is possible that early colonisation by the dominant species here may provide the basic vegetation matrix into which very few other species can penetrate whether or not the substrate is suitable, such that the dominant species is 'competitively excluding' other potential colonisers.

This could be developed further as a consequence of this study in the context of plant strategy (Grime *et al*., 1979) where species can be characterised as Competitors, Stress-Tolerators and Ruderal in a theoretical framework of practical application (Hodgson, 1986).

Other communities appear much more plastic, and the early pioneer communities, for instance seem to provide a very loose matrix of the constant species, with a very wide range of associates, some of which may patchily develop e.g. *Arrhenatherum*, providing a momentum towards the development of other communities.

Vegetation succession

Strong inferences can be made about potential development pathways for vegetation on deep-mine sites. Whilst many of the communities described closely resembled the NVC, invasion of some communities could be detected in the field and through trends in the data, for instance, the gradual and increasing frequency of *Deschampsia cespitosa* from pioneer to grassland communities associated with substrate compaction and waterlogging.

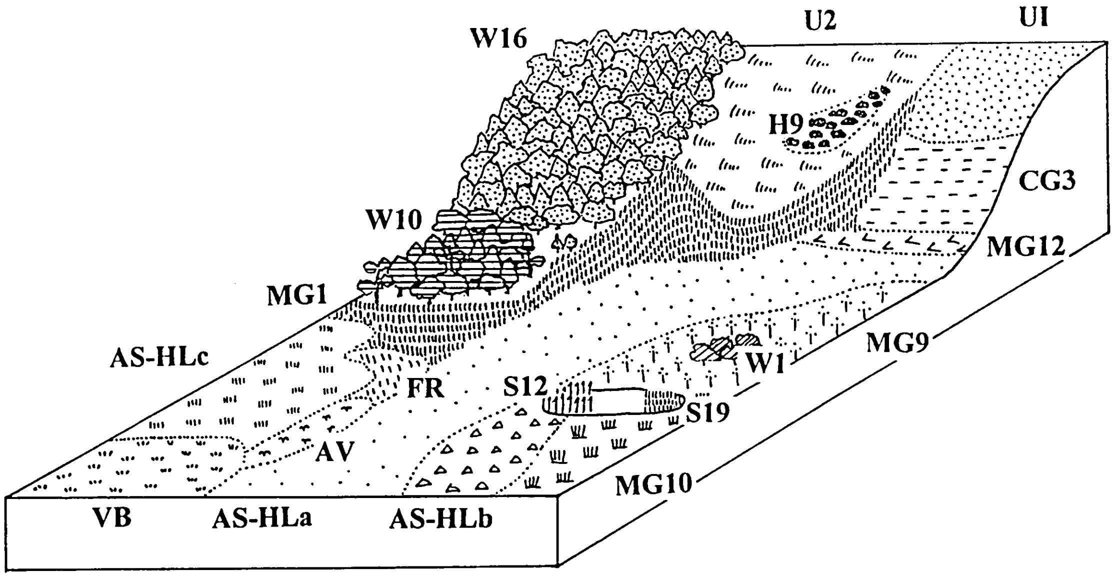
A schematic representation of the plant communities of naturally regenerated deep-mine sites, and zonation showing nearest neighbours is given in Figure 13. This is compiled from the basic topographic information collected in the survey of slope (gradient), aspect, altitude, soil wetness, together with information of the relationship of the identified NVC communities to each other on sites. For example, the majority of W16 woodlands were found on the steeply sloping sides of colliery tips; the P2 pioneer sub-communities were frequently observed adjacent to each other with the wetter P2c sub-community itself being then found adjacent to swamp communities. In essence, the parameters in the diagram have been simplified to illustrate slope vs flat ground, and wet vs dry conditions and are thus simplistic. No conclusions could be drawn from aspect.

Altitudinal variations were difficult to ascertain, given the few samples taken at higher elevations, however the highest sites sampled supported species and communities such as U4 grassland and H9 heath more associated with the vegetation of moorland and upland grasslands found in the Pennine hills of the surrounding landscape. The diagram therefore largely reflects the situation on the low-lying ground covering the majority of the study area. The schematic diagram does not encompass aspects of soil chemistry which were not addressed in this study and are known to have significant influences on vegetation. As the communities were all encountered on colliery spoils derived from the same Coal Measure sub-strata, they are all illustrated as a composite, including the calcareous grassland CG3 community which may have occurred because of the unique circumstances (on the junction of Coal Measures and Magnesian Limestone solid geology) on the one site where it was found, where some mixing of Magnesian Limestone material may have occurred. Clearly, the schematic is illustrative, and reflects observations made and data gathered. It does not prove cause and effect, and there is significant variation between sites, habitats and communities which cannot be represented.

However, the diagram can serve as a simple model for the succession of plant communities on the shales of the Coal Measures of Yorkshire, northern England, and could be applied at regional scale (2500 km sq.), contributing to knowledge of plant succession at this scale (Glenn-Lewin *et al*, 1992).

For subsidence wetlands and opencast sites, a strong feature of colonisation by vegetation is its rapidity. Many of the newly created sites quickly develop luxuriant aquatic and marginal vegetation, whilst development on subsidence wetlands can also be rapid leading to extensive areas of reedswamp and marsh. Early colonisation by many of the newly created water bodies seems to be by Charophytes although to what extent these communities persist is unknown. In some waterbodies these seem be overtaken by aquatic macrophytes. These early stages of aquatic colonisation also have faunal links, and records of large numbers of wildfowl feeding on newly created lakes e.g. Pochard and Goldeneye at Anglers would repay further investigation.

The natural colonisation of vegetation on deep-mine sites is characterised by a wide range of plant comunities and species. This richness of vegetation is also reflected in those opencast restorations in which natural development has been allowed to proceed, well illustrated by the heathland site at Seckar Wood and the grassland at Scholes Common. In other words, the richer vegetation is produced by natural regeneration. By contrast, landscaped opencast and deep-mine sites have a much poorer range of plant communities present, and even those communities are inherently poor in species e.g. the *Lolium perenne* grasslands. To a certain extent this may be due to a homogenising of the physical features of the sites through the creation of gentle topographical profiles followed by a standard finishing treatment of topsoiling and vegetation establishment, thus reducing the variability of ecological niches caused by wetness, slope, substrate and fine-grained topographical variation which are found on untreated sites and which offer naturally colonising vegetation a wide range of opportunity.



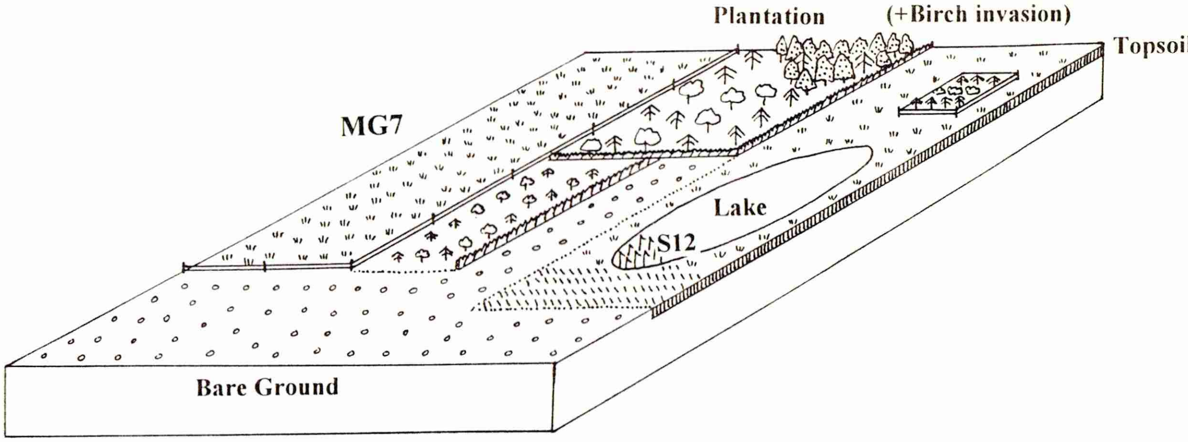
Key:

AS-HL	*Agrostis stolonifera-Holcus lanatus* pioneer vegetation
AS-HLa	*Agrostis stolonifera* sub-community
AS-HLb	*Tussilago farfara* sub-community
AS-HLc	*Hypochoeris radicata* sub-community
VB	*Vulpia bromoides-Arenaria serpyllifolia* pioneer vegetation
U1	*Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland
U2	*Deschampsia flexuosa* grassland
H9	*Calluna vulgaris-Deschampsia flexuosa* heath
MG1	*Arrhenatherum elatius* grassland
MG9	*Holcus lanatus-Deschampsia cespitosa* grassland
MG10	*Holcus lanatus-Juncus effusus* rush pasture
MG12	*Festuca arundinacea* coarse grassland
CG 3d	*Bromus erectus* grassland
AV	*Anthyllis vulneraria* lawns
FR	*Festuca rubra-Lotus corniculatus* grassland
W10	*Quercus-Pteridium aquilinum-Rubus fruticosus* woodland
W16	*Quercus spp.-Betula spp.-Deschampsia flexuosa* woodland

Figure 13.
Schematic representation of natural plant community development on abandoned collieries and spoil tips in Yorkshire. (Note that the substrate is constant being mixed horizons extracted from the Coal Measures, except for CG3 which has additional material from the Magnesian Limestone).

However, the aims of most restorations to date have been to agriculture, whether arable or grassland, or amenity, where biodiversity considerations have not been considered. Some attempts at diversifying the types of vegetation on restored sites have been tried e.g. the creation of 'wild-flower meadows' and those sampled in the study such as the Banks site represent early attempts to mirror more naturally developed grasslands.

A schematic representation of plant communities found on restored sites is shown in Figure 14. This reflects the artificial nature of the restorations, with sculpted landscapes and sown/planted vegetation. Some naturally colonised communities may be present in the waterbodies, and failed plantations may be re-invaded by birch woodland. There is no natural relationship between one community and another.



Key:

MG7	*Lolium perenne* grassland
S12	*Typha latifolia* swamp
Plantation	Planted woodland/scrub
+ Birch	Plantation naturally invaded by Birch

Figure 14.
Schematic representation of plant communities on landscaped mining land - deep-mine and opencast sites in Yorkshire.

Plantation woodland on colliery site invaded by *Betula.* Mitchell Main Colliery. May 1993.

At a landscape scale, the study area of 2500 sq.km represents a large enough area to predict the direction of vegetation development on Coal Measure substrates, given no intervention (Figure 13), and indeed even with human modification, this trend is still apparent unless management intervenes. The re-invasion by *Betula* spp. and *Quercus* spp. of failing plantations e.g. on Mitchell Main Tip (Plate 28) strongly signals the natural development of *Betula-Quercus* woodland (W10 or W16), although ground flora composition is somewhat less clear to be able to accurately predict which. It is likely however, that the development of W16 woodland would represent a relatively stable woodland community in the study area on such sites.

Faunal colonisation

Faunal colonisation of all types of sites by a range of fauna appears to be rapid, not only following vegetation establishment, but sometimes in parallel, for instance the use of deep-mine sites by open-ground invertebrates and birds such as Little Ringed Plovers. A feature of these early stages of colonisation is the establishment of faunal assemblages which are rare in the mature landscape e.g. by open ground species.

