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Limestone Pavement in the Yorkshire Dales National Park

Assessing 30 years of change.

Thom, T.J., Swain, J., Brandes, E., Burrows, H., Gill, A., Tupholme, A., Vernon, N

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1. SUMMARY

1. A survey was carried out between 2000 and 2002 to determine the current Floristic Index values and carry out an English Nature Condition Assessment of limestone pavement within the Yorkshire Dales National Park.

2. 211 out of 235 limestone pavement stands were surveyed.

3. Results showed that there had been a 33% decrease in the number of pavement stands in the high Floristic Index categories.

4. Ninety-two percent of pavement stands were classed as being in Unfavourable Condition with 28% estimated to be declining in quality.

5. The Condition Assessment method was effective at differentiating the very best and very worst pavements but was less sensitive in assessing pavements of moderate to high botanical quality.

6. Area of pavement, amount of pavement damage and percentage scrub cover explained 51% of the variation in Floristic Index with the remainder unexplained by the variables analysed.

7. It was discussed that physical attributes such as grike depth and width were likely to explain much of the remaining variation.

8. It was argued that a better classification of limestone pavement based on physical attributes may be necessary in upland areas.

9. Where pavements are of moderate to low botanical value, further work is required before being able to set management prescriptions.

10. Where pavements are of high nature conservation value, the current focus on reducing grazing should continue but with greater monitoring and research to assess the impact on floristic value.

2. INTRODUCTION

Limestone Pavement is a unique and irreplaceable habitat that has developed over 10,000 years. It is made up of flat expanses of limestone rock with surface features and deep cracks, known as grikes, along natural joints in the rocks resulting in the formation of separate blocks known as clints.

In Britain limestone pavement covers <3000 ha with the majority of this in northern England. The Yorkshire Dales National Park contains an estimated 1360 ha (45%) with the majority of the remainder in Cumbria and Lancashire (1276 ha, 43%). 296 ha occurs in Scotland and a further 70 ha in Wales. There are also small areas of limestone pavement in County Fermanagh in Northern Ireland. The largest amount of limestone pavement is found in the Republic of Ireland, in the Burren. In the rest of Europe there are only tiny areas in Sweden and Sardinia.

Limestone Pavement is important for two main reasons. It is a unique geological feature providing a record of glacial and post-glacial history. It also has unusual and diverse combinations of plant communities that include 20 rare or scarce species.

In the early 1970s Ward & Evans (1975) carried out an assessment of the botanical value of limestone pavement in the United Kingdom in response to growing concern about the amount of damage being done by removal for the garden rockery trade. The results of the survey have been used subsequently to provide strong protection for limestone pavements through designation as Sites of Special Scientific Interest and the making of Limestone Pavement Orders by local authorities.

In the United Kingdom this process of designation has been successful in stopping further destruction of limestone pavement.

Conservation efforts are now being focussed on the impacts of land management on limestone pavement and, in particular, the impacts of grazing on the pavement flora.

Since Ward & Evans' (1975) survey there has been no systematic assessment of the botanical value and condition of limestone pavement in the Yorkshire Dales National Park. The Yorkshire Dales National Park Authority and English Nature recognised that there was a need for such an assessment so that specific management objectives could be produced and implemented for individual limestone pavement management units.

Between 2000 and 2002, using funds from the English Nature Biodiversity Grant Scheme, staff and volunteers from the Yorkshire Dales National Park Authority carried out an assessment of the majority of the limestone pavement in the National Park.

This report discusses the results of this assessment in comparison to the Ward & Evans (1975) survey, suggests some outline management objectives, and makes recommendations for further work on limestone pavement in the Yorkshire Dales National Park.

3. SURVEY AIMS

The original aims of the survey set out in the bid to the English Nature Biodiversity Grant Scheme were:

- To assess the current nature conservation condition of limestone pavement in the Yorkshire Dales National Park.

- To produce management action plans that will assists in targeting resources to maintain and, where necessary, enhance the biodiversity value of limestone pavements in the Yorkshire Dales National Park.

4. SURVEY OBJECTIVES

The original specific objectives of the survey were:

- To assess the current biodiversity value of limestone pavements in the Yorkshire Dales National Park using English Nature condition assessment methods by the end of September 2000.

- To complete the Yorkshire Dales National Park Geographical Information System (GIS) database of limestone pavements by adding the results of the present survey by the end of September 2000.

- To compare the current biodiversity value of limestone pavements in the National Park with the Ward & Evans (1975) survey and assess any changes that have taken place by the end of December 2000.

- To use this information to develop management plans and targets for the future conservation of limestone pavement in the Yorkshire Dales National Park by the end of December 2000.

- To produce a glossy promotional publication on the history, current condition and future management needs of limestone pavement in the Yorkshire Dales National Park for disseminating to the general public and land management community by the end of March 2001.

During the 2000 field season it soon became apparent that it was going to take two seasons to complete the survey and the National Park Authority requested an extension to the project. The 2001 season was then cancelled due to an outbreak of Foot & Mouth Disease in the survey area. As a result all the dates for completion of the objectives were moved back two years.

5. METHODS

5.1. Site selection

Prior to the survey the original Ward & Evans (1975) survey results were converted into a digital format. This was in two parts. The maps were digitised into a MAPINFO layer as accurately as possible given the scale of the original survey maps. Data on site location, description and all species records were entered into an ACCESS database with each pavement stand linked by a unique reference code to the MAPINFO layer.

At the same time landowner information was collated for all pavement stands. All landowners were then contacted in writing to request permission to carry out the survey.

5.2. Survey methods

Two methods for assessing the quality of limestone pavement were used in the survey – a repeat of the Ward & Evans (1975) survey and a Condition Assessment. In addition a landscape assessment was also carried out.

