3. GRASSLANDS

3.1 Introduction

Grasslands are the most common target community in habitat creation projects, forming 43% of the projects in the *Review*. The objectives of these projects were wide ranging from the creation of "wild flower grasslands" on urban sites, to attempts to create grassland types similar to communities described in the National Vegetation Classification (NVC; Rodwell, 1992).

Grassland is the most common and widespread vegetation type in the UK. Much of it consists of grasslands which have been improved for agriculture by the input of lime and inorganic fertilisers and often reseeded with productive grasses such as ryegrass *Lolium perenne* and white clover *Trifolium repens*. Unimproved grasslands, that is pastures and hay meadows which have not been reseeded or subjected to inorganic fertiliser application, are now sadly fragmented in the UK, now only occupying some 5% of their 1945 area. The need to reverse this nature conservation tragedy has been the spur of many grassland habitat creation projects.

Information gathered in this *Review* and from published accounts suggests that grassland habitat creation takes place on the following five main types of site:-

1. *Arable farmland* - this is the most common type of site for a grassland habitat creation project and the current programme of set aside has created a large number of potential sites for ambitious programmes (Firbank et al, 1992).

2. *Mixed/pastoral farmland* - this land has similar problems and potential to arable farmland, but pastoral farmland might be better treated by a habitat enhancement programme rather than the "something from nothing" habitat creation approach.

3. *New roadside verges* - with the current large road building programme, many opportunities are arising for the creation of attractive and ecologically interesting grasslands on new roadside verges and embankments.

4. *Derelict land reclamation* - large amounts of money are spent on the reclamation of derelict land, that is land which has damaged by past industrial activity; depending on the proposed end-use, many of these sites present excellent opportunities for grassland habitat creation.

5. *Urban and urban-fringe display sites* - a large amount of habitat creation in the urban and educational sector concerns grassland projects, mostly of the "wild flower grassland" type.

There is a real need at the present time for more publication/dissemination of real examples of grassland habitat creation projects. Whereas we have excellent accounts of the present situation (such as Hopkins, 1989), the *Review* found that grassland projects are rarely publicised. This is especially true for projects with a low level of success. The situation with heathland habitat creation is better with more published practical examples and experiments.

This chapter will now proceed with a brief description of grassland types in the UK. This description will show the diversity and complexity of semi-natural grasslands in Britain and the consequent need for grassland habitat creation projects to take account of this diversity in a local context.

3.2 Types of grassland

3.2.1 General description

Within Britain there are a wide variety of grasslands which are determined by their geographical location, underlying geology and soil type, topographical position, management history and current management. The NVC and earlier published descriptions of grasslands have divided grasslands into three main types:-

1. *Mesotrophic grasslands* - more commonly known as "neutral grassland" and occurring on lowland clay and loam soils with neutral pH and are largely managed as agricultural land. These grasslands do not support species with a pronounced calcicole (lime loving) or calcifuge (lime hating) tendency. Unimproved mesotrophic grassland has declined dramatically since 1945. The improved grasslands of intensive agriculture are, however, included within the NVC system.

2. *Calcicolous grasslands* - including both "chalk" and "limestone" grassland occur on limestones such as the chalk, carboniferous limestone and the oolitic limestones of the Cotswolds and coastal Dorset. These grasslands have also suffered a massive decline since 1945 and losses continue with agricultural improvement and neglect.

3. *Calcifugous grasslands* - more commonly known as "acid" or "acidic" grasslands occur mainly in upland areas of the north and west, but also as grass-heaths in the south and east. Acid grassland in the lowlands can occur independently of heathland vegetation. Many of these communities have an affinity with heathlands and moorlands. This section of the NVC system also includes locally confined montane vegetation which is outside the scope of this *Guide*.

It could be argued that there is a fourth broad grassland type which are those grasslands produced by man using "wild flower seeding" techniques. The creation of attractive grasslands containing certain herbaceous species has been a feature of many schemes in such divergent places as urban derelict land, public parks and trunk road verges. The creation of an NVC grassland type has not formed part of the planning of these schemes but, despite this, these grasslands have a valuable part to play in a landscape, amenity and educational sense. They also have some ecological value.

This *Guide* is not the place to present a comprehensive account of the complex range of variation found in the grasslands of Britain. This can be found in the excellent NVC account (Rodwell, 1992) and many other texts. However, a summary of the main grassland types and their range of variation is presented in the following sections.

3.2.2 Mesotrophic (neutral) grasslands

These grasslands are found in the lowlands of Britain and consist of closed swards on drought-free mesotrophic to nutrient-rich mineral soils, of pH 4.5-6.5 and located in areas with a moist and mild climate with a long growing season. The NVC has distinguished some 13 communities grouped into five main types. These communities are characterised by the relative frequency of the grasses, cock's-foot *Dactylis glomerata*, meadow fescue *Festuca pratensis*, red fescue *F. rubra*, Yorkshire fog *Holcus lanatus*, smooth meadow-grass *Poa pratensis* and rough meadow-grass *P. trivialis*, and the herbs common mouse-ear *Cerastium fontanum*, ribwort plantain *Plantago lanceolata*, meadow buttercup *Ranunculus acris* and white clover *Trifolium repens*. The 13 communities are divided as follows:-

(a) False oat-grass *Arrhenatherum elatius* grasslands (2 communities);
(b) Well-drained pastures and meadows (4 communities);
(c) Long term leys and related grasslands (1 community);
(d) Poorly drained pasture with poor-fen element (3 communities);
(e) Grass-dominated inundation communities (3 types).

(a) False oat-grass *Arrhenatherum elatius* grasslands. These ungrazed,coarse and tussocky grasslands are the widespread and familiar grasslands of road and motorway verges. Some cutting may take place, often only once per year, but this serves to prevent the succession to scrub. Other species which are abundant in these communities are the grasses *Holcus lanatus* and *Dactylis glomerata* and the tall herbs hogweed *Heracleum sphondylium*, angelica *Angelica sylvestris* and nettle *Urtica dioica*. The NVC communities are:-

MG1 *Arrhenatherum elatius* grassland
MG2 *Arrhenatherum elatius-Filipendula ulmaria* tall herb grassland

Most grasslands of this type belong to the MG1 *Arrhenatherum elatius* grassland community, with the MG2 *Arrhenatherum elatius-Filipendula ulmaria* grassland being confined mainly to carboniferous limestone outcrops in northern Britain. This community has additional herb species including meadowsweet *Filipendula ulmaria*, common valerian *Valeriana officinalis*, crosswort *Cruciata laevipes* and male fern *Dryopteris filix-mas*.

(b) Well-drained permanent pastures and meadows. These grasslands include the bulk of the permanent agricultural grasslands used for grazing and hay production in Britain. They include the traditionally managed and species-rich hay meadows and the improved permanently grazed grasslands which have been derived from the unimproved type. They belong to four NVC communities:-

MG3 *Anthoxanthum odoratum-Geranium sylvaticum* grassland
MG4 *Alopecurus pratensis-Sanguisorba officinalis* grassland
MG5 *Cynosurus cristatus-Centaurea nigra* grassland
MG6 *Lolium perenne-Cynosurus cristatus* grassland

The most interesting of these communities is MG5 *Cynosurus cristatus-Centaurea nigra* grassland. This is widely known as "Old Meadow" grassland although this can also be said of a number of other communities. What marks out MG5 (as well as MG3 and MG4) is species-richness, the long continuity of hay meadow management and the use of only stock and organic manures (but not slurry) to fertilise the sward. The traditional management is hay cutting in June/July followed by aftermath grazing through until the winter. Grazing does not normally take place in the spring to allow the hay to grow. Hay cutting takes place later at cooler, upland locations. An alternative management is permanent pasture.

Hay meadows of this kind are found throughout lowland Britain on neutral brown-earth soils. They are perhaps at their best on the clay-rich soils of the Midlands, with some of the best examples in Worcestershire. Typical species in such meadows are hardhead *Centaurea nigra*, oxeye daisy *Leucanthemum vulgare*, bulbous buttercup *Ranunculus bulbosus*, cowslip *Primula veris*, cat's-ear *Hypochaeris radicata* and the much reduced green-winged orchid *Orchis morio*.

Where the MG5 meadows extend up into higher valleys, especially in northern England, there is a transition to MG3 *Anthoxanthum odoratum-Geranium sylvaticum* grassland. Here the sward supports species such as wood crane's-bill *Geranium sylvaticum*, great burnet *Sanguisorba officinalis*, pignut *Conopodium majus* and the lady's mantles

Alchemilla glabra and *A. xanthochlora*. The management system tends to be different to MG5 with grazing during the winter period (Rodwell, 1992).

The MG4 *Alopecurus pratensis-Sanguisorba* meadows are found on periodically flooded meadows on alluvial soils close to rivers, mainly in central and southern England. They resemble the MG3 upland meadows floristically but have a characteristic presence of meadow foxtail *Alopecurus pratensis*, meadowsweet *Filipendula ulmaria*, creeping buttercup *Ranunculus repens* and the grass, creeping bent *Agrostis stolonifera*. This meadow type is that present at the spectacular North Meadow at Cricklade, Wiltshire, with its abundant snake's-head fritillary *Fritillaria meleagris*.

In recent years traditionally managed meadows have become altered by factors such as the introduction of permanent grazing, agricultural improvement by the application of artificial fertilisers, ploughing and reseeding. This has reduced the diversity of the grassland and has favoured dominance by grasses. It has resulted in a huge loss of biodiversity in Britain. Improved permanent pasture with this origin is grouped in MG6 *Lolium perenne-Cynosurus cristatus* grassland. Ryegrass *Lolium perenne*, the major fodder species, together with clover *Trifolium repens* are usually the major components of this grassland. However, given less intense agricultural management, some reversion is possible. Much coastal grassland known as "grazing marsh" is grouped within this NVC type; this grassland is derived from salt marsh which has long been isolated from the sea by the construction of sea walls.

(c) Long-term leys and related grasslands. These grasslands are usually sown as short or long term leys, often in part of a rotation which includes an arable phase. These grasslands are distinguished from MG6 by the absence of the grass, crested dog's-tail *Cynosurus cristatus* and the presence of ryegrass *Lolium perenne*, white clover *Trifolium repens* and often other grasses which have been sown to maximise production from a particular location; these grasses include rough meadow-grass *Poa trivialis*, meadow foxtail *Alopecurus pratensis* and meadow fescue *Festuca pratensis*. They are grouped together in the NVC category:

MG7 *Lolium perenne* leys and related grassland.

These grasslands have low ecological interest in themselves, but they can be of ecological importance, for example as winter grazing for migrant wildfowl such as brent geese *Branta bernicla* or wigeon *Anas penelope*.

(d) Ill-drained permanent pastures. These pastures are found where mesotrophic soils derived from impervious bedrocks such as clays and shales lead to high soil moisture content and some soil gleying. These pastures, especially in the most wet and nutrient-poor situations, show transitions to mires and inundation vegetation, the latter being described in (e) below. Typical species are the grasses, Yorkshire fog *Holcus lanatus*, rough meadow-grass *Poa trivialis*, creeping bent *Agrostis stolonifera*, tufted hair-grass *Deschampsia cespitosa* as well as soft rush *Juncus effusus*. Common herbs are creeping buttercup *Ranunculus repens*, silverweed *Potentilla anserina*, curled dock *Rumex crispus*, meadowsweet *Filipendula ulmaria* and marsh marigold *Caltha palustris*. The NVC communities in this type are as follows:-

MG8 *Cynosurus cristatus-Caltha palustris* grassland;
MG9 *Holcus lanatus-Deschampsia cespitosa* grassland;
MG10 *Holcus lanatus-Juncus effusus* rush pasture.

Both the *Holcus lanatus-Deschampsia cespitosa* grassland (MG9) and *H. lanatus-Juncus effusus* rush pasture (MG10) form similar communities on heavy (clay-rich), unimproved

or neglected agricultural land which is permanently moist, gleyed and periodically inundated. MG9 has *Deschampsia cespitosa* as the dominant species and its dominance is due to its ability to survive in often anaerobic and oligotrophic soils which are inhospitable to other neutral grassland species. In MG10 it is *Juncus effusus* which is dominant and the community occurs on permanently moist brown earth and alluvial soils in the lowlands and on the upland fringes. It does not occur on organic soils.

The *Cynosurus cristatus-Caltha palustris* (MG8) grassland is sometimes found on traditionally managed "water meadows". These are uncommon grasslands which survive in a few traditionally treated sites by rivers and streams, mainly in southern Britain. The most widespread development of this was in chalk-stream valleys of such counties as Dorset, Hampshire and Wiltshire. The traditional system was a highly labour intensive system of winter irrigation and flooding to encourage the early and productive growth of pasture (see Rackham, 1986). This can be a species-rich grassland, with many herbs characteristic of moist conditions such as ragged robin *Lychnis flos-cuculi*, sneezewort *Achillea ptarmica* and marsh bedstraw *Galium palustre* growing together with more widespread unimproved meadow herbs. A high number of grass and sedge species are present together with marsh marigold *Caltha palustris*, buttercup species *Ranunculus repens* and *R. acris* and the clovers *Trifolium repens* and *T. pratense*. Many surviving water meadows do not conform to MG8, but appear to be semi-improved and perhaps derived from MG8.

(e) Inundation grasslands. These grasslands occur in fine-textured mesotrophic soils alongside slow-flowing or standing waters of varying level. Typical meadow plants, with the exception of red fescue *Festuca rubra*, are sparse with creeping bent *Agrostis stolonifera* and silverweed *Potentilla anserina* becoming increasingly common. Also present are species typical of periodically inundated land such as curled dock *Rumex crispus* and common couch *Elymus repens*. The NVC communities in this type are:

MG11 *Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland;
MG12 *Festuca arundinacea* grassland;
MG13 *Agrostis stolonifera-Alopecurus geniculatus* grassland.

The MG11 community is characteristic of a wide variety of moist but free-draining soils which are frequently inundated by fresh or brackish surface water. It is found in the lowlands, most often close to sea level, and occurs in extensive areas of the flood plains of major rivers and on the upper parts of saltmarshes where it is often used as pasture. The sward is species-poor and is dominated by varying mixtures of creeping bent *A. stolonifera*, red fescue *Festuca rubra* and silverweed *Potentilla anserina*. Salt-tolerant species are often present, such as spear-leaved orache *Atriplex prostrata* and sea mayweed *Matricaria maritima*.

The MG12 tall fescue *Festuca arundinacea* grassland occurs in similar conditions to MG11, but not in freshwater locations, and is largely, if not exclusively coastal. It occurs mainly where there is frequent inundation by brackish water, occasional tidal inundation or small amounts of salt spray. These locations are the banks of tidal rivers, the upper saltmarsh and on slumping clay sea-cliffs, most often in ungrazed situations. The grassland is dominated by *F. arundinacea* and is characterised by the presence of many saltmarsh species.

The MG13 *Agrostis stolonifera-Alopecurus geniculatus* grassland is more exclusively associated with the fluctuating margins of fresh waters. The dominant species are creeping bent *A. stolonifera* and marsh foxtail *Alopecurus geniculatus* with Yorkshire fog *Holcus lanatus*, rough meadow-grass *Poa trivialis*, creeping buttercup *Ranunculus repens*, flote grasses *Glyceria spp.* and docks such as *Rumex crispus*. This vegetation overlaps

somewhat with water margin vegetation but the NVC separates it out because it often occurs beside streams and pools in pasture with other mesotrophic grassland. A good example of this juxtaposition can be seen in the Ouse Washes, Cambridgeshire.

3.2.3 Calcareous grasslands.

Calcareous grasslands occur throughout the British Isles on a range of soils derived from limestone bedrocks. The main rock types are chalk, from Dorset to the Yorkshire Wolds; Jurassic (oolitic and liassic) limestone, from Dorset to North Yorkshire; carboniferous limestone, from the Peak District along the Pennines to southern Scotland; Magnesian limestone, from Nottingham north to Co. Durham; Cambrian and Precambrian limestones in the Scottish Highlands, especially Durness, Inchnadamph, Caenlochan - Glen Clova and Breadalbane (Ben Lawers).

The feature which these bedrocks have in common is the production of thin neutral to alkaline soils, mainly of a rendzina type. They are often nutrient-poor, with very low available phosphorus, which restricts the growth of competitive species and favours the presence of a species-rich sward containing calcicolous (lime-loving) species. According to Rodwell (1992) it is climate and not the presence of limestone rock which is of prime importance in determining the composition and distribution of communities. Climate affects plants both directly and, through its influence on soil development, has a further profound influence on vegetation. However, it is not rock type and climate which maintain these vegetation types as grassland; this is due to the continuous effect of grazing animals.

Rodwell (1992) divides calcicolous grasslands into 14 community types which are then divided into two geographical areas leaving two intermediate communities:

(a) Calcicolous grasslands of the south-east lowlands (7 types);
(b) Calcicolous grasslands of the north-west uplands (5 types);
(c) *Sesleria albicans* grasslands (2 types).

