THE RESTORATION OF SPECIES-RICH GRASSLAND ON RECLAIMED LAND[1]

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Abstract: Restoration projects in the United Kingdom are increasingly targeted toward the reestablishment of land of nature conservation value, as loss of natural habitat is now a major concern when granting planning permission. Many of the techniques used for habitat creation are of limited value as they focus unduly on the introduction of plants in patterns which simulate the original countryside. However unless the processes that support the development and maintenance of biodiversity are also restored, there can be uo confidence in the long term value of the mitigation. This paper explores some processes that contribute to the development of diverse plant and animal communities and the ways in which these can be addressed in the practice of land reclamation. In the case of species-rich grassland this involves creating a diverse environmental framework, managing nutrient levels, and devising appropriate long term management. Allowing natural colonisation also helps to restore the abstract conservation value of naturalness.

Additional Key Words: habitat creation, wlldflowers, environmental impact assessment, conservation planning.

Introduction

The implementation of legislation requiring environmental impact assessment in the United Kingdom has coincided with a growth in the technology of habitat and ecosystem restoration. One of the specific requirement of an environmental assessment is the identification of appropriate mitigation measures that will minimize the harmful effects of a development. Developers are also finding that nature conservation issues frequently present major barriers to the process of obtaining planning permission. This has inevitably given a boost to the practice (or attempted practice) of habitat restoration. In some instances developers have obtained planning permission as a consequence of promises to restore wildlife habitats.

Before an appropriate habitat restoration methodology can be developed, it is essential that clear goals are recognized from the start. Possibilities include -
<u>Species-targeted programs</u> e.g. aiming to reestablish one, or a few, identified flowering plants with little concern for other components of the system.
<u>Community-targeted programs</u> e.g. restoring specific vegetation complexes identified by predisturbance surveys.
<u>Maximum diversity</u> i.e. encouraging the widest possible range of plants and animals, but with little concern for the detailed make-up of these communities.
<u>Maximum popular appeal</u> i.e. working with easy, common and showy species for public enjoyment. Aesthetics, location, and access may be more important than actual plant community makeup. A relatively low species diversity can be acceptable if the visual impact is satisfactory.

Much early research into habitat *creation* in the United Kingdom was specifically concerned with the latter goal, creating attractive species-rich vegetation but using common, resilient plants in high profile situations such as urban parks (Wells 1983). The work was of indirect value to nature conservation in that it could alleviate pressure on existing seminatural habitats, bring more people into contact with nature, and encourage support for wider conservation objectives. However, the use of rare species in such initiatives was positively discouraged.

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In contrast, *mitigation* or *recreation* work often aims to rescue, or compensate for the loss of, species or communities of local or national importance. **The methodology appropriate to these two situations will fundamentally differ.** However, landscape architects, ecologists, and restorationists working in mitigation have often been misdirected by the, widely publicised, technology developed for amenity vegetation development and have failed to address deeper issues associated with the development of habitats of conservation value.

Research onto the creation of wildflower-rich communities has been carried out at Reading University and on reclaimed industrial land for over ten years (Kendle 1992; Bisgrove 1988). This work has confirmed the ease with which it is possible to create simulations of a wide range of plant communities on sites which have previously been much less diverse. The technology employed has obvious uses, but the critical issue concerns the reasons why these communities were previously depauperate given that the environmental conditions lie within the range of physiological tolerence of the plants introduced. Were they limited by the arrival of propagules, by lack of opportunities to colonise, by factors which limit reproduction, or by factors which will damage even established plants but which recur unpredictably? It can be argued therefore that these trials, by succeeding, point towards the weaknesses rather than strengths of current habitat creation methodology. Rather than reproduce here any of the data which have been collected from trials using wildlflower seeds and plants, the intention is to look towards the need for a change in research philosophy and in restoration practice. What is needed is a more assessment of how natural habitats develop conservation importance, and how these principles can be converted into techniques which can be employed in the habitat creation process.

When Is Habitat Restoration Successful?