As vegetation establishes, different assemblages which may be found elsewhere appear. Some of these appear to support abundant populations e.g. common butterflies and whilst this may be a function of lack of management of grasslands on colliery sites in comparison to agricultural grasslands, the study sites may act as sources of individuals for colonisation of other sites i.e. as population sources. Scrub and coarse grasslands appear to be productive for birds and invertebrates. Similarly, the early stages of aquatic communities may also appear productive e.g. the large newt populations flourishing in a pond with few obvious competitors.

Mining sites can support sparse mammal populations, and fulfil some aspects of individual species' requirements, e.g. the use of old adits as Badger setts, or as resting/foraging areas for Brown Hares. The most abundant mammal, Rabbit, can also thrive and contribute to the gradual development of sites via excavations and dung. Amphibians can colonise rapidly, especially Common Frogs found breeding in temporary ponds on deep-mine sites and other wetlands, whereas large population increases can occur if conditions are right e.g. the newt pond. Few data are available for fish, although many of the created water-bodies support stocked fisheries which provide food for birds e.g. grebes, Cormorant.

The highly unusual brackish water fauna and flora at Mickletown Ings clearly demonstrates that colonisation of unexpected biota can occur if conditions are suitable, here supported by the saline run-off from the adjacent colliery spoil tip. Work on 'restoring' the tip began in the mid-1990's and monitoring changes in these features may be instructive.

4.3. Restoration

The study found little evidence to support the suggestion that nature conservation was seen as an important element in the restoration of sites, particularly deep-mine sites, although specialist ecological input was available, and advice was provided on some schemes. Some results of 'successful restorations' of Yorkshire sites in the traditional sense of providing vegetation cover are published as case studies (Land Use Consultants, 1996), with generalisations of their value for wildlife. Studies of the bird assemblages of opencast sites restored to farmland in Wales (Tyler & Geach 1989, Anon. 1990) concluded that the bird faunas were impoverished relative to farmland control sites, although insufficient data are available in this study to compare with these conclusions.

In contrast, wetland opencast restorations were much more successful in terms of the eventual nature conservation value of the sites, and ecological advice had been clearly incorporated. However, a variation in the quality of some restorations was apparent, with wildlife clearly the major aim at the most successful site (St. Aidans), but wildlife a subsidiary but still successful aim at others e.g. Anglers, Rother Valley. Here, attempts are now being made to try and improve the wildlife component of the former site through management and incorporation of new features (D. Stokoe, *pers. comm.*), a practice which would have been easier if the features had been designed in from the start (Merritt, 1994). Deep-mine restorations including water features have had the benefit of some previous experience, and the contouring can be potentially more sympathetic to wildlife (Plate 29).

Plate 29.
Restored deep-mine site with some provision for wildlife in the form of water features. Walton Colliery. July 1995.

In contrast, perhaps the most striking example of the low priority given to nature conservation possibilities on deep-mine site restorations is that of Upton Colliery, arguably the 'best' naturally regenerated site found in the study supporting the widest range of plant communities, including two communities not replicated elsewhere, where a restoration scheme implemented during the course of this study failed to safeguard any features of significance despite detailed ecological input from a range of organisations (Plates 30 and 31).

Plate 30.
Natural colonisation of vegetation on colliery site prior to restoration. Flower rich swards, Upton Colliery. July 1993.

Plate 31.
Colliery site stripped of natural vegetation prior to restoration scheme. Upton Colliery. August 1994.

5. RECOMMENDED FURTHER WORK

5.1. Safeguard of sites of importance for nature conservation

The study has highlighted the need for some of the best sites found in the study area to be safeguarded for their nature conservation value or ecological significance for education or research.

Mechanisms for safeguard of sites include designations, incentives for management, and information dissemination to enable decision makers involved on those sites to be aware of their significance.

Designation as SAC, SSSI and second-tier sites is already given to a number of the study sites, but consideration should be given to progressing further designations by the appropriate authorities to the following sites:

Broomhill	Breeding & wintering birds
Manvers	Invertebrate assemblage, *Corrigiola litoralis*
Tankersley Golf Course	U1 grassland, historical
Tankersley Colliery	*Vulpia* pioneer vegetation
Walton colliery	Odonata, birds,
St. Aidans	Birds
Falthwaite	Insects, GCNewt, pioneer vegetation, badgers
Upton	Most diverse plant community site*
Skiers Spring	Nturally developed woodland
Mitchell Main	Scientific potential, woodland
Thorne	Pioneer vegetation
Denby Grange	Amphibians
Altofts	Wildfowl
Old Denaby	Breeding bird community

No pioneer vegetation is currently apparently recognised for its nature conservation value as reflected in any designation, but four deep-mine sites are proposed as having the best interest (Upton, Tankersley, Thorne and Falthwaite), which would be representative of these plant communities. One opencast site (Scholes Common) is currently recognised for its grassland interest, and one deep-mine site (Tankersley Golf Course) is proposed because of its U1 grassland community. One opencast lowland heath (Seckar Wood) is already recognised of national significance, and although fragments of heath exist elsewhere, no further substantial sites are proposed. Ten openwater/swamp/marsh sites are already recognised (7 subsidence flashes, 2 opencast sites and one deep-mine site). One deep-mine woodland (Silkstone Fall Wood) is currently recognised, and two deep-mine sites (Skiers Spring and Mitchell Main) are proposed for purposes of research/recorded history.

One deep-mine site (Havercroft) is recognised for its plant interest (*Ophrys apifera*), and although other significant species are recorded for all category of site, most species and populations are located on sites already recognised or proposed for other reasons. The grounds for designation of this site is inconsistent with the evaluation carried out in this study, as this species is as widespread as others of arguably more conservation concern. One deep-mine site is proposed for *Corrigiola litoralis* (Manvers) though this reinforces that sites's invertebrate interest.

As far as faunal interest is concerned, two deep-mine sites (Denby Grange and Falthwaite) are proposed for herptile interest, one at international level. Seven sites are already recognised for their bird interest (three subsidence sites and four opencast sites), mainly wintering wildfowl but also from a migratory point of view (hirundine and passerine roosts, autumn waders), and two further subsidence sites are proposed (Old Denaby and Altofts). Some re-evaluation of individual sites is warranted in this category, since one site (Broomhill) merits national recognition for both wintering and breeding birds, and two sites (Denaby and Sprotborough) clearly do not merit national recognition for their bird interest, although other attributes at these sites may be relevant.

No 'sites' as such for mammals are either recognised or proposed, but the presence of Badgers at three sites contributes to the overall interest there, and both Water Vole and Harvest Mouse contribute to the overall interest of other recognised sites. It is however apparent that some deep-mine sites can contribute to the conservation of Brown Hares (a BAP species). It is likely that many of the sites will contribute in the general landscape to the conservation of other mammals, notably bats (Chiroptera) which have been recorded on some sites, but about which an extensive review was not possible.

The use of management incentive schemes to secure appropriate management of the sites is recommended, however it must be recognised that for many of the habitats and plant communities, especially the pioneer communities, technical knowledge is scant, and there is the danger that methods appropriate to other traditional ecosystems will be substituted. This area should be the subject of further research.

Dissemination of information is important to decision makers involved in the reclamation of sites so that nature conservation and ecological considerations can be incorporated into site assessments, design plans, implementation schemes and subsequent management programmes.

5.2. Research

The study has highlighted the value of all categories of study site for ecology, and in particular studies of plant colonisation, plant community establishment and development, seral succession, animal colonisation, animal population changes and trends. These studies can illuminate techniques for land restoration. Some specific investigations could include:

1. Techniques for the acceleration of natural regeneration, such as investigation of the use of Mycorrhiza in conjunction with primary colonisers such as birch.
It is suggested that one of the reasons for failure of many tree planting schemes into spoil-heaps is that the root-ball is buried into a sterile environment and can only flourish with the sustained application of nutrients and management. In contrast, the success of some natural regeneration may be through associations with Mycorrhiza in the seed and seedling establishment phases by species such as birch.

2. Mimicry of the establishment of the naturally occurring NVC plant communities found during this study using local seed sources, rather than the creation of other

artificial communities such as hay-meadows. For instance the creation of *Deschampsia flexuosa* grassland in its own right as well as a precursor for other vegetation types, could be a novel approach to restoration.

3. The enhancement of established but immature vegetation e.g. *D. flexuosa* grassland to accelerate succession to a more diverse end-point. For instance, the eventual creation of H8 or H9 heathlands using both seed inoculation and seedling plantings.

4. The use of animal population enhancement, focusing on those species of significance, for instance research into why butterfly populations are significant.

5. Autecological studies leading to management recommendations for species of note e.g. Dingy Skipper, Strapwort, to aid their effective conservation.

6. Consideration of management techniques for arresting succession of pioneer communities in order to preserve examples in the landscape for nature conservation purposes.

7. Further investigation into the ecology of pioneer and early grassland plant and animal communities especially further analysis of soil types in relation to community distribution and character with a view to underatanding cause and effect.

8. The monitoring of colonisation and community development at restored sites e.g. wildfowl on open waters inorder to gain insights into the ecology of such groups and provide future guidance on management.

9. Monitoring the development of transplanted communities (marsh, grassland) on virgin colliery spoil for success (Allerton Receptor Site).

10. Autecological studies into species difficult to identify, notably *Hieracium* spp., *Vulpia* spp. and *Agrostis* spp., to clarify and investigate occurrence, niche and hybridisation.

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7. APPENDICES

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Appendix 1. ***Agrostis stolonifera-Holcus lanatus*** **pioneer vegetation**

	a	b	c	d
Agrostis stolonifera	V (2-9)	V (2-9)	V (2-8)	V (2-9)
Holcus lanatus	IV (1-9)	IV (1-5)	V (1-8)	IV (1-9)
Tripleurospermum inodorum	II (2-4)		I (1-2)	I (1-4)
Reseda luteola	II (1-3)			I (1-3)
Atriplex prostrata	I (2-5)			I (2-5)
Arenaria serpyllifolia	I (3-5)			I (3-5)
Centaurea nigra	I (1-5)			I (1-5)
Bromus hordeaceu	I (1-5)			I (1-5)
Polygonum aviculare	I (1-4)			I (1-4)
Senecio viscosus	I (4)			I (4)
Corrigiola litoralis	I (2-4)			I (2-4)
Potentilla reptans	I (4)			I (4)
Senecio squalidus	I (1-3)			I (1-3)
Spergularia rubra	I (2-3)			I (2-3)
Achillea millefolium	I (2-3)			I (2-3)
Linaria vulgaris	I (3)			I (3)
Melilotus officinalis	I (1-2)			I (1-2)
Reseda lutea	I (1-2)			I (1-2)
Holcus mollis	I (2)			I (2)
Equisetum arvense	I (1)			I (1)
Poa annua	I (1)			I (1)
Rumex obtusifolius	I (1)			I (1)
Aira praecox	I (1)			I (1)
Anagallis arvensis	I (1)			I (1)
Tanacetum vulgare	I (1)			I (1)
Dactylorhiza praetermissa	I (1)			I (1)
Melilotus albus	I (1)			I (1)
Vicia hirsuta	I (1)			I (1)
Epilobium spp.	I (1)			I (1)
Tussilago farfara	I (1-8)	IV (2-6)	II (3-4)	II (1-8)
Hieracium sabaudum group	II (1-3)	II (1-3)	I (1)	II (1-3)
Festuca rubra	I (1)	II (1-4)	I (1-6)	I (1-6)
Taraxacum Sect. vulgare	I (1-2)	II (1-3)	II (1-3)	I (1-3)
Campylopus introflexus	I (1-4)	II (1-7)	I (5-6)	I (1-7)
Deschampsia cespitosa	I (1)	II (1-8)		I (1-8)
Mnium hornum		I (1-2)		I (1-2)
Dactylorhiza fuchsii		I (1)		I (1)
Potentilla erecta		I (1)		I (1)
Hypericum perforatum		I (1-4)		I (1-4)
Matricaria discoidea		I (1)		I (1)

