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AN ASSESSMENT OF CONSERVATION VALUES WITHIN A LARGE SITE OF SPECIAL SCIENTIFIC INTEREST IN NORTH YORKSHIRE

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ABSTRACT

The criteria useful in assessing the conservation value of land are considered. Discussion concentrates on area, diversity of species and habitats, relationships between area and number of species especially in relation to limestone pavements, naturalness and typicalness of the site, presence of rare species, and the interpretation of expressions such as "fragility" and "stability".

The environment of an important conservation area, the Malham-Arncliffe S.S.S.I., is described. The criteria used in assessment are considered in relation to this S.S.S.I., and only three—size, diversity of species and habitats, and rarity—are found to be particularly useful in assessing the importance of parts of a large area of overall importance. The conceptual differences between some criteria, which can be measured or estimated by scientific means, and other criteria, that are dependent upon value judgements of the assessor, are stressed.

INTRODUCTION

THE study area for the assessment of conservation values was the Malham-Arncliffe Site of Special Scientific Interest (S.S.S.I.), which is situated at approximately 54°06′N, 2°06′W. The natural history of this area is perhaps the best known in the Yorkshire Pennines, since it has attracted botanists for three centuries, and many rare and local species have been recorded. Parts of the S.S.S.I. were included in a Nature Conservancy study carried out in 1967 (McCarthy *unpublished*), and the whole S.S.S.I. has subsequently been described in a botanical report (Tregenza *unpublished*). These two reports, which contain introductions to the environment of the area, have been brought up to date, especially in relation to the area near the Field Studies Council Centre at Malham Tarn, by Disney (1975). The higher plants of the limestone pavements of the S.S.S.I. are described in detail by Ward and Evans (1975b). The S.S.S.I. itself has an area of 4593 ha, and is approximately bounded to the south by the village of Malham and the valley of the River Aire, to the north west by the valley of the Cowside Beck, and to the north east by the Valley of the River Skirfare (Littondale).

The geology of the area is the most important environmental influence. A majority of the S.S.S.I. consists of Great Scar Limestone. This is crossed by two important faults, which conveniently divide the S.S.S.I. into three portions (O'Connor 1964). To the north of the North Craven Fault, which runs in an approximately east to west direction, the Great Scar limestone occurs over the whole area except near Malham Tarn and on the highest plateau areas above about 500 m. Above this altitude rocks of the Yoredale series are exposed: they also consist of limestone except for a small layer of sandstone at the highest point, Parson's Pulpit (538 m). From Malham Tarn southwards to the fault, westwards to SD879666 (National Grid Reference) and eastwards to the area of the Gordale Beck, at SD911656, the rocks are slates of the Silurian period. Although these rocks are not seen around the Tarn, they are clearly exposed by Gordale Beck (especially in the small, west flowing tributary at SD912656).

The Middle Craven Fault, or Mid-Craven Fault, also runs approximately in an east to west direction in the south of the S.S.S.I., from SD896634 to SD912634. The whole of the portion between the two faults is of Great Scar Limestone with the exception of a little limestone of the Yoredale series from approximately SD924635 to SD928650. South of the Mid-Craven Fault the whole area is still limestone, Cawden Hill being a reef knoll.

In many places the solid geology directly influences the plant communities, though in the flatter areas the limestone is overlain by glacial deposits. In some areas these deposits are calcareous, but elsewhere they contain little calcium carbonate and, with leaching by the heavy rainfall, give rise to acidic soils. The soil types of both limestone and drift parent material have been described by Bullock (1971). There is a close correlation between the nature of the soil's parent material, the type of soil profile developed, the plant communities present, and the animal communities, as demonstrated by Wood (1967) with his studies of the soil arthropods (mites and springtails). The climate of the area, which is generally cool and wet, has been described by Manley (1953).

Although the limestone geology and the high elevation, 95% of the area being over 300 m, have a major effect on the habitats available for wildlife, these habitats are modified by the systems of agricultural management which have been, and are being, practised. The majority of the area is grazed: although sheep have been and continue to be the most numerous livestock, the number of cattle has increased during the past decade. Grazing animals have a selective impact on vegetation, favouring some plant species and leaving others. For example, in ungrazed, base-rich areas *Geranium sanguineum** is often common, though in fields grazed by sheep or cattle it is rare. Prostrate herbs such as *Thymus drucei* and *Helianthemum chamaecistus,* whilst occurring in all the base-rich grass swards, are more abundant where the sward is grazed. Sheep under-graze the grass *Nardus stricta,* selecting instead species of *Festuca* and *Agrostis,* and hence seeding culms of the former are abundant whilst culms of the latter species are much scarcer.

Agricultural improvement has taken place over much of the area of the S.S.S.I. At the most extreme the land has been ploughed and seeded either to arable crops or to grass ley. Other areas have been fertilised, and rye and brome grasses introduced to the sward. Neither of these practices has been widespread within the S.S.S.I. There has, however, been widespread improvement by liming (spreading either lime or ground basic slag over the land). To many farmers the appearance of *N. stricta* in a pasture indicates that the pasture needs "sweetening". In the drift grasslands the high precipitation leads to a leaching of nutrients and, slowly, to the acidification of the soil profile. *N. stricta* tends to invade when the pH becomes acid, and with the differential grazing by animals it slowly spreads. In order to reduce this unpalatable grass, liming is carried out. An indication of liming is the increase in abundance of both *Cynosurus cristatus* and thistles. In this limestone area it is difficult to recognise fields which have been limed in the past, though the frequent occurrence of thistles and *C. cristatus* is a reasonable clue (Tregenza *unpublished*; Usher *unpublished*). It might seem paradoxical that the presence of lime geologically leads to the richest

*In the text all species are given by their scientific names. The vernacular equivalents can be found in the Appendix. Nomenclature for higher plants follows Clapham, Tutin and Warburg (1962).

biological communities of the greatest conservational importance, whereas the use of lime agriculturally leads to a reduction of species diversity and to a lesser conservation importance. No experimental work has been done on the effects of regular liming over a long period of time, though in the vicinity of the quarry at Kilnsey the deposition of lime dust appears to have led to a community of low diversity, dominated by *Sesleria albicans*.

Much of the recent scientific knowledge of the Malham-Arncliffe S.S.S.I. has been stimulated by the Field Centre of the Field Studies Council, which is located on the north shore of Malham Tarn, in the west of the S.S.S.I. The centre provides a focus for three types of scientific activity: first, environmental survey and research (many references have been quoted above); second, management of an estate with wildlife conservation as a primary aim (Disney, 1975); and third, education both of parties of students on residential courses and of day visitors who use the nature trail (Field Studies Council, *undated*). The estate is situated within land owned by the National Trust, an organisation which is becoming increasingly aware of the importance of many of its properties for wildlife conservation (Usher and Priest 1977).

The national and international importance of this S.S.S.I. has been recognised by the Nature Conservancy Council (Ratcliffe 1977). Malham Tarn, its outflow stream, and Cowside and Gordale Becks, are included in the open water site OW47 which is graded as internationally important. The complex of base-rich fen and acidic raised bog at the west of Malham Tarn forms the peatland site P52, and the remainder of the S.S.S.I. is upland grassland site U24 which is an important karst (limestone) area with fault scarps, dry valleys, disappearing streams and underground caves: both P52 and U24 are graded as nationally important.

The Plant Communities

Methods of Survey

The basic scientific information on the Malham-Arncliffe S.S.S.I. is rather patchy. In the vicinity of Malham Tarn Field Centre the fauna and flora are among those best documented in the United Kingdom. However, the fauna and flora are successively less well-known as the distance from the Centre increases. In the centre of the S.S.S.I., and towards its eastern boundary, there was no published information on the fauna, and very little information on the flora.

Two surveys, for the National Trust (Usher and Priest 1977, 1978) and for the Nature Conservancy Council (Usher *unpublished*), represent a total of approximately 11.5 days of field work during the period June 1977 to September 1978. The intensity of survey was thus approximately 400 ha per day. Although both surveys were primarily concerned with the assessment of conservation value and with making recommendations for management, the large area of ground covered per day meant that data could only be collected systematically on the plant communities. Hence, these communities have to form the basis of the evaluations of conservation importance.

At this intensity of survey it was impossible either to sample the vegetation quantitatively or to produce maps as detailed as those produced for Tennant Gill Farm (Williams, 1963). However, the majority of the 328 "fields" (generally defined as areas enclosed by a dry stone wall) were visited, and the few "fields" not visited were observed with binoculars. On site, extensive notes were made and boundaries of some vegetation types were sketched onto maps at a scale of 1:10560. The greatest intensity of field effort was given to those areas which were either not included, or barely discussed, in previous reports and publications.

Particular attention has been paid to the flowering plants and ferns. Such a survey has the advantage that it can be undertaken at most seasons of the year and in the majority of weather conditions. The field notes also included details of birds and insects, especially butterflies. Despite the relative ease of recording these two groups of animals, there were strong seasonal and climatic influences on their observation. Many of the birds were nesting in June, and, despite all June survey days being in wet weather, the birds were more in evidence then than in late summer when drier weather prevailed. There was some seasonal influence on observations of plants. Thus, some flowering plants which were seen in June were not seen at all in late summer (e.g. *Saxifraga granulata*): other plants were seen plentifully in June but only rarely as dead, dried-up remains in late summer (e.g. *Saxifraga tridactylites*); but most species were obvious throughout the spring, summer and early autumn (e.g. *Saxifraga hypnoides*). No plants seen in late summer were missing in the June survey period: but some species were difficult, if not impossible, to identify in June (for example, in the genus *Juncus* the species *J. inflexus, J. effusus,* and *J. conglomeratus* were difficult to separate in June, and the *J. acutiflorus, J. articulatus* and *J. alpinoarticulatus* complex, with their possible hybrids, proved impossible to identify before late summer).