Given the complexity of the species interactions we can never *prove* to have succeeded in a habitat restoration project; i.e. that everything has survived and will continue to function as desired. Simberloff (1992) suggests that as long as it is impossible to tell that a restored system differs structurally or functionally from an undisturbed system, we can, conditionally, accept that successful restoration has been achieved. Most projects will not achieve even this goal, and some loss of quality is likely. Although this does not remove the justification for the attempt, it makes it hard to assess what is reasonable for the mitigation program to achieve. However, the objective should be to produce a habitat of lasting value and importance.

Assessing the success of a mitigation scheme implies that we could fully characterize the system before disturbance but grasslands are dynamic systems constantly open to change. All of the species exist in an intimate web of competition and mutual support. The more precisely defined or sophisticated the target community is, the more difficult it will be to replicate. Some restoration projects rely upon simple measures such as species composition before and after disturbance. However to match an original grassland these species should also have the desired population numbers and also be found in the "correct" mosaic and pattern of distribution. There should also be an absence of any detrimental species that threaten the integrity of the system, e.g. invasive weeds. Of course, as well as the higher plants all other essential components of the ecosystem need to be present (invertebrates, fungi, etc.) and many of these groups are ignored, or are almost impossible to study, in site surveys.

Assuming a community could be restored which has the desired patterns and abundances of componant species, is this proof of success? Again, there has to be consideration of the likely processes and changes that will occur in the ecosystem over time. Under the prevailing environmental conditions and the management planned, will these communities continue to thrive, and if not how quickly will deficiencies in the restoration become apparent? Some species have a short lifespan and rely upon new generations. If there is a lack of correct regeneration opportunities these will show problems quickly, but others may survive vegetatively for over 100yr before recruiting a new generation. The planning system requires rapid assessment methods, but we also need long-term monitoring programs to determine how stable created grasslands are. Ideally, experience will allow researchers to identify those species that occur early and that are good indicators of long term success.

What Is Required To Restore Conservation "Importance"?

It does not follow that a restoration program that fails to match the pre-disturbance conditions will necessarily lack any nature conservation value, indeed it may at times be possible to make significant gains for local wildlife by a fundamental change in landscape and land use. However, it is often less well understood that it may be possible to exactly match the conditions and communities previously found on a site rich in wildlife, and yet there could still be a decline in the importance of the habitat in the eyes of conservation planners.

In any attempt to create or restore habitats of conservation importance, it seems sensible to take as a reference the criteria that conservationists would use in assessing the importance of existing habitats. In the United Kingdom the guiding criteria used by the main government organization charged with nature conservation were outlined by Ratcliffe (1977) and have been used as a basic framework by conservation bodies ever since. Most of these criteria are pragmatic and obvious. Many can be applied as easily to the evaluation of a manmade habitat as to an existing seminatural one.

Ratcliffe's criteria for evaluating conservation significance are listed below:

Size	Typicalness
Diversity	Recorded History
Naturalness	Position in an ecological or geographical unit
Rarity	Potential value
Fragility	Intrinsic appeal

A key concept is that of naturalness. A habitat that has been heavily modified or influenced by man is regarded as of inherently less value than one that has developed in response to purely natural processes. This idea embodies many concepts, such as irreplaceable information value. An unmodified environment is scientifically worthy of study, and although it is always possible to introduce a human influence, it is impossible to ever erase it. There is also a cultural importance; in many people's minds a habitat that is exposed to human influence loses some spiritual quality, a touch of 'wilderness' perhaps, and is hence degraded. Not surprisingly therefore, the greatest limitation to habitat creation in the eyes of traditional conservationists is that the new or restored community, no matter how superficially successful and viable, is devoid of "naturalness".

These attitudes may change. Global environment change and nutrient pollution present a great challenge to a noninterventionist stance. Although species migrations in response to climate have occurred many times in history, the rapidity of the changes sometimes predictted, and the intensity of United Kingdom land use, which fragments and isolates seminatural communities, means that positive intervention may be necessary. It is likely that restorationists may have to influence plant and animal distribution in a much more active way than ever before, but it is also vital to find ways of doing this in a way that maintains or repairs the emotional and cultural values that people attribute to the land.