There is a major floristic distinction between the grasslands of the south-east of Britain and those of the north and west (Rodwell, 1992). These areas are separated by a line running from Durham, through Derbyshire to the Mendips and including in the south-eastern area, the coasts of north and south Wales. This boundary is approximately the 1000mm annual isohyet or 160 wet days per year line. It also corresponds well with the 26°C mean annual maximum isotherm.

(a) Calcicolous grasslands of the south-east lowlands. Within this zone, the drier conditions leads to the development of base-rich rendzina soils with low nutrient status and supporting grasslands rich in calcicolous species. These conditions have developed on the four main limestone bedrocks in the region, Devonian limestone, Carboniferous limestone, Oolitic (Jurassic) limestone and (Cretaceous) chalk. The core of this vegetation is *Festuca ovina-Avenula pratensis* grassland (NVC CG2 community) which is the most widespread calcicolous grassland in this lowland area. The full range of NVC communities in this lowland zone is as follows:-

CG1 *Festuca ovina-Carlina vulgaris* grassland;
CG2 *Festuca ovina-Avenula pratensis* grassland;
CG3 *Bromus erectus* grassland;
CG4 *Brachypodium pinnatum* grassland;
CG5 *Bromus erectus-Brachypodium pinnatum* grassland;
CG6 *Avenula pubescens* grassland;
CG7 *Festuca ovina-Hieracium pilosella-Thymus praecox/pulegiodes* grassland.

The *Festuca-Avenula* grassland (CG2) community occurs on a variety of calcareous bedrocks, most commonly on unimproved steep slopes but also on artificial habitats such as ancient earthworks, abandoned quarry workings and road verges. A group of calcicoles of Continental distribution occur in the warmest areas and, on northern sites such as the Peak District and Yorkshire Wolds, these species are confined to south-facing slopes. Such species include stemless thistle *Cirsium acaulon*, horseshoe vetch *Hippocrepis comosa* and squinancywort *Asperula cynanchica*, as well a nationally rare calcicolous plants.

There is a transition from the CG2 grassland to a limestone grassland found in the hottest, most Mediterranean-like conditions, with hot summer temperatures and frequent drought conditions. This is the CG1 *Festuca ovina-Carlina vulgaris* grassland found in the warm oceanic zone on hard limestones with south and west facing slopes. In these conditions, the hard rock weathers to produce open and rocky, but essentially stable slopes. These areas are found, for example, on the carboniferous limestone rocks of The Gower, in South Wales, the northern side of the Avon Gorge and Brean Down, in Somerset. Characteristic species include hoary rockrose *Helianthemum canum*, spiked speedwell *Veronica spicata*, several national rarities, and commoner species such as carline thistle *Carlina vulgaris*.

Especially in the Breckland of East Anglia, where thin, highly nutrient-poor rendzina soils occur in the driest and most continental part of Britain, a specialised limestone grassland has developed with a dominance of herbaceous species over grasses. Characteristic species of this grassland include the thymes *Thymus praecox* and *T. pulegioides*, mouse-ear hawkweed *Hieracium pilosella* and abundant bryophytes and lichens. This vegetation is CG7 *Festuca ovina-Hieracium pilosella-Thymus praecox/pulegioides* grassland.

The other NVC grassland types in this category are those resulting from a reduction in grazing pressure on the vegetation types described above. The reduction or elimination of grazing by rabbits and/or stock leads to the development of ranker, tussocky swards dominated by various combinations of upright brome *Bromus erectus*, tor-grass *Brachypodium pinnatum*, red fescue *Festuca rubra* and downy oat-grass *Avenula pubescens* (communities CG3, CG4, CG5 and CG6). If the absence of grazing persists, then scrub invasion takes place, especially with hawthorn *Crataegus monogyna* to form calcicolous *Crataegus-Hedera* scrub (W21).

Recognition of the vital nature of grazing to the persistence of species-rich calcicolous grassland is a vital message for habitat creation projects involving these communities.

(b) Calcicolous grasslands of the north-west uplands. The high rainfall in these areas increases the surface leaching of the limestone soils and leads to the dominance in the grasslands of widespread species such as red fescue *Festuca rubra* growing with calcifuge species such as common bent *Agrostis capillaris*, mat-grass *Nardus stricta*, tormentil *Potentilla erecta* and a number of other species. In such areas, a calcicolous element is often dependent on flushing of base-rich waters which can offset the effects of leaching.

The NVC communities present in this zone are as follows:-

CG10 *Festuca ovina-Agrostis capillaris-Thymus praecox* grassland;
CG11 *Festuca ovina-Agrostis capillaris-Alchemilla alpina* grass heath;
CG12 *Festuca ovina-Alchemilla alpina-Silene acaulis* dwarf-herb community;
CG13 *Dryas octopetala-Carex flacca* heath;
CG14 *Dryas octopetala-Silene acaulis* ledge community.

The CG10 *Festuca ovina-Agrostis capillaris-Thymus praecox* grassland is the counterpart of the *Festuca-Avenula* grasslands of the southern limestones and is the most common calcicolous grassland in this zone. The grassland is present over fairly base-rich and moist brown earth soils and can be found up to 750m altitude. On the Dalradian mica-schists in the central Highlands of Scotland above 500m, this community is replaced by CG11 characterised by the presence of alpine lady's mantle *Alchemilla alpina*.

The communities CG12, CG13 and CG14 are restricted mainly to montane sites in Scotland extending down to sea level in the far north. It is considered that these communities are outside the likely scope of this *Guide* although the *Dryas* communities at low altitudes in the far north may be an exception to this.

(c) *Sesleria albicans* grasslands.

Calcicolous grasslands with blue moor-grass *Sesleria albicans* as a dominant part of the flora occur at the dividing line of the northern and southern zones described above. Grasslands of this type are found in Durham, the Craven Pennines and the southern Lake District and comprise two NVC communities as follows:-

CG8 *Sesleria albicans-Scabiosa columbaria* grassland;
CG9 *Sesleria albicans-Galium sterneri* grassland.

The CG8 *Sesleria albicans-Scabiosa columbaria* grassland is confined to rendzina soils on the Magnesian Limestone of County Durham. Blue moor-grass is the dominant species within a species-rich grassland which includes such species as meadow oat-grass *Avenula pratensis*, salad burnet *Sanguisorba minor*, common rockrose *Helianthemum nummularium* and small scabious *Scabiosa columbaria*. This vegetation is seen as a link between upland and lowland limestone grasslands having elements of both in a distinctive community. It has been much reduced in extent by agricultural improvement and limestone quarrying. It has also been the subject of one of the largest transplantation programmes in Britain. This work was carried out at Thrislington Plantation SSSI as part of the quarrying programme on the site.

The CG9 *Sesleria albicans-Galium sterneri* grassland is mostly found on high level limestone areas within the north-western zone as described above. It also occurs at low altitudes on limestone around Morecambe Bay. This grassland is highly variable and includes the highly species-rich sugar limestone communities in Upper Teesdale.

3.2.4 Calcifugous (acid) grasslands.

Calcifugous grasslands occur on base-poor and leached soils throughout lowland and upland Britain, although they are most characteristic of upland areas where ericaceous communities are absent. The NVC classification of 21 communities includes certain montane grassland, snow-field, ledge and scree communities which are outside the scope of this *Guide*.

The more widespread and less montane grasslands are given the title "sub-montane calcifugous grasslands" in the NVC. This covers some five communities (U1-U5) with the heath rush *Juncus squarrosus* dominated community forming the sixth. U1-U3 NVC communities are principally found in the lowlands. Also considered in this *Guide* is U20, the widespread bracken *Pteridium aquilinum* dominated community.

The acid grasslands in Britain are characterised by the dominance of certain grasses including the fescues *Festuca ovina* and *F. rubra*, common bent *Agrostis capillaris*, bristle bent *Agrostis curtisii* (south-west England only), sweet vernal grass *Anthoxanthum odoratum*, mat-grass *Nardus stricta* and wavy hair-grass *Deschampsia flexuosa*.

In lowland Britain, in the Midlands and southern England on acid sands, brown earths and podzol soils, acid grasslands occur which are grouped in the U1 *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland. This is the most widespread calcifuge sward over southern Britain and is dependent on grazing for its maintenance. Its most characteristic manifestation is in the acid grasslands of the Breckland. This is a community of soils which are very prone to drought in the summer and support tolerant perennials such as sheep's sorrel *Rumex acetosella* and common mouse-ear *Hieracium pilosella*. On the Breckland, this community supports a number of rare species. More widely, annual species occur which germinate in the autumn and flower in the spring such as the uncommon shepherd's-cress *Teesdalia nudicaulis*, and the more common early hair-grass *Aira praecox*, common whitlow grass *Erophila verna* and common stork's-bill *Erodium cicutarium*.

In the warmer, more oceanic climate of south west Britain, U3 *Agrostis curtisii* grassland occurs on acid, well-drained soils and, more widely throughout Britain in similar habitats, U2 *Deschampsia flexuosa* grassland occurs.

The counterpart of the lowland *Festuca-Agrostis-Rumex* grassland on the permeable acidic soils in the cooler and wetter uplands in the north and west of Britain is U4 *Festuca ovina-Agrostis capillaris-Galium saxatile* grassland. This predominantly upland (sub-montane) grassland is also known as "species-poor *Festuca-Agrostis* grassland" although it not always low in associated species. The grassland sward is closed with an intermixture of *Festuca ovina, F. rubra, Agrostis capillaris* and *Anthoxanthum odoratum*, with relatively few associated herbs and bryophytes. These include heath bedstraw *Galium saxatile*, tormentil *Potentilla erecta* and field wood-rush *Luzula campestris*. Drought conditions rarely occur in soils supporting this community. Grazing is essential for its maintenance and this grassland has major agricultural importance in its place as upland "rough grazing". This grassland has been improved in some areas and with such treatment species such as Yorkshire fog *Holcus lanatus* and white clover *Trifolium repens* occurs. In contrast, where this grassland degenerates, then this leads to an increase in mat-grass *Nardus stricta*.

In even wetter conditions in the uplands, the mineral soils obtain a covering of organic material (mor or peat) and these highly infertile conditions lead to the increasing dominance of *Nardus stricta* with U5 *Nardus stricta-Galium saxatile* grassland. In this community *Festuca ovina, Agrostis capillaris* and *Anthoxanthum odoratum* remain common but subordinate to *Nardus*. Transitions commonly occur to heaths with the presence of bilberry *Vaccinium myrtillus* on more free-draining slopes. This is very poor grassland with increased floristic diversity only present where there is local flushing of more nutrient-rich or less acidic water. The heath rush *Juncus squarrosus* is a frequent plant in the *Nardus* grasslands but on deeper peats and peaty mineral soils on gentle slopes and plateaux, *J. squarrosus* can become dominant to form the U6 *Juncus squarrosus-Festuca ovina* grassland. This community has frequent *F. ovina* and *Deschampsia flexuosa*, but other grasses with the exception of velvet bent *Agrostis canina* are uncommon. The herbs *Galium saxatile* and *Potentilla erecta* occur, and common sedge *Carex nigra* and the moss *Polytrichum commune* are also characteristically found in this community.

3.2.5 Artificial grasslands

Apart from the artificial grasslands which are such a feature of our parks, sports pitches and gardens, there is a further type of "amenity grassland" where the objective has been to create a grassland of interest for its wild flowers. The creation of such areas is carried out in urban areas, rural trunk road verges and in school projects. It has created a small industry of its own in the supply of "wild flower" seeds from commercial seed houses as well as charitable trusts such as Landlife.

This topic will be considered in more detail in Chapter 7 but, especially in the context of road projects and "ecological landscaping schemes", it does need to be considered in this grassland chapter.

The grasslands created under the term "wild flower" or "attractive grasslands" are highly varied. Their success is also variable and dependent on the degree of planning and subsequent management which the site receives. As with all habitat creation, objective setting is important. For example, some of the most attractive recently created roadside verge grasslands are those recently produced along the A55 in Clwyd where the objective has clearly been the establishment of large clusters of cowslip *Primula veris* which appear in the late spring. Similar success has been achieved with ox-eye daisy *Leucanthemum vulgare* on many roadside verges in north-west England.

3.2.6 Saltmarshes

For the purposes of this *Guide* saltmarsh will be included in this chapter. There is indeed a transition from brackish and inundation grasslands through to salt marsh vegetation. Habitat creation involving saltmarshes is receiving prominence at the present time with the discussions on the managed retreat of coastlines. English Nature has been discussing targets in this area (Pye and French, 1993). Whereas this will only be a realistic option in counties such as Essex, it forms a habitat creation programme of some potential and, therefore, needs to be included in this *Guide*.

3.3 Planning of a grassland habitat creation scheme - the preliminary site survey

The first stage before the preparation of a habitat creation **Project Plan** is to critically examine the proposed habitat creation site to determine whether it is suitable for a grassland project and, if it is, to determine the most appropriate target grassland for the site.

3.3.1 Site location and history.

It is important at the outset to examine the proposed site in its local context. For example, there may be semi-natural grasslands in the vicinity which can be used as models or as a source of seed. The characteristic vegetation of the appropriate English Nature *Natural Area* should also be taken into account.

The history of the site is also of importance. The most important factor on a farmland site is the soil and the history of the agricultural management of the site. For example, has the agricultural improvement of the grasslands changed them irreversibly? Has the agricultural management of the site been so intensive that soil nutrient levels are so elevated that this may rule out certain types of grassland creation projects?

3.3.2 Existing vegetation

The habitat creation site should be examined for the presence of remnant semi-natural vegetation. This can be a guide to both soil conditions and to a potential target community. In the agricultural landscape the most likely places are adjoining hedgerows and tracks, on prehistoric earthworks, rocky outcrops and on steep slopes. The finding of significant semi-natural vegetation may change the focus of the project from habitat creation to habitat enhancement or management. The faunal use of the site must be identified, especially by protected species such as badger.

It is also important to survey the immediate locality for semi-natural grasslands. This will give some guidance as to target community and to species which do well in the locality. If an NVC grassland community is a proposed objective, then this is the time to carry out an NVC survey of both remnant grasslands and grasslands in the locality.

This *Review* has found that NVC targeted projects should preferably take place on sites adjoining semi-natural grasslands, such as SSSIs, SINCs and nature reserves. The work of Gibson & Brown (1991) supports this assertion, although evidence presented in this paper does indicate that the timescale for the development of communities akin to semi-natural grassland is many decades and not the 5-10 year period often used in local authority restoration planning conditions.

3.3.3 Soils.

The soils of the habitat creation site should be examined using the guidance set out in Chapter 2 (section 2.3.5) of this report, asking the question whether the soils of the site are (or could be made) suitable for the target community or project objective.

3.3.4 Physical conditions.

The physical condition of the site is an important consideration in project planning. The presence of steep slopes and changes of level, drainage lines and seepage zones, may have an influence on the type of project which is chosen. Physical considerations may also influence project methodology and thereby cost. An example of this would be overriding need to stabilise unvegetated soils on a steep slope.

3.4 Preparation of the Project Plan

3.4.1 Setting objectives

Once the preliminary survey is complete, it will then be possible to prepare the **Project Plan**. The purpose of the Project Plan is to record and to plan out every stage of the habitat creation project. As with all habitat creation projects, the most important early item is to set out the project objectives. With grassland creation, possible objectives may include the following:-

1. To create grassland which conforms to a semi-natural model, ie. an NVC grassland type. This is most likely to be the case on a site adjoining semi-natural grassland and be part of English Nature's *Natural Areas* strategy.

2. To create grassland which does not conform to a semi-natural model, but which aims to have certain target species in the sward, eg. to create roadside verge grasslands with a good display of cowslips *Primula veris* in the spring.

3. To create grasslands which are of greater visual interest than the ryegrass-clover grasslands which have recently become the norm in such locations as roadside verges and amenity grasslands.

4. To create grasslands which have an educational function, eg. within an urban nature park.

5. To create grasslands for a specific nature conservation objective, eg. providing winter grazing habitats for brent geese *Branta bernicla*, habitats for small mammals and invertebrates.

6. To provide a buffer zone to sensitive habitats.

3.4.2 Realising the objectives

Once the objective of the project has been set, then the methodologies need to be developed to cover the establishment, monitoring and long term management phases.

Each Project Plan will be site specific and can be built up using the guidance in this chapter read in conjunction with Chapter 2.

The resourcing and cost implications of the scheme can be a major determining factor with project objectives. This aspect should always be to the fore and should include both for project implementation and for long term management. Should the projected costs of the project be beyond what is available, then the objectives of the project will have to be changed. This might mean scaling down or changing the nature of the scheme.