Two criteria were essential in deciding the categories of vegetation to be mapped. First, Sinker's (1960) studies on the vegetation of the areas surrounding Malham Tarn provide the basic framework for a classification into mappable categories. Secondly, the more extensive survey by Tregenza (*unpublished*) used a framework which was compatible with that of Sinker. Without sampling the vegetation of the S.S.S.I. quantitatively and deriving a new system of vegetation classification, and in advance of the publication of a national system, it seemed logical to have a system of classification which broadly agreed with those of previous workers and which was easy to use in the field.

Description of Major Communities

Four categories of limestone-dominated communities were recognised, ranging from vertical limestone in cliffs and horizontal limestone in pavements, to screes, with a substantial quantity of exposed limestone between vegetated pockets, and base-rich limestone grassland.

The limestone cliffs provide two distinct habitats for plants. First, growing in cracks in the limestone rock, there are many of the calcicole species associated with the pavements (see below). Thus, it is not uncommon to find *Mycelis muralis* growing from a cliff, and many of the small ferns are also found in these situations (e.g. *Ceterach officinarum,* which is rare in this part of Britain). Second, cliffs also provide ledges which are completely protected from grazing. In the north and east of the S.S.S.I. many of these habitats contain small trees of species such as *Fraxinus excelsior* and *Sorbus rupicola.* However, where the ledges are wider, and especially where they are damp, there is a lush growth of tall herbaceous species; such plants as *Centaurea nigra* and *Origanum vulgare* are locally abundant. The development of the vegetation on cliff faces and ledges is dependent upon the aspect: those between the north and east tend to have the greatest diversity of species.

Limestone pavements consist of more or less flat expanses of limestone (known locally as 'clints') frequently interrupted by deep, irregular cracks ("grykes"). In general there is no vegetation on the clints, though some early spring flowering annuals may flower and set seed. The most frequent of these is *Saxifraga tridactylites,* but *Erophila verna* and *Veronica arvensis* are also relatively common. Some of the wider, shallower grykes support a rabbit-grazed neutral grassland with *Festuca* and *Agrostis* grasses dominant. However, in the deeper grykes, which are protected from grazing, either woodland species or species characteristic of the limestone rocks occur. Of the former *Anemone nemorosa, Oxalis acetosella, Geranium robertianum, Mercurialis perennis* and *Urtica dioica* are extremely common, and many other woodland species such as *Paris quadrifolia, Convallaria majalis, Allium ursinum, Carex sylvatica* and *Sanicula europaea,* are found. The species characteristic of the limestone rocks include higher plants such as *Actaea spicata, Ribes spicatum* and *Mycelis muralis,* and an abundance of ferns including rare or local species such as *Dryopteris villarii, Asplenium viride* and *Thelypteris robertiana.*

The scree slopes underneath the cliffs are more difficult to characterise, but in general *Sesleria albicans* is the most frequent grass, though both *Festuca rubra* and *Festuca ovina* are abundant. In the late summer many labiates are in flower, especially such species as *Thymus drucei, Clinopodium vulgare* and *Teucrium scorodonia.* These scree slopes grade from the cliff rock and ledge habitats already described into the base-rich grassland habitats which are described below.

A continuum of unimproved grassland habitats exists. At one extreme one can recognise the base-rich grassland which is usually dominated by *S. albicans* and *Festuca* spp., in which both *T. drucei* and *Helianthemum chamaecistus* are abundant. In these base-rich grasslands there are usually limestone fragments occurring in the sward (i.e. an incomplete vegetation cover). At the other extreme there are the acid grasslands dominated by extensive tussocks of *Nardus stricta,* though in general there are small areas of neutral *Agrostis/Festuca* grassland between the tussocks. In dry areas, the extreme development towards an acid grassland is a community of *N. stricta* with *Deschampsia flexuosa* as a co-dominant, and with abundant *Galium saxatile.* In wetter areas, *N. stricta* is co-dominant with *Molinia caerulea,* whilst in the wettest areas *N. stricta* is scarce, the dominant plants being either *Juncus* spp., *M. caerulea, Trichophorum cespitosum* and/or *Eriophorum vaginatum.* At no place within the S.S.S.I. do the ericaceous dwarf shrubs (mostly heathers) dominate the community. Between these two extremes of base-rich and acid grassland there are many transitional forms. In the transition from base-rich to neutral grassland *S. albicans* and *H. chamaecistus* are quickly lost from the sward. In the neutral grassland the dominant grasses are *Festuca* spp. (both *F. ovina* and *F. rubra* occur) and *Agrostis* spp. (*A. tenuis* is the most abundant, but *A. canina* and *A. stolonifera* are locally frequent), and there are usually some plants of *T. drucei* and *Potentilla erecta.* In the transition to acid grassland both *P. erecta* and *N. stricta* occur in the sward, the latter as small isolated plants, and *G. saxatile* becomes more frequent. It is virtually impossible to map the occurrences of these various grassland types due to the intricate mosaic in which they occur. Over much of the area where there is drift material, the community would be in the neutral or slightly acid grassland type. However, wherever a limestone boulder crops out, within a metre or two of it there is the transitional type of grassland between the base-rich and neutral forms. Near every limestone boulder there is thus an *Agrostis/Festuca* community in which such species as *Viola lutea* and *Viola riviniana* are relatively common.

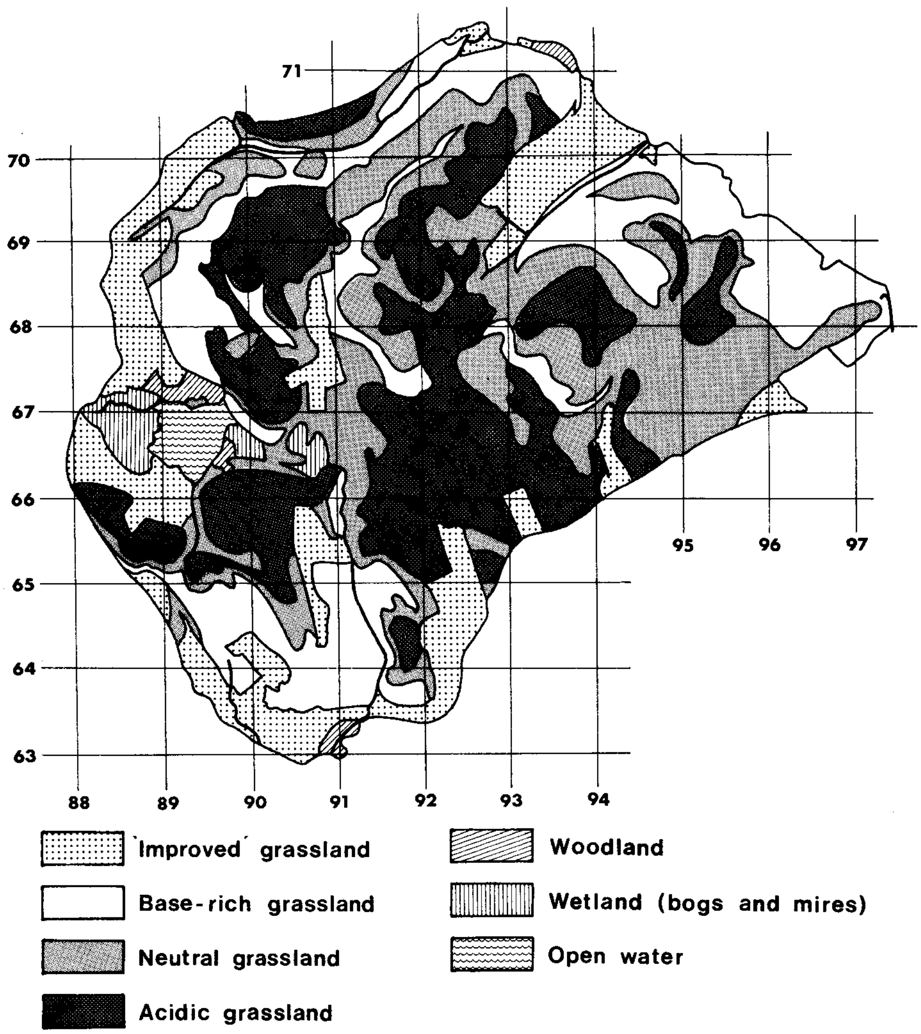

FIG. 1

Vegetation map of the Malham-Arncliffe S.S.S.I. (scale 1 : 87000 approximately). In many parts of the S.S.S.I. the mosaic of grassland types cannot be mapped at this scale, and hence the mapped categories represent broadly dominant vegetation communities. The lines represent the National Grid system.

Many of the grasslands which do not fit into any of the above categories have been improved. *Cynosurus cristatus* is generally rare in natural grassland, and the presence of this species is a fairly good indicator of past improvement. All grasslands in which *Lolium perenne* occurs have almost certainly been improved.