How To Restore 'Naturalness'

In a small, intensively exploited country like the United Kingdom there are no areas of land that have had no human influence, and evaluating "naturalness" becomes a question of assessing the degree and severity of interference. Most communities of high conservation value are rated as seminatural, which is usually taken to mean that although mankind has intervened in some way with the management or functioning of the ecosystem, no direct control has been exerted over the species which are found there. It is interesting in this context to note that nature reserve managers feel able to use different maintenance operations to manipulate and artificially diversify plant communities in their care, yet they would feel horrified at the suggestion of deliberately introducing plants. The psychology of conservation is such that humans are allowed to modify the environmental and management framework that allows certain patterns of species diversification to occur, but nature must be allowed to do the work of colonizing this framework.

In restoration work the option therefore exists to concentrate upon the development of the environmental framework rather than the introduction of seed or plants. In Holland Londo (1994) has developed a system whereby habitat creation is achieved entirely by site manipulation, importing different soil types, spreading these in varying depths and aspects and with diverse topography, and with diverse management overlaid. Much of the interest comes from waiting to see what comes up naturally. The value of this approach is that it -

1. focuses attention on the importance of modifying the environment.
2. utilizes natural processes to make the end result more "valid" and acceptable to many traditional conservationists.

Does A Restoration Project Need Plants?

Natural colonization is often overlooked as an option in restoration and the professionals involved rely upon transplanting or seed sowing instead, but it may have technical as well as cultural justification. The planning process tends to assume that landscapes are instantly creatable. However, there is a danger that setting the wrong standards and demanding early performance will encourage the use of exactly the wrong techniques for habitat creation. Certainly Londo identifies an inverse relationship between the speed with which a habitat revegetates and the potential development of botanical diversity in the long term.

It is well understood that stress in habitats can allow the establishment of unusual species with specific requirements and may also limit the growth of competitive plants more severely than it does that of many poor competitors (Grime 1979). Transplanting and seed sowing are horticultural techniques, and not surprisingly initial establishment success is greater when conditions are improved in line with horticultural practice, i.e. when a uniformly fertile and moisture-retentive growing medium is provided. However, the creation of this uniform and favorable habitat, while increasing early plant establishment success and hence high ratings by planning authorities, may in the long term undermine the heterogeneity and stresses that allow the sward to maintain species-richness.

Of course the fragmentation of habitats may make natural colonization too slow to be acceptable. A compromise may be to establish some areas quickly using plants, but to allow opportunities for continued invasion. This approach again creates the risk that communities could be created that have no long-term integrity, but that exist long enough to pass initial evaluation.

There is inevitably an interaction with the management intensity. Domestic and botanic gardens testify to the fact that plant species taken from a variety of habitats around the world and placed in a range of combinations of species and vegetation structure can, once established, thrive and grow for as long, or sometimes longer, than they do in the wild. They are therefore tolerant of wide variation in edaphic and climatic factors. This contrasts sharply with the ecologists' perception of the highly subtle variations that can naturally control plant distribution. The most obvious factor that differs in an intensively managed landscape is competition which is controlled by weeding. To avoid providing false results it is therefore vital that the aftercare period following restoration does not involve prolonged reliance upon a management type or intensity that could not be realistically maintained in the long-term.

Competition is in fact most serious at certain vulnerable stages in the life cycle. Weins (1977) proposes the concept of the ecological "crunch". This suggests that plant distribution is controlled by occasional very severe periods of environmental hostility rather than by prolonged low-level adversity. The horticultural manager's role is often to nurture desired plants through such critical stages. The most likely time for a "crunch" is when a plant is young; the seedling stage is when plants are most vulnerable and show their most specialized ecological requirements. Therefore many problems will only become obvious when a second plant generation is being established.