3.5 Methods of grassland habitat creation

3.5.1 Introduction

Before specific grassland habitat creation methods are discussed it is necessary to discuss the ecological and practical principles which research has shown is necessary for the successful creation of grassland vegetation. The methodologies which are proposed are strongly dependent on the objectives which are set, most especially, the target community. The source of seed and propagules is also important and will form a key part of project planning.

Space does not allow for the inclusion of all the detail which is present in the literature and for further information the reader should refer to the publications of Wells (1981, 1986 and 1989) and Firbank et al (1992). Other more general texts have useful information including Buckley (1989), Fry and Lonsdale (1991) and Ash et al (1992).

3.5.2 Ecological principles

(a) Soil condition and nutrient status. The condition and nutrient status of a soil on a grassland habitat creation site is crucial. There has been a good deal of research in the last ten years on the analysis of such soils and the effectiveness of mechanisms to reduce soil fertility down to levels found in semi-natural grasslands. Much of this work is summarised in Marrs (1993) and this has been discussed with respect to habitat creation planning in Chapter 2 (section 2.3.5).

Grasslands occur on a wide range of soils from the most acidic sands to the most alkaline limestone soils. At the acidic end, there is a fine dividing line between acid grassland and heathland habitat creation, but one aspect in common is low pH and available plant nutrients in the soil. There is an equivalent low available nutrient situation with thin rendzina soils over limestone but here the pH is high and the free calcium can chemically bind free phosphorus and make it unavailable to plants.

As Marrs (1993) suggests, there is some scope for exploiting inherent differences in soil fertility. In many parts of Britain nature reserves tend to be situated on relatively poor soils and although the agricultural land surrounding them produces good crops, the land is often not as fertile as the best quality arable land. This soil factor reinforces the argument that habitat creation projects should take place adjoining sites supporting semi-natural vegetation. Cultivated land adjacent to nature reserves with their semi-natural grasslands is likely, although not always, to be at the low end of the agricultural fertility spectrum and this will give an inherent advantage to grassland habitat creation on these soils.

On a given grassland habitat creation site there is a need to measure soil fertility, especially extractable (plant-available) phosphorus and mineralisable nitrogen. The levels of these nutrients in typical semi-natural grassland soils shown in Table 2.1 then needs to be compared with results from the proposed habitat creation site and the examples of agricultural soils given in the Table. Once these results are available, decisions need to be taken on the following:-

1. Whether the soil nutrient level is at a level which is low enough to proceed with the projected scheme and no fertility reduction measures are required.

2. Whether the soil nutrient level is much higher than that which is recommended for the target grassland and fertility reduction measures are required.

3. With the situation in 2. above, whether the fertility reduction measures are capable of producing a soil with a low enough nutrient level to achieve the target grassland.

This is the most crucial stage in a grassland habitat creation project. It is recommended that professional advice is sought at this stage.

The difficulty is that the answer to the questions will also depend on other factors such as soil type and the nature of the targeted grassland. Whereas the techniques which can be used for fertility reduction are summarised in Chapter 2 (section 2.3.5) and in more detail in Marrs (1993), these actions could all be a massive waste of time and money if a poor decision is made at this stage. Unfortunately, it is questionable whether there is sufficient research and practical experience available from which to enable a scientific decision to be made. Decisions, therefore, will have to be made using experience and professional judgment.

Certainly for most sites it is more than likely that the habitat creation itself, ie. seeding the grassland, may not be possible for some years until fertility levels have been reduced. Time requirements are likely to be shortest on marginal chalk soils (Firbank et al, 1992), longer on acidic soils which have been limed and fertilised (see Evans et al, 1993) and perhaps longer still on more neutral loam soils (Marrs, 1993). The need for good, long term project planning cannot be over-emphasised. A good published example of the long term planning which is required is that of the RSPB at Minsmere (Evans et al, 1993) where the intention is to restore arable land back to acid grassland and heathland.

(b) Soil surface stability. The creation of large areas of bare soil, especially on sloping ground, can potentially create problems of soil erosion. This can be most pronounced where there are gullies through which water will drain. It is therefore necessary to establish vegetation quickly at the establishment phase. On sites where the stability of the soil is poor, the use of companion "nurse" grass species should be considered.

(c) Seed germination and seedling establishment. The soil surface must present a suitable environment for the germination and establishment of grassland species. Research suggests that the microtopography of the soil should be uneven to provide suitable germination sites. Humidity levels should also be at a satisfactory level and this can be aided by the use of companion grass species and by sowing at the right time of year.

Recommending an ideal time of year to sow grasslands is difficult and depends on a number of factors including the weather over the previous months and the location and elevation of the site. Early spring (late February in lowland Dorset, late April in the upland Yorkshire Dales) is usually the best time, but May can be a dry and hot month which can inhibit germination. Autumn sowing can often be best for hay meadows because many of the meadow species would naturally be germinating in the late summer/early autumn following the shedding of seed. Autumn sowing should be done early enough for there to be sufficient growth to enable winter survival; the sowing of companion grasses is a distinct advantage in the autumn.

(d) Source of seed and propagules. The sources of seed for grassland schemes was, in the past, limited to a few species of uncertain provenance which could be purchased from seed houses, or seed collected by hand from species-rich grasslands. Both the commercial availability of seed and research on seed sources has moved on from this and sources of seed can be summarised as follows:-

- commercially produced seed of grasses and herbs of UK provenance;

- collection of seed-rich hay from meadows with semi natural vegetation, especially hay meadows;

- the use of topsoil from semi-natural grassland which has had to be destroyed for development or other purposes; the transplantation of turves also becomes a possibility in this instance.

If the decision is made to purchase wild flower seed from commercial sources, then decisions on what is purchased need to be made with care. The main factors to consider are:-

- whether the UK provenance of the seed can be guaranteed and whether the seed supplier can do better than this by having seed derived from UK regions or different altitudes, for example;

- whether a ready-made or customised seed mix is to be purchased.

There is no doubt that the major wild flower seed houses are supplying seed from UK populations, but a direct check is to be recommended. The larger houses are offering technical guidance on the choice of wild flower seed mixes for particular sites. The technical competence of this advice is not known, but it is the case that the current literature is aimed at a non-scientific audience. It is, for example, landscape architects who are often the professionals who are taking decisions on grassland habitat creation and purchasing the required materials, including seed. There is a continuing debate on this subject, most notably in the role that non-native seed is having on UK biodiversity (eg. Akeroyd, 1994).

The question of whether to purchase ready-made habitat mixes or individual plant species will depend totally on the objective which has been set in the grassland habitat creation project. Is a "wild flower grassland" or an NVC target community the aim of the project? Ready made mixes are likely to be cheaper, but are the mix of species, including the grasses, the correct ones? Sound thinking on these questions will assist in the production of clear project objectives.

(e) Use of a nurse crop. Nurse crops have three basic functions:

1. To provide a pleasing visual effect as quickly as possible.

2. To produce a stabilising vegetation cover preventing soil erosion.

3. To provide shelter for the developing community of introduced plants.

The species used as nurse crops are quick-growing species and are easily removed once they have served their purpose. The subject of nurse crops is considered in section 2.4.3(f).

(f) Protection of developing vegetation. The degree of protection required by the newly sown and establishing grassland depends on the characteristics of the site and its management requirements. Generally though, newly sown areas need to be protected from grazing animals, including rabbits, and human trampling. Most grasslands require cutting once or more during the year and deciding when this management is to start is crucial.

3.5.3 The use of grassland topsoils

Evidence in the literature suggests that grassland topsoils are an unsuitable source of seed for habitat creation projects with the exception of soils from unimproved grasslands. This is because the topsoil seedbank in semi-improved or improved grassland tends to be dominated by long-lived arable weed seeds. Whereas these may not be present in the oldest grassland soils, the poor longevity of many perennial grassland species and their low level of seed production, also makes grassland topsoils unattractive for use in habitat creation.

3.5.4 The use of grassland litter

Although this is a common technique in heathland habitat creation, no published information has been found on the use of grassland litter as a seed source in grassland habitat creation projects. There has been some discussion in English Nature concerning the use of vacuuming equipment to collect litter and seed from chalk grassland, but no projects have been reported. Given the poor seed production in many perennial grassland species, it is likely that seed collected using this method would be sparse or consist of a few species only. However, the use of this technique demands further study.

3.5.5 The use of harvested seed

(a) Seeds in hay. In Holland and Sweden hay-bales have been successfully used for some years to introduce plant species to a meadow creation site. Existing species-rich meadows and other semi-natural grasslands form an ideal source of seed for habitat creation projects. The collection and use of seed collected from these grasslands has been a technique which has been investigated by a number of workers. There have also been a number of successful schemes using this technique. Its use confers a number of advantages:-

1. It enables the habitat creation practitioner to obtain seed from a known source and from a known NVC grassland type. This would be difficult to obtain in any other way.

2. It is a relatively inexpensive way to obtain seed when compared with the cost from commercial sources (English Nature give a cost as low as £15/kg).

3. It is a method of seed collection which causes little or no damage to the hay meadow donor site.

Research on the use of hay started in the early 1980s with examination of hay bales made using traditional techniques in species-rich meadows. This work (Wells et al, 1981; Wells et al, 1986) suggested that hay bales could be a significant source of seed. At this time the work was concentrating on separating the seed from the hay. Later work using "green hay", cut slightly earlier that the traditional time to ensure that the more seed remained in the fruiting heads, has concentrated on the use of the hay itself, spreading it over the habitat creation site during the summer/autumn (Wells et al, 1989). The hay then acts as a mulch and seed germination takes place both straight away and in the following spring. The mulch tends to suppress many weed and grass species which can cause a problem in such schemes.

This method relies on the fact that the grassland species are adapted to germinate under a thin covering of hay, while the weed species germinate best under direct sunlight. The species composition of the resulting meadow is often similar to the donor site, and this is a valuable feature if nature conservation is a primary aim.

However, there is some evidence that the hay itself can inhibit the germination of herbaceous species and some guidance now suggests the removal of the hay 3-4 weeks after application. At this time most of the seed should have been shed and a decision needs to be taken whether the beneficial effect of the hay acting as a mulch is outweighed by its potential inhibitory effect on seed germination and plant establishment. The project manager will need to use professional judgment on this matter, but the balance of argument is to leave the hay once applied.

In the Wolverhampton Meadows case study, the research has suggested that the green hay is best not baled but taken unbaled directly to the recipient site, thus conserving more seed on the plants and preventing fermentation damaging the seed. It is then spread over the prepared site and left to degrade over the winter.

CASE STUDY No.5: WOLVERHAMPTON MEADOWS, WOLVERHAMPTON

This is a long standing project (commenced, 1982/83) which has used "green hay" from existing species-rich meadows to create similar hay meadows on amenity land in the Wolverhampton area.

This is a complex project, involving a number of techniques which include different methods of collecting green hay and methods for reducing soil fertility at the habitat creations. However, an attempt was made to chose habitat creation sites whose soils resembled that of the donor site. The management of the created grasslands has relied on traditional summer cutting and, on one site, a late summer grazing regime has been introduced.

Critical comments

1. Although this project has been going for over 10 years, apart from a recent PhD thesis, it has not been written up in detail. As the project is a unique example of long term work of this kind, the researchers must be encouraged to write up their findings in a comprehensive way and to make recommendations to guide the activity of others. It is understood that information on these studies will begin to be published in 1995.

2. The work has successfully extended the exploratory work of Wells and confirmed that the use of "green hay" is a technique which is preferable on technical and cost grounds, in similar situations, to the use of separated seed.

3. The research has confirmed that the development of a naturalistic sward takes time and that the long term management of the grassland is a critical factor.

Some potential difficulties with the use of hay have been reported by Wells et al (1986) and repeated in later reviews, although no new published information has been found. These difficulties are:

1. The composition of the hay seed may not fully reflect the species composition of the donor site. The main reasons for this are a great annual fluctuation in the quantity of seed produced by particular species and the small quantities of seed produced by certain perennial species.

2. There may be seed of unwanted species present in the hay, including couch grass *Elymus repens* and vigorous grass species such as cock's-foot *Dactylis glomerata*. However, these species can be controlled by cutting management during the first year.

3. The viability of the seed may be low and, for this reason, the immediate use of hay is recommended. The use of green hay is also a method of reducing this problem.

The subsequent management of habitat creation sites treated with a hay seed source will be similar to that discussed in detail in section 3.5.6 which describes the establishment of a species-rich sward in the first year. Subsequent management will depend on objectives. For example, the use of hay from an NVC MG5 neutral grassland which has been managed as a hay meadow will suggest a management based on no cutting from March to July at which point the hay is cut and removed. Cutting may or may not be required in the late autumn depending on the growth of the sward. Alternatively, grazing can be resumed in the August to March period. The habitat creation Project Plan needs to define the objectives of the project at the outset which will include decisions about subsequent management and whether grazing will be possible or whether cutting will be required.

(b) Hand gathering of seed. The hand gathering of seed is the labour intensive alternative to the use of hay. The seed can be used according to the methods outlined in section 3.5.6 below. Hand gathering is a time consuming task but there are a number of advantages that make the technique worthwhile. These include:

1. The provenance and species composition of the seed stock will be fully known.

2. If volunteers can be called upon to assist with the seed collection, then this method can represent substantial financial savings.

3. It may be possible to obtain seeds that are not available by any other means and to select out undesirable species.

This technique is most likely to be used on donor sites where the entry of tractor-driven machinery is not possible or desirable.

(c) Mechanical seed harvesting from semi-natural grasslands. There are now some new techniques which are available for the mechanical collection of seed from semi-natural grasslands. The most effective of these is the tractor-mounted suction harvester which vacuums the litter layer of the grassland which includes shed seed. The advantages of this technique are similar to the hay and hand-gathering techniques.

3.5.6 The use of commercially available seed

(a) Seed availability. Commercial seed mixes are now widely available and, in more recent times, the companies concerned have responded to the need to provide seed from UK sources and in appropriate seed combinations where seed mixes are sold. These companies will also make up a specified mix if the quantities required are significant. Given the need for assurance concerning the UK provenance of seed, enquiries should be made directly to the supplier. Particular assurance needs to be obtained for bird's-foot trefoil *Lotus corniculatus* and kidney vetch *Anthyllis vulneraria* where, according to Wells et al (1989), seed is purchased in large quantities from abroad due to the difficulties of producing seed in commercial quantities in the UK.

Brown (1989), speaking on behalf of the wild flower and horticultural industry, pointed out that the industry is expected by the customer (the habitat creation practitioner) to provide a great deal of advice concerning the choice of species in grassland mixes for a

particular project. The industry has responded to these demands by taking on ecologists and by providing more informative catalogues and better seed mixes. It is not the place of this report to make recommendations, but the habitat creation practitioner is advised to make inquiries to the suppliers and to not rely totally on catalogues. English Nature can make recommendations on suitable companies and a number are listed in Ash et al (1992).

(b) Practical guidance. There is guidance available on the use of commercially produced seed in grassland habitat creation, both on the choice of seed mix and on the establishment of the grassland. The early published work of Wells et al (1981) and Wells et al (1989) continues to be the most valuable in this area with many subsequent publications such as Ash et al (1992), Firbank (1992) and Department of Transport (1993)) summarising this work and adding theoretical detail.

Perhaps the best general account is Wells et al (1989) but the Department of Transport (1993) *Wildflower Handbook* presents a practical approach to planning a grassland habitat creation project involving a consideration of many site factors and possible methods. This handbook includes much information on appropriate seed mixes for different types of grassland and species information on 64 recommended herbs (forbs) suitable for use in highway habitat creation projects.

Whereas the information contained in this publication is of value, it presents a number of problems for practitioners. For example, the guidance is not clear on whether an ecological or visual objective is the main aim of the highway grassland habitat creation programme.

The recommended ratio for seed mixtures is by weight, 85% grasses and 15% wildflowers (Wells et al, 1989). The grass component should consist of species which have a low productivity and vigour and which can flourish in nutrient-poor soil. Vigorous species such as rye-grass *Lolium perenne*, cock's-foot *Dactylis glomerata*, tall fescue *Festuca arundinacea* and timothy *Phleum pratense* are wholly unsuitable. More compatible grasses include red fescue *Festuca rubra*, sheep's-fescue *F. ovina*, common bent *Agrostis capillaris*, crested dog's-tail *Cynosurus cristatus* and some cultivars of the meadow grasses *Poa pratensis* and *P. trivialis*. Other low-productivity meadow grasses are also becoming available. If a semi-natural grassland is being used as a model, then suitable grasses will be evident from a survey of this grassland.

However, care does have to be taken with the use of wildflower mixes and three major problems can arise:

1. Loss of seed viability during seed storage; ideally seed should be stored for the minimum possible time and under cool dry conditions.

2. Commercial seed mixes are expensive and may be limited in the species available. The species availability situation is improving and a summary of some published costs is given in Table 3.1.

3. Commercial seed mixes containing inappropriate cultivars and native species not of local provenance can lead to concern with respect to the genetic integrity of adjacent high quality semi-natural grasslands.