A whole series of wetland communities occurs in isolated parts of the S.S.S.I. Near Malham Tarn itself, there are the fen communities associated with the inflow streams, there is a large raised bog to the west of the Tarn (Proctor 1974, Adam *et al.* 1975), and there are mire communities associated with the outflow stream. There are also important mire communities associated with the low lying areas between Malham Tarn and Gordale Beck, the two most extensive being Ha Mire and Great Close Mire. These communities have attracted considerable botanical interest in the past: the species occurring in them are listed by Sinker (1960), and a more recent account is given by Ratcliffe (1977). There is relatively little natural woodland remaining in the S.S.S.I. In the north of the S.S.S.I. the dominant tree species are ash *(Fraxinus excelsior)* and birch *(Betula pubescens),* though there is an extensive understorey of hazel *(Corylus avellana)* and whitebeam *(Sorbus rupicola)*, and a very diverse ground flora, dominated by *Mercurialis perennis* in the denser areas, but containing such species as *Filipendula ulmaria, Geranium sanguineum, Succisa pratensis,* and *Rubus saxatilis* in the more open areas. Many of the woodlands in the S.S.S.I. are of plantation origin, and in these sycamore *(Acer pseudoplatanus)* predominates. An attempt has been made around Malham Tarn House to create a diverse, mixed woodland, including natural hardwood species but also introducing conifers for forest management purposes. The woodland in the valley of the Gordale Beck, Wedber Wood, contains a mixture of deciduous species, and is perhaps a remnant of natural woodland. In it *Urtica dioica* is abundant and occurs with such typical woodland species as *M. perennis.* Presumably the yew *(Taxus baccata)* used to be more widespread: it is now more or less confined to cliff faces on Gordale and Yew Cogar Scars.

There are many other interesting habitats which are very small and locally distributed throughout the area. One of these is the debris left after working the old Galena mines. In some of these the community is still open, the only plants surviving the toxic spoil being *F. ovina, Minuartia verna* and *Thlaspi alpestre.* The latter species is restricted to such sites in the S.S.S.I., and *M. verna* hardly occurs elsewhere.

Extent of the Communities

The areas occupied by each of the plant communities are listed in Table 1. All of the communities of plants dominated by limestone, as well as the transitional grasslands between the base-rich and neutral types, have been lumped into a "base-rich grassland" category. Similarly the acidic and transitional grasslands between neutral and acidic, and the acidic wetland communities which are dominated by rushes, have been lumped into an "acidic grassland" category. The distribution of these categories, as well as of neutral and improved grasslands, has an interesting spatial pattern (Fig. 1).

All of the lower lying ground at the south of the S.S.S.I. has been improved, as have areas near to roads where it is easier to import lime or slag. The base-rich grasslands are essentially confined to four areas. First, in the vicinities of Gordale Beck and Malham Cove the steep, south-facing slopes and shallow soil have militated against agricultural improvement. Second, the steep sides of the Cowside Beck, together with Yew Cogar Scar and its limestone screes, provide an area in the north of the S.S.S.I. which is limestone dominated. Third, there is an extensive area of base-rich and transitional grassland towards the east of the S.S.S.I. This occupies the steep slopes facing north-east, and, with extremely limited vehicular access, it has remained "remote" and unimproved. Fourth, in the centre of the S.S.S.I., there are some bands of outcropping limestone, forming linear pavements which roughly follow the contour lines. The western-most of these link up with the Cowside Beck, and join the base-rich communities of the Cowside Beck with those occurring near Malham Tarn and on Great Close Scar. Centrally, and at a higher altitude, there is a whole series of limestone pavements which are more or less linked up by areas of

Table 1. *The categories of plant communities recognised and mapped during the surveys of the Malham-Arncliffe S.S.S.I.*

Category	Area (ha)	Percentage of total S.S.S.I. area
Limestone pavements	269	5.9
Limestone cliff, scree, and base-rich grasslands	225	4.9
Mosaic grasslands, including elements of both base-rich and neutral grassland communities	479	10.4
Neutral grassland, and mosaics including elements of both base-rich and acidic grassland communities	1391	30.3
Mosaic grasslands, including elements of both neutral and acidic grassland communities	930	20.3
Acidic grasslands	304	6.6
Bogs, mires, fens and fen woodlands	137	3.0
Woodland	37	0.8
Open water (Malham Tarn)	60	1.3
Improved grassland or arable land	746	16.2
Farms, farmyards, gardens, quarries, etc.	15	0.3
TOTAL	4593	100.0

base-rich grassland or grassland transitional between the base-rich and neutral types.

Surrounding much of the base-rich grassland is the neutral grassland. This mapped category is not very distinct on the ground since it frequently forms transitional communities towards base-rich grassland wherever limestone crops out, and towards acidic grassland where there is an accumulation of drift material. This mosaic of neutral and transitional grassland types varies every few metres. The areas of neutral grassland shown in Fig. 1 have thus to be interpreted as indicating the presence of neither strongly base-rich nor strongly acidic grassland communities.

The acidic grassland formations occur widely throughout the S.S.S.I. They form an extensive area running across the highest ground, breaking into successively smaller blocks, each associated with glacial drift material, towards the lower ground. In many places on the drift material, where the drainage is poor, the communities are dominated by *Juncus effusus* or by the other plants associated with wet acid habitats.

The woodland, which is scarce within the S.S.S.I., occurs only in four small blocks. Three of these, in the north, the south, and the northern half of that on the east bank of Malham Tarn, are probably semi-natural. The largest block of woodland, that on the north bank of Malham Tarn, is largely planted. The extent of the wetland communities is also very limited. Three of these are shown in Fig. 1: the raised bog and fen communities to the west of Malham Tarn, and both Ha Mire and Great Close Mire to the east of the tarn. The small, acidic wetland communities are too small to be mapped at the scale of Fig. 1.

THE CRITERIA FOR ASSESSING CONSERVATION VALUE

A Consideration of Potential Criteria

When faced with large areas, land managers, such as foresters, have generally evolved some system of classification in order to make their task easier. Thus, early in the development of Finnish forestry, Cajander (1943) developed a forest classification with classes indicating forest productivity. In Great Britain, Anderson (1932) developed a classification for the re-afforestation process that started after the First World War. His classification contained 20 categories, representing the dampness and fertility of the site, and for each he described the characteristic herbaceous species and listed suitable tree species for planting. Graham (1944) proposed a detailed classification of land into categories of different quality according to their potential for agriculture, a concept that has been very much extended in more recent Canadian work (for example, Hills (1961)). In agriculture or forestry, where production can be measured relatively easily, it is at least feasible to produce a classification which spans the range of sites from those with maximum production to those which are least productive.

In nature conservation, although the concept of production is no longer valid, it is useful to have some criteria for measuring the quality of a site. The word "quality" implies that a value judgement is being taken by a person, or a group of people, and hence the criteria for assessing conservation value cannot be considered as completely scientific. There has been a number of attempts to list such criteria. The most comprehensive is that of Ratcliffe (1977), who was concerned with selecting a series of "key sites" for the whole of the British Isles. In doing this he judged each candidate site in terms of the ten criteria:

1. Size (extent)
2. Diversity
3. Naturalness
4. Rarity
5. Typicalness
6. Fragility
7. Recorded history
8. Position in an ecological/geographical unit
9. Potential value
10. Intrinsic appeal.

A site can be scored on each of these ten criteria, but Ratcliffe gives no way in which the ten individual scores can be combined, a process known as the "aggregation" of criteria. Indeed the importance of the individual criteria appears to vary with the type of habitat under consideration.

In assessing the importance of parts of a single S.S.S.I. some of these criteria cannot be used. The first two criteria are unique to the whole site, since they can be assessed on a single visit, without reference to the surrounding area, and require no judgement on the part of an assessor. The next three criteria, naturalness, rarity and typicalness, rely heavily upon the amount of survey work done in the area; fortunately in Great Britain the rare species are known, and there are reasonably clear ideas about what constitutes a natural or seminatural ecosystem, thus leading to ideas of what is typical. The sixth criterion, fragility, is also relatively simple to assess for a single S.S.S.I. since case histories indicate that certain natural and semi-natural habitats are very sensitive to human impacts. However, in a large S.S.S.I. there may be some areas which could be considered very fragile, and other areas which would be particularly robust in the face of human impact or disturbance. Thus, the wetland communities on each side of Malham Tarn are extremely fragile, whereas much of the grassland is extremely robust. It is also useful to consider the fragility of individual species: examples of fragile species are plants which are extremely sensitive to trampling and nesting birds which are very sensitive to disturbance. Assessment of this criterion is often based on "case-law", and hence it is likely to include an element of value judgement.

Recorded history is a criterion that has only limited use in site assessment. Ratcliffe (1977) states that the criterion should not be over-rated, but that it should add value to sites which would score highly on other criteria. Thus the amount of work which has been done around Malham Tarn, during 300 years since the initial surveys of John Ray in 1671, adds a historical interest to this particular part of the S.S.S.I.

