More evidence gaps than grikes: how limestone pavements have fallen through the cracks of British conservation

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Abstract

Limestone pavements in Great Britain are a rare and internationally important habitat. They are highly protected for geological and ecological conservation. However, there are many knowledge gaps around conservation of this habitat as a consequence of a lack of research. The British National Vegetation Classification (NVC) scheme is difficult to apply to limestone pavements with no widely used alternative available which contributes to the lack of available information. Together with the lack of research this contributes to a lack of management advice targeted at the variety of British pavements. Habitat Directive reporting assessment criteria are out of date and at times, difficult to interpret or inappropriate. However, using existing criteria we can see that negative indicator species have increased over the last 50 years. These factors, combined with a lack of incentives for land owners, may be contributing to the poor condition of British limestone pavements.

Keywords Alvar; Common Standards Monitoring; Habitat management; Karren; Karst; Lapaiz.

Limestone pavements are defined as "natural exposures of limestone, usually horizontal or gently inclined (a few are steeply inclined) with a surface divided into blocks (clints) by narrow crevices (grikes) (Webb& Crowle 2023). Pavements can be open or wooded and while the distribution of open pavements was mapped in the 1970s (Ward& Evans 1975), wooded pavements have only been mapped very recently (Webb& Crowle 2023). Figure 1 shows an open limestone pavement. Limestone pavements in Great Britain are of international importance. While they cover a relatively small area, 2343 ha (Webb& Crowle 2023), they support a number of nationally rare species of plants, birds and invertebrates. Limestone pavements are a UK Biodiversity Action Plan (BAP) Priority Habitat and many individual sites are protected for conservation as Sites of Special Scientific Interest (SSSIs), Special Areas of Conservation (SACs) and National Nature Reserves (NNRs). Furthermore, many pavements are protected through limestone pavement protection orders and they are also likely to be on the list of Irreplaceable Habitats under Biodiversity Net Gain planning legislation (Defra Land UseTeam 2023). However, despite their importance for conservation limestone pavements have fallen through the cracks of British conservation, they have received little research attention and there is virtually no evidence base to support management decisions, and protection for geological interest can potentially be at odds with protection for ecological interest. In this paper we outline the major knowledge gaps and research needs.

Figure 1. Open limestone pavement at Ingleborough, Yorkshire, showing the clint and grike structure.

A lack of research

Internationally limestone pavements (also known as Alvar, Lapiaz and Karren) occur in a number of regions of Europe and the Americas but many areas have received little research attention, especially in recent scientific literature. Searching Web of Science for "limestone pavement" reveals a large number of papers but only a total of 43 papers since 1968 were actually about the habitat limestone pavement, a majority are on road construction or engineering. Of these only 29 were about the ecology or flora of limestone pavements. Adding in alternative names for limestone pavement and removing any references not about actual pavement (for example Alvar returns many results for Alvar grasslands) gave another 10 references. The small number of published papers and the complete lack of recent studies highlights the paucity of recent research which can be used to support management decisions. The evidence gaps are particularly apparent in British limestone pavements where there is a complete absence of studies focussed on management approaches. While there are studies from other parts of the world such as those in Swedish alvars (Rosén & van der Maarel 2000) that could be used to support management decisions these may not fit the vegetation, environmental context or physical structure of British pavements.