Hypochoeris radicata	II (1-3)	III (1-6)	IV (1-4)	II (1-6)
Cirsium arvense	II (1-3)	II (1-3)	III (2-3)	II (1-3)
Centaurium erythraea	I (1-4)	I (2-3)	III (2-4)	I (1-4)
Medicago lupulina	I (1)	I (1)	III (2-4)	I (1-4)
Agrostis capillaris	I (1)		III (2-5)	I (1-5)
Trifolium pratense		I (2)	III (1-3)	I (1-3)
Cerastium fontanum	I (1-3)	I (1-3)	II (1-3)	I (1-3)
Trifolium repens	I (3-4)	I (1-5)	II (1-4)	I (1-4)
Senecio jacobaea	I (1-2)	I (1)	II (1-2)	I (1-2)
Crepis capillaris	I (1-5)		II (2-5)	I (1-5)
Linum catharticum			II (2-3)	I (2-3)
Anthyllis vulneraria			I (3-6)	I (3-6)
Bellis perennis			I (3)	I (3)
Geranium molle			I (2-3)	I (2-3)
Silene uniflora			I (2-4)	I (2-4)
Carex flacca			I (6)	I (6)
Cynosurus cristatus			I (4)	I (4)
Poa trivialis			I (3)	I (3)
Trifolium campestre			I (2)	I (2)
Artemisia absinthum			I (1)	I (1)
Brachypodium pinnatum			I (1)	I (1)
Lotus pedunculatus			I (1)	I (1)

Rubus fruticosus agg.	I (1-8)	I (1)	I (1-2)	I (1-8)
Cerastium glomeratum	I (2-4)	I (1-2)	I (2)	I (1-4)
Lotus corniculatus	I (1-3)	I (1-3)	I (1-2)	I (1-3)
Sagina apetala	I (1-3)	I (1-3)	I (3)	I (1-3)
Sagina procumbens	I (1-2)	I (1-2)	I (2)	I (1-2)
Deschampsia flexuosa	I (1)	I (1)	I (2)	I (1-2)
Plantago major	I (1)	I (1-2)	I (1-2)	I (1-2)
Elytrigia repens	I (4-6)	I (3-7)	I (2)	I (2-7)
Dactylis glomerata	I (1-3)	I (1)	I (1)	I (1-3)
Festuca ovina	I (1)	I (1)	I (1-4)	I (1-4)
Sonchus asper	I (5)	I (1)	I (1)	I (1-5)
Sonchus oleraceus	I (1)	I (1-2)	I (1)	I (1-2)
Vulpia myuros	I (2-7)	I (1)	I (4)	I (1-7)
Poa pratensis	I (3-5)	I (2-3)		I (2-5)
Poa compressa	I (2)	I (1-2)		I (1-2)
Ranunculus repens	I (1)	I (1-2)		I (1-2)
Rumex acetosella	I (1-2)	I (1-4)		I (1-4)
Hieracium murorum group	I (1)	I (1)		I (1)
Arrhenatherum elatius	I (2)	I (1)		I (1-2)
Juncus effusus	I (2-3)	I (1)		I (1-3)
Lolium perenne	I (1)	I (2)		I (1-2)
Oenothera glazoviana	I (1-3)	I (1)		I (1-3)
Pulicaria dysenterica	I (1)	I (1)		I (1)
Trifolium arvense	I (1)	I (3)		I (1-3)
Prunella vulgaris		I (1)	I (3)	I (1-3)
Leucanthemum vulgare		I (1)	I (2-3)	I (1-3)
Pilosella officinarum		I (2)	I (2)	I (2)

Chamerion angustifolium	I (2-3)		I (2)	I (2-3)
Daucus carota	I (1)		I (1)	I (1)
Epilobium montanum	I (2)		I (1)	I (1-2)
Vicia sepium	I (1)		I (1)	I (1)
Vulpia bromoides	I (3)		I (5-7)	I (3-7)
Artemisia vulgaris	I (2)		I (2)	I (2)
Carex otrubae	I (1-3)		I (1)	I (1-3)
Filago vulgaris	I (1)		I (1)	I (1)
Phragmites australis	I (1)		I (3)	I (1-3)
Alnus glutinosa sapling	I (1)	I (1)		I (1)
Alnus incana sapling	I (1)			I (1)
Betula pendula sapling	I (4-8)	I (2-8)	I (1-8)	I (1-8)
Betula pendula seedling	I (1)	I (3)		I (1-3)
Betula pubescens sapling	I (8)			I (8)
Betula pubescens seedling	I (1)	I (3-4)		I (1-4)
Betula X seedling	I (4)	I (1)	I (2)	I (1-4)
Crataegus monogyna sapling	I (1)	I (1)		I (1)
Crataegus monogyna seedlin	I (2)	I (1)		I (1)
Fagus sylvatica sapling	I (3)			I (3)
Populus canescens sapling	I (2)			I (2)
Populus canescens seedling		I (2)		I (2)
Quercus petraea sapling	I (1-4)			I (1-4)
Quercus petraea seedling	I (2-3)	I (1)		I (1-3)
Quercus robur sapling	I (1)			I (1)
Salix caprea sapling		I (2)	I (1)	I (1-2)
Salix cinerea sapling	I (8)	I (1)	I (5)	I (1-8)
Salix cinerea seedling	I (2)		I (1)	I (1)
Rosa canina	I (1)			I (1)
Cytisus scoparius	I (1)			I (1)
Ulex europaeus	I (1)			I (1)
Number of samples	57	36	17	110
Number of species/samples	7 (2-16)	8 (4-16)	11 (8-16)	8 (2-16)

a *Agrostis stolonifera* sub-community
b *Tussilago farfara* sub-community
c *Hypochoeris radicata* sub-community
d *Agrostis stolonifera-Holcus lanatus* community (total)

Appendix 2. *Vulpia bromoides-Arenaria serpyllifolia* pioneer vegetation

Vulpia bromoides	V (1-9)
Arenaria serpyllifolia	III (1-4)
Holcus lanatus	III (1-5)
Plantago lanceolata	III (2-4)
Hypochoeris radicata	III (1-3)
Cerastium fontanum	II (1-3)
Leucanthemum vulgare	II (1-3)
Lotus corniculatus	II (1-6)
Medicago lupulina	II (1-4)
Pilosella officinarum agg.	II (1-4)
Vulpia myuros	II (2-5)
Dactylis glomerata	II (1-3)
Poa annua	II (1-3)
Poa pratensis	II (1-6)
Trifolium pratense	II (2-4)
Aira praecox	II (1-4)
Anthyllis vulneraria	II (1-5)
Sagina apetala apetala	II (1-2)
Taraxacum sect. *vulgaria*	II (1-2)
Agrostis stolonifera	I (3-5)
Agrostis capillaris	I (2-4)
Aira caryophyllea	I (1-3)
Anisantha sterilis	I (1-3)
Catapodium rigidum	I (1-3)
Crepis vesicaria	I (1-2)
Sedum acre	I (5-7)
Bellis perennis	I (1-2)
Cerastium glomeratum	I (1-2)
Crepis capillaris	I (1)
Trifolium repens	I (1-2)
Campylopus introflexus	I (2-3)
Achillea millefolium	I (1-2)
Bromus hordeaceus hordeaceus	I (1-2)
Cirsium arvense	I (1-2)
Erodium cicutarium	I (1-4)
Festuca ovina	I (1-6)
Rumex acetosella	I (2-3)
Sonchus oleraceus	I (1)
Spergularia rubra	I (1-2)
Tussilago farfara	I (1-3)
Arrhenatherum elatius	I (1)
Artemisia vulgaris	I (2)
Capsella bursa-pastoris	I (1)
Centaurea nigra	I (2)
Centaurium erythraea	I (2)
Chaenorhinum minus	I (1)
Cirsium vulgare	I (1)

Daucus carota	I (2)
Erophila verna agg.	I (1)
Festuca rubra	I (2)
Heracleum sphondylium	I (1)
Hieracium sabaudum group	I (2)
Holcus mollis	I (3)
Hypericum perforatum	I (3)
Linaria repens	I (2)
Linaria vulgaris	I (1)
Linum catharticum	I (2)
Milium effusum	I (3)
Myosotis discolor	I (1)
Ononis repens	I (4)
Plantago major	I (1)
Poa compressa	I (3)
Reseda luteola	I (2)
Rubus fruticosus agg.	I (1)
Rumex obtusifolius	I (1)
Senecio jacobaea	I (2)
Senecio squalidus	I (2)
Senecio viscosus	I (1)
Trifolium campestre	I (2)
Trifolium dubium	I (1)
Trisetum flavescens	I (1)
Veronica polita	I (2)
Vicia sepium	I (1)
Vicia sativa	I (1)
Apera interrupta	I (2)
Number of samples	20
Number of species/sample	12 (6-22)

Appendix 3. U1 *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland

Festuca ovina	V	(4-9)
Rumex acetosella	IV	(1-4)

Pilosella officinarum	III	(2-5)
Agrostis capillaris	III	(2-6)
Hypochoeris radicata	III	(2-5)
Aira praecox	III	(2-5)
Hieracium sabaudum group	II	(1-3)
Lotus corniculatus	II	(2-4)
Cerastium fontanum	I	(1)
Deschampsia flexuosa	I	(3-5)
Galium saxatile	I	(3-4)
Chamerion angustifolium	I	(1-3)
Poa pratensis	I	(1)
Anthyllis vulneraria	I	(4)
Arrhenatherum elatius	I	(1-6)
Dactylis glomerata	I	(2)
Holcus lanatus	I	(2-5)
Betula pendula tree	I	(6-8)
Bromus hordeaceus hordeaceus	I	(1)
Campanula rotundifolia	I	(3)
Galium verum	I	(3)
Lolium perenne	I	(1)
Poa compressa	I	(1)
Taraxacum sect. *vulgaria*	I	(1)
Tussilago farfara	I	(1)
Veronica officinalis	I	(1)
Polytrichum juniperinum	I	(4)
Elytrigia repens	I	(4)
Agrostis stolonifera	I	(5)
Aira caryophyllea	I	(1)
Calluna vulgaris	I	(1)
Carex flacca	I	(1)
Centaurium erythraea	I	(2)
Cirsium arvense	I	(1)
Digitalis purpurea	I	(2)
Festuca rubra	I	(4)
Holcus mollis	I	(4)
Lathyrus pratensis	I	(1)
Plantago lanceolata	I	(1)
Quercus petraea tree	I	(4)
Quercus robur tree	I	(4)
Quercus x rosacea tree	I	(4)
Rumex acetosa	I	(1)
Senecio jacobaea	I	(2)
Trifolium medium	I	(1)
Trifolium repens	I	(2)