The ecological/geographical position of the S.S.S.I. is a criterion that is appropriate when considering the value of a whole site, and often inappropriate when assessing the relative importance of its component parts. Basically, this criterion assesses how common the habitat type is within the geographical area. The open water of Malham Tarn is particularly uncommon in the karst countryside of the Craven Pennines (where the only two extensive open water areas are Semer Water and Malham Tarn). However, most of the Malham-Arncliffe S.S.S.I. is a variety of grasslands which are common in the Craven Pennines. This criterion is thus opposed to the criterion of typicalness, since the communities within this S.S.S.I. could be valued because they are typical of the karst landscape, but not valued because they are common in the North Yorkshire Pennines.

The final two criteria have little importance in assessing small parts of a larger area. The potential value is essentially applied to sites which are undergoing some sort of change in land-use, and thus it would be particularly suitable when considering such areas as quarries, some of which could become important conservation sites in the future. The final criterion, intrinsic appeal, is difficult to evaluate since it is concerned with the social aspects of conservation. In order to conserve areas of land for their wildlife there has to be a demand in the population as a whole for the use of financial resources to preserve these areas. As Ratcliffe indicates, there is a lot of interest in flowering plants and birds, but very little interest in relation to insects and spiders. Thus, on political grounds it may be appropriate to weight more strongly those habitats which have this intrinsic appeal. Both potential value and intrinsic appeal rely heavily on the assessor's value judgements about how a site might develop or about public opinion. There are very few objective attempts to assess which organisms are rated highly by the public: studies in a forested area of the North York Moors National Park (Everett 1978) indicate that mammals, especially large ones such as deer, are particularly favoured.

The criteria which have been found to be particularly useful in assessing the conservation importance of parts of a large S.S.S.I. are the first four—size, diversity, naturalness, rarity—since these involve a minimum of value judgements. They are discussed in more detail in the following sections.

Size

As a rule-of-thumb, larger areas are more important for conservation than small areas. There are two reasons for this statement.

First, as an area of land increases so does the number of species that one might expect to find on it. If the number of higher plant species found on nature reserves in Yorkshire is plotted (on arithmetic axes) against the area of the nature reserve, the data show an increase which tends to flatten out with increasing area (Fig. 2a). How-

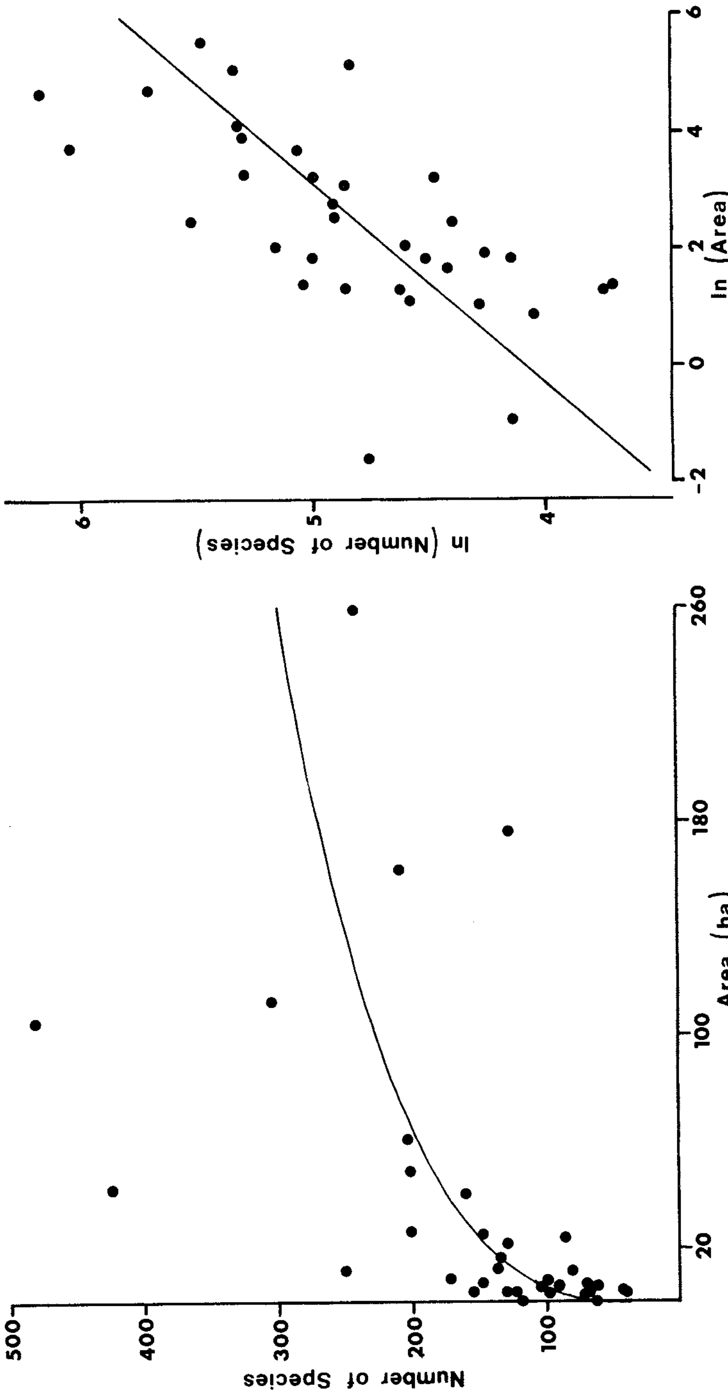

FIG. 2

Species-area relations for the higher plants on 35 nature reserves in Yorkshire. In (a) the plot is on arithmetic axes, whilst in (b) the axes are logarithmic (natural logarithm). The regression lines are of the form of equation (1).

ever, if the data are plotted on logarithmic axes, as in Fig 2b, the curve is usually transformed into a straight line. Preston (1962) uses the empirical relation

$$S = cA^z \tag{1}$$

where S is the number of species, A is the area, and c and z are constants. The slope of the graph in Fig. 2b is z, a measure of the rate at which reserves accumulate more species with increasing size, and c reflects the abundance of the particular organisms under study. This empirical relationship has been used widely in studies of island biogeography (May 1975) to account for the number of species on islands. Although Miller and Harris (1977) found no relation between area and the number of game animals on reserves in East Africa, Usher (1973, 1979) has demonstrated that this relationship describes the occurrence of higher plants in nature reserves reasonably well. These studies, as well as those of Dony (1977) on the British vegetation, indicate that large areas tend to contain more species than small areas.

Second, large areas are essential for the conservation of animal species at the end of a food chain (the top carnivores). Many birds of prey require a large area in which to hunt for their food, and hence their population densities, even in semi-natural areas, are very low. It must also be remembered that species with low population densities are more likely to become extinct than species with large population densities.

The large area, 4,593 ha, of the Malham-Arncliffe S.S.S.I. is thus important. If one is designating the most important conservation areas within this large area, it would be preferable not to cause fragmentation into a lot of small units, but to maintain as large a core of units as possible.

Species-Area Relationships of the Limestone Pavements

A survey of the limestone pavements of the Malham-Arncliffe plateau (Ward and Evans 1975*a*, 1975*b*) included 49 limestone pavements, 40 of which were located within the S.S.S.I. All of the species of higher plants, the total area of the pavement (called cartographic area) and the area of intact pavement (called pavement area) are listed, and each of the 155 species was allotted to one of four groups.

Table 2. *The group A species which are recorded from the Malham-Arncliffe plateau* (Ward and Evans 1975b). The 49 pavements on the plateau represent 9.1% of the 537 pavements included in the national survey (Ward and Evans 1975a).*

Species	Number of occurrences in national survey of 537 pavements	Number of occurrences in Malham-Arncliffe survey of 49 pavements	% of national occurrences
Actaea spicata	30	8	26.7
Cardamine impatiens	13	4	30.8
Dryopteris villarii	258	11	4.3
Polygonatum odoratum	57	3	5.3
Ribes spicatum	16	14	87.5
Thelypteris robertiana	212	17	8.0

*The group A species not recorded on the Malham-Arncliffe pavements are: *Carex ornithopoda* (42), *Daphne mezereum* (1), *Dryas octopetala* (7), *Epipactis atrorubens* (72), *Hypericum montanum* (23), *Potentilla crantzii* (6) and *Salix myrsinites* (1), the number in brackets indicating the number of occurrences in the national survey.

Species in group A are those which would appear to be dependent on the limestone pavement habitat for the maintenance of their populations. They are nationally rare, occurring in fewer than 15 of the 100-kilometre squares of the national grid, and in any one of these squares occurring with fewer than 20 dots (a dot corresponds to a square 10 kilometres by 10 kilometres, see Perring and Walters 1962). Only six group A species are recorded on the Malham-Arncliffe plateau (Table 2). Two of these species, *Dryopteris villarii* and *Polygonatum odoratum,* occur less frequently than they do in the national survey. One species, *Thelypteris robertiana,* occurs with approximately the expected frequency of 9.1%. Two other species, *Actaea spicata* and *Cardamine impatiens,* are rather more frequent on the Malham-Arncliffe plateau, and one species, *Ribes spicatum,* is particularly striking since it occurred on only 16 of the 537 pavements included in the national survey, 14 of these pavements being on the Malham-Arncliffe plateau.

The species in group B are those which are relatively uncommon nationally and which tend to be associated with limestone pavements. There are varieties of distributional patterns, including some which are characteristically northern (e.g. *Asplenium viride, Cystopteris fragilis* and *Melica nutans*), and others with a more southern distribution e.g. *Convallaria majallis* and *Mycelis muralis,* and some which are widespread but generally scarce (e.g. *Arabis hirsuta, Geranium sanguineum, Paris quadrifolia* and *Polystichum aculeatum*).