If natural colonization is allowed to take place, it is at least an initial test that environmental conditions support the juvenile as well as adult stages. Of course, even then there are other reasons to doubt whether the community that establishes early on will reflect that which will survive in the long term. For example, in a recreated grassland, soil disturbance could affect mineral release and fertility, at least temporarily promoting the growth of nutrient demanding species. Weed germination will increase, and unfilled niches in the sward will allow these weeds to become established.

The population of associated animals and microflora will also be badly affected. Some plant species may depend upon mycorrhiza, pollinators, or seed dispersal agents that may not initially be there and pests may be present in higher numbers until controlling species also invade.

Building An Ecosystem That Has The Potential For Diversity

Given the problems that exist with a pattern-oriented approach to habitat creation, despite the obvious appeal appeal for planners, it seems preferable to address the processes and underlying environmental factors which support and maintain the functioning of the desired ecosystem. People working on agricultural restoration recognise that the most important task is to improve soil fertility and drainage before attention can be given to the crops. The same principles must hold true for habitat restoration. So what are the key factors controlling diversity in plant communities?

A fundamental tenet of plant ecology is the Competitive Exclusion Principle, which argues that under any given set of environmental conditions there will be one species that is physiologically and ecologically favored and that would eventually come to dominate the community to the exclusion of all else. Diversity exists where there are factors that mitigate against the trend to monoculture. Not surprisingly several theories have been developed to attempt to identify these. Crawley (1986) identified the following main models, which he emphasizes are not necessarily mutually exclusive; indeed many are closely linked processes. The task of the restoration ecologist is to determine which of these mechanisms have practical implications for the design, construction, and management of restored environments. Many of these models invoke mechanisms that prevent the plant community from reaching equilibrium, i.e. they assume that perfect competition is not possible in a community that is in some way disturbed. Environmental fluctuations allow species to grab transient opportunities before their competitors can reinvade or exert their full dominance. Other models attempt to identify processes or factors that can maintain species-richness within more stable ecosystems.

The Lottery Model assumes that establishment microsites appear randomly, and that colonization is opportunistic and random, reflecting the timing and method of propagation relative to gap formation. Once established, the individuals may remain for a long time.

Spatial Heterogeneity models suggest that apparently uniform areas do in fact contain many subtly different microsites that favor competition by different species. The idea is embodied in the Regeneration Niche ideas of Grubb (1977). In a classic ecological experiment Harper et al (1969) showed that very minor alterations in soil surface texture were enough to control the germination of different plant species.

The Musical Chairs Model argues that if the overall environment is patchy such that different species live close to each other, migration between patches may occur at a rate that balances the rate of extinction of the less competitive types in each location.

Niche Separation models argue that in many cases plants avoid or reduce the severity of competition by exploiting sufficiently different resources or sources of resources in the habitat. As with many such models, arguments that can easily be followed for one dimensional resources become very complex when attempting to understand interactions across all possible resources, as presumably direct competition for just one resource may be enough to lead to exclusion if that resource is fundamental to survival.

Selective Herbivory may be important in some settings. Although in some cases herbivory may select against diversity, by eradicating palatable species, it may also be expected to increase diversity if the dominant competitors are edible. If nothing else, frequency dependent feeding may influence the strongest competitors most seriously and hence give an advantage to rare plants. "Keystone" predators may therefore be necessary to maintain a certain plant community (Paine 1966).

Refuge models propose that species-richness will be enhanced if poor competitors have some locations where they can survive free from competition and can act as a source of propagules to exploit opportunities. Obviously the refuge does not need to be very close if the species have very effective dispersal (e.g. orchids). The survival of poor competitors may be achieved by many mechanisms ranging from ability to tolerate extreme conditions that others cannot and herbivore resistance, through to the existence of long lived seed in the soil bank.

Disturbance models refer to the destruction of existing vegetation, often associated with soil disturbance that allows new species to invade. Obviously there are similarities with the lottery model, but the emphasis is on the effect of the rate of disturbance. At high disturbance only a few species will be adapted to survive, at low disturbance competitive exclusion occurs, but at intermediate disturbance levels species-richness can be high (Grime 1979).