Vicia sativa nigra	I	(1)
Campylopus introflexus	I	(1)
Hypnum cupressiforme	I	(2)
Cladonia fimbriata	I	(1)
Crataegus monogyna tree	I	(1)
Teucrium chamaedrys	I	(2)
Number of samples	47	
Number of species/sample	6.4 (2-11)	

Appendix 4. U2 *Deschampsia flexuosa* grassland

Deschampsia flexuosa	V	(2-9)
Agrostis capillaris	III	(1-8)
Calluna vulgaris	II	(1-8)
Festuca ovina	II	(3-8)
Campylopus introflexus	II	(2-8)
Chamerion angustifolium	II	(1-3)
Rumex acetosella	II	(1-3)
Agrostis stolonifera	I	(1-4)
Galium saxatile	I	(1-3)
Nardus stricta	I	(2-6)
Hieracium murorum group	I	(2-3)
Hieracium sabaudum group	I	(1-3)
Hupochoeris radicata	I	(1-2)
Anthoxanthum odoratum	I	(2)
Deschampsia cespitosa	I	(1-2)
Juncus effusus	I	(1-3)
Vaccinium myrtillus	I	(1-2)
Polytrichum juniperinum	I	(2-4)
Quercus petraea sapling	I	(3-5)
Holcus lanatus	I	(3)
Poa pratensis	I	(2-4)
Potentilla erecta	I	(1-2)
Mnium hornum	I	(3)
Polytrichum commune	I	(2-3)
Betula pubescens sapling	I	(1-4)
Fagus sylvatica sapling	I	(1-3)
Betula pendula sapling	I	(6)
Carex nigra	I	(1)
Cirsium arvense	I	(4)
Holcus mollis	I	(2)
Lathyrus pratensis	I	(4)
Lotus corniculatus	I	(1)
Luzula campestris	I	(4)
Pilosella officinarum agg	I	(2)
Rubus fruticosus agg	I	(1)
Salix cinerea sapling	I	(1)
Taraxacum sect. vulgaria	I	(1)
Ceratodon purpureus	I	(3)
Funaria hygrometrica	I	(3)
Hupnum cupressiforme	I	(3)
Sphagnum fimbriatum	I	(2)
Cladonia fimbriata	I	(3)
Fraxinus excelsior sapling	I	(1)
Castanea sativa sapling	I	(1)
Betula seedling	I	(1)
Quercus seedling	I	(2)

Number of samples	28
Number of species/sample	5.9 (2-11)

Appendix 5. MG1 *Arrhenatherum elatius* grassland

Arrhenatherum elatius	V	(4-9)
Holcus lanatus	V	(2-7)
Centaurea nigra	III	(1-4)
Agrostis capillaris	II	(3-6)
Plantago lanceolata	II	(1-3)
Agrostis stolonifera	II	(2-3)
Cirsium arvense	II	(1-5)
Senecio aquaticus	II	(1-2)
Artemisia vulgaris	II	(2-4)
Carex flacca	II	(2)
Dactylis glomerata	II	(1-4)
Poa pratensis	II	(1-4)
Ranunculus repens	II	(1-3)
Senecio jacobaea	II	(2-3)
Trifolium repens	II	(2-3)
Vicia cracca	II	(1-2)
Deschampsia cespitosa	I	(3-4)
Lathyrus pratensis	I	(2-3)
Lotus corniculatus	I	(1-3)
Prunella vulgaris	I	(1)
Silene latifolia	I	(1-2)
Taraxacum sect. *vulgaria*	I	(1-3)
Trifolium pratense	I	(1-3)
Tussilago farfara	I	(2-3)
Achillea millefolium	I	(2)
Carex hirta	I	(2)
Chamerion angustifolium	I	(2)
Leucanthemum vulgare	I	(2)
Crataegus monogyna seedling	I	(1)
Heracleum sphondylium	I	(1)
Hieracium sabaudum group	I	(2)
Hypochoeris radicata	I	(1)
Lolium perenne	I	(3)
Pilosella officinarum agg	I	(1)
Reseda lutea	I	(4)
Stachys sylvatica	I	(1)
Trifolium campestre	I	(2)
Urtica dioica	I	(5)
Campylopus introflexus	I	(2)
Crataegus monogyna	I	(6)
Hieracium murorum group	I	(1)
Number of samples	14	
Number of species/sample	8 (3-11)	

Appendix 6. MG7 *Lolium perenne* grassland

Lolium perenne	V	(7-10)
Dactylis glomerata	V	(3-4)
Trifolium repens	II	(4-7)
Cirsium arvense	I	(1)
Lolium multiflorum	I	(9)
Lotus corniculatus	I	(2)
Poa pratensis	I	(5)
Number of samples	6	
Number of species/sample	2.67	(2-4)

Appendix 7. *Holcus lanatus - Deschampsia cespitosa* grassland

Holcus lanatus	V	(2-8)
Deschampsia cespitosa	IV	(2-9)

Cirsium arvense	III	(1-4)
Agrostis stolonifera	II	(2-4)
Juncus effuses	II	(1-4)
Arrhenatherum elatius	II	(1-9)
Tussilago farfara	II	(1-4)
Achillea ptarmica	I	(1-7)
Agrostis capillaris	I	(3-5)
Festuca rubra	I	(1-4)
Lotus corniculatus	I	(1-5)
Lotus pedunculatus	I	(2-8)
Ranunculus repens	I	(1-4)
Rumex acetosella	I	(1-3)
Carex flacca	I	(4-7)
Centaurea nigra	I	(3-4)
Hieracium sabaudum group	I	(1-3)
Plantago lanceolata	I	(2)
Poa pratensis	I	(2-3)
Senecio aquaticus	I	(3)
Betula pendula seedling	I	(7-8)
Alnus incana sapling	I	(2-7)
Carex disticha	I	(3-4)
Chamerion angustifolium	I	(1)
Cirsium palustre	I	(1)
Crataegus monogyna sapling	I	(1-2)
Dactylis glomerata	I	(1-3)
Dactylorhiza fuchsii	I	(1-5)
Deschampsia flexuosa	I	(2-4)
Equisetum arvense	I	(2-3)
Hypochoeris radicata	I	(3-4)
Juncus inflexus	I	(2-5)
Lathyrus pratensis	I	(3-4)
Rumex acetosa	I	(2)
Rumex obtusifolius	I	(1)
Taraxacum sect. *vulgaria*	I	(1)
Trifolium repens	I	(1-2)
Alnus glutinosa sapling	I	(2-4)
Salix cinerea seedling	I	(1)
Acer pseudoplatanus sapling	I	(4)
Elytrigia repens	I	(2)
Alopecurus geniculatus	I	(3)
Artemisia vulgaris	I	(3)
Calamagrostis epigejos	I	(5)
Leucanthemum vulgare	I	(2)
Cynosurus cristatus	I	(1)
Epilobium palustre	I	(1)

Genista tinctoria	I	(2)
Heracleum sphondylium	I	(3)
Leontodon autumnalis	I	(2)
Lycopus europaeus	I	(3)
Plantage major	I	(1)
Poa trivialis	I	(3)
Quercus cerris sapling	I	(3)
Ranunculus acris	I	(1)
Rubus fruticosus agg.	I	(1)
Cytisus scoparius	I	(8)
Senecio jacobaea	I	(1)
Trifolium pratense	I	(2)
Urtica dioica	I	(3)
Vicia cracca	I	(1)
Vicia hirsuta	I	(1)
Acer campestre sapling	I	(5)
Betula hybrid seedling	I	(1)
Crataegus monogyna seedling	I	(2)
Quercus robur sapling	I	(1)
Salix caprea	I	(1)
Prunus spinosa	I	(2)
Rosa canina	I	(1)
Robinia pseudacacia	I	(1)
Number of samples	21	
Number of species/sample	8.9	(5-19)

Appendix 8. *Holcus lanatus - Juncus effusus* rush pasture

Holcus lanatus	V	(3-6)
Juncus effuses	V	(5-9)
Deschampsia cespitosa cespitosa	III	(1-6)
Cirsium palustre	III	(1-3)
Cirsium arvense	II	(2)
Ranunculus repens	II	(3)
Rumex crispus	II	(1)
Rumex obtusifolius	II	(1-2)
Senecio jacobaea	II	(1-2)
Campylopus introflexus	II	(2-3)
Achillea ptarmica	I	(1)
Arrhenatherum elatius	I	(2)
Leucanthemum vulgare	I	(2)
Epilobium hirsutum	I	(2)
Festuca rubra	I	(1)
Lathyrus pratensis	I	(4)
Lotus pedunculatus	I	(4)
Plantago lanceolata	I	(3)
Poa trivialis	I	(3)
Tussilago farfara	I	(3)
Number of samples	7	
Number of species/sample	6.14	(2-11)

Appendix 9. MG12 *Festuca arundinacea* grassland

Festuca arundinacea	V	(2-8)
Festuca rubra	V	(2-7)
Leucanthemum vulgare	V	(1-3)
Pilosella officinarum agg.	V	(4-8)
Plantago lanceolata	V	(1-4)
Linum catharticum	IV	(2-4)
Daucus carota	IV	(1-3)
Lotus corniculatus	IV	(2-4)
Trifolium repens	III	(2-3)
Ophrys apifera	III	(1-2)
Trifolium pratense	III	(2-3)
Tussilago farfara	III	(2-4)
Hieracium sabaudum group	II	(1-3)
Holcus lanatus	II	(1-3)
Trisetum flavescens	II	(3)
Elytrigia repens	I	(1)
Anthyllis vulneraria	I	(1)
Arrhenatherum elatius	I	(1)
Cerastium fontanum	I	(2)
Cirsium arvense	I	(2)
Crataegus monogyna seedling	I	(1)
Dactylis glomerata	I	(1)
Erigeron acer	I	(2)
Hypochoeris radicata	I	(4)
Leontodon hispidus	I	(2)
Medicago lupulina	I	(1)
Poa compressa	I	(1)
Senecio jacobaea	I	(1)
Taraxacum sect. *vulgaria*	I	(1)
Vicia sativa	I	(1)
Hieracium murorum group	I	(1)
Number of samples	9	
Number of species/sample	11	(6-18)

Appendix 10. ***Anthyllis vulneraria*** **lawns**

Anthyllis vulneraria	V	(1-7)
Lotus corniculatus	V	(1-4)
Pilosella officinarum agg.	V	(1-6)
Plantago lanceolata	V	(1-4)
Dactylis glomerata	IV	(1-3)
Hypochoeris radicata	IV	(2-4)
Leucanthemum vulgare	IV	(1-3)
Linum catharticum	IV	(1-3)
Hieracium sabaudum group	III	(1-3)
Holcus lanatus	III	(1-3)
Deschampsia cespitosa cespitosa	III	(1)
Festuca pratensis	III	(5-6)
Festuca rubra	III	(7-9)
(*Festuca pratensis/rubra*	V	(5-9))
Achillea millefolium	II	(2-3)
Arrhenatherum elatius	II	(1-2)
Centaurium erythraea	II	(1-2)
Daucus carota	II	(2-3)
Trifolium repens	II	(1-2)
Campylopus introflexus	II	(3-4)
Heracleum sphondylium	I	(1)
Leontodon hispidus	I	(1)
Lolium perenne	I	(1)
Bromopsis erecta	I	(1)
Cerastium fontanum	I	(1)
Chamerion angustifolium	I	(1)
Dactylorhiza fuchsii	I	(1)
Leontodon saxatilis	I	(1)
Melilotus officinalis	I	(1)
Ophrys apifera	I	(1)
Poa pratensis	I	(2)
Potentilla reptans	I	(3)
Rumex acetosella	I	(2)
Senecio jacobaea	I	(1)
Trisetum flavescens	I	(2)
Tussilago farfara	I	(1)
Hieracium murorum group	I	(1)
Number of samples	10	
Number of species/sample	13.2	(10-17)