The species of group C are widely distributed and common, and are fairly typical of base-rich habitats. Many of them are characteristic of woodlands, for example *Geranium robertianum* and *Mercurialis perennis* which both occur on all 49 pavements on the Malham-Arncliffe plateau. The species in group D are essentially incidental on the limestone pavement, being characteristic of the surrounding grasslands or heathlands. Thus, *Sesleria albicans* was recorded from all but one of the 49 limestone pavements, but it is a species of the surrounding grassland and is not dependent upon the open nature of the pavement.

This classification into four categories, albeit slightly arbitrary, provides an interesting hypothesis from which to investigate species-area relationships. Thus, using cartographic area, which includes both limestone pavement and some enclaves of the surrounding grasslands, one would expect a species-area relationship of the form $S=cA^z$ to be applicable. The number of group A species is too small for statistical analysis (Fig. 3). However, if the group A and B species are pooled, there is a significant relationship between the logarithms of area and number of species (Table 3). Similarly, the relationship is significant for all the species of base-rich environments (group A, B and C species pooled) and also for all species considered together.

However, if one considers the actual area of the pavement, one might make an hypothesis that only the species associated with limestone pavements would show a species-area relationship. Excluded from the area consideration are peripheral habitats in which the group D species might be expected to occur. It is debatable whether the group C species would show a significant relationship. In Fig. 4 the pavement area is plotted against the number of species. There is a significant relationship between area and the pooled group of A and B species, but no significant relationship between area and either "all species" or the group A+B+C species pooled (see Table 3). Thus, it would appear that a species-area relationship is only applicable to the species which are characteristic of limestone pavements, for

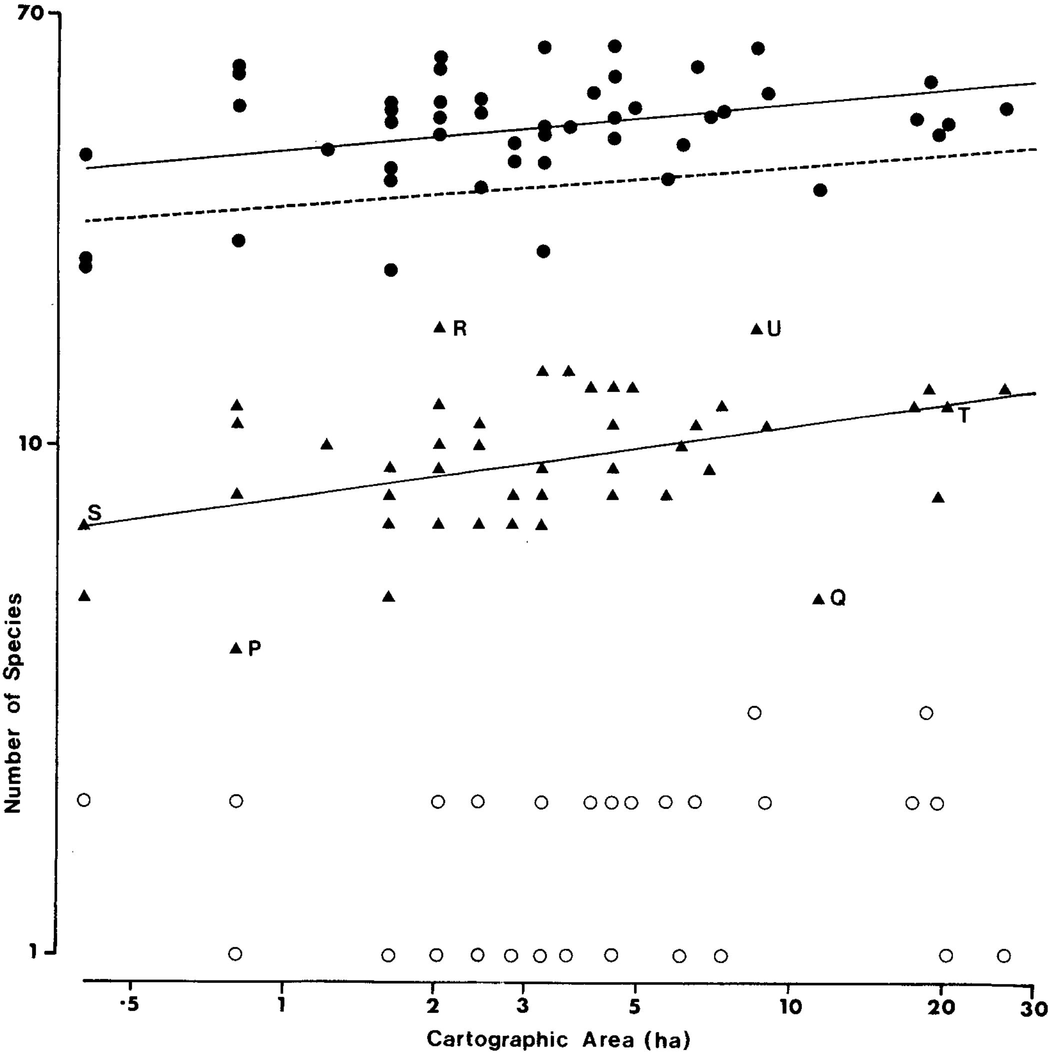

FIG. 3
Species-area relations for higher plants on the 49 limestone pavements included in Ward & Evans' (1975*b*) survey of pavements on the Malham-Arncliffe plateau. The data are plotted on logarithmic axes, the area being the cartographic area (see text for definition). Open circles represent group A species, filled triangles group A and B species pooled, and filled circles all species recorded, irrespective of group. The continuous lines represent regression lines through the filled circles and triangles: the dashed line represents that through the data (unplotted) of the group A, B and C species pooled. Further data are given in Table 3.

which one might postulate that the number of limestone niches increases as the size of the pavement increases.

Ward and Evans defined a floristic index to measure the richness of individual limestone pavements. They excluded the group D species from this index, and weighted the other categories, giving weighting factors of three to each group A species, two to each group B species, and one to each group C species. The index is calculated by multiplying the species abundance (measured for each pavement on a

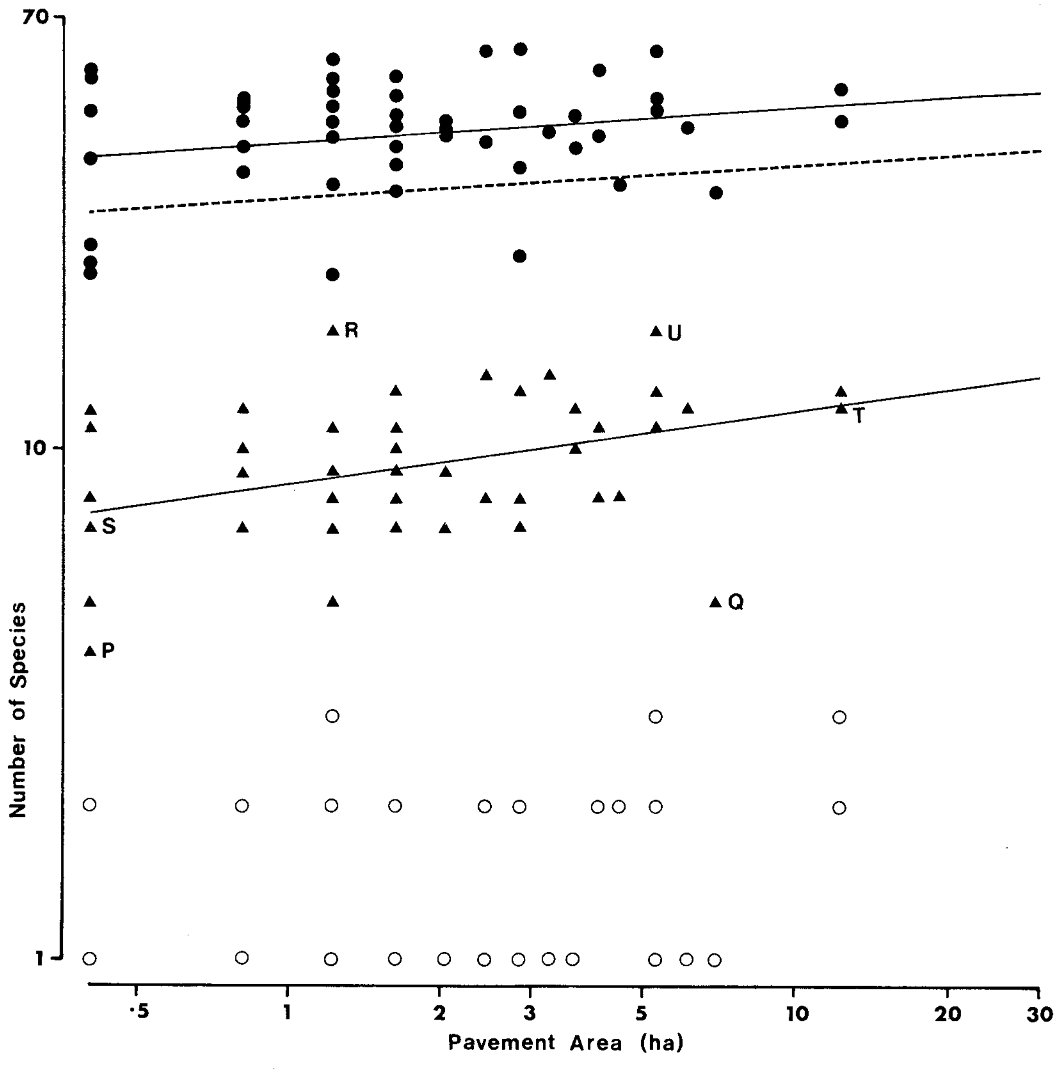

FIG. 4
Species-area relations as in Fig. 3, except that the actual area of the limestone pavement has been plotted on the abscissa. The symbols have the same representation as in Fig. 3, and statistical data are given in Table 3.

three point scale, from 1 for uncommon species to 3 for common ones) by the weighting factor, and summing over all species. The floristic index is plotted against both cartographic area and pavement area (Fig. 5), and this confirms that larger pavements tend to have larger floristic indices (Table 3).