Grime also proposes that similar principles apply with regard to stress, or environmental adversity that limits plant productivity. He suggests that species-richness is often associated with moderately hostile conditions. High fertility is of course recognized as a threat to the maintenance of diversity in many ecosystems (Marrs and Gough 1990). The development of diversity may therefore depend upon an understanding of the appropriate nutrient 'capital' for the biome in question (Roberts et al 1981) and of how to maintain low level nutrient cycling in the new ecosystem (Kendle 1992). Reclamation technology is often geared toward building the maximum fertility, which can be much easier than aiming at a specific level of nutrient cycling.

Of course the above models refer to situations where the diversity is great within a sample of a plant community, but different samples may be similar. Whittaker (1975) refers to this as alpha diversity. However, overall diversity may also be great in situations where environmental heterogeneity leads to the creation of a complex mosaic of community patches, each of which, individually, need not necessarily be species-rich. Samples may therefore be low in species, but differences between samples are great. This latter situation is referred to as beta diversity. Obviously in a restoration project the appropriate patterning of species distribution should be determined and emulated for each target community, but it is worth recognising that designing and engineering beta diversity can be much simpler than the task of creating alpha diversity .

In amenity situations high alpha diversity is not necessarily the best objective to set. In trials carried out at Reading University, wildflower seed mixtures were sown onto a range of different soil types. High ratings for visual preference were often most closely associated with the swards of lowest biodiversity. Aesthetically people often prefer situations where individual species have a strong visual effect as a result of forming large vigorous free-flowering clumps. These conditions are often characteristic of environments that show strong beta diversity and poor intermixtures of species. Similarly some of the characteristics that may help to maintain high alpha diversity, such as grazing or disturbance, may not result in a sward that is visually pleasing.

When considering the zoological components of the habitat, it must also be recognized that diversity is not always linked to the same criteria as is the case with plants (Kirby 1992). For example, some ground nesting bees require bare soil and are in particular danger of their habitat needs being ignored in any predisturbance survey, whilst effective restoration from the bee's perspective may be rated as poor establishment by the monitoring authority!

Some animals are specialist feeders and will only survive if their host plants are present. High plant diversity will increase diversity in these animals. However, insect diversity is often associated with diversity of physical structure as well. We also find that some insects may not be very effective at dispersal and may have less successful methods of surviving prolonged adversity compared with plants. Not surprisingly these vulnerable species are often the ones that are under greatest threat and hence rate highest in conservation terms. Because of their specialized life cycles the concept of refuges becomes of acute importance for their survival. To encourage insect diversity, a management framework (e.g. rotational burning) needs to be imposed that allows different plant communities to express a range of different morphologies and also allows the animals to avoid overall destruction.

For mobile species the concept of environmental heterogeneity takes on additional complexity, and the habitat mosaic within the entire ecosystem to be restored must be considered. If two habitats, e.g. a grassland and a woodland, are created adjacent to each other, then diversity within the overall area may be increased by several means. Most obviously the site will contain species that need either woodland or grassland conditions. There will also be species that require intermediate conditions provided within the ecotone, and those that depend on both of these habitats in order to survive. In the latter case this may include, for example, animals that shelter or nest in woodland and feed in grassland and insects that require different habitat conditions at adult and juvenile stages in their life. Habitat mosaic will also influence the patterns and rates of dispersal of different species.

Habitat mosaic is a complex subject that conservation ecologists are only just beginning to explore in depth, and the species that depend upon the existence of certain *patterns* within the countryside rather than any specific habitat are certainly the cinderellas of natural science. We are a long way from being able to develop consistent rules that can be applied with confidence in restoration projects. However if this goal could be accomplished, the construction of a diverse mosaic of landscape types is clearly open to relatively easy manipulation by landscape designers and engineers during land reclamation programs. Of course it must also be remembered that if an area of land is diversified into several different biotypes, there may be species that have extensive area requirements for feeding and that may disappear because of the fragmentation of the extensive landscape they need.