5.2.1. Repeat Ward & Evans survey

Ward & Evans (1975) surveyed the botanical species composition of limestone pavement using an exploratory walk across each identified stand. The time taken to conduct the walk was proportional to the pavement's size with a moderate sized pavement taking 30-45 minutes to complete.

Ward & Evans (1975) noted all the species recorded during the survey but restricted the most rigorous assessment to deep grikes (defined as grikes that were twice as deep as wide). An abundance score was also devised as follows:

1 = one to a few. Extremely sparse

2 = locally abundant or widely scattered.

3 = abundant

Ward & Evans (1975) classified each species found during the survey on the basis of significance criteria defined as:

i) whether the species depended on pavement for its continued survival
ii) the species' distribution within Britain.

These criteria were used to define the following classes of species:

Group A: Nationally rare species generally restricted to limestone pavement;
Group B: Nationally uncommon species with a strong affinity to limestone pavement;
Group C: Nationally common species with a strong affinity to limestone pavement;
Group D: Species occurring in limestone pavement but not dependent on the habitat for continued survival.

This classification was used to produce a measure of botanical quality called the Floristic Index that was calculated for each stand using the following formula:

$$\text{Floristic Index} = 3(\Sigma a_A) + 2(\Sigma a_B) + \Sigma a_C$$

Where 'a' is abundance on the 1 to 3 scale.

Based on this Floristic Index Ward & Evans assigned each pavement stand to one of three categories

>90	Pavement of exceptional botanical interest.
>70≤90	Pavement of high botanical interest.

≤70	Pavement of low botanical interest.

In the present survey the Ward & Evans (1975) method was used except that a longer period of time was spent on each pavement stand to enable more rigorous recording of all species present.

5.2.2 Condition Assessment

The Ward & Evans (1975) survey method is time-consuming and requires a high level of botanical identification skills. Recently English Nature has been developing Rapid Condition Assessment methods for a number of habitats including limestone pavement. The intention of these is to enable conservation agencies to rapidly assess the impacts of management on the nature conservation interest of a site or habitat. They were designed for surveyors with different levels of botanical skill and for use during a short field survey period. The condition assessment method for limestone pavement is described in Appendix I and was used by the surveyors in the present survey after an initial training session in its use.

5.2.3. Landscape Assessment

The landscape value of limestone pavement stands was assessed from popular vantage points. These were determined by travelling roads and public rights of way in the survey area and stopping at all vantage points overlooking limestone pavement. At each vantage point a digital photograph was taken and a form filled out describing the impact the pavement has on the landscape (see Appendix 2). This description was subjective but based on established methods for describing landscapes.

5.3. Data Management

All data collected during the survey was transferred to an ACCESS database linked to a MAPINFO GIS layer. The digital photographs were also accessible via a linked field within the database. Statistical analyses were conducted using EXCEL combined with the additional statistical package XLSTAT.

6. RESULTS

6.1. Sites surveyed

211 out of a total of 235 individual limestone pavement stands were surveyed as part of the present survey ranging in size from 0.06 ha to 76.73 ha (Mean = 5.66ha). Only 11 of the stands surveyed were greater than 15 ha in size.

Floristic index values were calculated for 182 of these pavement stands. Floristic Index values were not calculated for the remaining stands because they were either not surveyed because the stand was predominantly grassed over or wooded or due to lost records (n = 2).

Condition assessments were conducted on 209 of the pavement stands.

Ward & Evans (1975) did not assess 22 of the pavement stands surveyed in the present survey.

6. 2. Pavement Quality

6.2.1. Floristic Index

Floristic index values were available from the 1970s and the present survey for 182 of the stands surveyed. The number of sites in each of the three Ward & Evans (1975) Floristic Index categories was compared between the 1970s and the present survey (see Figure 1). The results showed that there had been a 33% decrease in the number of pavement stands in the high Floristic Index categories with a corresponding increase in the number of sites in the low Floristic Index category.

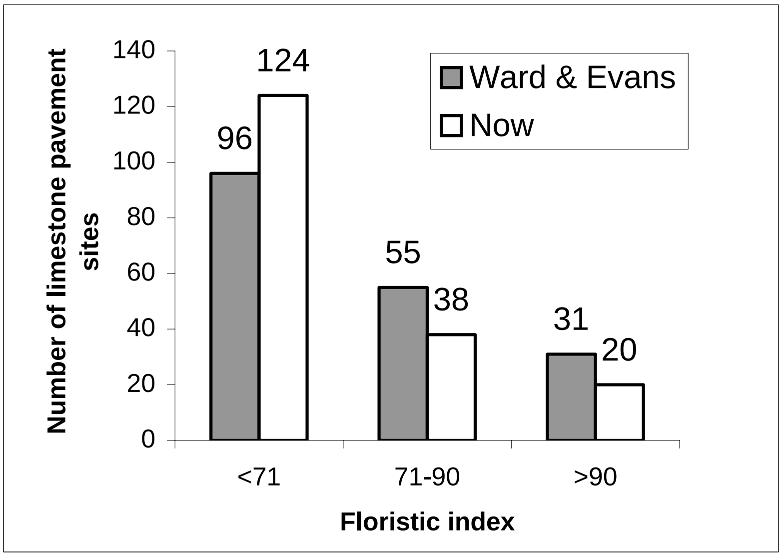

Figure 1: Comparison of floristic index scores for limestone pavement sites between the 1970s (Ward & Evans, 1975) and 2000-2002.

6.2.2. Condition Assessment

Condition was assessed for 209 of the pavement stands. Table 1 shows that the majority of pavement stands were classed as Unfavourable. Of the 16 Favourable sites, 5 were wooded.