What implications do these analyses have for conservation? Since large areas tend to have more species than small areas, larger limestone pavements would tend to have greater conversation value than smaller ones if judged solely by the number of species. However, by fitting species-area relationships it is possible to investigate species richness as a criterion from which area has been eliminated. Thus, in Figs. 3 and 4, using only group A and B species, one of the limestone pavements is

Table 3. *Coefficients from regression analyses relating the number of plants occurring on 49 limestone pavements on the Malham-Arncliffe plateau to area by the equation* $S = cA^z$ *(S is the number of species,* A *is the area in ha, and* r *is the correlation between* ln S *and* ln A, *where* ln *represents the natural logarithm). The groups of species, the floristic index, and the assessment of area are discussed in the text.*

Group of species analysed	*c*	*z*	*r*	Significance†
Cartographic area:				
A and B	7.85	0.141	0.440	**
A, B and C	29.35	0.078	0.290	*
All (A, B, C and D)	37.56	0.086	0.341	*
Floristic index	65.62	0.075	0.292	*
Pavement area:				
A and B	8.52	0.141	0.391	**
A, B and C	30.93	0.064	0.211	n.s.
All (A, B, C and D)	39.87	0.068	0.238	n.s.
Floristic index	68.61	0.072	0.250	n.s.

†Statistical significance is indicated by the following: n.s., not significant;
*$0.05 \geqslant P > 0.01$; and
**$0.01 \geqslant P > 0.001$.

particularly species-rich (lettered R). This pavement is of very small area, being only slightly more than 2 ha. Also, in Figs. 3 and 4, two pavements, lettered P and Q, have exceptionally few species. Pavement Q, of 11.3 ha, shows the greatest discrepancy from the regression line and it can therefore be considered to be the poorest pavement, in terms of its species diversity, of all of those occurring on the Malham-Arncliffe plateau. Since it is one of the largest pavements, it does not have the smallest of the floristic indices measured by Ward and Evans' method.

Two pavements which are "typical", having the expected number of species, are lettered S and T on Figs. 3 and 4. If species diversity is to be the overriding criterion for assessing conservation value, then the pavements which deviate most in a positive direction from the lines in Figs. 3 and 4 would be those of greatest conservation value. Pavement R, albeit small in area but with the greatest floristic diversity, and pavement U, also with a large positive discrepancy from the line, are thus both worthy of special consideration when deciding conservation priorities.

Diversity and Naturalness

These two criteria are to some extent inter-related. In the grasslands the main feature causing unnaturalness is agricultural improvement by liming, thus encouraging the more vigorous growth of grass species which are palatable to grazing animals (cattle and sheep). Sampling the vegetation communities, by recording the number of plant species within a half metre square quadrat (Table 4), shows the number of species to be greatest in the base-rich limestone grasslands. There is a reduction of species in moving from base-rich through neutral to acid grassland types, but the number of species in agriculturally improved grasslands is intermediate between the neutral and base-rich types. The use of lime or slag thus tends to have a similar effect on species diversity to the natural occurrence of lime, although the greater grazing pressure in these areas results in swards which are

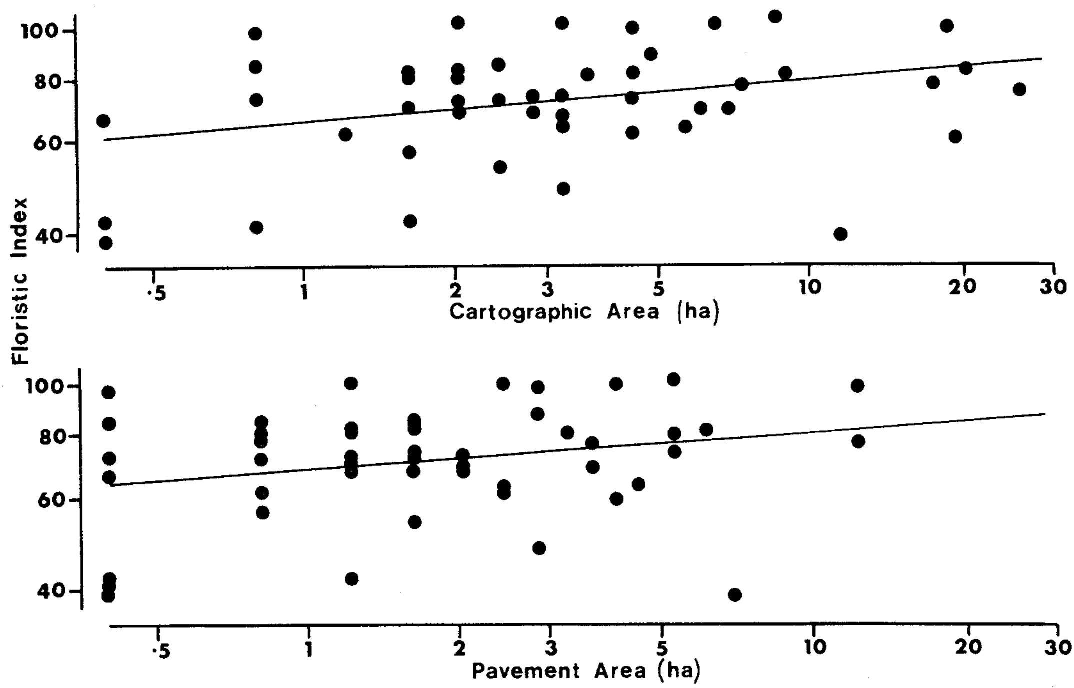

FIG. 5

The relation between Ward and Evans' "Floristic Index" and area. The data are plotted on logarithmic axes, and the lines represent the regression equations indicated in Table 3.

superficially species-poor. Another difference between improved and semi-natural grasslands is in the "quality" of species represented: the lists of species in improved grasslands usually contain buttercups (*Ranunculus* spp.), thistles (*Cirsium* spp.) and chickweed (*Stellaria media*), species much less common in the semi-natural grasslands. Table 4 shows that base-rich grasslands have a greater diversity than the acidic grasslands, and hence that they would score more highly on the diversity criterion. Both grasslands would, however, have the same score on the naturalness criterion.

Table 4. *Data showing the quantitative differences in species composition in base-rich, neutral, acidic and improved grasslands. The number of higher plant species was counted in half metre square (0.25m²) quadrats. Sample sizes are of the order of 60 quadrats scattered throughout the area of the S.S.S.I.*

	Number of Higher Plant Species		
Grassland type	Mean	95% Confidence Limits	Range
Base-rich	13.7	±1.16	5*-16
Neutral	10.8	±1.33	6 -14
Acidic	6.9	±1.13	5 -15†
Agriculturally improved	12.7	±1.58	7 -18

*The minimum recorded was 12 species except on steep slopes where *Sesleria albicans* was dominant, when between 5 and 10 species were usually counted.

†The maximum recorded was 11 species except near the drainage channels of some hill mires when the number could rise to 15 species.

However, diversity as a concept can be applied to habitats as well as to species within a habitat. Thus, those in base-rich grasslands are different from the species present in acidic grasslands, and a sensible conservation plan would include areas of all the semi-natural grassland types, thus maintaining the great habitat diversity within this S.S.S.I.

The Paradox of Rarity and Typicalness

Rarity is included as a criterion for assessing conservation value on many grounds. Rare species are particularly interesting since they undoubtedly have unusual ecological requirements. There is therefore some scientific interest in preserving them within the British Isles, and there is a wealth of research potential in understanding more about the factors which regulate small populations and limit their geographical distribution. There is a scientific challenge in devising systems of management that prevent the extinction of these rarities. This challenge is associated with the vulnerability of rare species which experience shows are more likely to become extinct than common ones. Often, there is an apparently moral interest in the conservation of rare species: it being argued that no species should be allowed to become extinct, and hence conservation takes on the mantle of an open-air museum in which the last remaining individuals of these rare species are preserved. Rare species also have a political weight, since the public is interested in them. The argument tends to be that if a species is common, then there is no harm in sacrificing populations of it. However, if the species is rare, many planners feel that there will be much more pressure on them to conserve it. Since the conservation of wildlife requires not only scientific knowledge but also popular support, it is important that the political aspects of rare species should be realised, and exploited if need be, in order to retain a large body of favourable public opinion.