The loss of seed viability during inappropriate storage was blamed for the poor performance of a herb-rich meadow creation project at Kenwood, Hampstead Heath, London.

Table 3.1 Typical costs of commercial wild flower seed mixes

Grassland type given in reference	No. of species in mix		Sowing rate kg/ha	% herbs in mix	Cost		Reference
	Grasses	herbs			£/ha	£/acre	
Limestone grassland	8	25	30	20	1029	416	DoT (1993)
Calcareous meadow	9	24	30	20	1156	468	"
Acid meadow	8	19	30	20	1148	465	"
Acid grassland	6	12	30	20	839	340	"
Wet acid grassland	3	5	25	4	519	210	"
"General purpose" meadow	5	10	30	20	653	264	"
Meadow	?	8	30	20	600	244	Ash et al (1992)
Meadow	?	8	30	10	360	146	"
Meadow	?	8	30	5	240	98	"
Calcareous grassland	8	25	25	-	700-1000	285-407	Firbank et al (1992)
Calcareous grassland	2-3	8	25	-	200	8.1	"

CASE STUDY No.3: KENWOOD MEADOW, HAMPSTEAD HEATH, LONDON

This project aimed to create 3 acres of herb-rich hay meadow on an old pasture area which had remained unploughed since 1928, grazed to 1956 and cut thereafter. The site was prepared in September, 1981 by ploughing and cultivating, but seeding consisting of a wildflower seed mix was delayed until April, 1982. The seed had been purchased some 8 months before use and had been stored in poor conditions which was likely to have affected the viability of the seed.

From this time until the present (1993), the site has been managed by an annual hay cut and the hay is removed from the site. The sward is grass-dominated with few herbaceous species. It is considered by the site manager that the failure of the project was due to poor herbaceous seed viability. Whereas this may be true, the delay in seeding the site could have allowed a significant number of weeds to colonise and affected the establishment of sensitive herbaceous species.

Critical comments

1. This case study is a good example of a well funded project, on a site where long term management was assured, largely failing due to poor project planning. The first problem resulted from ordering the seed too early, its poor storage and its subsequent use some 8 months after purchase. No records were kept of the seed mix which was used and it is therefore not possible to determine whether an appropriate mix for the site was specified.

2. No soil nutrient information was available for this project and so, therefore, it is not known whether nutrient levels were too high to support the desired grassland type. There is some circumstantial evidence that high nutrient levels may have been a contributory cause to the poor performance of the case study.

3. The evidence which has been seen does suggest that the site did support semi-natural species-poor relatively acidic grassland before the habitat creation project commenced. The presence of this grassland, unploughed since at least 1928, does suggest that habitat creation might have been the wrong approach on this site.

The high cost of commercial wildflower seed mixes, especially if a good range of grass and herbaceous species are included, makes their use more attractive on small rather than large sites. For this reason they are much in favour for use on roadside verges, urban habitat creation sites and demonstration areas in parks and school grounds.

The concern which has been expressed with the use of commercial wildflower seed next to and of high ecological interest poses a particular dilemma. On the one hand is the potential genetic damage to semi-natural grasslands caused by pollen, seed and propagules from the created grasslands and, on the other, is movement of pollen, seed and propagules in the other direction thus improving the species diversity and "naturalness" of the created grassland. Little research has been done on this problem with the exception of looking at the colonisation of improved agricultural land adjoining nature reserves (for example, Gibson & Brown, 1991). The following case study, at Durlston Country Park, Dorset, is an example of this situation.

CASE STUDY No.8: DURLSTON MEADOWS, PURBECK, DORSET

This case study is located in the Durlston Country Park which was established in 1973 and is managed by Dorset County Council through wardens who are based at the park. The park consists of a mosaic of farmland, downland and coastal cliff habitats and includes a limestone grassland SSSI supporting semi-natural grasslands. With the objective of extending the limestone grasslands in the park, a programme of habitat creation was started in 1983.

A former arable field was left fallow for two years, a hay crop taken and, in autumn, 1983, the field was shallow ploughed and sown with a native wildflower seed mixture consisting of 23 species based on the species present in the local limestone grasslands. The number of species which was commercially available was limited at the time and the UK provenance of the seed is uncertain.

Since seeding, the 1 acre field has been managed by an annual hay crop in August and by 1993, the field is being integrated with the 10 year rotational cut management used for the semi-natural grasslands. The species composition of the field has been monitored in detail on an annual basis and butterflies have also been monitored. The project has benefited from the low fertility of soils on the habitat creation site.

In 1990, all but two of the original wildflower seed mix species were present in the field and some 40 species were present in the monitoring quadrats. Not all of the sown species were recorded in 1984 and it is possible that these took time to establish or colonisation has taken place from the adjacent limestone grasslands. Certain significant species have colonised from the semi-natural grasslands and this process is improving its diversity and similarity to these grasslands.

In 1993 it was reported that the monitoring of this field is continuing and that further grassland creation projects are underway in the park.

Critical comments

1. This case study is, in many ways, a model example for others to follow. Records have been kept of the species and procedures used, the site has been monitored on at least an annual basis and the grassland creation has been successful in creating "semi-natural type" grassland. The case study has benefited from being in a wardened country park with a staff who remain committed to habitat creation within the park.

2. The case study has confirmed the principle of locating grassland habitat creation projects adjoining semi-natural grasslands from which colonisation can take place. At Durlston, the monitoring indicates that the process is continuing, now some 10 years after the project started.

3. This project has demonstrated the long term monitoring and management commitment which is required for successful grassland (and other) habitat creation.

4. The early date of the start of this project has meant that the UK provenance of the wildflower seed cannot be guaranteed. To what extent this has affected adjacent semi-natural grasslands is uncertain; as colonisation has been demonstrated to occur from the limestone grasslands to the created grasslands, it is likely that there has been some movement the other way.

(d) Sowing of seed. The practical matter of the successful germination and establishment of seed requires attention to four main points (Wells et al, 1989):

1. Careful selection of species suitable for the ecological conditions of the site.

2. A weed-free seed bed.

3. Good seed bed preparation.

4. Careful management of the site, especially in the first year.

Research has shown that for successful seed germination to occur with the generally very small seeds, it is necessary to have a fine and firm seed bed. Rough, uneven seed beds will not produce such good results and should be treated by repeated harrowing and rolling. Autumn sowing is preferable as this most closely mimics the germination pattern of the herbaceous species, although spring and early summer sowings can be successful. The seeding rate should be about 30kg/ha. Herbicides, such as glyphosate, should be used if necessary to produce a weed-free seed bed.

The method of seed application will largely depend on the size of the site. It is important to mix grass and wildflower seeds before sowing to prevent settling out. This can be reduced and the spreading of seed assisted by the addition of small quantities of an inert material such as fine sand or sawdust. On small sites hand broadcasting can be used, but on larger sites tractor mounted spreaders are more effective. Hydroseeding is best suited to steep slopes and inaccessible areas such as quarry cliff terraces. On accessible sites, after the seed is sown, a light raking or harrowing followed by rolling will ensure good contact between the seed and soil.

(e) Short-term management. Following sowing, the management of the site during the first year is critical. Guidance is given on this period in most of the source references for this chapter. Again, probably the best summary is given in Wells et al (1989). Management during the first year will have two major objectives:-

- the control of weeds and,
- the encouragement of herbaceous species.

Both objectives can be achieved by cutting. Perennial and annual weeds can become established quickly and have high growth rates. Cutting at a height of 80-100mm when the weeds have reached just beyond this height can be an effective control. Cut material should always be removed. Cutting is necessary to encourage herbaceous species if the nurse crop or sown grasses are seriously overtopping the smaller herbaceous plants. The number of cuts required will depend on soil fertility and growing conditions. It is possible on some (infertile) subsoil sites, cutting may not be required but, on more fertile sites, four or five cuts may be necessary during the first year. Clearly, the role of the site manager is crucial at this stage.

In the second and subsequent years, management requirements will lessen and one or two cuts only may be required. If the establishment of the grassland has proved successful, a grazing regime might be more appropriate and convenient, depending on the location and the project objective.

3.5.7 The direct planting of grassland species

Most of the published information on this subject refers to planting into a pre-existing grassland sward and, therefore, does not qualify as habitat creation under the definition used in this *Guide*. However, the use of pot-grown plants can form part of a habitat creation project when the grassland, with or without herbaceous species, is newly created and the pot-grown plants are used to introduce certain herbaceous species into the sward. It is also useful when wishing to introduce species with poor field germination.

There is some confusion in the literature on whether greater success is to be achieved from the use of seed or the introduction of mature plants. One factor is certain, however, the use of mature plants will raise the cost of a habitat creation project. The cost of pot-grown plants can be as much as 40-45p for an individual plant in a 90mm pot (DoT, 1993). However, costs can be reduced to 16p per plant (26p including planting costs) using modular transplant systems where plants are produced in small "plugs" (DoT, 1993). Plug plants are grown from seed and are supplied in plastic or biodegradable trays of about 200 plants. Given the small amount of soil for each plant, the trays are vulnerable to desiccation and also to planting into dry soil. Some watering provision is therefore required for some weeks following planting.

Although the use of pot grown plants is costly both in terms of time and money, the vast majority of native species can be successfully grown using horticultural methods. Wells et al. (1986) recommends planting out the specimens into existing grassland when they have four true leaves, or are between four or five months old. A high degree of success has been achieved using this technique with Wells reporting 80% of individuals of Ragged Robin *Lychnis flos-cuculi*, cowslip *Primula veris*, and betony *Stachys officinalis* surviving into the third year after planting.

The transplantation of grassland turves has value in that small units of whole plant communities may be transplanted, including mosses and liverworts. The technique can be used to diversify areas of existing herb-poor grassland or be placed within a newly created open grass sward or bare ground. Transplantation is outside the definition of habitat creation used in this *Guide* and the reader is referred to the review for the Nature Conservancy Council prepared by Byrne (1990).

3.5.8 Natural colonisation.

This technique is particularly appropriate in areas adjacent to existing semi-natural grasslands and where the soil fertility of the habitat creation site is low. This technique can be used together with seed introduction as has been successfully demonstrated at Durlston Country Park. Habitat creation of saltmarshes (next section) is most effectively carried out by natural colonisation.

3.5.9 Saltmarsh habitat creation.

The possibility of large scale saltmarsh creation in Britain has developed due to discussions concerning managed coastal retreat and the opportunity afforded by set-aside policy. The principle of managed retreat centres around the breaching of sea walls and allowing land formerly reclaimed from the intertidal zone to revert to saltmarsh. It will not be possible to adopt this policy in the whole of the UK as suitable sites mainly occur in the south and south-east of England. Pye & French (1993) in the English Nature publication *Targets for coastal habitat re-creation* estimate that 2750 ha of saltmarsh will be lost over the next 20 years from both human and natural causes. There is, therefore, a strong case for direct action to recreate saltmarsh habitat.

Saltmarsh habitat creation as part of managed retreat has been undertaken at an experimental site at Northey Island in Essex where the sea wall has been removed. The development of high value intertidal habitats, including saltmarsh and mudflat has taken place. Given the dynamic nature of much saltmarsh vegetation and the presence of seed in coastal waters, there seems to be no reason why saltmarsh creation cannot take place more widely in Britain. Indeed, saltmarsh habitat creation is an excellent example of Strategy 1 of Jones (1990) where habitat creation relies on natural processes. In this case it assumes a local natural supply of seed and the presence/creation of sediments at the correct tidal level. Evidence of likely success comes from examples where breaches have occurred in sea walls and the subsequent restoration of saltmarsh and mudflat habitats, eg. Pagham Harbour, Sussex.

Another approach is to extend saltmarsh seawards using a combination of potential methods (Pye & French, 1993). These methods are: the construction of offshore breakwaters and polders; raising of foreshore levels by sediment nourishment using dredged spoil or other suitable material to allow vegetation to colonise; and artificial transplanting of pioneer marsh vegetation. These options are being researched at the present time.

The current proposals for long term set-aside provide opportunities for saltmarsh creation. Firbank (1992) regards the restoration of saltmarsh on set-aside land as a long term option best regarded as an integral part of coastal defence management. The new MAFF environmental measures under the Agri-environment Regulation include a *habitat scheme* which includes funding the creation of intertidal habitats and targeting saltmarshes in particular.

The question of the target saltmarsh communities which may be created in these programmes is somewhat difficult to predict. The wide range of true saltmarsh vegetation, from sea-meadow grass *Puccinellia maritima* and red fescue *Festuca rubra* grasslands to pioneer communities of *Salicornia* and *Suaeda maritima* should be possible to create given the right foreshore level, a suitable tidal regime and a source of seed. Unfortunately, the *Review* did not locate any examples of habitat creation projects of this type with the exception of Northey Island and the Blythe Lagoons. At the transitional zone to freshwater marshes, inundation grasslands occur (NVC MG11 and MG12), which should be possible to create given the right hydrological conditions.

There is much research and practical work to do in this area. For example, there is no commercially available source of seed for saltmarsh plants. The supply of seed is not normally a problem in an estuarine coastal environment, but difficulty will be found seeding sites which are inland of current saltmarsh and are rarely reached by the tide. It is possible that the set-aside programme may produce a demand for seed which will be taken up by the commercial suppliers. What is required is a general purpose mix containing the main saltmarsh species with the exclusion of cord grass *Spartina anglica*.

A second area of necessary research is into the use of imported fill to raise beach levels. A likely source of fill is dredgings which in the Thames Estuary, for example, are disposed of in inland deposit grounds which are now in short supply. The use of these dredgings to raise beach levels seems logical but further research is required into the contamination status of the dredgings. Many dredgings are contaminated with heavy metals and oil-derived organic materials. The government guidance which is available on this subject refers to the use of contaminated materials on terrestrial sites. The use of dredgings for beach recharge therefore has implications for coastal water quality, the uptake of pollutants by flora and fauna, and whether effective growth of salt marsh plants can take place on the material.

3.6 Monitoring and long-term management

3.6.1 The importance of monitoring and management

The importance of management cannot be overemphasised with grassland habitat creation projects. Most semi-natural grasslands in the British Isles require grazing (or cutting) management otherwise there is a steady progression to rank coarse grasses and scrub with a loss of species diversity. To quote Rackham (1986): "*All sites of old grassland, almost without exception, were once wildwood and revert to woodland in a few decades if not grazed or mown*". With this dependency of UK grasslands on grazing (or cutting) management to maintain their current species diversity and plant community character, it is not surprising that the management of grassland habitat creation projects is so vital.

With habitat creation schemes, monitoring must form an essential part of site management. The monitoring provides information on the condition of the grassland sward so that appropriate decisions can be taken on its management. For example, monitoring of a limestone grassland habitat creation scheme might reveal that the height of the grassland was beginning to eliminate a set of target species from the sward. With the monitoring information, the manager is now likely to introduce a late October cut and removal of the cut material to aim to reduce the height of the sward and the dominance of certain competitive grass species.

In the *Review*, good monitoring of grassland habitat creation projects was found to be uncommon. Effective monitoring was found in local authority country parks such as Durlston, Dorset and Seven Sisters, East Sussex, but lacking at Levenhall Links Leisure Park in East Lothian, Scotland (see below) and at Kenwood Meadow, Hampstead Heath. As one would expect in long term research projects, monitoring has formed an essential component, such as the work of Wells et al (1981, 1986, 1989), Gibson & Brown (1991) and Trueman (Wolverhampton Meadows, unpublished).

3.6.2 Special long term management required on grassland projects

The management required on a grassland project depends on the objectives of the project and the local site conditions. Whereas hay meadow management requires cutting in summer, limestone grassland management will generally need a single cut and removal of material in late October or the introduction of grazing.

The most important requirement with grassland management is an ability to respond to the results of monitoring which has detected problems appearing in the sward. An example of this might be grasses in limestone grassland dominating the vegetation at the expense of the herbs. The correct response to this would be to cut in late March to clear away the winter growth and to reduce the vigour of the grasses.

The management of grassland habitat creation projects will need to take place in perpetuity and this needs to be a central theme of the project planning. The *Review* has suggested that this planning and action is most likely on sites such as country parks and nature reserves where there is a constant wardening presence working on a site. If it is not possible to assure long term management at the project planning stage, then consideration should be given to abandoning the project or changing objectives to a project which can be achieved within the available resources.

CASE STUDY No.1: LEVENHALL LINKS LEISURE PARK, EAST LOTHIAN

This project was established to create herb-rich grassland on fly ash lagoons at the Cockenzie Generating Station. It was to provide habitat diversity in an otherwise impoverished amenity grassland area by attempting to produce alkaline coastal grassland similar to semi-natural grasslands in East Lothian. During the initial restoration works, 150mm of moderately fertile topsoil was imported to cover the fly ash and an *Agrostis/Festuca* amenity grass mix was sown.