Challenges for classification

In the UK habitats are generally well mapped and phytosociological descriptions and classification through the National Vegetation Classification (NVC, Rodwell 1991-2000) have excellent coverage. However, this is not the case for limestone pavements. The difficulty of applying the NVC to limestone pavements is recognised and although Rodwell argues that "there is nothing encountered on the various forms of limestone pavement that cannot be described in terms of fragments or complexes of a variety of vegetation types already represented in British Plant Communities" (Rodwell *et al*. 2000) actually applying the NVC to pavements presents many challenges. The survey approach of selecting typical areas to place quadrats of a fixed size (Rodwell 1991-2000) is difficult to apply since the clint and grike structure can lead to extensive areas of bare rock in quadrats and highly variable amounts of grikes where a majority of vegetation is found. While transects may provide a suitable alternative they are not part of the NVC methodology. Limestone pavements are highly heterogenous which itself presents a challenge in mapping vegetation types, but there are also more practical challenges. Rodwell *et al*. (2000) identify ten vegetation communities in limestone pavement and while there may be some small gaps where vegetation communities, such as those dominated by bryophytes, are not described, data generated from a limestone pavement do not always fit community descriptions well. For example, for woodland or grassland communities like W9 *Fraxinus-Sorbus-Mercurialis* woodland or MG5 *Centaureo-Cynosuretum* grassland make no mention of limestone pavements in their extensive descriptions of habitat and physiognomy. The ten communities are also spread across four different volumes of the NVC however, there is no master key one needs to know which volume you should be looking at before beginning to key your vegetation data out. For limestone pavements this presents a very real practical hurdle in assigning a community. An alternative classification has been devised for pavements which classifies pavement based on their vegetation and physical structure (Willis 2011) but this is not widely used or indeed widely available to organisations wanting to conduct surveys. UKHab does identify limestone pavements as a habitat type (UKHab 2023) but does not give any further subdivision.

Monitoring habitat condition

The Natural Environment and Rural Communities Act 2006 and the European Habitats Directive (92/43/EEC) require routine assessment and reporting of habitat condition. In Great Britain this is done through Common Standards Monitoring (CSM). Criteria for limestone pavements are set out by the Joint Nature Conservation Committee (JNCC) CSM Guidance for Upland habitats

(JNCC 2009). For limestone pavements this includes reporting on extent, physical damage, signs of grazing and emergent vegetation, tree cover, and indicator species as well as the presence of species from the Ward and Evans national survey of limestone pavements conducted 1972 to 1975 (Ward et al. 1975). However, criteria are in urgent need of updating and there are many areas where there is the potential for criteria to be applied inconsistently. An example of this is the target that 'less than 10% of native trees and shrubs should show any evidence of bark stripping, a browse line or distinct shaping of the canopy by browsing (topiary-like effect)' (JNCC 2009).

The use of indicator species to evaluate habitat condition is contentious (Carignan & Villard 2002). When indicators are used they should typically represent a range of taxa and life histories included in the monitoring programme and their selection be based on a sound quantitative database from the study region (Carignan *et al*. 2002). Indicators in CSM do not all fit these criteria including, for example, some very rare species as positive indicator species such as *Salix myrsinites* L., a species restricted to Scottish mountains (Stroh *et al*. 2023) and only found in one limestone pavement in the UK. A recent survey of 516 British pavements (Stevens, 2025) showed 2 of a total of 29 named positive indicator species were not found in pavement grikes at all. Three negative indicators, *Cynosurus cristatus* L., *Lolium perenne* L. and large docks, were found in less than 5 % of pavements even though many more pavements are not in good condition which suggests that they are not good indicators. Furthermore, the heavy reliance on comparison with species lists from the original Ward and Evans report (Ward& Evans 1975) presents further challenges. First and foremost this raw data is not readily available and many regional conservation offices do not have access to the data required. Secondly the pavement units identified and mapped in the Ward and Evans survey pre-date the designation of protected status for many sites and the units mapped do not match up with the boundaries of the protected sites. This means that some sites may include part units and species lists may not be fully relevant.

A lack of management guidance…

Perhaps the most important consequence of the lack of research in limestone pavements in Great Britain is that government and non-governmental conservation organisations have no data to support decision making processes about how best to manage limestone pavements. Advice on management is provided in the Natural England upland management handbook (Backshall *et al.* 2011) but more evidence is needed to support this advice. There are many challenges facing pavements and the extent of these issues and how best to reduce impacts and improve habitat resilience is not understood. Stevens (Submitted) demonstrated the dual threats of under- and over-grazing. In over-grazed pavements grazing animals lead to very low or absent tree cover, a lack of emergent vegetation and reduction in species richness as species intolerant of grazing are lost. This is linked to problems around pest control where rabbits and wild deer herds contribute to overgrazing. On the contrary, under-grazing leads to scrub invasions and is recognised as the greatest threat to limestone pavements in Europe (Mikolajczak *et al.* 2015). As the canopy above the pavement closes light levels in grikes become very low and a thick bryophyte layer forms (Fig. 2a). While pavements can support a diversity of bryophytes including some rare species, monocultures can also form and may impact adversely on the germination of higher plant species (Zamfir 2000). Control of 'weeds' is another challenge in limestone pavements. Levels of some generalist species such as *Cirsium arvense* (L) Scop., *Urtica dioica* L., and *Pteridium aquilinum* (L) Kuhn as well as invasive species such as *Cotoneaster* spp. and *Acer psudoplatanus* L. have all increased in abundance over the last 50 years (Stevens 2025). Control of these species presents unique challenges in limestone pavements where terrain prevents mechanical removal (Rosén 2006) and may also prevent use of non-chemical approaches such as bracken rolling. Eutrophication is a challenge in some limestone pavements either as a result of atmospheric deposition of nitrogen or the use of inorganic fertilisers leading to fertiliser drift or redistribution of nutrients by grazing animals but the extent and severity of this issue is largely unknown. The likely impacts of climate change are also not well understood and while there is potential that grike habitats may provide a temperature buffered refuge for some species (York & Burek 2011) the potential importance of this is unknown.