There is a large number of rare plant species within the Malham-Arncliffe S.S.S.I. On the limestone pavements the most important of these is *Ribes spicatum,* and in some of the wetland habitats there are others such as *Juncus alpinoarticulatus* and *Bartsia alpina.* There are also rare spiders (for example, *Erigone capra*) and many rare insect species. Parts of the S.S.S.I. are well-known for the occurrence of rare species, and these undoubtedly add to the overall conservation value.

However, typicalness is also a criterion. As a whole, the S.S.S.I. appears to be typical of the karst areas of the Craven Pennines. By its definition a typical community includes examples of the plants and animals which would be found widely in such habitats, and thus it will contain all (or most) of the commoner and more widespread species. Limestone pavements with *Actaea spicata* are typical of the karst formations of North Yorkshire, since this plant, although nationally rare and occurring as a group A species, occurs widely on limestone pavements across North Yorkshire and Lancashire. However, the rarities make an area atypical. The relative abundance of *Ribes spicatum* on the Malham-Arncliffe plateau, where 87.5% of the British occurrences of this species on limestone pavement occur, makes the area atypical in relation to this species.

A typical habitat might contain one or two rare species, but it would not contain an assemblage of rare species. The large number of rarities known to occur in the Malham-Arncliffe S.S.S.I. might therefore indicate that it is not typical. The question "at what point are there so many rare species that the habitat is no longer typical?" has not yet been answered. The relative weightings that would be given to typicalness and rarity in defining an overall conservation value vary from assessor to assessor. However, typicalness is a criterion that would have only scientific weight, whereas rarity would be likely to have both scientific and political weight when considering an assessment of conservation value. Rarity may therefore be more important than typicalness.

Fragility or Stability?

The concept of fragility of an ecosystem is regarded as complex by Ratcliffe (1977), who states that it reflects the "degree of sensitivity of habitats, communities and species to environmental change". Since the environmental change can be due either to physical factors, such as climate, or to land-use practices, Ratcliffe indicates that fragile sites are usually highly fragmented, dwindling rapidly, and difficult to re-create. However, the concept of fragility, or the inverse concept of resilience, can have different interpretations for different types of ecosystem.

Consider an ecological succession where, during a long period of time, one community follows another until some end-point, the climax, is reached, this end point being when the community no longer changes (in general, no further change relates to a generation or two of Man since records do not allow for a longer assessment). Ratcliffe's definition of fragility obviously applies easily to climax communities since one is expecting them not to change unless there is a change in physical conditions or a change in the management of the community. However, during the course of a succession, the intermediate or seral communities are naturally changing and it might be difficult to determine how much of an observed change is due to the process of succession and how much to some form of perturbation. Fragility would therefore appear to be more a property of climax communities than of seral communities.

The field biologist has used the words fragility or resilience to assess something which is observable only over a long period of time. Survey work requires that observation be made at only one point in time, and that this observation, perhaps with historical records, be used to assess the criterion. Thus, although fragility cannot in itself be measured, case histories available to ecologists have indicated some of the characteristics of fragile sites and fragile species. Many wetlands are considered to be fragile because of their reliance on the water table which can be lowered by many operations extrinsic to the site, and species on the edge of their distributional range are fragile since a slight increase in adverse environmental influences could reduce their ability to persist.

Although the field biologists has this intuitive feeling for "fragility", a similar concept is used by the theoretical ecologist when using the word "stability". Populations are considered to exist at stable sizes, and many mathematical models have been put forward to account both for the growth of a population to, and the magnitude of, its stable size. The theoretical ecologist might be interested in the behaviour of a population whose size is near this stable value. If a relatively small perturbation of the population results in it returning to the stable size, then the population is said to be "locally stable". If the population tends to this stable size from any given size, then this stable size is considered to be "globally stable". A detailed consideration of models and populations, and their stability properties, is given by May (1973): some examples of analyses and populations are given in Usher and Williamson (1974).

Much the same property is being measured either in field assessments of fragility or in mathematical models of stability. It is unfortunate that the study of model populations has not yet advanced to a stage of being particularly useful in field assessments. Also, whereas the field biologist assesses the fragility of communities, the modeller has hardly started to assess the stability properties of simple ecosystems, let alone complex ecosystems such as occur in nature. Although many theoretical advances have been made during the past decade in the study of stability, it is likely to be a long while before fragility can be assessed quantitatively.

DISCUSSION

In considering the criteria for assessing conservation value two separate concepts have been intertwined. Firstly, how is a block of land recognised for its conservation importance? Secondly, having located an area of importance, how can it be subdivided into zones of greater and lesser conservation importance?

The first of these questions can be answered in relation to the criteria proposed by Ratcliffe (1977). A site which ranks highly on many of the criteria would be accepted as important. It must, however, be realised that there is no simple way of combining the criteria together so as to give an overall index of conservation value. An experiment to produce such an index for woodland sites in the North York Moors (Everett 1978) has indicated that multivariate statistical techniques can be used to combine rather heterogeneous data. However, the generality of this methodology has not yet been proven, nor are there adequate methods for comparing the results of such an objective system with the subjective systems used for deciding whether to declare S.S.S.I.s, or how to grade sites nationally (Ratcliffe 1977).

When assessing the individual parts of a large S.S.S.I. there are two distinct parts to the process. The first part concerns the collection and evaluation of scientific data. Relatively intensive survey work is required to determine what species of plants and animals are present, their distribution, and the influence of physical factors such as geology, geomorphology, etc. These data will need to be analysed, and classified in a way that is immediately useful and mappable for recognition and management purposes. These basic survey data, and their analysis, are essentially the task of a scientist, and they can be handled by a trained and experienced ecologist. Assessment of some of Ratcliffe's criteria for all units mapped on the basis of their geomorphology and/or biological communities can then proceed. The criteria of size, diversity, and rarity, are all essentially scientific in nature, and involve a minimum of value judgements on the part of the assessor. However, these are about the only decisions that can be based on scientific fact and analysis. Other criteria of Ratcliffe's are intermediate in their nature since a considerable scientific knowledge is required: naturalness, fragility, typicalness and position in an ecological/geographical unit are in this category since elements of judgement are required on the part of the assessor. Other criteria, such as potential value and intrinsic appeal, require little factual scientific data and are almost entirely based on value judgements.

The greatest challenge comes in the second part of the assessment process, when all of these data, some basic scientific data and some already based on judgements and hence derived data, have to be combined into the overall assessment of those parts of greatest and those of least conservation importance. This task involves a considerable number of value judgements in order to weigh up the various types of data and reach some form of decision. The assessment of the Malham-Arncliffe S.S.S.I., Fig. 6, provides an example of this process.

In producing this map four considerations were found to be important. First, the whole area had been designated an S.S.S.I., all of which is graded as of at least national importance. Thus, the whole area can be assumed to be conservationally extremely important, though some parts might be more important and other parts less so. As a first attempt this logically leads to three categories of importance: above average, about average, and below average for the S.S.S.I., and these have been mapped approximately in Fig. 6. These broad categories could be sub-divided later, but such subdivision has not been attempted here.

Secondly, size was a criterion that was used. The whole S.S.S.I. is of importance because of its large size, but, if areas of it are to be graded, should the higher

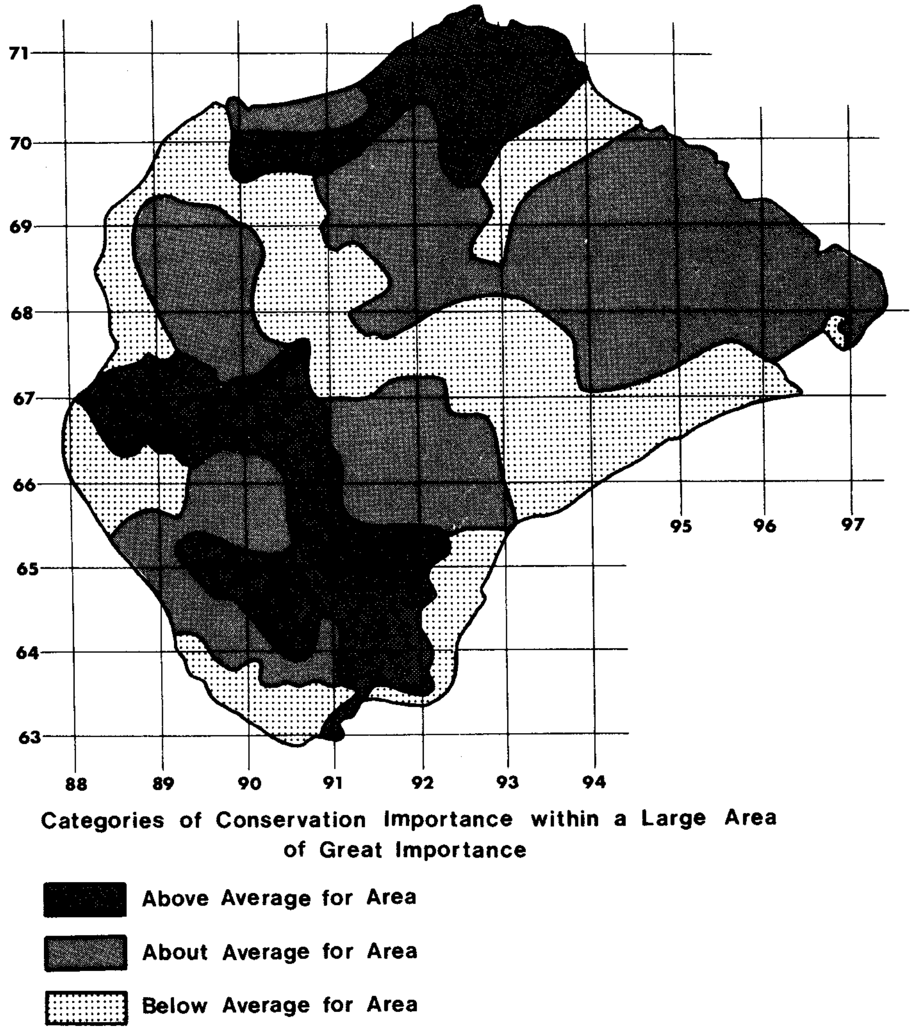

FIG. 6

Zones of conservation importance within the Malham-Arncliffe S.S.S.I., the whole of which is an area of considerable conservational importance. The scale is approximately 1 : 87000, and national grid lines are shown.

conservational category be given to many small areas or to a few large areas? With the concepts both of large areas holding more species and being less vulnerable to chance extinctions of species, it was felt that a few substantial blocks of the S.S.S.I. should be designated as being of maximum conservation value even if they included enclaves of land rated less highly and even if a few isolated areas of high value were to be excluded.