Condition	Number of pavement stands (%)
Favourable	16 (8)
Unfavourable	193 (92)

Table 1: Condition of limestone pavement stands surveyed between 2000 and 2002 assessed using English Nature's rapid condition assessment method.

In order to estimate the direction of change in condition of limestone pavement since the Ward & Evans (1975) survey the Floristic Index (where this had been calculated in both surveys) was used to determine whether a pavement stand was declining in condition (see Table 2). 28 % of stands were declining with 10 % of stands improving.

Condition	Number of pavement stands (%)
Favourable - improving	1 (1)
Favourable – no change	7 (4)
Favourable - declining	4 (2)
Unfavourable - improving	17 (9)
Unfavourable – no change	105 (58)
Unfavourable - declining	48 (26)
TOTAL	**182**

Table 2: Condition of limestone pavement stands surveyed between 2000 and 2002 assessed using English Nature's rapid condition assessment method. Change in floristic index values between the two surveys was used to assess the direction of change in condition.

6.2.3. Comparison of Floristic index with condition

Both the Floristic Index and the Rapid Condition Assessment are measures to assess the botanical and conservation value of limestone pavement. Table 3 shows how the two different assessments relate to each other.

The majority of pavement stands are in the <71 Floristic Index category and of these most were classed as Unfavourable – no change or Unfavourable – declining. Only 3% of these sites were classed as Favourable or Unfavourable-improving. The Favourable sites in this Floristic Index category were also declining. The two measures are, therefore, in broad agreement when looking at the poorest quality pavements.

However, those pavements with High Floristic Index values were also categorised as predominantly Unfavourable with only a small number of sites with the highest Floristic Index classed as Favourable.

This indicates that Condition Assessment will distinguish the very best and the very worst sites but not those that are somewhere in between.

Condition	Floristic index category	
	<71	**≥71**
Favourable	0 (0)	7 (11)
Favourable declining	2 (2)	2 (4)
Unfavourable improving	1 (1)	16 (28)
Unfavourable no change	85 (68)	22 (39)
Unfavourable declining	37 (29)	10 (18)
Total number of stands	125	57

Table 3: Comparison between the number of sites in each Floristic Index category and condition category based on a survey of 182 limestone pavement stands between 2000 and 2002. Figures in brackets give the percentage of sites of each Floristic Index category that were classified in each Condition Assessment category.

6.2.4. Change in the status of indicator species

Baneberry (*Actaea spicata*), Rigid Buckler Fern (*Dryopteris submontana*), Limestone Fern (*Gymnocarpium robertanium*), Lesser Meadow Rue (*Thalictrum minus*), Blue Moor-grass (*Sesleria caerulea*) and Limestone bedstraw (*Galium sterneri*) have all increased in the number of positive sites since the Ward & Evans (1975) survey. Downy currant (*Ribes spicatum*), Bloody Cranesbill (*Geranium sanguineum*) and Marsh Hawk's-beard (*Crepis paludosa*) have shown small declines while the rarest species - Narrow-leaved Bittercress (*Cardamine impatiens*), Pale St. John's Wort (*Hypericum montanum*) and Globeflower (*Trollius europaeus*) - have become rarer still.

Species	Number of sites found		% Change	Number of former sites lost
	Ward & Evans	Now		
Baneberry *Actaea spicata*	31	37	+19	1
Rigid Buckler fern *Dryopteris submontana*	66	70	+6	9
Downy currant *Ribes spicatum*	13	11	-15	4
Angular Solomon's seal *Polygonatum odoratum*	10	10	0	4
Narrow-leaved bittercress *Cardamine impatiens*	10	6	-40	4
Limestone Fern *Gymnocarpium robertanium*	74	80	+8	5
Pale St. John's wort *Hypericum montanum*	3	2	-33	1
Bloody cranesbill *Geranium sanguineum*	18	17	-6	5
Lesser Meadow-rue *Thalictrum minus*	94	107	+14	5
Globeflower *Trollius europaeus*	8	3	-63	5
Marsh Hawk's-beard *Crepis paludosa*	29	24	-17	7
Blue Moor-grass *Sesleria caerulea*	147	171	+16	5
Limestone bedstraw *Galium sterneri*	51	80	+57	10

Table 4: Comparison of the presence of rare, scarce and Condition indicator species for limestone pavement stands surveyed in the 1970s (Ward & Evans, 1975) and 2000-2002. The last column of the table shows the number of sites that a species was recorded at in the Ward & Evans (1975) survey but was not found in the recent survey.

6.3. What determines current botanical value?

This survey was not intended as a scientific study of the factors determining the botanical value of limestone pavement. However, the Condition Assessment method records a number of variables such as emergence, scrub cover and percentage damage which, combined with other variables such as area, enable a tentative analysis of the factors that may influence botanical value.

6.3.1. Location

The nature of the Dales landscape means that Limestone Pavement can be separated into distinct geographical areas. These were identified as follows:

1	Yoredale stands:	5
2	Whernside/Kingsdale stands:	21
3	Ingleborough stands:	59
4	Malham-Arncliffe stands	37
5	Conistone stands	27
6	Pen-y-Ghent stands	12
7	Feizor stands	19
8	Miscellaneous	4

Sample sizes for groups 1 and 8 are too small to use in any meaningful analysis so these were excluded from the following statistical tests.

An Analysis of Variance (ANOVA) test showed that the mean Floristic Index (FI) differed significantly between locations (Fisher's F = 8.96, $p < 0.001$, 22.2% of the variance explained).