Appendix 11. *Festuca rubra - Lotus corniculatus* grassland

Festuca rubra	IV	(3-9)
Lotus corniculatus	IV	(3-6)

Leucanthemum vulgare	III	(1-4)
Holcus lanatus	III	(1-4)
Taraxacum sect. *vulgaria*	III	(1-3)
Poa pratensis	III	(1-7)
Trifolium pratense	III	(1-6)
Dactylis glomerata	III	(1-3)
Medicago lupulina	III	(1-4)
Plantago lanceolata	III	(1-4)
Agrostis stolonifera	II	(1-7)
Trifolium repens	II	(2-5)
Cynosurus cristatus	II	(1-4)
Carex flacca	II	(4-8)
Agrostis capillaris	II	(3-5)
Senecio jacobaea	II	(1-2)
Anthyllis vulneraria	I	(3-7)
Arrhenatherum elatius	I	(1-5)
Cerastium fontanum	I	(2)
Prunella vulgaris	I	(1-4)
Centaurea nigra	I	(3-6)
Cirsium arvense	I	(2-3)
Festuca ovina	I	(4-6)
Hypochoeris radicata	I	(1-4)
Pilosella officinarum agg	I	(3)
Tussilago farfara	I	(1-3)
Aira praecox	I	(3-4)
Arenaria serpyllifolia	I	(2)
Centaurium erythraea	I	(1-3)
Hieracium sabaudum group	I	(3)
Leontodon autumnalis	I	(1-2)
Lolium perenne	I	(3)
Rumex acetosella	I	(1-2)
Vicia hirsuta	I	(1-3)
Vicia sepium	I	(1-2)
Crataegus monogyna seedling	I	(2)
Achillea ptarmica	I	(3)
Alopecurus geniculatus	I	(3)
Bromus hordeaceus hordeaceus	I	(2)
Campanula rotundifolia	I	(2)
Dactylorhiza fuchsii	I	(2)
Deschampsia cespitosa cespitosa	I	(4)
Deschampsia flexuosa	I	(4)
Equisetum arvense	I	(2)
Genista tinctoria	I	(2)
Heracleum sphondylium	I	(2)
Leontodon hispidus	I	(2)

Lotus pedunculatus	I	(1)
Melilotus officinalis	I	(1)
Plantago major	I	(1)
Poa annua	I	(4)
Ranunculus repens	I	(1)
Rubus fruticosus agg.	I	(1)
Rumex obtusifolius	I	(1)
Cytisus scoparius	I	(8)
Sedum acre	I	(7)
Senecio aquaticus	I	(3)
Sonchus oleraceus	I	(3)
Trisetum flavescens	I	(4)
Urtica dioica	I	(4)
Vicia cracca	I	(1)
Vicia sativa	I	(4)
Number of samples	23	
Number of species per sample	10.43	(3-19)

Appendix 12. CG3. *Bromopsis erecta* grassland

Bromopsis erecta	V	(5-8)
Pilosella officinarum agg.	V	(3-4)
Poa pratensis	V	(1-4)
Trifolium pratense	V	(2-5)
Campanula glomerata	IV	(2-5)
Festuca rubra	IV	(1-2)
Leontodon hispidus	IV	(2-4)
Leucanthemum vulgare	II	(2-3)
Crepis capillaris	II	(1)
Dactylis glomerata	II	(1)
Erigeron acer	II	(1-3)
Helictotrichon pratense	II	(2)
Helictotrichon pubescens	II	(2-3)
Holcus lanatus	II	(2)
Lotus corniculatus	II	(2-3)
Trifolium repens	II	(1-2)
Agrostis stolonifera	I	(1)
Arenaria serpyllifolia	I	(2)
Arrhenatherum elatius	I	(1)
Bellis perennis	I	(1)
Centaurea nigra	I	(2)
Cerastium fontanum	I	(1)
Chamerion angustifolium	I	(1)
Crataegus monogyna seedling	I	(1)
Plantago media	I	(1)
Rubus fruticosus agg.	I	(1)
Number of samples	5	
Number of species/sample	13.2	(10-15)

Appendix 13. S12 *Typha latifolia* swamp community

Typha latifolia	V	(3-9)
Juncus effusus	V	(1-3)
Agrostis stolonifera	III	(5)
Alisma plantago-aquatica	III	(1)
Carex disticha	III	(9)
Epilobium hirsutum	III	(4)
Lycopus europaeus	III	(1)
Solanum dulcamara	III	(2)
Number of samples	2	
Number of species/sample	5	(3-7)

Appendix 14. S19 *Eleocharis palustris* swamp community

Eleocharis palustris	V	(8-9)
Alisma plantago-aquatica	IV	(1-5)
Agrostis stolonifera	II	(1-2)
Alopecurus geniculatus	II	(1-2)
Eriophorum angustifolium	II	(2-4)
Juncus articulatus	II	(2-3)
Typha latifolia	II	(2-3)
Epilobium hirsutum	I	(2)
Juncus effusus	I	(4)
Ranunculus repens	I	(3)
Number of samples	6	
Number of species/sample	3.83	(2-6)

Appendix 15. W10 *Quercus robur-Pteridium aquilinum-Rubus fruticosus* agg. woodland

Betula pendula	III	(1-9)
Alnus glutinosa	II	(2-9)
Fagus sylvatica	II	(4-7)
Acer pseudoplatanus	II	(4-6)
Fraxinus excelsior	II	(2-4)
Quercus petraea	I	(3-6)
Salix caprea	I	(1-2)
Sorbus aucuparia	I	(2)
Crataegus monogyna	I	(1)
Pinus nigra	I	(1)
Salix cinerea	I	(1)
Alnus incana	I	(2)

Fraxinus excelsior sapling	II	(8)
Salix caprea	II	(1-3)
Ulmus glabra	I	(2-3)
Betula pendula	I	(3-4)
Salix cinerea	I	(1)
Acer pseudoplatanus	I	(3)
Betula pubescens	I	(3)
Rosa canina	I	(1)

Rubus fruticosus agg.	IV	(4-9)
Agrostis capillaris	III	(3-4)
Chamerion angustifolium	III	(1-3)
Galium aparine	II	(1-5)
Holcus lanatus	II	(4-7)
Holcus mollis	II	(2-5)
Milium effusum	II	(3)
Urtica dioica	II	(3)
Arrhenatherum elatius	II	(4-6)
Epilobium montanum	II	(1-2)
Poa trivialis	II	(2-7)
Artemisia vulgaris	I	(1-2)
Centaurea nigra	I	(1-2)
Circaea lutetiana	I	(2-3)
Dactylis glomerata	I	(1)
Geum urbanum	I	(1-2)
Hieracium sabaudum group	I	(3)
Trifolium pratense	I	(3)
Teucrium chamaedrys	I	(2)
Agrostis stolonifera	I	(1)
Leucanthemum vulgare	I	(1)
Cirsium arvense	I	(2)
Deschampsia cespitosa cespitosa	I	(4)

Deschampsia flexuosa	I	(6)
Digitalis purpurea	I	(1)
Dryopteris filix-mas	I	(2)
Geranium robertianum	I	(2)
Heracleum sphondylium	I	(3)
Lathyrus pratensis	I	(2)
Plantago lanceolata	I	(3)
Pteridium aquilinum	I	(2)
Saponaria officinalis	I	(2)
Senecio jacobaea	I	(1)
Taraxacum sect. *vulgaria*	I	(3)
Trifolium repens	I	(3)
Campylopus introflexus	I	(2)
Mnium hornum	I	(2)
Crataegus monogyna seedling	I	(1)
Number of samples	12	
Number of species/sample	10.67	(4-16)

Appendix 16. W16 *Quercus* spp.- *Betula* spp.- *Deschampsia flexuosa* woodland

Betula pendula canopy	V	(5-9)
Quercus petraea	IV	(1-7)
Acer pseudoplatanus	II	(1-5)
Quercus robur	II	(1-5)
Quercus x rosacea	II	(2-7)
Betula pubescens	I	(2-4)
Alnus glutinosa	I	(4-5)
Crataegus monogyna	I	(1-3)
Acer campestre	I	(2)
Castanea sativa	I	(1)
Fraxinus excelsior	I	(2)
Sorbus aucuparia	I	(1)
Corylus avellana	I	(2)
Pinus nigra	I	(1)
Alnus incana	I	(4)
Robinia pseudacacia	I	(3)
Rubus fruticosus agg.	II	(1-5)
Betula pubescens	I	(1-3)
Betula pendula	I	(4-8)
Corylus avellana	I	(2)
Acer campestre	I	(2)
Acer pseudoplatanus	I	(1)
Quercus petraea	I	(4)
Quercus cerris	I	(1)
Deschampsia flexuosa	V	(2-10)
Chamerion angustifolium	IV	(1-3)
Agrostis capillaris	III	(2-8)
Hieracium sabaudum group	III	(1-3)
Galium aparine	II	(2-4)
Holcus lanatus	II	(1-6)
Quercus seedling	II	(1-2)
Arrhenatherum elatius	I	(1-2)
Pteridium aquilinum	I	(1-3)
Festuca ovina	I	(3-7)
Hypochoeris radicata	I	(1-4)
Poa trivialis	I	(3)
Stellaria media	I	(1-3)
Teucrium scorodonia	I	(2-3)
Campylopus introflexus	I	(3)
Dactylis glomerata	I	(1)
Epilobium montanum	I	(1)
Holcus mollis	I	(2)
Pilosella officinarum agg	I	(1)

Poa pratensis	I	(1)
Sonchus asper	I	(1)
Taraxacum sect. vulgaria	I	(8)
Vicia cracca	I	(1)
Polytrichum commune	I	(1)
Number of samples	18	
Number of species per sample	9.89	(7-20)