In 1987 an experimental area was cleared of vegetation and a wildflower grass mix was sown and nursery raised stock of certain wild flower species planted. Its species composition was loosely based on those present on alkaline coastal grassland sites in East Lothian. A hay meadow management regime was introduced at the outset with a late summer/early autumn cut and the hay taken off-site.

The site was surveyed in June, 1990 and a moderately diverse artificial sward recorded over a neutral to slightly alkaline topsoil. Of the 26 species introduced as seed, 15 were recorded in the sward. There was some weed invasion, with the thistle *Cirsium arvense* being particularly abundant. The annual hay cut on this site has been maintained to 1993 and there are no plans to stop this. No vegetation monitoring is taking place at the site.

Critical comments

1. The importation of topsoil onto the site and its lack of incorporation into the fly ash has created a substrate which has proved to be too fertile to allow a highly diverse sward to establish and be maintained. This experience does indicate that the substrate was not wholly compatible with the target community and suggests that more careful consideration was necessary at the project planning stage.

2. Although annual management of the site is occurring, the lack of monitoring is not allowing any feedback to take place to guide site management. Financial constraints are blamed for the lack of monitoring but it appears that monitoring was not built from the outset into the site management regime. Again, more consideration was necessary at the project planning stage.

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4. WOODLAND AND SCRUB

4.1 Introduction

Woodland habitat creation (some 12% of the projects reported in the *Review*) is perhaps the most misunderstood type of habitat creation scheme. The *Review* has shown that most schemes of this kind are in reality tree planting schemes and little or no thought has been given to ground flora and naturalistic tree and shrub species composition. However, there are some notable exceptions to this and, with the recent establishment of a number of forest and woodland initiatives, such as the National Forest, the nature conservation component of woodland planting is achieving a greater significance. This chapter also covers woodland habitat creation along watercourses (which formed some 2.4% of the projects in the *Review*) and the creation of hedgerows.

Recently published reviews of woodlands in the British countryside, such as Peterken & Allison (1989), present a picture of the decline in deciduous woodlands, trees and hedgerows in the lowlands and an increase in the planting of predominantly coniferous woodlands in the north and in the uplands. In lowland Britain, many surviving ancient woodlands are becoming increasingly isolated from an ecological point of view due to the loss of hedgerows, trees and small areas of woodlands which formerly helped to link the larger woodlands. With this background, woodland habitat creation presents an opportunity to reverse this trend. Although not all the planting which will take place as a result of initiatives such as the Farm Woodland Scheme (MAFF), the Woodland Grant Scheme (Forestry Commission) and the National Forest (Countryside Commission and others) will be carried out with nature conservation objectives as priority, the increasing coverage of woodland that these initiatives represent is likely to be significant in the long term.

Information gathered in this *Review* and from the literature suggests that woodland habitat creation has taken place on the following types of site:

1. *Arable farmland* - the Farm Woodland Scheme and Woodland Grant Scheme have encouraged the planting of small areas of woodland on farms, some of which have been designed with habitat creation for wildlife and game rearing as an objective. Arable land coming out of cultivation into long term set-aside will present a major opportunity for woodland planting.

2. *Mixed/pastoral farmland* - the situation is similar to that of arable farmland including future set-aside opportunities.

3. *New towns and cities* - some of the most extensive deciduous woodland planting has taken place in these places such as Warrington New Town and Milton Keynes. Whereas much of this has been planting with native species, there are only a few examples of woodland ground flora introductions.

4. *New road schemes* - the current road building programme includes an increasing amount of tree planting as part of mitigation packages. Whereas most of this planting is on roadside embankments and cuttings, there is also a significant amount of off-line planting for screening purposes. Little of this planting has had an ecological objective as its primary aim.

5. *Land reclamation sites* - the planting of trees, not always native species, forms an important part of the reclamation of derelict and degraded land. Little of this has been with an ecological objective although, on some sites, interesting woodland habitat has been created.

6. *Development-related sites* - there has been much woodland planting associated with development, some of which has had a nature conservation objective.

7. *Country Parks* - there is a great deal of woodland planting in country parks with a range of amenity and ecological objectives.

It is important that the nature conservation objectives of woodland planting are set at the right level. Evidence suggests that it will not be possible to create deciduous woodland of ancient woodland quality with all its associated woody species, ground flora, soils and invertebrates. Ancient woodland is defined as a woodland which has had continuous woodland cover and management since 1600. The National Vegetation Classification (NVC) system for woodlands (Rodwell, 1991) defines and describes the woodland types which occur in Britain. The best examples of these woodland types are ancient woodlands, although some NVC types are more characteristic of recent woodlands. Secondary woodland and scrub communities may also be described by the NVC system and can be of high nature conservation importance.

In order for planted woodlands to conform both regionally and locally to semi-natural woodlands, NVC can provide part of the "model" for new woodland creation. An excellent new guide to woodland habitat creation has been published by the Forestry Commission (Rodwell & Patterson, 1994) which uses the NVC as the framework for its recommendations, but it also extends to some non-NVC woodland planting. In fact it would be unwise to say that all planting must be based on the NVC "models". Examples where this wouldn't be the case is be the planting of Douglas Fir in SE England for firecrest conservation, or the planting of alder and birch on reclaimed colliery spoil where few other species would survive the difficult soil conditions.

There is, therefore, a need for woodland habitat creation to have modest objectives and to make the most of local opportunities. The choice of site is very important, for example it may be possible to carry out the habitat creation scheme adjoining an ancient or secondary woodland, or associated with a species-rich hedge which has some woodland ground flora species. The choice of the appropriate native species for the site is the vital next step. Is woodland ground flora going to be planted and/or will this be done at some later stage? These questions and many others need to be addressed at the project planning stage.

4.2 Types of woodland and scrub

4.2.1 General description

This section will consider the types of woodland and scrub found in Britain. It will concentrate on the ecologically more important types, that is, woodland with a natural or semi-natural composition. Other woodlands and deciduous plantations will be considered including tree/shrub planting on verges, embankments and cuttings of new trunk road and motorway schemes, amenity woodland planting and poplar plantations. Blanket conifer plantations will not be considered.

The National Vegetation Classification (NVC; Rodwell, 1991) recognises some 25 communities of woodland and scrub in Britain. A full description of these communities will not be given here and the reader is referred to Rodwell (1991) for more detailed information. A summary of these communities is given in Whitbread & Kirby (1992).

The NVC woodland communities are grouped under a number of headings as follows:-

1. *Mixed deciduous and oak-birch woodlands* - six communities.

2. *Beech and yew woodlands* - four communities.

3. *Pine and juniper woodlands and montane willow scrub* - three communities.

4. *Wet woodlands with alder, birch and willows* - seven communities.

5. *Scrub and underscrub communities* - five communities.

4.2.2 Mixed deciduous and oak-birch woodlands.

Within this woodland category falls the majority of woodlands in lowland Britain including the familiar oak and ash woodlands. The type of woodland which is found is heavily dependent on the type of soil which is present and local climatic conditions. Possible soil types range from calcareous, through neutral brown earth soils to acid podzols and acid ranker soils.

There are two woodland communities characteristic of rendzinas and calcareous brown earth soils on limestone bedrock:-

W8 *Fraxinus excelsior-Acer campestre-Mercurialis perennis* woodland;
W9 *Fraxinus excelsior-Sorbus aucuparia-Mercurialis perennis* woodland.

These are amongst the most floristically rich woodlands in Britain with a dominance of ash *Fraxinus excelsior*, but with oaks, small-leaved lime *Tilia cordata* and, especially in southern Britain, species such as field maple *Acer campestre*, dogwood *Cornus sanguinea* and wayfaring tree *Viburnum lantana*. The ground flora of these woodlands is diverse with many herb and bryophyte species and is characterised by an abundance of dog's mercury *Mercurialis perennis* and other species including enchanter's nightshade *Circaea lutetiana*, sanicle *Sanicula europaea* and wood dog-violet *Viola reichenbachiana*.

The most species-rich oak woodlands generally occur on neutral, less base-rich brown earth soils found throughout lowland Britain. Two communities have been distinguished:-

W10 *Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland;
W11 *Quercus petraea-Betula pubescens-Oxalis acetosella* woodland.

Although small-leaved lime, hornbeam *Carpinus betulus* and sweet chestnut *Castanea sativa* can be important local dominants in these woodlands, it is the oaks and birches which provide the most consistent components of the canopy. Understorey shrubs are mainly hazel *Corylus avellana*, hawthorns *Crataegus*, holly *Ilex aquifolium* and rowan *Sorbus aucuparia*. The ground flora of these woodlands is typified by bluebell *Endymnion non-scriptus* or wood anemone *Anemone nemorosa* in the spring and for the rest of the year by bracken *Pteridium aquilinum*, bramble *Rubus fruticosus agg.* and honeysuckle *Lonicera periclymenum*.

On the most acidic soils, the oak woodlands have been assigned to two further communities:-

W16 *Quercus spp.-Betula spp.-Deschampsia flexuosa* woodland;
W17 *Quercus petraea-Betula pubescens-Dicranum majus* woodland.

In these woodlands, the canopy is dominated by oak and birch with holly and rowan the commonest understorey species. The ground flora is typified by wavy hair-grass *Deschampsia flexuosa*, tormentil *Potentilla erecta*, heath bedstraw *Galium saxatile* and, locally, by ericoid species such as bilberry *Vaccinium myrtillus* and heather *Calluna vulgaris* in less shaded areas.

4.2.3 Beech and yew woodlands.

There are three woodland types in which beech *Fagus sylvatica* is the dominant species. These occur on highly calcareous, neutral and acidic soils, mainly in southern England. Beech casts dense shade and exerts intense root competition and this restricts ground flora and associated woody species with the exception of the evergreens holly *Ilex aquifolium* and yew *Taxus baccata*.

Southern England is the main natural zone for beech in Britain, which corresponds to the outcrops of chalk, oolitic limestone and some carboniferous limestone, although beech is not wholly confined to areas of calcareous rocks. Within this zone there are four NVC communities:-

W12 *Fagus-Mercurialis* woodland;
W13 *Taxus* woodland;
W14 *Fagus-Rubus* woodland;
W15 *Fagus-Deschampsia* woodland.

W12 *Fagus-Mercurialis* woodland is the characteristic beech woodland of the calcareous soils of the scarp slopes of the chalk in southern England. This woodland supports a number of other tree species, but beech forms the bulk of the canopy. Dog's mercury *Mercurialis perennis* typically forms the ground flora under the dense shade of the beech together with bramble and smaller quantities of such species as woodruff *Galium odoratum*, enchanter's nightshade and bluebell.

In some locations on the chalk and in the New Forest, yew *Taxus baccata* becomes the dominant species, forming the NVC W13 community. Few other species occur where yew is dominant, the most frequent being whitebeam *Sorbus aria* and dogwood *Sambucus nigra*. Ground flora is very sparse under the dense shade and dry ground produced by yew.

On base-poor, but permeable brown earth soils, beech W14 *Fagus-Rubus* woodland occurs forming a transition to oak NVC W10: *Quercus-Pteridium-Rubus* woodland on heavier, less well drained soils. A wide range of trees and shrubs occur in this beech woodland and ground flora is typified by bramble, bracken, grasses and bryophytes.

On the most acidic soils, beech W15 *Fagus-Deschampsia* woodland occurs also showing a transition to oak NVC W16 *Quercus-Betula-Deschampsia* woodland. Oak *Quercus robur* is the most common associated tree and the ground flora is dominated by wavy hair-grass and bryophytes.

4.2.4 Pine and juniper woodland and montane willow scrub

The three NVC communities are:-

W18 *Pinus-Hylocomium* woodland;
W19 *Juniperus-Oxalis* woodland;
W20 *Salix-Luzula* scrub.

Native and modified pine woodland with *Pinus sylvestris* occurs in the Highlands of Scotland. It falls within the W18 *Pinus-Hylocomium* community and has an ericaceous herbaceous ground flora including bilberry *Vaccinium myrtillus*, cowberry *Vaccinium vitis-idaea* and heather *Calluna vulgaris*. The soil surface is often a carpet of calcifugous bryophytes and rare Northern Montane and Continental Northern plants occur such as wintergreens *Pyrola spp.* and creeping lady's tresses *Goodyera repens*.

Very similar *Pinus sylvestris* woodland with similar bryophytes and ericaceous flora also occurs in south-east and north-west England, but this has been planted and so is not included in the NVC community account. In south-east England much of the woodland of this type was planted or became self-sown on open heathland.

Within the same region of Scotland, W19 *Juniperus-Oxalis* woodland occurs generally on more mesotrophic soils but which may be derived from the *Pinus-Hylocomium* woodland in which, in the past, juniper *Juniperus communis* was more common. This forms a scrubby woodland which supports many of the common and rare species of the pine woodlands. Wood sorrel *Oxalis acetosella* is a constant member of this community which extends as far south as northern England.

On high ground in the southern and central Highlands of Scotland, on moist mesotrophic/calcareous soils, the *Juniperus-Oxalis* community is replaced by W20 *Salix-Luzula* scrub. This consists of isolated growths of arctic-alpine willows with tall herbs, especially giant woodrush *Luzula sylvatica*. Unfortunately, this uncommon but attractive community is most unlikely to feature in a habitat creation project.

4.2.5 Wet woodlands with alder, birch and willows

These woodlands are characterised by the dominance in the canopy of various mixtures of alder *Alnus glutinosa*, downy birch *Betula pubescens* and willows *Salix spp.* and the overriding wetness of the soil. The seven NVC communities are as follows:-

W1 *Salix cinerea-Galium palustre* woodland;
W2 *Salix cinerea-Betula pubescens-Phragmites australis* woodland;
W3 *Salix pentandra-Carex rostrata* woodland;
W4 *Betula pubescens-Molinia caerulea* woodland;
W5 *Alnus glutinosa-Carex paniculata* woodland;
W6 *Alnus glutinosa-Urtica dioica* woodland;
W7 *Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum* woodland.

Space does not allow a detailed account of all these woodland types to be given here; as with all the communities, a full account is given in Rodwell (1991) and a summary in Whitbread & Kirby (1992). A number of communities are especially associated with the primary colonisation of swampy vegetation bordering open water and can fall under the category of riparian habitat. Others are associated with mires where the open mire vegetation has been colonised by woody species as a result of lack of cutting or grazing management of the mire vegetation. These communities are all associated with a wetland ground flora dominated by sedges, bryophytes, *Phragmites australis* and aquatic herbs.

4.2.6 Scrub and underscrub communities

Scrub for the purposes of the NVC has been defined as sub-climax woody vegetation and underscrub dominated by hawthorn *Crataegus monogyna*, bramble *Rubus fruticosus agg.* and/or bracken *Pteridium aquilinum*. The five NVC communities are:-

W21 *Crataegus monogyna-Hedera helix* scrub
W22 *Prunus spinosa-Rubus fruticosus* scrub
W23 *Ulex europaeus-Rubus fruticosus* scrub
W24 *Rubus fruticosus-Holcus lanatus* underscrub
W25 *Pteridium aquilinum-Rubus fruticosus* underscrub

The bulk of sub-climax woody vegetation in the lowlands of Britain is W21 *Crataegus monogyna-Hedera helix* scrub. This scrub has commonly developed on ungrazed pastures

or from degraded woodland. It is especially common on neglected chalk and other limestone grasslands and here can be associated with calcicolous shrubs such as dogwood, wayfaring tree, privet *Ligustrum vulgare* and traveller's joy *Clematis vitalba*.

Blackthorn *Prunus spinosa* scrub W22 is most commonly found as sea cliff scrub in conditions of high exposure. Gorse *Ulex europaeus* scrub W23 is most common on acidic soils especially on sea-cliffs, roadside verges and heathlands. Bramble is always a feature of this scrub.

The two bramble-dominated undershrub communities W24 and W25 are common vegetation types of woodland and scrub margins, clearings and rides, hedgebanks and newly colonised ground. The W25 *Pteridium-Rubus* community has woodland affinities and the W24 *Rubus-Holcus* community has affinities with weedy species being present from the colonised waste ground on which the community has developed.

4.2.7 Other woodlands and plantations

Whereas these do not have high botanical interest for the habitats which are produced, they can be of significant value for protected and/or faunal species. An example of this is the value of poplar plantations in the Thetford Forest area for breeding golden orioles, or the value of lowland conifer plantations for crossbill, redpoll and firecrest.

There are a large number of woodland planting schemes which are associated with development such as highways or housing, or with land restoration/reclamation. This woodland planting has mainly been carried out to enhance the visual quality of the landscape and, in the case of development, to mitigate against woodland losses caused by the development. On land reclamation sites, the function of the planting is for visual and amenity purposes, but it can also have a soil stabilisation function.

The species used in tree/woodland planting schemes vary considerably. The most recent highway planting, for example, has been of native tree and shrub species. This has been less so on reclamation sites where there can be major constraints to plant growth and the choice of species is limited. On these sites, such as reclaimed colliery spoil heaps, different species of alder *Alnus*, poplar *Populus*, willow, birch and conifer have been planted.