A Bonferroni's test showed that Pen-y-Ghent (Mean FI = 55.3+/-13.5), Feizor (Mean FI = 41.7+/-15.5) and Conistone (Mean FI = 51.9+/-21.8) were statistically grouped (Feizor did not overlap with any other group) on the basis of their Floristic Index values. Pen-y-Ghent was also the lowest member of a group made up of Whernside/Kingsdale (Mean FI = 68.4+/-21.9), Ingleborough (Mean FI = 72.0+/-25.9) and Malham-Arncliffe (Mean FI = 71.1+/-11.5). The latter two do not overlap statistically with any other group of pavements and have the highest FI. This is not surprising as these latter two groups are part of large SSSI and SAC sites and include the Ingleborough NNR and as such are specifically managed for nature conservation.

6.3.2. Pavement Area

Figure 2 shows that there is a logarithmic relationship between limestone pavement stand area and Floristic Index distribution with a rapid fall off in FI below the 5ha mark. After Log_{10} transformation of the area data a linear regression test showed that the relationship between area and Floristic Index was significant ($r^2 = 0.291$, Fisher's F = 71.55, $p < 0.001$) with a higher probability of larger pavements having higher Floristic Index values.

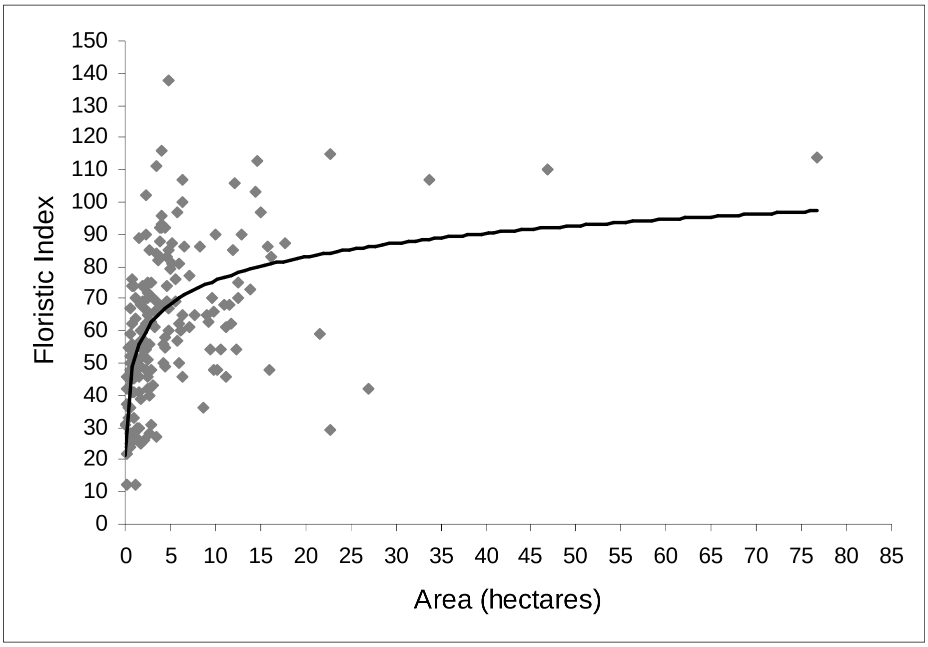

Figure 2: Relationship between area in hectares and Floristic Index for limestone pavements surveyed between 2000 and 2002.

6.3.3. Impact of damage

The Condition Assessment method recorded the proportion of damage on each pavement stand. The mean percentage intact was 42±3%. When this was compared with the Floristic Index it was found that the more intact a pavement was the more likely it was to have a higher Floristic Index value (r2 = 0.134, Fisher's F = 28.35, $p < 0.001$)

6.3.4. Percentage emergence

The Condition Assessment method also recorded the percentage emergence of vegetation from the grikes. This was found to be extremely low across the sample with a mean of 3.0%. When this was compared with the Floristic Index it was found that higher Floristic Index values were more likely from pavements with emergent vegetation although the amount of variation explained was very low ($r^2 = 0.063$, Fisher's F = 12.26, $p < 0.001$).

6.3.5. Percentage scrub cover

In a similar way to the measurement of emergent vegetation, the Condition Assessment method recorded the percentage scrub cover on each pavement stand. This was also found to be low across the sample (mean 0.4±0.6%) with the majority of pavements having no scrub at all. When this was compared with the Floristic Index it was found that higher Floristic Index values were more likely from pavements with scrub cover although the amount of variation explained was low ($r^2 = 0.148$, Fisher's F = 31.85, $p < 0.001$).

6.3.6. Rabbit damage

Rabbit damage was recorded during the survey into the following three categories based on the presence of dung, scuffing and burrowing.

	Number of sites
None	31
Light	88
Moderate/Heavy	63

An ANOVA test was carried out which showed that the mean Floristic Index did not differ significantly between these rabbit damage categories.

6.3.7. Combined variables

In order to determine which of the above variables contribute most to explaining the variation in Floristic Index a stepwise multiple regression test was carried out using area, damage, emergence and scrub cover. The resulting regression model explained 50.6% of the variation in Floristic Index ($r^2 = 0.5055$, Fisher's $F = 57.58$, $p < 0.001$). Limestone pavement area explained 29.0% of the variation followed by, percentage damage (14.3%) and scrub cover (7.3%) with 49.4% of the variation unexplained.

6.4. Landscape Assessment

Due to time constraints it has not been possible to complete an analysis of the landscape importance of the individual pavement stands.

7. DISCUSSION

7.1. Pavement Quality

The results of this survey showed that 67% of limestone pavement stands in the Yorkshire Dales National Park have very low botanical interest.

Both Floristic Index values and Condition Assessment suggested that 28-33% of limestone pavement stands have declined in botanical quality since the Ward & Evans (1975) survey. It is also important to note that, in the current survey, surveyors spent a lot longer searching for species than in the 1970s survey. This means that Floristic Index values for all pavements should have been higher in the current survey due to the increased likelihood of finding species.