Thirdly, the diversity of higher plant species was used, though animal species data were considered where any were available. This leads automatically to the base-rich grassland and areas dominated by limestone (cliffs, screes and pavements), as well as woods and wetlands, being valued more highly than other habitats. The concept can also be used for the diversity of habitats as well as for diversity of species, and hence it was felt that the areas of greatest conservation importance should include not only base-rich grasslands and limestone dominated habitats but also the less diverse acid grassland communities.

Fourthly, the known occurrence of rare species should be reflected. These are difficult to include since, in some respects, their distribution reflects the spatial distribution of scientific effort. Most of the rare species are known from the south west portion of the S.S.S.I. (in the vicinity of Malham Tarn, Malham Cove and Gordale Scar). However, many of them, as well as a few others, are known from the valley of the Cowside Beck and the limestone formations at the north of the S.S.S.I.

The first two of these considerations did not affect the spatial distributions of the zones of conservation importance since they merely indicated that there should be a small number of categories and that these should be mapped as relatively large blocks. Extensive areas of the diverse base-rich grassland and limestone-dominated habitats occur in four areas, as shown in Fig. 1. These thus form four candidate areas for the highest conservational rank, though two have a greater habitat diversity, including within them the small pieces of semi-natural woodland. These two also contain all the rare species that are known to occur within the S.S.S.I. Thus, in Fig. 6, only these two areas have been demarcated as those of above average conservation importance for the S.S.S.I.

The northern area includes the Cowside Beck and its southern bank, as well as Yew Cogar Scar and the land to the south-east of this scar. The boundaries on the map (Fig. 6) should not be interpreted too closely on the ground since they were drawn to reflect botanical changes, not ownership or field boundaries, and have been "smoothed". The south-western area contains all the communities around Malham Tarn and extends eastwards to include the head-waters of Gordale Beck, and then southwards to include the limestone pavements, cliffs and woodland that flank the Beck.

Two obvious areas for the second category of conservation importance are those two areas of base-rich grassland and limestone-dominated communities that were not included in the first category. The small area around grid square 8968 is largely flanked by agriculturally improved grassland or acidic grassland of relatively low species diversity, and hence it remains of relatively small size in Fig. 6. However, the area in the east of the S.S.S.I. is flanked by neutral grassland of relatively high species diversity, and hence it has been extended to include the whole area between Kilnsey and the headwaters of Cote Gill. Other areas have been selected adjoining the two areas in the highest category so as to include the majority of the base-rich and neutral grassland, together with substantial samples of acidic grassland. Again, boundaries in Fig. 6 cannot be interpreted too literally on the ground, since they are "smoothed" and give only a general indication of the categories of conservation importance. The S.S.S.I. is divided into two parts, one in the north-east and the other in the south-west, separated by a corridor of essentially acid high ground with agriculturally improved grassland at each end. This corridor contains a small quantity of limestone pavement, but these pavements generally ranked low on their floristic index (Fig. 5) and themselves have a low conservation value when compared to other limestone pavements in the S.S.S.I.

In conclusion, a comparison should be drawn between the maps in Figs. 1 and 6. The vegetation map in Fig. 1 is derived from survey data and, given the classification of vegetation types that have been mapped, should be repeatable in that any trained ecologist could produce a similar map. The conservation importance map in Fig. 6 is based on a series of value judgements. Although the criteria on which these judgements have been based have been discussed above, it is unlikely that two trained ecologists would produce identical maps. When scientific facts are mapped there is relatively little scope for disagreement: when values are mapped there is ample opportunity for argument.

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APPENDIX

SCIENTIFIC AND VERNACULAR NAMES OF PLANTS REFERRED TO IN THE TEXT

This list includes all of the plant species referred to by their scientific names in the text or tables. The scientific names throughout follow those of Clapham, Tutin and Warburg (1962), and the vernacular names are taken from Dony, Perring and Rob (1974).

Acer pseudoplatanus L.	Sycamore
Actaea spicata L.	Baneberry
Agrostis canina L.	Brown bent
Agrostis stolonifera L.	Creeping bent
Agrostis tenuis Sibth.	Common bent
Allium ursinum L.	Ramsons
Anemone nemorosa L.	Wood anemone
Arabis hirsuta (L.) Scop.	Hairy rock-cress
Asplenium viride Huds.	Green spleenwort
Bartsia alpina L.	Alpine bartsia
Betula pubescens Ehrh.	Downy birch

Cardamine impatiens L.	Narrow-leaved bitter-cress
Carex ornithopoda Willd.	Bird's-foot sedge
Carex sylvatica Huds.	Wood sedge
Centaurea nigra L.	Common knapweed
Ceterach officinarum DC.	Rustyback fern
Clinopodium vulgare L.	Wild basil
Convallaria majalis L.	Lily-of-the-valley
Corylus avellana L.	Hazel
Cynosurus cristatus L.	Crested dog's-tail
Cystopteris fragilis (L.) Bernh.	Brittle bladder-fern
Daphne mezereum L.	Mezereon
Deschampsia flexuosa (L.) Trin.	Wavy hair-grass
Dryas octopetala L.	Mountain avens
Dryopteris villarii (Bell) Woynar	Rigid buckler-fern
Epipactis atrorubens (Hoffm.) Schultes	Dark-red helleborine
Eriophorum vaginatum L.	Hare's-tail cottongrass
Erophila verna (L.) Chevall.	Common whitlow grass
Festuca ovina L.	Sheep's-fescue
Festuca rubra L.	Red fescue
Filipendula ulmaria (L.) Maxim.	Meadowsweet
Fraxinus excelsior L.	Ash
Galium saxatile L.	Heath bedstraw
Geranium robertianum L.	Herb-robert
Geranium sanguineum L.	Bloody crane's-bill
Helianthemum chamaecistus Mill.	Common rock-rose
Hypericum montanum L.	Pale St. John's-wort
Juncus acutiflorus Hoffm.	Sharp-flowered rush
Juncus alpinoarticulatus Chaix	Alpine rush
Juncus articulatus L.	Jointed rush
Juncus conglomeratus L.	Compact rush
Juncus effusus L.	Soft rush
Juncus inflexus L.	Hard rush
Lolium perenne L.	Perennial rye grass
Melica nutans L.	Mountain melick
Mercurialis perennis L.	Dog's mercury
Minuartia verna (L.) Hiern	Spring sandwort
Molinia caerulea (L.) Moench	Purple moor-grass
Mycelis muralis (L.) Dum.	Wall lettuce
Nardus stricta L.	Mat-grass
Origanum vulgare L.	Marjoram
Oxalis acetosella L.	Wood-sorrel
Paris quadrifolia L.	Herb-Paris
Polygonatum odoratum (Mill.) Druce	Angular solomon's-seal
Polystichum aculeatum (L.) Roth	Hard shield-fern
Potentilla crantzii (Crantz) G. Beck	Alpine cinquefoil
Potentilla erecta (L.) Räusch.	Tormentil
Ribes spicatum Robson	Downy currant
Rubus saxatilis L.	Stone bramble
Salix myrsinites L.	Whortle-leaved willow
Sanicula europaea L.	Sanicle
Saxifraga granulata L.	Meadow saxifrage
Saxifraga hypnoides L.	Mossy saxifrage
Saxifraga tridactylites L.	Rue-leaved saxifrage
Sesleria albicans Kit. ex Shult.	Blue moor-grass
Sorbus rupicola (Syme) Hedl.	(a Whitebeam)
Stellaria media (L.) Vill.	Common chickweed
Succisa pratensis Moench	Devil's-bit scabious

Taxus baccata L.	Yew
Teucrium scorodonia L.	Wood sage
Thelypteris robertiana (Hoffm.) Slosson	Limestone fern
Thlaspi alpestre L.	Alpine penny-cress
Thymus drucei Ronn.	Wild thyme
Trichophorum cespitosum (L.) Hartm.	Deergrass
Urtica dioica L.	Common nettle
Veronica arvensis L.	Wall speedwell
Viola lutea Huds.	Mountain pansy
Viola riviniana Rchb.	Common dog-violet