4.2.8 Hedgerows

Hedgerows do form the subject of habitat creation projects and, with their woodland affinities, are best placed in this chapter. Most of the native trees and shrubs of Britain can be found in hedgerows together with associated woodland ground flora. They can have considerable nature conservation and historical interest. In order to understand the significance of hedges it is necessary to consider their origins which can be broken down into three main types:-

1. *The planting of woody species to create a stock-proof barrier or to mark the boundary of land ownership or an administrative unit, such as the boundary of a parish* - the age of hedges with this origin can be very wide, with some hedges having an ancient origin, others planted during the 18th and 19th century Enclosure Acts and others planted in modern times. The oldest hedges have the greatest species diversity and can have considerable nature conservation interest as well as being of historical importance.

2. *The natural colonisation of boundary lines by woody species during times of neglect* (Rackham 1986) - this can have occurred at any time but examples have been

traced from the Dark Ages and periods such as the Black Death where much rural depopulation took place.

3. *Hedges which are the remnant of the boundary of an ancient woodland which has been removed* - these hedges can be recognised by the presence of woodland species not normally present in hedgerows such as small-leaved lime and wild service *Sorbus torminalis*. They can have considerable nature conservation interest as they can also support a significant remnant of the woodland ground flora and associated woodland invertebrates.

The commonest and most familiar hedgerow plant is common hawthorn *Crataegus monogyna*, with hazel, blackthorn, elder *Sambucus nigra* and oak also common. The historical background of hedgerows and their role in providing some habitat continuity and linkage in the wider countryside, makes hedgerows an ideal subject for habitat creation projects. The restoration of degraded hedgerows by planting and subsequent management should also form part of this activity.

4.3 The planning of a woodland habitat creation scheme - the preliminary site survey

4.3.1 Site location and history

The first stage in the planning of a woodland habitat creation project is to examine the proposed site in detail. It is important to place the site into its local context in terms of the types of semi-natural woodlands in the area and the presence of old hedgerows. These can provide a model for the habitat creation which is proposed, including a list of tree and shrub species and characteristic ground flora species.

The history of the proposed habitat creation site is important. If the site is former arable or pasture, the fertility of the soil may be somewhat elevated and steps may need to be taken to reduce it. On derelict land and restored mineral sites, information is required as to the substrates which are present and whether any contamination is present which may present problems for plant growth.

4.3.2 Existing vegetation

If the objective of the proposed project is a particular NVC woodland type, then evidence suggests that the site should preferably be adjoining a site supporting the target vegetation. This may be woodland, or an ancient hedgerow which supports some woodland flora. Rodwell & Patterson (1994) have some additional guidance on this subject.

It is also important to carry out a full ecological survey of the proposed habitat creation site in order to be sure that the site does not have ecological value for, say, its grassland flora. If the existing ecological interest of the site is found to be high then a change of habitat creation site is advisable. Alternatively, the existing interest could be turned to advantage by integrating it into a habitat creation project which includes woodland and other habitats. Changing problems into advantages is what good project planning is all about.

4.3.3 Soils

The soils of the proposed habitat creation site should be examined using the guidance set out in Chapter 2 (section 2.3.5) of this *Guide*. Most agriculturally managed soils have been improved and have higher levels of plant available nutrients, especially nitrogen and phosphorus, than are found in woodland soils. Whereas these levels may not be a long term problem, at the planting stage there is likely to be problems with weeds and, if woodland ground flora has been sown, with competition with vigorous grass species.

The soil type will have a substantial determining influence on the type of woodland and the species of tree which are best planted. The woodland description account in this *Guide* (section 4.2) has related woodland type to soil type. The most important parameters are soil composition (relative proportions of sand, silt and clay), pH and degree of wetness. Under arable management in particular, the soil type itself will have been modified and the distinctive brown earths and podzol soils will be difficult to relate to the undisturbed soil profile which may still be present if the site is a long-standing pasture.

4.3.4 Physical conditions

The topography of the site, especially changes of level and the presence of steep slopes, is an important consideration in that it can impose priorities in the habitat creation scheme, such as the need to plant to fix unstable ground. The presence of seepage zones and therefore waterlogged soils are important and care is needed as some sites may only be waterlogged in the winter. The relationship between site drainage and soil type should also be established.

4.4 Preparation of the Project Plan

4.4.1 Setting objectives

The completion of the preliminary survey should then lead to the preparation of a **Project Plan**. The purpose of the Project Plan is to record and to plan out every stage of the habitat creation project. As with all habitat creation projects, the most important first item is to set out the project objectives.

With woodland creation, possible objectives may include the following:

1. *To create woodland which is modelled on a semi-natural woodland type and involves the creation of a woodland canopy, shrub layer and ground flora* - this is the most ambitious woodland habitat creation and is most likely to take place adjoining existing semi-natural woodland which can act as a source of seed and propagules.

2. *To create woodland which is more loosely modelled on a semi-natural woodland type but which does not aim to create the whole woodland ecosystem* - for example, woodland ground flora might not be included in the scheme.

3. *To create blocks of mainly single-species woodland planting within existing sites in order to increase the ecological diversity of the site as a whole* - an example of this would be the planting of alder or willow along a watercourse.

4. *To create woodland for amenity or educational purposes on former derelict land, urban sites and in the wider countryside* - whereas the primary purpose of this woodland might not be "habitat creation" in an ecological sense, such woodland, if composed of native species, can be of ecological value.

5. *To create woodland, scrub or hedgerow habitats for a specific nature conservation objective* - examples of this would be the establishment of poplar plantations for golden oriole, new hedgerows with standard trees to increase the diversity of farmland birds and mammals, or blackthorn scrub as breeding habitat for the brown hairstreak butterfly.

4.4.2 Realising the objectives

Once the objectives of the project have been set, then methodologies need to be developed to cover the establishment, monitoring and management of the project. It is possible during the development of these methods that a fundamental problem will arise which cannot be solved. If this is the case, then the objective of the project will need to be revised.

The Project Plan can be built up using the guidance in this chapter read in conjunction with Chapter 2.

As with most habitat creation, woodland projects will require both short and long term management, with the long term management measured in decades and centuries rather than years. The resourcing and cost implications of this should always be to the fore in the project planning. If there is a problem with this, then the objectives of the project will have to be changed.

4.5 Methods of woodland habitat creation

4.5.1 Introduction

In the literature on the establishment of woodlands there has been, with a few exceptions, no particular emphasis on the process as one of habitat creation. Indeed there is a very blurred distinction and misconception between the planting of trees and habitat creation. In many ways whether or not the tree planting is habitat creation will depend on the objectives which have been set.

This methods section aims to guide the practitioner in an effective planning of their habitat creation project. It firstly summarises the ecological and practical principles behind woodland habitat creation and then outlines possible methodologies. Part of this description will include relevant case studies.

This *Guide* is not meant to include all specific details of design and methodologies and reference should be made to specialist texts and papers. These include Peterken (1981), Countryside Commission for Scotland (1985), Emery (1986), Brooks (1988), Buckley & Knight (1989), Coppin & Richards (1990), Department of the Environment (1992) and Forestry Commission handbooks and bulletins. The recently published guide to woodland creation by Rodwell & Patterson (1994) should also be consulted.

4.5.2 Ecological principles

(a) Soil conditions and nutrient status. In the habitat creation literature, very little attention has been paid to soil conditions and soil nutrient status in woodland habitat creation projects. It is an area where more research is needed. The preliminary site survey (section 4.3.3) will have considered soil type and likely nutrient levels in relation to the woodland planting being considered.

Most native tree species do well in relatively infertile soils and the soils which are present on most lowland sites, especially on former farmland, are likely to have reasonable fertility. Whereas this is a problem with grassland habitat creation, it need not be a problem with the planting of trees. Given effective control of weeds, the establishment of trees to produce a canopy will be more rapid in these soils. Indeed, many of our semi-natural woodlands are on deep, naturally fertile soils.

Fertility will, however, be a problem with the establishment of woodland herbs where competition problems would be intense in a fertile soil. Given this problem, there are two possible solutions:

1. Undertake soil fertility reduction procedures as outlined in Marrs (1993) and summarised in section 2.3.5 before starting the woodland habitat creation.

2. Delay the introduction of woodland herbs until a closed canopy has been produced; the delay will allow the leaching of some nutrients and the closed canopy will help to suppress vigorous weed and grass species.

To summarise, the weight of evidence would suggest that woodland habitat creation sites where nature conservation is a priority should have shallow or nutrient poor soils. Topsoil stripping of the most fertile soils is a possibility; this is not only likely to reduce the fertility of the site, but will also remove existing vegetation and its seedbank of non-woodland species which reduces competition for the introduced woodland flora. The sale of the topsoil can also provide revenue for the project.

(b) Soil surface stability. As with all habitat creation sites, there can be large areas of bare soil at the start of the project which can be eroded by wind and rain. For this reason, the rapid establishment of a vegetation cover is recommended but this can be incompatible with the establishment of the target species. It is possible that the instability problem can be brought under control with the use of groundforming methods such as, for example, terracing. More information on such techniques can be found in Coppin & Richards (1990).

(c) Sources of plant material. There is not a problem of commercial supply with native trees and shrubs, although there is some problem with the unacceptable supply of cultivars of native species and a greater problem with the supply of stock which is not of local provenance. There is also a difficulty with the supply of woodland ground flora species. This situation does not seem to have improved from the position summarised by Buckley & Knight (1989).

Sources of plant material can be summarised as follows:

1. Commercially produced native species of trees and shrubs, supplied as seed, whips (small, bare-rooted stock), nursery transplants and container grown plants.

2. Commercially produced seeds of woodland ground flora ("woodland mix") and woodland edge species. Commercial supply of container grown woodland species.

3. Topsoil and turves from a woodland about to be lost to development.

4. Hand collection of seed/mast and saplings from existing woodlands (with the owner's consent).

5. Production of cuttings from source trees (works well with *Salix*, *Crataegus*, *Populus*, etc.).

6. Facilitating natural colonisation.

As with the commercial supply of grassland seed, enquiries should be made to determine the British provenance of supplied material. Particular care should be taken with this as continental European stock can be used to grow on British native species, both for trees and for herbaceous species.

(d) Constraints imposed by the ecology and life history of herbaceous woodland species. Whereas it is reasonably straightforward to plan and plant the tree and shrub species required to create a particular type of woodland, the question of methods to establish woodland and woodland-edge ground flora is more difficult. In resolving this situation it is helpful to understand something of the nature and dynamics of woodland ground flora.

An analysis of this with respect to habitat creation is presented in Buckley & Knight (1989). They report that the National Vegetation Classification has indicated that the commonest ground flora species of semi-natural woodlands are the invasive bramble *Rubus fruticosus agg.*, ivy *Hedera helix*, bracken *Pteridium aquilinum* and wavy hair-grass *Deschampsia flexuosa*. These are not species included in woodland mixes and, particularly with bramble and bracken, might even be controlled as weed species. The typical deciduous woodland plants bluebell *Endymion non-scriptus*, wood sorrel *Oxalis acetosella* and dog's mercury *Mercurialis perennis* are in the commonest group of species, but the latter two are not in commercial seed mixtures because seed production is very difficult and germination success is poor.

Peterken (1981) divided woodland ground flora species into three groups:

Group 1 - poorly colonising species normally associated with ancient woodland sites;

Group 2 - fast-colonising species of recent woodlands;

Group 3 - shade-tolerant species widespread in other habitats besides woodlands.

The poor colonising ability of the Group 1 plants and their poor seed production presents major difficulties for habitat creation projects. These plants are long-lived perennials which invest more resources into vegetative spread than into seed. The species are the majority of the well known woodland plants mentioned above with the addition of such species as wood anemone *Anemone nemorosa*, ramsons *Allium ursinum*, moschatel *Adoxa moschatellina* and lesser celandine *Ranunculus ficaria*. To quote Buckley & Knight (1989), if these species are desired in a habitat creation scheme *"...they would have to be put there"*; in other words, they would have to be introduced by transplantation or by using container-grown plants.

Group 2 species are mainly woodland edge species which persist at low densities within woodland once the canopy has closed. These species produce large quantities of seed and are able to rapidly colonise bare ground from seed. Such species include red campion *Silene dioica*, wood avens *Geum urbanum*, herb robert *Geranium robertianum* and hedge woundwort *Stachys sylvatica*.

Group 3 species include a large number of copious seed producing hedgebank and woodland edge species which are not confined to these habitats, including cow parsley *Anthriscus sylvestris*, hemp agrimony *Eupatorium cannabinum*, foxglove *Digitalis purpurea* and meadowsweet *Filipendula ulmaria*.

It is largely Group 2 and 3 species which feature in woodland ground flora and woodland edge "mixes" and this has to be borne in mind in the habitat creation planning. There will be real difficulty in creating woodland ground flora with Group 1 species both due to the lack of commercial seed and due to the poor powers of natural colonisation of these species. Hence, even colonisation from adjacent ancient woodland will occur only slowly and this has been demonstrated in a number of studies (Rackham, 1986). Further information on this subject is given in Francis *et al* (1992).

(e) The woodland canopy. There is no real way of overcoming the problem that at the start of a woodland creation project, shade-tolerant woodland ground flora species will not have the canopy shade they require. This problem can only be resolved by delaying the planting of ground flora until the canopy has formed, or by using an existing woodland planting scheme as the habitat creation site (eg. Francis *et al*, 1992).

(f) Use of a nurse crop Nurse crops will not normally need to be a part of woodland habitat creation. However, on difficult and nutrient-poor substrates, nurse species can have a role. An example is on china clay waste, where the nitrogen fixing legume tree lupin *Lupinus arboreus* has successfully acted as a nurse species allowing the colonisation of the substrate by the willows *Salix cinerea* and *S. aurita* (Bradshaw & Chadwick, 1980).

Grass seed is normally included in commercial woodland herb mixes to act as a nurse. However, evidence cited in Buckley & Knight (1989), suggests that when used the grasses can suppress the herbaceous species. This effect would be enhanced if soil fertility were high.

(g) Protection of developing vegetation. There will be a need for the protection of developing vegetation from grazing animals and human and animal trampling. Electric fencing may be more suitable for the protection of relatively small sites on agricultural pastures. If deer are present, then deer-proof fencing will be required. Newly planted trees in exposed situations may need the protection of wind fencing, at least in the early stages. Methods to protect vegetation should form part of the design and management plan for the project.

4.5.3 Methods of woodland habitat creation planting

(a) The use of commercially produced trees. The widespread commercial availability of native species makes this the most likely source of trees in a woodland habitat creation project. The methodologies which are available for the planting of trees are part of standard forestry and landscape architecture practice. There is a considerable literature on this and also British Standards such as BS3936:1980 which defines the types of tree stock which are available and other British Standards which cover the methodology of tree planting.

Once the objective of the woodland habitat creation has been set and the local research on soils, existing vegetation, etc carried out, then the practitioner will need to design the woodland (tree/shrub) planting which is required. Decisions will need to be taken on a number of subjects:

1. *The size and shape of the site*. The largest possible woodland should be planned and with the lowest possible edge:core ratio. A circular shaped woodland will have the lowest ratio but, as circular woods are not a typical shape in the UK landscape, the value of this principle will depend on local circumstances. Small and narrow blocks of woodland have proportionately more edge habitat than a larger, more square or circular block.

2. *The choice and the mix of species*. Whether the aim of the project is to create a semi-natural woodland (including, therefore, ground flora) or a less defined amenity woodland, the chosen species will be ecologically suited to the site and its soil conditions. Particularly if the objective is an imitation of semi-natural woodland, then much thought will need to be given to planting density, the mix of species and any phasing of planting which might prove necessary.

3. *The size of stock to be used.* Obviously, instant visual effect can be achieved using large stock, but the use of smaller stock or bare-rooted whips (0.6-1.2m tall) will give better long term results. Observations suggest that their growth overtakes older stock within a few years and they are better suited to subsoils. The size of stock used also has considerable cost implications and available resources might better be spent on management or some other item.

4. *Immediate post-planting management.* The growth of vegetation between the newly planted trees and shrubs should be prevented until at least a partial canopy has been achieved. Better growth will result from this practice as root competition is eliminated. A clear ground policy can be maintained using mulches or herbicides although bark mulch may later need to be cleared if ground flora is to be introduced. On subsoils, the infertile conditions may result in little growth of ruderal vegetation and little or no management may be required.

5. *Planning for long term management.* Thought must also be given at this planning stage to the long-term (10, 25, 50, 100 year) development and management of the woodland as this will have implications for the mix and planting pattern of species. Study of model woodlands in the locality can help this long term planning.