There have also been some small changes in a number of the rare, scarce and indicator species recorded in the survey. Baneberry, Rigid Buckler Fern, Limestone Fern and Lesser Meadow Rue were found at an increased number of sites in the current survey. These are species associated with the more inaccessible parts of limestone pavement such as deep grikes or crevices and are, therefore, less prone to grazing pressure. Blue Moor-grass and Limestone Bedstraw were also found at an increased number of sites. These are, however, species associated with calcareous grassland habitats and may well benefit from increased grazing or establishment of new habitats through pavement damage. Given that these latter two species are more associated with calcareous grassland their use as indicators of pavement condition is questionable. Neither of these species was significant in the calculation of Floristic Index values.

The remainder of the key species, apart from Angular Solomon's Seal, were found at fewer sites in the present survey. Some of the differences were small and are likely to be simply a result of surveyors not locating individual plants within complex pavements. The very rarest species on limestone pavement - Narrow-leaved Bittercress, Pale St. John's Wort and Globeflower – have declined still further which now makes them very vulnerable to extinction from Yorkshire Dales pavements.

7.2. Comparing Floristic Index with Condition Assessment

The relationship between Condition Assessment and Floristic Index showed that the former method appears to be effective at recording the condition of the very worst and very best sites but is not sensitive to the floristic value of the pavements between these two extremes. This is probably because the main factors within the Condition Assessment that determine the condition of the Dales pavements are the amount of scrub and emergent vegetation which may not be closely coupled with the floristic value of the pavement (see Section 7.3.).

7.3. What determines botanical value?

The analysis of factors that may influence botanical value revealed that the physical variables of pavement area and amount of damage were the most significant in explaining variation in Floristic Index. The only habitat variable that was significant was the amount of scrub cover which explained a small amount of the variation. However, a significant amount of the variation in Floristic Index was unexplained.

The distribution and abundance of plant species within pavements is probably dependent on a number of factors. One of the most important is likely to be the physical structure of the pavement itself. As Ward & Evans (1975) stated, the depth, width and density of grikes is likely to play a significant role in determining the botanical communities within pavements. In addition, the amount of soil or post-glacial till remaining on the clint surfaces will also determine the character of the pavement communities. At Scar Close, for example, there are large areas of vegetation on the surface of the pavement due to the presence of till. This type of surface vegetation is almost unique to this one area within the Dales. It is likely that these physical attributes of limestone pavement are responsible for much of the unexplained variation in Floristic Index values.

It is also likely that grazing has had an important impact on the floristic diversity of limestone pavement. For example, after grazing was reduced on different parts of the Malham-Arncliffe SSSI as part of the Craven Limestone Grassland Wildlife Enhancement Scheme, Limestone Fern increased in abundance and shoot growth and Ash began to regrow in some of the grikes. In other parts of the SSSI

Baneberry increased in fruiting and Lily-of-the-valley was recorded for the first time in 20 years (Mercer & Evans, 1997).

There is, however, little quantified evidence as to the nature of the impact of grazing. The Condition Assessment method uses scrub cover and emergent vegetation as a surrogate measure of grazing impact. However, the results of the current survey showed that emergent vegetation did not explain any of the variation in Floristic Index in comparison with the other variables tested. Scrub cover did explain some of the variation but only a small percentage. It is however, important to point out that the vast majority of pavements in the Dales do not have any scrub or emergent vegetation, which may have skewed any statistical analysis. Nevertheless, it is clear that many pavements without scrub or emergent vegetation had high Floristic Index scores. Another explanatory factor may be that scrub and percentage emergence may not be a good measure of grazing impact. Those sites with high Floristic Index and low scrub cover may still have low grazing levels but other factors such as altitude, exposure and pavement structure may play a more important role in determining whether scrub is present.

A key factor that may be limiting the accuracy of the Condition Assessment method for Dales pavement may be that the categorisation of pavements into Wooded and Open may be too broad. If, as is suspected, the physical structure of pavements plays an important role in determining floristic values and, therefore, the likely success of management prescriptions, there is probably a need to classify pavements on the basis of this structure. The Condition Assessment may then need to be revised on the basis of this classification. For example, open pavements could be classified as follows:

A. Pavements with wide and shallow grikes.
B. Pavements with deep grikes with no soil on clint surfaces.
C. Pavements with deep grikes with soil on clint surfaces.

The Condition Assessment for A may need to reflect that the vegetation in the grikes on this type of pavement is usually dominated by grasses such as Blue-moor grass and may be more appropriately assessed as grassland. If grazing was reduced on such pavements the likely outcome would be establishment of species rich grassland but not the development of the more unique pavement flora. If grazing was restricted completely from such sites it is possible that an upland ash dominated woodland may develop but probably not with the attributes that would define wooded pavement. In this case it would probably be more appropriate to assess condition using woodland criteria.

A significant proportion of the Dales pavements are likely to be classified as A. The remainder would be those that could be considered as classical examples of limestone pavement and assessed as such.

7.4. Setting Management Objectives

One of the key objectives for this project was to set management objectives for each pavement. However, the results of the survey have shown that, for the majority of pavements, setting specific limestone pavement objectives may not be appropriate. In these cases, grassland enhancement objectives or woodland restoration may be more important nature conservation objectives. Alternatively, for those pavements with low Floristic Index values and with wide and shallow grikes it may be decided that nature conservation is not a primary objective. Other factors such as geological or landscape conservation may take preference. It is necessary, therefore, to look more closely at the physical attributes of these sites before management objectives can be set.