Appendix 17. Plantation woodlands/scrub on deep-mine sites

Alnus incana canopy	III	(1-7)
Betula pendula	III	(3-9)
Crataegus monogyna	III	(1-6)
Acer pseudoplatanus	II	(3-7)
Alnus glutinosa	II	(1-5)
Robinia pseudacacia	II	(3-5)
Betula pubescens	I	(1-4)
Pinus nigra	I	(2-6)
Acer platanoides	I	(1-4)
Fraxinus excelsior	I	(1-2)
Sorbus intermedia	I	(3-4)
Acer campestre	I	(4-5)
Quercus cerris	I	(1-2)
Quercus petraea	I	(1-5)
Quercus robur	I	(1-2)
Sorbus aucuparia	I	(2)
Larix decidua	I	(1)
Larix sp.	I	(2)
Crataegus monogyna sapling	II	(2-4)
Alnus glutinosa	II	(1-4)
Rosa canina	II	(1-4)
Acer campestre	II	(3-5)
Betula pendula	II	(4-7)
Populus canescens	II	(2-4)
Prunus spinosa	I	(4)
Salix cinerea	I	(4)
Cytisus scoparius	I	(2-4)
Sorbus aucuparia	I	(4)
Acer pseudoplatanus	I	(4)
Quercus petraea	I	(1-8)
Hippophae rhamnoides	I	(4)
Betula pubescens	I	(1-5)
Salix viminalis	I	(4)
Ulex europaeus	I	(4)
Larix decidua	I	(5)
Quercus robur	I	(2)
Prunus spinosa	I	(3)
Rosa rugosa	I	(4)
Quercus cerris	I	(3)
Rubus fruticosus agg.	I	(1-6)
Holcus lanatus	IV	(4-9)
Arrhenatherum elatius	III	(1-9)
Agrostis capillaris	II	(3-10)
Festuca rubra	II	(2-9)
Chamerion angustifolium	II	(1-3)

Agrostis stolonifera	II	(4-6)
Dactylis glomerata	II	(2-4)
Hypochoeris radicata	II	(1-3)
Trifolium repens	II	(3-4)
Heracleum sphondylium	I	(1-3)
Cirsium arvense	I	(1-3)
Lotus corniculatus	I	(2-3)
Medicago sativa	I	(3-4)
Taraxacum sect. *vulgaria*	I	(1-6)
Trifolium pratense	I	(3-4)
Betula pubescens seedling	I	(1-3)
Deschampsia cespitosa cespitosa	I	(2-7)
Epilobium montanum	I	(1-2)
Hieracium sabaudum group	I	(2-3)
Plantago lanceolata	I	(2-3)
Poa pratensis	I	(2-4)
Quercus seedling/sp	I	(1)
Achillea millefolium	I	(1-2)
Anthriscus sylvestris	I	(2)
Anthyllis vulneraria	I	(3-5)
Festuca ovina	I	(3-9)
Galium aparine	I	(2-3)
Ranunculus repens	I	(1-2)
Senecio jacobaea	I	(1)
Vicia sepium	I	(2-3)
Crataegus monogyna seedling	I	(1)
Elytrigia repens	I	(2)
Alopecurus pratensis	I	(3)
Calystegia sepium	I	(1)
Cirsium vulgare	I	(1)
Dryopteris filix-mas	I	(1)
Epilobium hirsutum	I	(3)
Galium verum	I	(1)
Holcus mollis	I	(2)
Lolium perenne	I	(4)
Medicago lupulina	I	(2)
Pilosella officinarum agg	I	(3)
Ranunculus acris	I	(1)
Sonchus oleraceus	I	(2)
Trifolium dubium	I	(3)
Vicia hirsuta	I	(1)
Campylopus introflexus	I	(1)
Teucrium chamaedrys	I	(2)

Number of samples	25	
Number of species/sample	14.24	(5-21)

Appendix 19. Inventory of vascular plants recorded at deep-mine sites.

Acer campestre
Acer platanoides
Acer pseudoplatanus
Achillea millefolium
Achillea ptarmica
Agrostis stolonifera
Agrostis capillaris
Aira caryophyllea
Aira praecox
Alisma plantago-aquatica
Alnus cordata
Alnus glutinosa
Alnus incana
Alopecurus geniculatus
Alopecurus pratensis
Anagallis arvensis
Anisantha sterilis
Anthoxanthum odoratum
Anthriscus sylvestris
Anthyllis vulneraria
Apera interrupta
Arenaria serpyllifolia
Arrhenatherum elatius
Artemisia absinthium
Artemisia vulgaris
Atriplex prostrata
Bellis perennis
Betula pubescens
Betula x aurata
Betula pendula
Brachypodium pinnatum
Bromopsis erecta
Bromus hordeaceus hordeaceus
Calamagrostis epigejos
Calluna vulgaris
Calystegia sepium
Campanula glomerata
Campanula rotundifolia
Capsella bursa-pastoris
Carex disticha
Carex flacca
Carex hirta
Carex nigra
Carex otrubae
Castanea sativa
Catapodium rigidum
Centaurea nigra
Centaurium erythraea
Cerastium glomeratum

Cerastium fontanum
Cerastium semidecandrum
Chamerion angustifolium
Circaea lutetiana
Cirsium arvense
Cirsium palustre
Cirsium vulgare
Corrigiola litoralis
Corylus avellana
Crataegus monogyna
Crepis capillaris
Crepis vesicaria
Cynosurus cristatus
Cytisus scoparius
Dactylis glomerata
Dactylorhiza fuchsii
Dactylorhiza praetermissa
Dactylorhiza purpurella
Daucus carota
Deschampsia cespitosa cespitosa
Deschampsia flexuosa
Digitalis purpurea
Dryopteris filix-mas
Eleocharis palustris
Elytrigia repens
Epilobium hirsutum
Epilobium montanum
Epilobium palustre
Equisetum arvense
Erigeron acer
Eriophorum angustifolium
Erodium cicutarium
Erophila verna agg.
Fagus sylvatica
Festuca arundinacea
Festuca ovina
Festuca pratensis
Festuca rubra
Filago vulgaris
Fraxinus excelsior
Galium aparine
Galium saxatile
Galium verum
Genista tinctoria
Geranium molle
Geranium robertianum
Geum urbanum
Helictotrichon pratense
Helictotrichon pubescens
Heracleum sphondylium
Hieracium murorum group

Hieracium sabaudum group
Hippophae rhamnoides
Holcus lanatus
Holcus mollis
Hypericum perforatum
Hypochoeris radicata
Juncus articulatus
Juncus effusus
Juncus inflexus
Larix decidua
Lathyrus pratensis
Leontodon autumnalis
Leontodon hispidus
Leontodon saxatilis
Leucanthemum vulgare
Linaria repens
Linaria vulgaris
Linum catharticum
Lolium multiflorum
Lolium perenne
Lonicera periclymenum
Lotus corniculatus
Lotus pedunculatus
Luzula campestris
Lycopus europaeus
Matricaria discoidea
Medicago lupulina
Medicago sativa
Melilotus albus
Melilotus officinalis
Milium effusum
Nardus stricta
Oenothera glazioviana
Ononis repens
Ophrys apifera
Phragmites australis
Pinus nigra
Pilosella officinarum agg
Plantago lanceolata
Plantago major
Plantago media
Poa annua
Poa compressa
Poa pratensis
Poa trivialis
Polygonum aviculare
Populus canescens
Potentilla erecta
Potentilla reptans
Prunella vulgaris
Prunus spinosa

Pteridium aquilinum
Pulicaria dysenterica
Quercus cerris
Quercus petraea
Quercus robur
Quercus x rosacea
Ranunculus acris
Ranunculus repens
Reseda lutea
Reseda luteola
Robinia pseudacacia
Rosa canina
Rosa rugosa
Rubus fruticosus agg.
Rumex acetosa
Rumex acetosella
Rumex crispus
Rumex obtusifolius
Sagina apetala apetala
Sagina procumbens
Salix caprea
Salix cinerea
Salix viminalis
Sambucus nigra
Saponaria officinalis
Sedum acre
Senecio aquaticus
Senecio erucifolius
Senecio jacobaea
Senecio squalidus
Senecio viscosus
Silene uniflora
Solanum dulcamara
Sonchus asper
Sonchus oleraceus
Sorbus aucuparia
Sorbus intermedia
Spergularia rubra
Stachys sylvatica
Stellaria media
Tanacetum vulgare
Taraxacum sect. *vulgaria*
Teucrium scorodonia
Trifolium arvense
Trifolium campestre
Trifolium dubium
Trifolium medium
Trifolium pratense
Trifolium repens
Tripleurospermum maritimum
Trisetum flavescens

Tussilago farfara
Typha latifolia
Ulex europaeus
Ulmus glabra
Urtica dioica
Vaccinium myrtillus
Veronica officinalis
Veronica polita
Vicia sativa nigra
Vicia cracca
Vicia hirsuta
Vicia sepium
Vulpia bromoides
Vulpia myuros

Appendix 20. Inventory of bird frequency and abundance, deep-mine sites.

Species	No.sites	No.birds	notes	activity	notable
Willow Warbler	20	47		b	
Skylark	20	45		b	
Whitethroat	12	19		b	
Wren	12	15		b	
Yellowhammer	11	18		b	
Linnet	10	17		b	
Blackcap	9	14		b	
Meadow Pipit	8	11		b	
Green Woodpecker	8	8		f	y
Little Ringed Plover	7	8		b	y
Blackbird	7	9		b	
Woodpigeon	6	10		b	
Magpie	6	7		b	
Blue Tit	6	7		b	
Lesser Whitethroat	6	6		b	
Long-tailed Tit	6	12		b	
Chaffinch	5	6		b	
Chiffchaff	5	5		b	
Willow Tit	5	5		b	
Garden Warbler	5	5		b	
Grey Partridge	4	15	2 broods	f	y
Great Tit	4	4		b	
Reed Warbler	4	9		b	
Song Thrush	4	5		b	
Reed Bunting	4	7		b	roost-2 sites
Kestrel	3	4		f	
Red-legged Partridge	3	4		f	y
Redpoll	3	3		b	
Lapwing	3	9		b	
Goldfinch	3	3		b	
Robin	3	5		b	
Carrion Crow	3	4		b	
Dunnock	3	5		b	
Cuckoo	3	3		b	
Great Ringed Plover	3	6	1 brood	b	y
Tree Pipit	3	4		b	
Sedge warbler	3	7		b	
Quail	2	4		b	y
Jay	2	2		b	
Bullfinch	2	3		b	
Mistle Thrush	2	2		b	
Sparrowhawk	2	3		f	
Greenfinch	2	3		b	
Jack Snipe	2	2		f	y
Whinchat	1	1		b	
Curlew	1	2		b	y
Coal Tit	1	1		b	
Snipe	1	1		f	

Pied Wagtail	1	1		b	
Crossbill	1	1		flying over	
Corn Bunting	1	1		b	y-large roosts 2sites
Stock Dove	1	1		f	
Pheasant	1	1		b	
Collared Dove	1	1		f	
Heron	1	1		f	
Yellow wagtail	1	1		b	y-roost 1site
Siskin	1	1		flying over	
Grasshopper Warbler	1	1		b	
Redshank	1	2		b	
Great Spotted Woodpecker	1	1		b	
House martin				f	roost 3sites
Swallow				f	large roosts3 sites
Swift				f	
Sand Martin				f	large roosts 3 sites
Total	101	408			
				b -breeding	
				f - feeding	

Appendix 21. Invertebrate records from deep-mine sites

Manvers Colliery tip, Cortonwood Colliery tip, Falthwaite Colliert tip and Thorne Colliery tip (after Coldwell 1991a, 1991b, 1991c, 1993, 1995a, 1995b, 1997, Crossley 1977), (records refer to Manvers except where indicated - C=Cortonwood, F=Falthwaite, T=Thorne)

RDB= Red Data Book, N=Nationally Notable (after Ball 1986).