There are very few published examples of the design of new woodlands which are based on ecological principles and therefore fall under the definition of habitat creation. One of the best programmes has been carried out in Warrington New Town and is summarised in Tregay and Gustavsson (1983). (Warrington is also a case study location involving the introduction of woodland ground flora, section 4.5.4 (b)). In this programme a number of woodland types have been established using an initially high proportion of scrub/hedgerow species (hazel, birch, alder) designed to create a sheltered system in which the forest trees (oak, ash, beech) could become established. These plantings have been well managed and successful so far. A more typical example of a woodland planting case study where ground flora has not been considered is Case Study No. 25, Ladyloan Wood, Scotland.

(b) Direct tree seeding. The establishment of woodlands from seed has been part of commercial forestry in North America and land reclamation sites in continental Europe for some time. As a technique it has good potential in Britain. Early work was carried out by McVean (1966) on the establishment of trees from seed on degraded moorland sites in Scotland. In the early 1980s this was followed up commercially and projects took place, mainly on reclamation sites, throughout Britain, concentrating on sites where access was difficult. Direct tree seeding is particularly useful as it allows hydroseeding of tree and shrub species onto steep slopes.

Few practical examples of the use of this technique have been published and none could be described as having a wholly habitat creation objective. One example is the work of Putwain *et al* (1988) in South Wales using direct tree seeding to establish "amenity woodland" on new roadside embankments. The technique in this instance required the use of herbicides to control competition from both grasses and herbaceous species. The evidence suggests that direct tree seeding can have a role in woodland habitat creation projects but whether this can include full ecosystem habitat creation is uncertain and further research is needed to investigate this.

CASE STUDY No.25: LADYLOAN WOOD, GLASGOW

This woodland was planned and established in 1986 by the Central Scotland Countryside Trust and funded by forestry grants and the local authorities. It was planted on former pastureland which had gone out of agricultural management due to the construction of a housing estate.

The planting was mainly of native species but none of the stock was of local origin. The main species were ash, birch *Betula pendula*, wild cherry *Prunus avium*, alder and rowan and the edges of the wood were planted with scrub species including hazel, hawthorn and blackthorn. Small blocks of Scots pine and larch *Larix decidua* were also planted. The site is managed using herbicide and cutting and tree thinning operations are proposed.

Critical comments

1. This scheme is a good example of woodland habitat creation where the local perception was that the woodland had been planned partly with an ecological objective. This came through in the *Review* questionnaire survey and it was for this reason that the site was chosen as a case study. In actual fact the woodland has formed a good piece of amenity planting for the benefit of local people and was not developed with ecological objectives with the exception of the planting of native species.

2. The site is isolated from all other woodland and the possibility of the colonisation of this woodland by ground flora species is remote. It will require the introduction of such species for any woodland ground flora to develop.

3. Ladyloan Wood is also a good example of a scheme where a written Project Plan or a management plan would have helped greatly with setting, for example, of project objectives. The site visit took place some five years after establishment and it was difficult to draw conclusions about the success of the scheme with little knowledge of the objectives of the project.

(c) Scrub planting. Habitat creation projects involving the creation of scrub achieve a semi-natural condition due to the relative simplicity of the habitat. There is rarely any ground flora with hawthorn and blackthorn, for example, excepting that which has been derived from the former open-ground vegetation. Willow is very straightforward to establish from whips and cut shoots but, in semi-natural situations, different species of willow occur in association with a wide variety of ground flora whose composition depends on the history of the site, its hydrology and its pH and nutrient status. Despite the ease of willow establishment, no published examples of its creation for habitat creation purposes could be found.

(d) Marginal vegetation planting. This planting covers that which occurs along watercourses and open water. Much of the planting which occurs in this environment consists of standard trees positioned next to water. These are, therefore, barely habitat creation projects although, in time, substantial crack willow *Salix fragilis*, alder *Alnus glutinosa* and other trees will be present which will add to local value of the habitat. However, care needs to be taken when introducing willows and alders as they can be very invasive of other wetland habitats.

Much semi-natural woodland occurs adjoining watercourses and a case study on the creation of bank-side vegetation on the River Wye was examined for the *Review*:

CASE STUDY No.24: RIVER WYE, BUILTH WELLS, POWYS

This habitat creation project was in mitigation for the effect of widening the A470 on the River Wye and adjacent woodland habitat. Two parallel projects were carried out by two different organisations which has enabled a comparison to be made between the methods used. The planting took place on made ground associated with river erosion prevention measures.

One project planted commercially grown native tree species at the site while the second project used locally grown whips and transplants. The second project also included the planting of container grown woodland ground flora and river bank vegetation of native provenance. The planting took place in the 1987-88 winter period and was managed for one year; this involved weed control and the replacement of dead and missing plants.

On the case study site visit in 1991, most of the species introduced to the site were present and additional species had colonised the site, including a nationally uncommon species. The trees of the second project had outperformed the first project; this was attributed to the first project plants suffering desiccation during transportation to the site.

Critical comments

1. This project is one of the few found in the *Review* where herbaceous species had been introduced in a woodland habitat creation project. The apparent success of the ground flora, although it was only three years from its establishment, is encouraging. However, the species which were planted were those of river bank and open ground and not woodland species. It is possible that these species may decline on the site as the trees grow and begin to cast significant shade. The explanation for the persistence of the introduced herbaceous species is likely to be the infertility of the soil.

2. The project only benefited from one year of management and the site is now unmanaged. Whereas the situation in 1991 was good, there is no guarantee that this will continue. One can then question the expenditure made on this site which must have been considerable. There is clearly no point in planting native herbaceous species if the conditions for their survival do not continue. This site is a good example of a site where regular monitoring is required which will trigger management when this is needed.

(e) Hedgerow planting. There are well established techniques for the establishment of hedges and Devon banks which have been practised for many centuries. An excellent practical handbook on the creation and management of hedges is the BTCV publication (Brooks, 1984). Whereas the creation of new hedges with a nature conservation objective is to be recommended in its own right, they should also be considered as part of a woodland habitat creation project, serving to link the new woodland with other woodlands and hedge systems.

The species planting in new hedges should be planned in the same way as for woodlands. Surveys will reveal the species composition of local hedges and these species should be used. Priority should also be given to the enhancement of old degraded hedges within the habitat creation scheme. The creation of a hedge in association with a new hedge bank and ditch provides much scope for the creation of more diverse habitat. Fencing to protect

new hedges from grazing animals is essential and this may need to be continued indefinitely, especially if the hedge is combined with a bank and ditch. In terms of soils it would again be advantageous for the hedgebanks and ditches to be established with low-fertility soils although this will be of less importance to the hedge planting as long as weed control was undertaken.

4.5.4 Woodland ground flora establishment

(a) The use of woodland topsoil.

It is not possible to obtain commercially produced seed of most of the key ground flora species of ancient woodlands, the Group 1 species of Peterken (1981). The mixes being offered for sale contain few or none of these species. Furthermore, if the seed can be supplied, then germination and establishment success is likely to be low. For these reasons, the only method available for transfer of seeds, propagules (ie. stems, roots, rhizomes and bulbs) and even whole plants of these species, is the use of topsoil from an ancient woodland donor site.

In view of the convincing arguments for the conservation of all remaining ancient woodlands which retain their semi-natural character, the opportunity for their use as a donor source is likely to be rare. However, recent instances have arisen of ancient woodland topsoil being available from the Channel Tunnel terminal (Biggins Wood, Folkestone; Buckley & Knight, 1989) and a number of new Department of Transport road schemes.

The Biggins Wood topsoil transfer example as reported in Buckley & Knight (1989) and Helliwell (1990) had just taken place at that time and further results have not been published. However, the Buckley & Knight paper provides valuable information on a study of the soil profile in Biggins Wood with respect to the presence of a seed bank and the ability of other propagules to be transferred. This investigation showed that a substantial seed bank was present, although not for all species. In addition, for some species, such as enchanter's nightshade *Circaea lutetiana*, vegetative transfer from rhizomes was as important. Other studies of woodland soils summarised in Buckley & Knight (1989) have reported significant viable seed banks although some species (such as dog's mercury) have little buried seed. They also reported that the buried seed bank contained many woodland-edge and ruderal species which were not present in the woodland vegetation. This suggests that the longevity of the seeds of these species is considerable.

If ancient woodland topsoil is be used as a source of seed and propagules then it makes ecological sense to transfer a portion of the soil profile. A depth of 300 mm has been suggested and this will include most of the vegetative parts of the ground flora and will be the bulk of the A horizon of the woodland soil. The cost of this movement is estimated by Buckley & Knight (1989) at £9-15,000 /ha to move the soil 500 m. Apart from the ground flora species, soil transfer will include other important elements of the woodland ecosystem such as mycorrhizae, fungi and soil invertebrates.

With the transfer of woodland topsoil it is clearly necessary to have a receptor site with a similar soil profile and which has had its topsoil removed. A shaded receptor site is also essential and there is little point in transferring woodland topsoil without these conditions being available. Down & Morton (1989) report on experimental work carried out at Darenth Wood which examined the transplantation of semi-mature trees although the work was interrupted before ground flora establishment could be tested. They reported that useful shade was not achieved for five years, clearly too long for woodland flora to survive, although, given effective early weed control, woodland edge species would establish. Details of the Biggins Wood transfer site are not available.

The question of the availability of a shaded site is clearly going to be an intractable problem for many potential habitat creation projects. The only possible receptor site would be an existing deciduous woodland or tree-planting scheme where the ground flora is of little or no interest. There would then be the problem of the damage that would be caused to the surface root systems of the trees by the removal of 300 mm of topsoil. There would also be problems with the addition of transferred soil placed directly on top of the receptor site topsoil - trees do not respond well to the burial of their root systems and perennial weeds may be able to grow through the donor topsoil (although these could be controlled by herbicide). The answer may be the design of a compromise between the protection of the trees on the receptor site (root systems can take some damage) and the need to transfer 300mm of soil profile (perhaps less depth can be taken).

The use of topsoil transfer clearly has potential, given the (unfortunate) availability of ancient woodland donor sites. However, more large scale practical research is required and this will inevitably be over a long period of time. Clearly, the results and recommendations from the few examples which are known, such as Biggins Wood, must be published or made known to a wider audience.

(b) The use of woodland litter. The use of woodland litter as a source of seed of ancient woodland (Peterken Group 1) species does not appear to have been researched. This could be because it is known that many of these species do not produce large quantities of seed and the collection of woodland litter by, for example, the use of vacuuming equipment, would prove to be of little value.

In contrast, however, woodland edge and shade tolerant species such as red campion and foxglove produce copious quantities of seed as this is necessary to enable them to colonise open ground as it becomes available. The collection of seed using vacuuming equipment in the litter layer could, therefore, be expected to be quite successful. Again there appears to be no published information on this except advice in Emery (1986) on seed collection by voluntary groups.

(c) The use of commercially available seed. It has been discussed above that the majority of "woodland mixes" which are sold are mainly composed of woodland edge and more widespread, shade-tolerant species. Most of the key indicator and characteristic plants of ancient woodland (Group 1 species of Peterken, 1981) are not available and, if required, will have to be obtained from other sources.

Buckley & Knight (1989) report some research on the woodland seed mixes which were available in 1987. A review by the author of 1994 seed catalogues shows a similar position for woodland seed mixes, although some specialist growers will supply the seed of a wider range of woodland species including some from Group 1, such as bluebell. The findings of the review of seed available in 1987 indicated that the seed of certain widespread and reliable species was being included as a contingency in case of poor establishment of the woodland species. The review also found that the seed of less visually attractive Group 1 species which would readily germinate was not included in the woodland mixes; these included the woodrushes *Luzula pilosa* and *L. sylvatica* and the sedges *Carex sylvatica* and *C. remota*.

If the aim of the woodland mixes is to provide the mix of species one would find in a semi-natural woodland or a good hedgebank, then the commercial suppliers need to make some improvements to the mixes. For example, meadow grasses are normally included with the woodland mixes presumably to act as a nurse crop for the herbaceous species. However, the evidence suggests that these species present severe competition problems for the herbs (Buckley & Knight, 1989) and, therefore, should be removed from the mixes. Furthermore, if they are sown on shaded sites, nurse grasses will not be required. The

cost of woodland grass mixes given in Buckley & Knight (1989) is £1100-£1500/ha depending on whether grass is included in the mix. The supplier should always be contacted to ensure that the seed is of UK origin and not just produced in the UK from continental derived stock.

There is evidence of pressure on practitioners to sow woodland ground flora mixes before shade has been established. This is a complete waste of time and of resources which need to be redirected to a later stage in the habitat creation project.

Published guidance on methods of application of woodland seed mixes is very sparse. There is a need for published examples of habitat creation schemes where the use of commercial seed mixes has formed a part. Clearly, woodland mixes should be introduced into existing species-poor woodlands and into tree planting schemes which have achieved a canopy. Woodland or shade-tolerant species which are present should be carefully conserved but it is most likely that the ground flora will have the remnants of a grassland or ruderal flora which should be removed before the application of woodland seed mix. This can be done using a systemic herbicide such as glyphosate. Some woodlands will have much bramble and ivy, for example, but it should be remembered that these species are component of ancient woodland and, therefore, should be kept under control rather than eliminated.

Seeding is best carried out in the autumn or early spring; autumn sowing has the advantage of breaking dormancy in some seed which needs a cold treatment. The work of Boorman in Milton Keynes, reported in Dawe (unpublished), and information gathered in this *Review*, has indicated that spreading seed in patches in woodland produces nuclei from which seed-based colonisation can take place. This successful work has been based on a range of woodland edge species which spread rapidly from seed.

The short term management required will depend on the sowing environment. In well shaded conditions, little will be required unless undesired species (such as docks) become prominent. They will need to be treated by hand weeding or by spot herbicide treatment. Too fertile conditions will favour vigorous grasses but a woodland mix should be chosen which contains woodland grasses such as wood poa *Poa nemoralis* and wood millet *Millium effusum*.

In partially shaded conditions and hedgebanks, the presence of grasses and potential invasion by ruderal species will be a greater problem than in more shaded conditions. In these conditions problems can be reduced by having as low fertility soil as possible (subsoil would be preferable), avoiding grasses in the seed mix and by having the ability to remove unwanted ruderal species by hand or using herbicide. Subsequent management of these communities is difficult as they consist mainly of a mixture of biennial and perennial species. Cutting during the growing season will prevent seeding and the best option appears to be cutting in the late autumn when growth and seeding is complete. The cut material should be removed. Where the vegetation immediately adjoins a new hedge, then cutting close to the hedge may not be necessary as the scrub species may be encouraged to spread into this area. The herbaceous species are all adapted to colonise bare ground, so the creation of soil disturbance can favour the long term persistence of certain species.

(d) Direct planting of species. The final option for the introduction of ground flora is the direct planting of species. These will have been raised in cultivation preferably from material of local provenance. This option is obviously more expensive but, for smaller woodland creation schemes which have a semi-natural (NVC) objective, then they are a realistic option in terms of cost. This method also has the distinct advantage that the woodland plants such as dog's mercury, dog violet, primrose *Primula veris*, yellow archangel *Lamiastrum galeobdolon* and bluebell, which do not readily establish from seed, can be planted in an attempt to create a true woodland ground flora.

A case study in Warrington New Town has used this technique; no other published examples, apart from Francis *et al*, have been found although a number are known to be in press.

CASE STUDY No.24: SANKEY VALLEY PARK, WARRINGTON (NEW TOWN), CHESHIRE

The first stage in this project was the planting of native woodland species according to the principles presented by Tregay & Gustavsson (1983) and summarised in section 4.5.3 (a) of this *Guide*. This involved the planting of oak and ash amongst alder and downy birch *Betula pubescens*, with edge planting of blackthorn, hawthorn and elder. The Park and habitat creation site are both linear features and thus edge habitats predominated. The soil on the site was constructed using 300mm of clay subsoil covered with 300mm of "peaty soil" and spent mushroom compost.

For the next seven years, weed control was practised and the trees grew to the extent that canopy shade was being produced. Woodland ground flora and woodland edge species were then planted in the woodland. These included pendulous sedge *Carex pendula*, hairy brome *Bromus racemosus* and red campion *Silene dioica*. They were planted in groups rather than mixed together.

It is not certain how this project is being monitored, but the apparent fertility of the site and the variable amount of shade produced by the planting has required direct management in that regular hand weeding and the use of herbicide has been necessary to prevent the swamping of the planted species.

Critical comments

1. The created soil of the habitat creation site has proved to be too fertile for the successful establishment of herbaceous woodland species without intensive weed control management. It appears the imported peaty soil was quite fertile and mixed with the nutrient rich and alkaline mushroom compost has further increased fertility. It is probable that the clay subsoil mixed with sand would have been a less fertile and more appropriate substrate. It is also possible that inadequate shade has been a factor in aiding weed species.