Where pavements are of high nature conservation value (high Floristic Index values or where rare species are present) the current management objectives are to reduce grazing to enable vegetation emergence and increased scrub. The present survey is inconclusive in determining whether this will lead to enhanced nature conservation condition. There is, however, no evidence that current management prescriptions are causing declines in pavement quality. It is proposed, therefore that all sites with high nature conservation value should continue to be managed to reduce grazing pressure but the effects of increasing scrub cover should be carefully monitored.

7.5. Further work

This survey has shown that limestone pavement in the Dales is declining in quality. The survey was not established to determine what factors are responsible for this decline or, indeed, how to reverse this decline. In order to determine this the following areas of further work are needed:

1. Using data on grike depth and width collected by Ward & Evans (1975) attempt to classify pavements based on physical attributes.

2. Use this classification to determine whether the Condition Assessment method needs modifying and to set conservation objectives for pavements of low to moderate botanical value.

3. Monitor and research the impacts of reductions in grazing on limestone pavement in the Dales. (Note: a recent research contract let as part of the Yorkshire Dales Limestone Country Project will be analysing the impact of changing livestock numbers and type on the vegetation of limestone pavements within the Malham-Arncliffe and Ingleborough areas).

8. REFERENCES

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9. ACKNOWLEDGEMENTS

We are grateful to all the landowners that granted access to their land for the recent survey of limestone pavement. We would also like to express our thanks to the English Nature Biodiversity Grant Scheme for their funding for the limestone pavement project.

ENGLISH NATURE

YORKSHIRE DALES
National Park Authority

Appendix I Limestone Pavement Condition Assessment

Generic guidance on setting conservation objectives for Limestone Pavements: Explanatory Text

Limestone pavements are listed as a priority habitat type in Annex 1 of the Habitats Directive. The habitat is classified under *Chasmophytic vegetation on rocky slopes* and described in Corine 62.4.

NVC description of limestone pavements

The NVC classification does not separately describe the flora of limestone pavements. The flora of limestone pavements is best described as encompassing elements of the following community types: CG9, W8, W9, W21, OV38, OV39 and OV40.

Context for the attributes that define condition

1. Extent of Habitat

Limestone Pavements are extremely restricted habitat in Britain covering about 2300 hectares in England and less than 3000 hectares in Britain and Northern Ireland. The habitat is only found in areas of hard limestone which were scoured by glaciers during the ice ages. The habitat is also restricted in Europe. The greatest extent occurs in the Republic of Ireland centred around the Burren. The extensive montane platforms of central and south-eastern Europe lack the well-developed and characteristic surface patterning and the distinctive flora of British pavements.

Pavements are therefore restricted and non-renewable. Once damaged limestone pavement will not re-form as its formation was initiated by scouring during the ice ages. Any loss or damage to the physical structure of pavements will result in unfavourable condition being recorded. As recovery is not possible it could be argued that damage would lead to permanently unfavourable condition. Realistically any damage more than two years old should be regarded as historical and not trigger recording of unfavourable condition. It is however likely that damaged pavement can no longer be regarded as pavement for condition assessment. Loss of clints and grikes will leave an open vegetation characteristic of grassland or OV38-40 rather then vegetation characteristic of pavements.

2. Species Interest

Limestone pavement SSSIs and the SAC series have been selected wholly on the strength of their species assemblages and populations. The floristic index devised by Ward and Evans (1975) is the backbone for site selection. The index looked at on-site abundance and the national distribution of vascular plants. The GCR series does identify sites of geological importance but all sites selected already qualified for their floristic interest.

The habitat is notable for a number of rare and scarce species listed in the attributes table. It is therefore important that any condition assessment ensures that the notable species on a SSSI are still present. Assessment of population size is very time consuming on pavements (you would have to look into every grike). It is therefore proposed that a presence or absence recording for species is adequate. Population sizes will be picked up by other attributes in the condition assessment (see later) and by more elaborate quality monitoring.

There is significant altitudinal and geographical variation in limestone pavement species assemblages. No one pavement supports all of the listed species. Condition assessment will therefore focus on species which were recorded on the site at time of notification. It is accepted that many of the pavement SSSIs were notified in sub-optimal condition especially the open upland sites but most will have retained a good species assemblage in the shelter of the grikes.

Conservation Officers should amend field assessment forms to show which species will be expected on a site so that these can be ticked off as present. There will also be some merit in keeping a map showing where some of the rarer species are centred, to speed up field visits. The disadvantage of looking at species interest is that it restricts visits to between May and September and slows down the entire monitoring process. Species interest is however integral to pavements and a check on this element is essential.

Negative indicator species are also seen to be an important part in condition assessment. Some of the species are those identified in the grassland generic guidance and relate to poor agricultural management of the land. Further details should be sought from the grassland notes. Particular to pavements are exotic conifers (usually larch, red cedar or Corsican pine) and non-native beech. These species have a damaging impact on pavements through shade, needle fall, acidification and prolific seeding. Presence of these species at a frequency greater than rare will indicate unfavourable condition. The issue of sycamore and blackthorn is considered later in this note.

3. Structure and Function

Limestone pavements admirably demonstrate the relationship between the physical structure and vegetation community. Variation in morphology results in a distinct change in vegetation type. These relationships are distorted or masked on the majority of English pavements by the impacts of stock grazing.

Two elements in the condition assessment look at this structure and function and the impact of stock grazing. These are **emergent species** and **woody species on open pavement**.

The rationale behind inclusion of these two attributes is that grazing pressure on most English pavement is far too high and the special interest is being degraded. A reduction in grazing pressure will achieve the following:

4. Expansion of the populations of many of the rare and scarce plants discussed above. These plants are often grazing intolerant and are restricted to the depths of the grikes. We need them to expand luxuriantly onto the clint-tops, flower and set seed and expand into adjacent grikes.