Orthoptera		
Tetrix undulata		
T. subulata	Nb	
Batia lunaris		
Coleoptera		
Antherophagus pallens		
Bembidion obliquum	Nb	
B. genei		
Calathus ambiguus	Nb	
Ceutorhynchus campestris	Nb	
Chrysolina fastuosa		
Cryptocephalus fulvus	Nr (N.Eng)	
Curculio betulae	Nb	
Donacia vulgaris	Nr (N.Eng)	
Doritomus longimanus		
Doritomus tortrix		
Oedemera lucida		
Otiorhynchus rugifrons		
Necrobia violacea		
Ptilinus pectinicornis		
Subcoccinella 24-punctata		
Zeugophora subspinosa	Nb	
Hemiptera/Heteroptera		
Heterogaster urticae		
Mecomma dispar		T
Megalonotus chiragra		T
Nysius ericae		T
Peritrechus geniculatus		T
Piesma maculatum		
Pseudoloxops coccineus		
Scolopostethus affinis		T
Taphropeltus contractus		T
Lepidoptera		
Adscita statices	Nb	F
Eucosma pubillana	Nb	
Glyphipteryx lathamella	pRDB1	

Diptera

Anomoia purmundus		
Cephalops carinatus	Notable	
Cephalops subultimus	Notable (N.Eng)	
Cheilosia mutabilis	RDB3	
Coremacera marginata	Nr (N.Eng)	
Dioctria baumhaueri	Nr (N.Eng)	
Dolichopus signifer	RDB1	
Dorilomorpha extricata	Notable (N.Eng)	
Epitriptus cingulatus	Notable	
Eudorylas arcanus	Notable	
E. fascipes	Notable (N.Eng)	
E. longifrons	Notable (N.Eng)	
E. subultimus	Notable (N.Eng)	
Euphrantia toxoneura		
Leptogaster guttiventris	Notable	
Micrechrysa polita		
Monosoma pulverata		F
Nemotelus uliginosus		C
Oxycera morrisii	RDB2	M and C
Oxycera rara	Notable	C
Oxycera trilineata	Notable	C
Phasia obesa	Notable	
Platypalpus tonsus	RDB1	F
Platypalpus annulatus		
Platypalpus interstinctus	Notable (N.Eng)	
Praomia leachii		
Pristiphora ruficornis		C
Rhagoletia alternata	Nr (N.Eng)	
Terellia serratulae	Notable (N.Eng)	
Tropidia scita		
Triglyphus primus		
Rhagoletis alternata		
Solva marginata	RDB2	
Seioptera vibrans		
Sepedon spinipes	Notable (N.Eng)	
Stethomostus funereus	pRDB3	C
Stratiomys potamida	RDB3	C
Sphaerophoria rueppellii	Nr (N.Eng)	
Terellia serratulae		
Tropidia scita	Notable	
Triglyphus primus	Notable	
Verralia beatricis	Notable (N.Eng)	
Hymenoptera		
Ammophila sabulosa		M and C
Ancistrocerus gazella		
Andrena denticulatus		
Cleptes semiauratus	Nr (N.Eng)	
Colletes succincta		
Croesus varus		T
Ectemnius dives	Nr (N.Eng)	

Entomognathus brevis	Nr (N.Eng)	
Dipogon subintermedius		C
Dipogon variegatus		
Gorytes quadrifasciatus	Nr (N.Eng)	
G. tumidus	Nr (N.Eng)	
Hedychridium ardens		M and C
Heterarthrus ochropoda		
Hylaeus signatus		
Lasioglossum villosulum	Nr (N.Eng)	
Lindenius albilabris	Nr (N.Eng)	
Macrophya annulata		
Nematus coeruleocarpus		
Nematus melanaspis		
Neurotoma saltuum		
Nysson dimidiatus	Nr (N.Eng)	
Nysson trimaculatus	Nr (N.Eng)	M and C
Omalus violaceus	Nr (N.Eng)	
Pachynematus albipennis		
Pamphilius gyllenhali	pRDB3	F
Pamphilius sylvaticus		C
Pamphilius vafer		
Pemphredon morio	RDB3	
Priocnemis pertubator		
Priocnemis schioedtei		
Pristiphora coniceps	pRDB3	
Pristiphora conjugata		
Psenulus concolor	Nr (N.Eng)	
Pseudomalus violaceus		
Stauronematus compressicornis		
Tachysphex pompiliformis		
Xiphydria camelus	Nr (N.Eng)	

Appendix 22. Opencast site restorations to grassland. Details of 15 samples from Scholes Common and Banks, Tankersley sites.

1. MG10 *Holcus lanatus-Juncus effusus* rush pasture (n=4, all at Scholes).

Holcus lanatus	V	(3-8)
Juncus effusus	V	(4-9)
Poa trivialis	V	(4)
Ranunculus acris	IV	(3)
Epilobium hirsutum	IV	(2-5)
Rumex obtusifolius	IV	(1-3)
Lathyrus pratensis	IV	(2-3)
Ranunculus repens	III	(2-3)
Heracleum sphondylium	II	(1)
Festuca rubra	II	(4)
Dactylorhiza fuchsii	II	(1)
Phleum pratense	II	(2)
Agrostis capillaris	II	(3)
Dactylis glomerata	II	(4)
Anthoxanthum odoratum	II	(2)
Achillea ptarmica	II	(2)
Eriophorum angustifolium	II	(3)

2. MG9 *Deschampsia cespitosa-Holcus lanatus* grassland (n=4, all Banks).

Deschampsia cespitosa	V	(4-8)
Holcus lanatus	V	(5-6)
Tristum flavescens	V	(2-3)
Festuca rubra	V	(2-3)
Ranunculus acris	V	(1-3)
Agrostis capillaris	IV	(5-6)
Cynosurus cristatus	IV	(1-3)
Dactylis glomerata	IV	(1-2)
Trifolium dubium	IV	(1)
Trifolium pratense	IV	(1-4)
Stellaria graminea	IV	(1-2)
Plantago lanceolata	IV	(2-4)
Lolium perenne	III	(2)
Trifolium repens	III	(1-2)
Vicia sativa	III	(2-4)
Hypochoeris radicata	III	(1)
Centaurea nigra	III	(1)
Rumex obtusifolius	III	(1-2)
Leucanthemum vulgare	III	(2-3)
Rumex acetosa	II	(2)
Achillea millefolium	II	(2)
Poa pratensis	II	(1)
Cerastium fontanum	II	(2)
Rhinanthus minor	II	(1)
Festuca pratensis	II	(2)
Phleum pratense	II	(2)

Lathyrus pratensis	II	(3)

3. 'Hay-meadow' (n=7, both sites).

Festuca rubra	V	(4-7)
Holcus lanatus	V	(3-7)
Agrostis capillaris	V	(3-6)
Cynosurus cristatus	V	(2-4)
Dactylis glomerata	IV	(3-5)
Plantago lanceolata	IV	(3-4)
Lotus corniculatus	IV	(2-7)
Achillea millefolium	III	(2-4)
Hypochoeris radicata	III	(2)
Trifolium repens	III	(2-3)
Lathyrus pratensis	III	(4-6)
Ranunculus acris	III	(1-3)
Ranunculus repens	III	(1-3)
Anthoxanthum odoratum	II	(2-3)
Poa trivialis	II	(3)
Euphrasia spp.	I	(1)
Cytisus scoparius	I	(1)
Ophioglossum vulgare	I	(2)
Alopecurus pratensis	I	(1)
Taraxacum vulgare agg.	I	(2)
Rumex obtusifolius	I	(1)
Leucanthemum vulgare	I	(2)
Centaurea nigra	I	(2)
Senecio jacobaea	I	(1)
Arrhenatherum elatius	I	(2)
Crataegus monogna seedling	I	(1)

Appendix 23. Subsidence wetlands and restored wetland opencast sites. Peak winter wildfowl counts (WeBS) and national percentages of populations.

Site	grid ref	District	WeBs peak	%GB pop &species
Fairburn Ings	SE450276	Leeds/Selby	4419	lg.5,gcg.4,cm.5,ms.6,ws.8,gd1.7,t.3, ma.2,sv1.5,tu.7, gy.4,gs.6,co.9
Anglers	SE375155	Wakefield	2255	gcg0.2,wi0.1,gd0.2,po0.7,tu0.5,gy.4 ,gs.2,co0.8
Pugneys	SE330175	Wakefield	1951	lg0.2,gcg0.2,ms0.2,t0.1,sv0.6,po0.2 ,tu0.6,gy0.1co0.3
Rother valley	SK452825	Rotherham	1366	po0.3,tu0.2,co0.3
St.Aidans	SE387282	Leeds	1346	lg0.1,cm0.2,gw0.2,sv1,po0.5,tu0.8, gy0.2,gs0.2
Broomhill Flash	SE414030	Barnsley	1187	lg0.1,ws0.3,t0.2,ma0.1sv0.3,co0.1
Swillington lk	SE450276	Leeds	1072	lg0.2,ws0.1,gd1.1,sv0.8,tu0.2,gs0.2, co0.1
Mickletown Ing	SE400275	Leeds	493	lg0.7,ms0.1,gd0.3tu0.1,co0.2
Denaby Ings	SE503004	Doncaster	414	lg0.1, sv0.1
Catcliffe Flash	SE425881	Rotherham	402	po0.1,tu0.1
Sprotborough F	SE583004	Doncaster	356	lg0.2,sv0.3
Allerton Byw.	SE415279	Leeds	310	lg0.2,tu0.1,co0.1
Altofts	SE370248	Wakefield	299	sv0.2,po0.2,tu0.1
Old denaby Fl	SE486994	Doncaster	241	
S. Washlands	SE360220	Wakefield	218	
Stanley FFlash	SE353227	Wakefield	158	lg0.1
Edderthorpe In	SE413068	Barnsley	110	
Lowther North	SE405279	Leeds	98	
Manvers	SE430015	Rotherham	49	
TOTAL			16744	Key:lg=Little grebe, gcg=Great crested grebe, cm=Cormorant, co=Coot,sv=Shoveler
				tu=Tufted Duck,gw=Gadwall,gs=Goosander,gy=Goldeneye,ms=mute swan
				ws=Whooper Swan, ma=Mallard, po=Pochard

Appendix 25. Inventory of study sites, Yorkshire, detailing grid reference, current conservation status, creation of deep-mine, creation of present landscape (n=70).