2. The elongated shape of the site with its high proportion of edge habitats with respect to the central fully shaded woodland habitat has exacerbated the weed problem. This calls attention to the design and especially the shape of a woodland habitat creation project. If the objective is to create true woodland habitat with the maximum possible shaded area then the best design must be one which aims to have a circular outline. If a site is sinuous and necessarily narrow, then other options should be considered such as the creation of a hedge, bank and, if conditions allow, a ditch system. The herbaceous planting can then concentrate on woodland edge and associated wetland species.

3. A positive element of this project has been the long term commitment of the authorities to manage this site and to invest in a costly weed control programme. As with all habitat creation projects, long term planning is necessary and projects will not achieve their objectives without it.

Costings for the production of plant material have been difficult to obtain. Buckley & Knight (1989) give a cost of £1000 /ha (excluding labour) assuming that 2,500 plants would be needed per hectare of woodland and a 40p cost per container-grown plant.

4.5.5 Ensuring the integration of tree and herbaceous planting

Given the objective to attempt to create a woodland with semi-natural character, the integration of tree and shrub planting with ground flora planting is a difficult but crucial matter. In most cases with the planning of naturalistic woodlands, the introduction of the ground flora will take place at the stage at which the woodland canopy has approached that found in semi-natural woodlands. The deciduous biology of the trees creates an extreme of shade in the summer and allows almost full light penetration in the winter.

Most true woodland plants grow during the winter period, flower in the early spring before the canopy has formed and die back to an underground dormant stage from June to early the following year. The dense summer shade can reduce full daylight to 10% of its intensity but as little as 15-25% of ambient light will encourage the development of a non-woodland flora (Buckley & Knight, 1989). There is clearly a fine balance to be drawn between canopy and the growth of specialist woodland ground flora. This is perhaps the most difficult but crucial aspect of woodland habitat creation.

There is also a need for the temporal spacing of planting trees to create mixed aged and structured woodlands. This is an important factor but it requires a very long-term commitment to a project.

4.6 Monitoring and long-term management

4.6.1 The importance of monitoring and management

Monitoring and management are an essential part of project planning. Management plans should be established at the outset of the project and regular monitoring is necessary to establish any refinements and modifications which are necessary. Unfortunately, the findings of this *Review* agree with Dawe (unpublished) when he states: *"....the complete absence of biological monitoring of so many habitat creation schemes is a very severe hindrance to the acquisition of knowledge and hence to progress in the management of new woodlands"*. This contrasts with the monitoring and management of semi-natural woodlands where a good deal of information is available and guidance is given in such publications as Peterken (1981). Brooks (1988) is a good practical text on woodland management.

4.6.2 Special management required on woodland creation projects

(a) Early management. With both whip and standard planting good weed control is essential for several years to prevent root competition. This can be achieved using herbicides but other alternative methods are now becoming more common such as mulching. It is important to chose a mulch which is composed of an inherently infertile material, such as chipped bark. The use of mushroom compost, for example, will fertilise the soil, increase the soil organic content and become a seed bed for annual and, later, perennial weeds.

Weed control will be necessary until the canopy has begun to close and it may need to continue at the woodland edge until introduced woodland edge flora has become established. Thinning of trees may be required as planting density may have allowed for failures. Semi-natural woodlands have a mixed age structure and, if this is an objective of

the project, then planning has to be in place for the later planting of trees, thinning and allowing trees to seed and establish from seed. Even-aged stands of woodland planting are a common feature in Britain and these woodlands will always be of lower ecological value than mixed aged stands.

(b) Long term management. With woodland creation projects there is little published information to assist the practitioner. There is some information on woodland management by a number of authors (Scott, Usherwood, Campion, Higson, Moffatt) in *Landscape Design*, February 1991. Dawe (unpublished) has summarised the findings of a number of authors concerning the plantings at Warrington and in Holland. There is confirmation that a management plan is essential; in the context of this *Guide* this would form part of the Project Plan. The Plan will contain the objectives of the project and the original ideas of the project planner. The management plan itself should, for woodlands, run for a 25 year period and be regularly updated. This is for a longer period than is given the management plan handbook of the Nature Conservancy Council (NCC, 1991).

Long term management options for created woodland tend to merge in with the practices adopted for semi-natural woodlands, such as coppicing, selective felling, the opening up of rides and replanting. There may be a need to remove non-native species which have invaded the woodland such as sycamore *Acer pseudoplatanus* and *Rhododendron*. The maintenance and enhancement of structural diversity of woodland is essential. If this does not happen, then even woodlands composed of native tree species will become dense and dark in which woodland ground flora will not be able to survive. For the management plan to be effective it is necessary to continue to carry out monitoring so that feedback can occur.

It is possible to increase the diversity of woodland by a long term programme of measures such as the importation of dead timber to create habitat for invertebrates and fungi and the installation of bird nesting boxes and bat boxes.

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Plate 1. Habitat creation planning - use of field trials. If time is available, field trials, such as those established at Cove Radio Station, Farnborough, are an invaluable aid to habitat creation. The trials in the photograph are in their fifth year and clearly show the long term effects of differing establishment treatments involving the use of mulch, fertiliser, lime and different grass nurse treatments. August, 1989.

Plate 2. Habitat creation planning - use of field trial information. The results of the field trials at Cove Radio Station, Farnborough, were put into practice during the construction of the radio station. The results guided the creation of soil profiles, nutrient and pH adjustments, and the seeding prescriptions used in the restoration. September, 1990.

Plate 3. Cove Radio Station : establishment of heathland vegetation. Three years after the construction of the radio station, the establishment of *Calluna* and other heathland species has been successful. The site is being managed with a late summer cut, which although it keeps the vegetation below 150 mm in height, it successfully controls invasion by pine and birch. The radio station requires low vegetation for operational reasons. October, 1993.

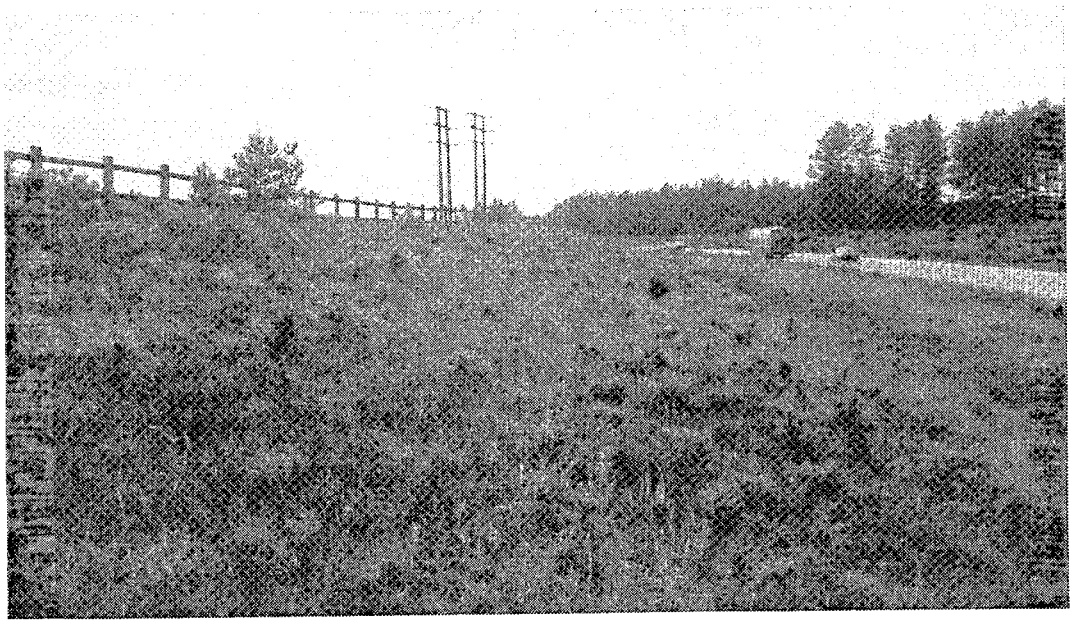

Plate 4. Ferndown Bypass, Dorset : establishment of heathland vegetation. The establishment of dwarf shrub heath vegetation has been successfully achieved. However, the development of gorse *Ulex europaeus* can be clearly seen and its control is essential if the dwarf shrub heathland vegetation is to be maintained. June, 1990.

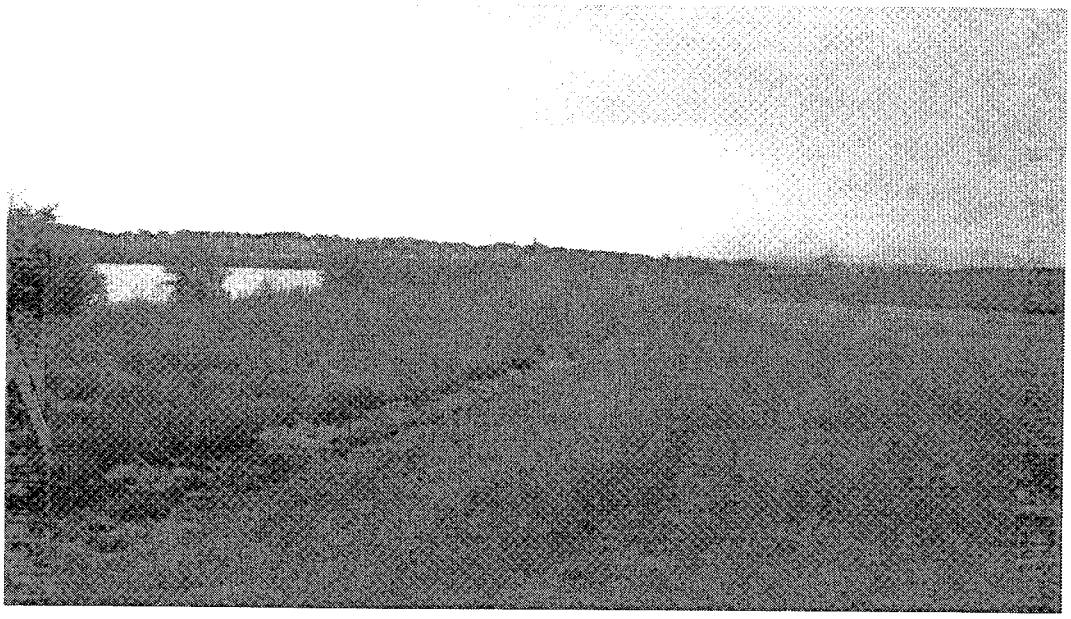

Plate 5. Levenhall Links Leisure Park, East Lothian : establishment of herb-rich grassland. This grassland has been established on old fly ash lagoons and is being managed by an annual hay cut. However, no vegetation monitoring is taking place to guide the management of the grassland. June, 1990.

Plate 6. Wolverhampton Meadows (Bushbury Hill) Wolverhampton : establishment of a neutral grassland hay meadow. This meadow was created in the summer of 1984 using a variety of site treatments followed by the application of green hay and subsequent management as a hay meadow. The sward which developed in the early years, as shown in the photograph, had an abundance of *Leucanthemum vulgare*, but which later declined to a finer, grass-dominated sward. June, 1988.

Plate 7. Durlston Country Park, Purbeck, Dorset : establishment of calcareous grasslands. This country park has achieved the successful establishment of calcareous grasslands which adjoin existing semi-natural grasslands in the Park. Monitoring takes place, both of flora and fauna, as this has been used to guide the management of the grasslands. This photograph shows a field within the Park where a typical arable weed flora is being maintained. June, 1990.

Plate 8. Glaisdale Moor, North York Moors National Park : restoration of dwarf shrub moorland vegetation. Heather brashings/cuttings from an autumn cut were applied, in 1988, to areas such as the one shown where the original vegetation and peat had been lost to bad fires in 1976. Two years later, the establishment of *Calluna* plants can be clearly seen. June, 1990.

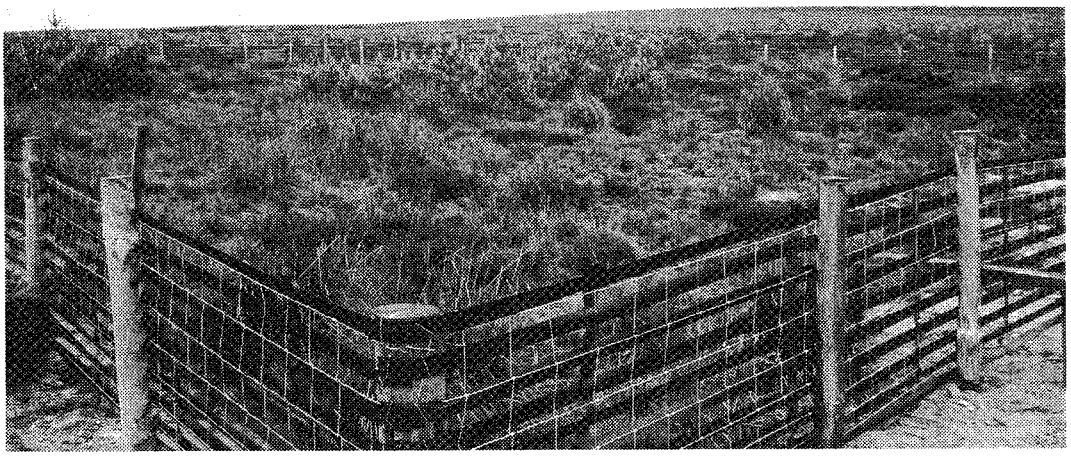

Plate 9. Glaisdale Moor, North York Moors National Park : restoration of dwarf shrub moorland vegetation. With the restoration/establishment of moorland and sometimes lowland heathland vegetation, it is usually necessary to exclude grazing in the first years of the programme. June, 1990.

Plate 10. Ropers Heath NNR, Breckland : establishment (restoration) of dwarf shrub heath adjoining existing heathland. This photograph illustrates a sound principle of habitat creation, which is the extension of existing areas of semi-natural habitat, whether it be heathland, grassland or woodland. August, 1990.

Plate 11. Ropers Heath NNR, Breckland : effects of rabbit grazing on the establishment of the desired vegetation. Intensive rabbit grazing is restricting the growth of *Calluna* plants and preventing their flowering and setting seed and the further establishment of *Calluna*. The grazing itself will also tend to remove newly germinating seedlings. August, 1990.

Plate 12. Kenwood Meadow, Hampstead Heath, London : creation of herb-rich hay meadow. This project, although well funded and managed, has failed in its aims mainly due to poor project planning and by not utilising existing ecological interest on the site. This photograph, taken in mid-summer following the hay cut, shows the present amenity use of the site. August, 1990.

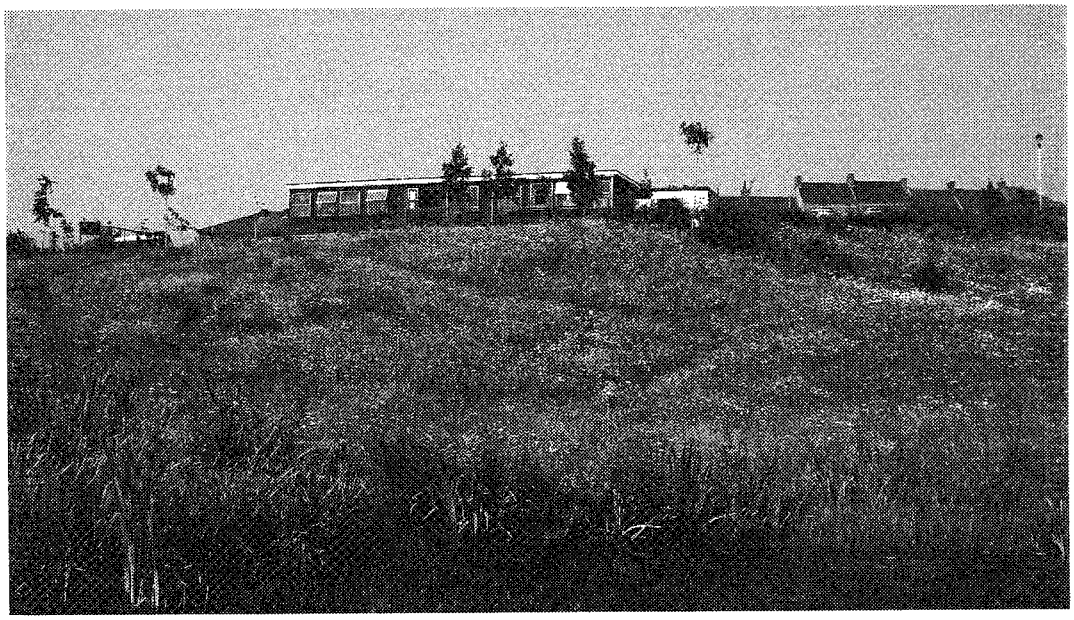

Plate 13. Benwell Nature Park, Newcastle-upon-Tyne : establishment of meadow vegetation in an urban nature park. Meadow vegetation has been successfully created on the slopes shown in the centre of the photograph. This vegetation has been designed to be part of a wider range of habitats on the site. June, 1990.