5. Better demonstration of the relationship between structure and vegetation. Limestone pavements are important because of their diverse niches, exploited by a wide range of species. The vegetation of some of these niches, particularly the clint-top ones, is

degraded by heavy grazing pressure. This attribute could also be considered in terms of naturalness.

6. Many of the important pavement species favour transitions between pavement and woodland, grassland or scrub. A reduction in grazing pressure will allow these transitions to fully develop and again increase populations of notable species.
7. The development of more structure in pavement vegetation and the development of transitions mentioned above will favour the invertebrate assemblage associated with limestone pavement. This includes nationally important butterflies, snails and flies. Increased vigour and flowering will also improve food plants and nectar sources.

The measurement of an appropriate grazing pressure in the field, for the purposes of condition assessment, is through two attributes: emergent species and woody species on open pavement.

Emergent species requires non-woody species to be growing beyond the confines of the grikes. Flower heads and fern fronds must survive without being grazed off. Emergent vegetation will also indicate conditions where species populations are stable or expanding. Emergent vegetation must be present on at least 25% of the pavement area for the site to be in favourable condition.

Woody species on open pavement is a further indication that grazing pressure is sustainable. Open pavement generally looks grey or white as a landscape feature and has vegetation mostly within the grikes. Its open and bare nature often reflects an unfavourable condition. The current picture of most English pavements is of new seedlings and saplings being grazed off every year. An expansion of (dwarf) woodland cover is needed. This does not mean that we would wish to turn open pavement into wooded pavement, just increase its structural diversity. We would not wish to push open pavements to the stage where the clints became bryophyte covered or a woodland cover of more than 25% was achieved. For favourable condition we need a minimum of woody species present on 5% of the pavement (this is not 5% cover). Sycamore or blackthorn component must be less than 10% combined of the woody element if the site is favourable.

4. Structural variety in wooded pavement

Wooded pavements are differentiated from open pavements as they have a closed canopy and clints are cloaked by dense green mosses. Structural variety is desirable to maximize transitions, shelter for invertebrates and to keep a variety of structural niches open (see above). Many pavements have natural clearings created by the clint and grike structure but in others (and in surrounding limestone woodlands) coppicing and woodland management will be the only way to ensure structural variety is maintained.

Visual assessment is required to ensure that structural variety is there. Seedlings, saplings, young trees, mature trees and open space should all be there in varying degrees. Be aware that root and drought stress on pavements may mean that a mature tree looks very stunted and small. Coppice regrowth must be vigourous and not suppressed by deer or stock grazing.

Conservation objectives

The conservation objectives for limestone pavement SACs and SSSIs will be to:

Maintain the limestone pavement in favourable condition

The habitat is judged to be in favourable condition when all attributes listed in the relevant table and text above meet the defined targets.

References

Ward S.D. and Evans D.F., 1975, A botanical survey and conservation assessment of British limestone pavements. Institute of Terrestrial Ecology

Limestone Pavements: Conservation Objectives

Operational Feature (= ENSIS level 1)	Criteria Feature (=ENSIS level 2)	Attribute	Measure	Target	Comments
Limestone Pavement	Limestone Pavement	Extent	Visual assessment of pavement for signs of damage in past 2 years. Signs are broken, white, lichen-free rock, rubble, displaced clints & infilled grikes	No loss of pavement	Limestone Pavement is non-renewable. Any recent damage results in unfavourable condition. Old damage is easy to differentiate from new damage due to the colonisation of lichens and the weathering of rock on older damage.
		Emergent Species (Plant species growing beyond the confines of the grikes)	Visual assessment of the plants emerging from the grikes and growing luxuriantly on the clint-tops Flower heads and fern fronds must survive without removal by grazing.	Emergent and clint-top plants on **25%** of pavement area.	All pavements must have non-woody emergent and clint-top vegetation if they are in favourable condition.
		Presence of negative indicator species	Record the frequency of **non-native** conifers and beech on the site	Species no more than **rare** on any site.	Juniper and Yew are important and valuable elements of pavement flora. Other conifers and beech damage the interest.
		Presence of negative indicator species	Record the frequency of the following species: spear thistle, creeping thistle, nettle & ragwort.	Species no more than **occasional** on pavement.	The list of negative indicator species are indicators of poor agricultural management.
		Rare and Scarce species.	Record the presence or absence of species from the following list where they have been recorded from the site at time of notification *Dryopteris submontana, Ribes spicatum, Actaea spicata, Epipactis atrorubens, Polygonatum odoratum, Gymnocarpium, robertianum, Carex digitata, Carex*	Known species recorded.	Limestone pavements are of special interest for their species assemblages and populations (as well as their geological, entomological and landscape values). The listed species are the nationally rare, nationally scarce and other characteristic species associated with pavements. These species are often grazing intolerant. Due to altitudinal and on site variance no

			ornithopoda, Cardamine impatiens, Arenaria anglica, Hypericum montanum , Dryas octopetala, Salix myrsinites, Galium sterneri, Sesleria caerulea, Potentilla neumanniana, Geranium sanguineum , Thalictrum minus, Trollius europaeus, Crepis paludosa.		pavement could support all species listed. It is therefore only proposed to record all species known from the site at time of notification. Recording is on a presence or absence basis and does not consider the population sizes of these species. These will be monitored by more detailed recording methodology.
Limestone Pavement	Wooded Pavement	Structural variety in wooded pavement	Visual assessment of structural variety in woody species and diversity of age class. Presence of clearings or coppice coups. Vigorous regrowth of any coppice stools	Structural variety present	*Wooded pavements have a closed canopy and clints are cloaked by dense green mosses. A complete and even-aged closed canopy will often be reflecting an unfavourable condition* Structural variety is often created by woodland management but can be an inherent feature of the structure and function of the pavement.
Limestone Pavement	Open Pavement	Woody species on open pavement	Visual assessment of the presence and overall cover of woody species.	Woody species occasional and present on at least **5%** of the whole pavement. Not exceeding a cover of **25%** of the whole pavement. The sycamore and blackthorn component must be less than 10% when combined	Open pavements need an element of woody growth and cover to be in favourable condition. (See also emergent vegetation). A dwarf woodland or scrub element needs to be developed on such sites. *The open nature of open pavement often reflects its unfavourable condition Open pavement generally looks grey or white as a landscape feature and has vegetation mostly within the grikes.*