Site	Grid reference	District	Colliery opened*	Site created**	Designation
Allerton Bywater	SE415279	Leeds	1875-1910		2ND
Allerton receptor site	SE424273	Leeds		1994	
Altofts	SE370248	Wakefield			
Anglers	SE375155	Wakefield		1984	LNR
Banks,Pilley	SK330994	Barnsley		late 1980's	
Barnburgh colliery	SE473040	Doncaster			
Barnsley main	SE362062	Barnsley			
Barrow	SE360030	Barnsley			
Beacon hill	SE103250	Halifax			
Bell ground	SK358992	Barnsley			
Bradshaw Quarry	SE212012	Barnsley			
Brodsworth colliery	SE523075	Doncaster			
Broomhill Flash	SE414030	Barnsley		1950's	2ND
Cadeby colliery	SE506006	Doncaster	1889		2ND
Carlton main	SE370094	Barnsley			
Catcliffe Flash	SE425881	Rotherham			LNR
Cortonwood colliery	SE408014	Rotherham			
Crigglestone colliery	SE308154	Wakefield	1898		
Crow Edge	SE184040	Barnsley			
Darfield Main	SE399040	Barnsley			
Darton	SE308108	Barnsley	1914		
Darton2	SE330097	Barnsley	1910		
Denaby Ings	SE503004	Doncaster		1950's	SSSI
Denby Grange	SE270153	Wakefield	1872		SAC,SSSI
Dodworth main	SE308058	Barnsley		1950's	
Edderthorpe Ings	SE413068	Barnsley			2ND
Elmley bellpits	SE265130	Kirklees			
Elsecar	SK371993	Rotherham			
Elsecar main	SE390003	Rotherham			
Elsecar tip	SE398008	Rotherham			
Fairburn Ings	SE450276	Leeds/Selby		1940's-50's	SSSI,LNR
Falthwaite	SE315035	Barnsley	1862		
Gipsy Marsh	SE421023	Barnsley		1960's	2ND
Grimethorpe colliery	SE415075	Barnsley			
Half moon	SE375208	Wakefield			2ND
Havercroft colliery	SE395138	Wakefield		1980's	2ND
Lowther North	SE405279	Leeds		1980's	2ND
Maltby main	SK544925	Rotherham	1910		
Manvers Main	SE430015	Rotherham			
Methley colliery	SE365253	Leeds	1878-1907		
Mickletown Ings	SE400275	Leeds		1940's-50's	SSSI
Mitchell Main	SE399043	Barnsley		1970's	

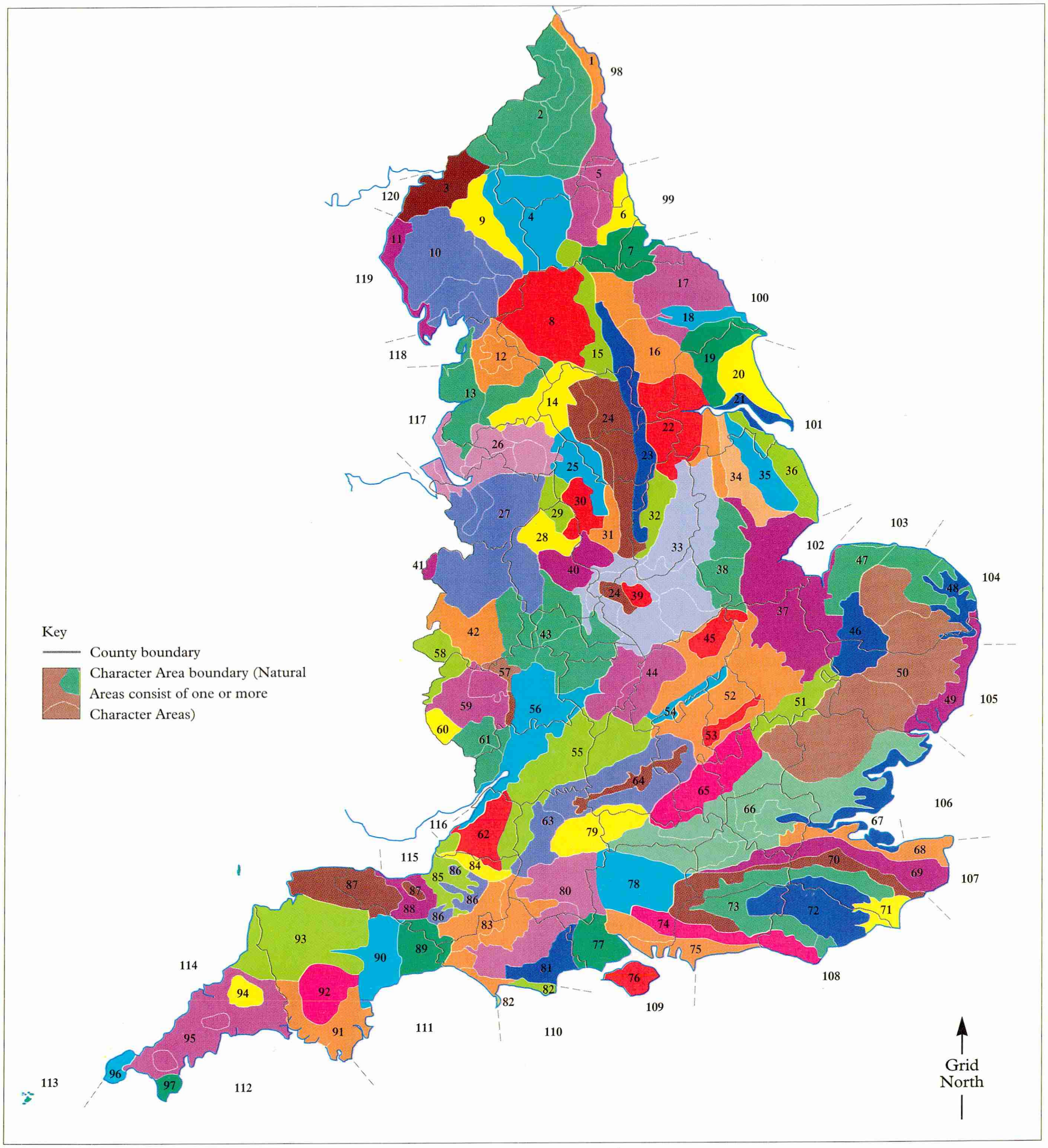
North Gawber	SE340090	Barnsley			
Old Denaby Flash	SE486994	Doncaster		1980's	
Pogmoor	SE320066	Barnsley			
Pugneys	SE330175	Wakefield		1970's	LNR
Redbrook	SE322080	Barnsley			
Rother Valley C.Park	SK452825	Rotherham			2ND
Rothwell colliery	SE355298	Leeds	1870-71		
Royston drift	SE380120	Wakefield			
S. Washlands	SE360220	Wakefield		1980's	LNR
Savin Royd	SE303126	Barnsley			
Scholes	SK392948	Rotherham		1940-45	LNR
Seckar Wood	SE328143	Wakefield		1949	SSSI
Silkstone fall	SE300057	Barnsley			2ND
Skiers Spring	SK364992	Barnsley			
Smithies	SE345083	Barnsley	1869		
Sprotborough Flash	SE583004	Doncaster		1950's	SSSI
St.Aidans	SE387282	Leeds			LNR
Stanley Ferry Flash	SE353227	Wakefield		1970's	LNR
Strafford colliery	SE320040	Barnsley			
Swillington lake	SE390278	Leeds		1986	
Tankersley colliery	SK352988	Barnsley			
Tankersley golf course	SK350987	Barnsley		19th C.	
Thorne colliery	SE710158	Doncaster	1912-1925		
Three sisters,Garforth	SE414342	Leeds	1843		
Tinsley Park	SE410885	Sheffield			
Upton colliery	SE480133	Wakefield		1965, 1994	
Walton colliery	SE364180	Wakefield		1995	
Wath Main	SE435019	Rotherham			

* from Wilcockson 1950
** from Brook 1976 (Wakefield), Rhodes 1988 (Doncaster), Denny 1995 (Anglers)

Notes:
1. Dates of colliery openings do not necessarily equate to time of abandonment - many sites continued to expand or operate well into the late 20th century.
2. Estimates of times of creation of subsidence wetlands refers to periods of major expansion - some sites already may have existed as small wetlands beforehand.
3. SSSI=Site of Special Scientific Interest; LNR=Local Nature Reserve; SAC=proposed Special Area of Conservation;2ND=second tier site identified in local conservation strategies and Unitary Development Plans.

ENGLISH NATURE

Natural Areas



1 North Northumberland Coastal Plain
2 Border Uplands
3 Solway Basin
4 North Pennines
5 Northumbria Coal Measures
6 Durham Magnesian Limestone Plateau
7 Tees Lowlands
8 Yorkshire Dales
9 Eden Valley
10 Cumbria Fells and Dales
11 West Cumbria Coastal Plain
12 Forest of Bowland
13 Lancashire Plain and Valleys
14 Southern Pennines
15 Pennine Dales Fringe
16 Vale of York and Mowbray
17 North York Moors and Hills
18 Vale of Pickering
19 Yorkshire Wolds
20 Holderness
21 Humber Estuary
22 Humberhead Levels
23 Southern Magnesian Limestone
24 Coal Measures
25 Dark Peak
26 Urban Mersey Basin
27 Mosses and Meres
28 Potteries and Churnet Valley
29 South West Peak
30 White Peak
31 Derbyshire Peak Fringe and Lower Derwent
32 Sherwood
33 Trent Valley and Rises
34 North Lincolnshire Coversands and Clay Vales
35 Lincolnshire Wolds
36 LIncolnshire Coast and Marshes
37 The Fens
38 Lincolnshire and Rutland Limestone
39 Charnwood
40 Needwood and South Derbyshire Claylands
41 Oswestry Uplands
42 Shropshire Hills
43 Midlands Plateau
44 Midland Clay Pastures
45 Rockingham Forest
46 Breckland
47 North Norfolk
48 The Broads
49 Suffolk Coast and Heaths
50 East Anglian Plain
51 East Anglian Chalk
52 West Anglian Plain
53 Bedfordshire Greensand Ridge
54 Yardley-Whittlewood Ridge
55 Cotswolds
56 Severn and Avon Vales
57 Malvern Hills and Teme Valley
58 Clun and North West Herefordshire Hills
59 Central Herefordshire
60 Black Mountains and Golden Valley
61 Dean Plateau and Wye Valley
62 Bristol, Avon Valleys and Ridges
63 Thames and Avon Vales
64 Midvale Ridge
65 Chilterns
66 London Basin
67 Greater Thames Estuary
68 North Kent Plain
69 North Downs
70 Wealden Greensand
71 Romney Marshes
72 High Weald
73 Low Weald and Pevensey
74 South Downs
75 South Coast Plain and Hampshire Lowlands
76 Isle of Wight
77 New Forest
78 Hampshire Downs
79 Berkshire and Marlborough Downs
80 South Wessex Downs
81 Dorset Heaths
82 Isles of Portland and Purbeck
83 Wessex Vales
84 Mendip Hills
85 Somerset Levels and Moors
86 Mid Somerset Hills
87 Exmoor and the Quantocks
88 Vale of Taunton and Quantock Fringes
89 Blackdowns
90 Devon Redlands
91 South Devon
92 Dartmoor
93 The Culm
94 Bodmin Moor
95 Cornish Killas and Granites
96 West Penwith
97 The Lizard
98 Northumberland Coast
99 Tyne to Tees Coast
100 Saltburn to Bridlington
101 Bridlington to Skegness
102 The Wash
103 Old Hunstanton to Sheringham
104 Sheringham to Lowestoft
105 Suffolk Coast
106 North Kent Coast
107 East Kent Coast
108 Folkestone to Selsey Bill
109 Solent and Poole Bay
110 South Dorset Coast
111 Lyme Bay
112 Start Point to Land's End
113 Isles of Scilly
114 Land's End to Minehead
115 Bridgwater Bay
116 Severn Estuary
117 Liverpool Bay
118 Morecambe Bay
119 Cumbrian Coast
120 Solway Firth

Revised to December 1996