Applying These Principles To The Restoration Of Species-Rich Neutral Grassland

In the light of the above discussions, it is possible to highlight some technical solutions suitable for specific goals, although in many cases there is still substantial research to be done to convert concepts into practice. The restoration of neutral grassland presents an interesting case study because it challenges our abilities to the extreme and yet is politically highly desirable. In the United Kingdom species-rich neutral grassland communities are often associated with alluvial soils in river valleys. They were usually managed as hay meadows and were prone to periodic winter flooding. They were frequently productive because of the high fertility of the alluvial deposits but had a short season of usefulness. Harvesting of the sward to make hay was typically carried out from midsummer. This may have been followed by aftermath grazing or by further hay cuts. These habitats are under various threats, including improvements to land drainage technology, greater control of river water levels, aggravated by abstraction of drinking water and herbiciding or ploughing and reseeding in order to improve the grassland mixtures.

These areas are also under pressure for extraction of sand and gravel, primarily for general construction and development. Because the economic transport distances for aggregates are so low, extraction is often undertaken in areas that are under pressure from development so that the likelihood is even greater that the remaining areas of grassland are of high local conservation importance. Wherever aggregate extraction directly damages a surviving meadow, it would now be almost impossible to conceive of a situation where planning obligations did not involve habitat restoration. Even where the gravel extraction takes place on areas where the habitat has already been degraded, it is often seen as desirable to attempt to recreate more meadowland.

Understanding and repairing the dynamic processes that preserves species diversity on such sites is of course essential. Neutral meadows are interesting because they are fertile and yet diverse; this is not a common situation in the United Kingdom flora (Grime 1979). In neutral meadows, species-richness is probably maintained by a combination of the stresses imposed by periodic flooding, and the disturbance caused by harvesting, grazing and alluvial deposition that creates recurrent opportunities for recruitment. Patterns of nutrient availability will change dramatically through the year, and this too may limit the growth of demanding perennials.

Techniques Of Meadow Creation

Currently proposals are under discussion with mineral developers to undertake a new phase of neutral grassland restoration research which will be focused on process rather than pattern. The key elements of the restoration will include:-

Habitat and Environment Design. Although the image of hay meadow communities is often one with moderate to high alpha diversity, a riverine ecosystem will often exhibit high beta diversity as well, with many different zones of vegetation reflecting mean water depth through the year, as well as different patches that reflect different frequencies, duration, and timing of seasonal flooding and the fate of the sediment load in the water. The composition of the soil on which these patterns are imposed will also influence the community that develops. Although we are only just beginning to understand the relationships between these variables (Rodwell 1993), if the right principles can be developed, flooded grasslands are open to an engineered approach where landforming, water pumping, or use of sluices can control community composition.

Where possible, therefore, a variety of soil types should be introduced into the site, even if these differ only slightly in composition. The opportunities and need for complex landforming is already recognised by the gravel industry when wetland restoration is attempted and these principles can fairly easily be adapted to terrestrial habitats. Inevitably a highly diverse topography may not be tolerable on all meadow sites, but it may still be possible to consider producing complex subsurface landforms which are then covered to a more even grade by the top layer of the soil profile. This will be particularly effective where a subsoil is used with extreme drainage characteristics, such as a clay or a sand. Site design must also recognize the potential value of a mosaic of different biotypes; the biodiversity of the grassland will probably be made richer by having features such as ditches, ponds or scrub nearby.

Species Introduction. Although plant introduction must not dominate the restoration process, there are still planning pressures that will require a reduced colonisation period. The main options available for introducing plants are -
Seed using either a commercial formulation or a 'haymeadow' mix taken from existing swards of conservation value. Seeding can be onto bare soil or into an existing sward using a slot seeder. Haymeadow mixes may be dominated by whichever species successfully set seed in the sward that season.
Transplants plugs or even pot grown plants. This is expensive and best reserved for those species that establish poorly because of slow or delayed germination. Again transplanting is often carried out into existing swards, although it is possible to plant into bare ground and to sow a low rate grassland mix over the top.
Plant Litter e.g. hay crop remains used as a substitute for a commercial seed mix.
Turves taken from a damaged site for inoculum, dotted into a new site, or as a complete cover.
Soil e.g. spreading topsoil salvaged from a damaged or destroyed habitat.