LIMESTONE PAVEMENT Condition Assessment Recording Form (derived from English Nature 1999 and adapted for YDNPA use)
Site Name: **Visit Date:**

Condition: Favourable / Favourable recovered / Unfavourable recovering / Unfavourable no change / Unfavourable declining / Partially destroyed / Destroyed

Recommended visiting period: May to September
Recommended frequency of visits: Annually
Key management activities affecting condition to discuss with manager:
Grazing intensity / stock type / grazing period
FYM or other input
Supplementary feeding
Scrub & weed control
Woodland management type & frequency
Deer control
Rabbit control

Attribute (= primary attribute. One failure among primary attributes = unfavourable condition)*	*Lower LAC*	*Upper LAC*	*Estimate for attribute (Describe and refer to map*
***Pavement damage by removal** Any signs of recent removal or damage to pavement clints. Evidence is broken white, lichen-free rock, rubble, infilled grikes, vehicle tracks. Old damage is easy to differentiate from new damage due to colonisation of lichens and the weathering of the rock on older damage	Any damage or pavement removal	--------------	
***Emergent grike species** Plant species growing beyond the confines of the grikes. Plants emerging from the grikes and growing luxuriantly on the clint tops and within the solution cups. Flower heads and fern fronds emerge from the grikes without removal by grazing.	Emergent and clint top plants on 25% of pavement area.	--------------	
***Scrub and woody species on open pavement** [Open pavement looks grey or white as a landscape feature and has vegetation mostly within the grikes] Presence of scrub or areas of woody species (tick) including juniper ( ) hazel ( ) ash ( ) yew ( ) hawthorn ( ) Blackthorn or sycamore component must be less than 10%	Woody species present on 5% of the whole pavement ----------------	Woody species cover not greater than 25% of the whole pavement 10 %	
***Scrub and woody species on wooded pavements** [Wooded pavements have a closed canopy and clints are cloaked by dense green mosses] A visual assessment of structural variety in woody species and diversity of age classes. Clearings or coppice coups present. Coppice regrowth should be vigorous. Such structural variation will often be as a result of woodland management but can also be an inherent feature of the structure and function of the	Structural variety present Vigorous re-growth of any coppice	--------------	

pavement itself. (yew or juniper stands should be dense & continuous)			
***Frequency of negative indicator species** (using **DAFOR** scale) Spear thistle *Cirsium vulgare* ( ) Creeping thistle *Cirsium arvense* ( ) Nettle *Urtica dioica* ( ) Ragwort *Senecio* spp. ( )	-----------------	No species / taxa greater than **Occasional** across the pavement	
***Frequency of negative indicator species** Presence of non-native conifers Beech stands or plantations	-----------------	No species more than **Rare** on any pavement	
***Rare or scarce species** Record the presence or absence of the following species which were recorded from this site at the time of notification: *Actaea spicata* Baneberry *Arenaria norvegica* ssp. *anglica* English sandwort *Cardamine impatiens* Narrow-leaved bittercress *Carex digitata* Fingered sedge *Carex ornithopoda* Bird's foot sedge *Crepis paludosa* Marsh hawk's beard *Dryas octopetala* Mountain avens *Dryopteris submontana* Rigid buckler fern *Epipactis atrorubens* Dark-red Helleborine *Galium sterneri* Limestone bedstraw *Geranium sanguineum* Bloody cranesbill *Gymnocarpium robertanium* Limestone fern *Hypericum montanum* Pale St. John's-wort *Polygonatum odoratum* Angular Solomon's seal *Potentilla neumanniana* Spring cinquefoil *Ribes spicatum* Downy currant *Salix myrsinites* Whortle-leaved willow *Sesleria caerulea* Blue moor-grass *Thalictrum minus* Lesser meadow rue *Trollius europaeus* Globeflower	Tick if still present ( )		
<u>Damage by rabbit grazing</u> Describe the type of damage and the area or percentage of pavement damaged	-----------------	---------------	
<u>Presence of sheep</u> Record numbers of sheep seen on the site during every visit	-----------------	---------------	

Appendix II Landscape Assessment Form

Landscape character assessment sheet   Limestone Pavement

Historical and ecological associations: are any of the following present?

○ Irregular fields	○ Narrow lanes	○ Bracken	○ Rough grass
○ Straight roads	○ Ancient woods	○ Meres	○ Plantations
○ Historic sites	○ Heathland	○ Pot holes	○ Scrub
○ Stone walls	○ Regular fields	○ Single trees	○ Mixed Hedges

Landscape elements

TREE COVER (on limestone pavement, on grassland, Plantations…?)

SCRUB COVER (on limestone pavement, on grassland…)

FIELD PATTERN (hedgerows, fences, walls…)

LANDFORM (steep/flat, rocks/stones, exposition…)

WATER

HABITATION (state of sheds, houses etc, neglect?)

TRANSPORT/POWER LINES

Aesthetics

PROPORTION/BALANCE OF ELEMENTS (dominance of limestone pavement)

TEXTURE/COLOUR

SCALE OF LANDSCAPE (related to scale of limestone pavement, trees, …)

DIVERSITY (state, increasing/decreasing)

SHAPE

UNITY

Brief description