The latter two are favoured because they will act as carriers of many organisms, ranging from seeds, vegetative propagnles, soil fauna, fungi, and other microorganisms. These may be invaluable in establishing a diverse and functioning habitat. They may also help to introduce plants that are impossible to buy through the trade and to preserve local genotypes. However, the proportions and composition of the mix are unpredictable. Low density plug planting is often useful to give a good visual aspect and to introduce those plants with limited seed bank survival without pre-empting all colonisation niches.

Management Of The New Grassland Habitats

Duffey et al (1974) state that "management is often the major factor affecting the floristic composition of a lowland grassland". Management is clearly one source of those environmental factors that encourage diversity by influencing whether refuges exist, the degree of disturbance, nutrient cycling and gap formation that affect alpha diversity. Zonation in management can also reinforce beta diversity and control structural diversity in the vegetation,.

In the majority of restoration programs management, while accepted as important, has been seen as a largely routine and one-dimensional operation by which a target plant community is preserved once created. However, it is also possible to consider management as a primary tool for habitat creation. It is often the sole factor which has dictated whether different biotypes such as grassland or woodland cover have developed over most of the United Kingdom countryside. Some studies have looked at the way different cutting regimes can lead to profound changes in grassland vegetation (Parr and Way 1984). Such maintenance processes should be used in a less ad hoc way so that the habitats that we create are reinforced over time rather than possibly degraded.

Together with environmental design, ensuring adequate and correct management is therefore an essential factor in habitat creation, especially when the target community is a plagioclimax. However, many existing conservation areas in the United Kingdom are in a management crisis following revolutionary changes in farming technology that have undermined traditional practices. It is clearly pointless to create new habitats that also cannot be looked after. Perhaps a worse scenario would be if new habitats dissipated maintenance efforts and increased the threat on relict areas. This is of such fundamental importance that management considerations must be fed back into planning assessment and evaluation of proposals. An existing species-rich habitat cannot be rated as any less valuable whether or not there is a management plan for its long-term survival; a planned habitat could be judged on just such pragmatic criteria.

The techniques available for the grassland manager are of course to mow, to graze or to do both. The timing and the frequency of these operations will also influence the sward composition. The long-term reduction of fertility, through removal of cuttings or folding livestock, is often recommended as a key part of grassland habitat creation (Marrs and Gough 1990). However, in many lowland neutral grasslands it is impossible to significantly reduce soil nutrient stores by this means, particularly since annual flooding may restore fertility. The most important aspect of the removal of cuttings is to reduce the direct physical damage caused by smothering.

The most specific management task associated with new swards is weed control, selectively eradicating those species encouraged by disturbance such as *Cirsium*. In a traditional nature conservation area, the management program will often be oriented towards maintaining a plagioclimax. The major problem weeds often arise from later successional stages, e.g. scrub invading grass. In new habitats the manager may be trying to encourage the movement towards a plagioclimax that has not yet been reached and there may be a need to deal with species that belong to earlier successional stages or that are relicts from a previous land use. The standard solution for weed control is to cut with high frequency in the first year. Some meadow species may not tolerate this and must be introduced as transplants after year one.

The reinforcement of populatious of desirable species may also be necessary, requiring reseeding or further planting. Habitat creation schemes are usually based on a single sowing or planting, but research has shown that random or unquantifiable factors can influence colonization, and that several attempts may be necessary before any given species "takes" (Simberloff 1992). Interestingly, many traditional grasslands were oversown with hay sweepings and this may have played a role in maintaining species-richness (Rodwell 1993).

Above all, the development must provide funding for long term management support. Many restoration schemes in the United Kingdom are based on a 5yr aftercare period, and this is completely inadequate. Some developers rely on the naive hope that community or non-governmental groups such as wildlife trusts will take on the maintenance, but these organizations are overstretched looking after their existing responsibilities. Bonds or the establishment of management trusts are essential.

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