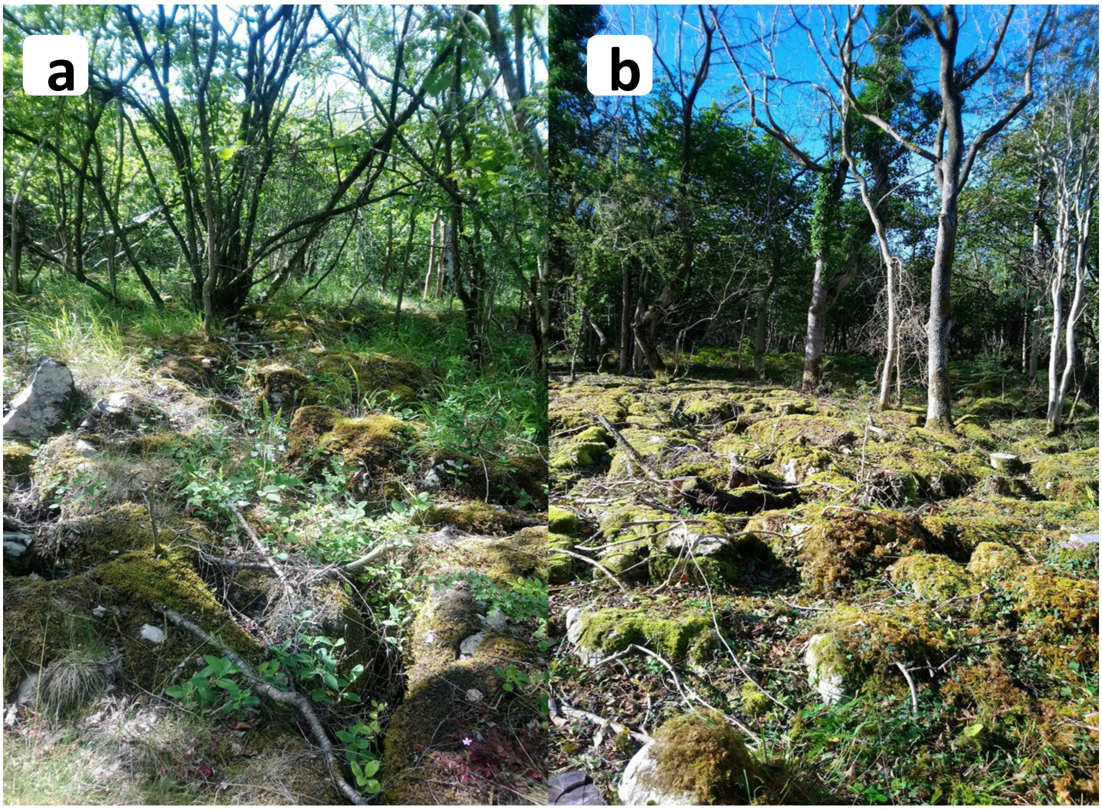

Figure 2. a) At high levels of canopy closure species richness in grikes is typically impoverished b) When trees are removed typical pavement vegetation does not always seem to re-establish

A consequence of the lack of management information is that many limestone pavements are currently classed as in unfavourable condition. Using data from 516 pavements originally surveyed by Ward and Evans in 1972 to 1975 (Ward and Evans 1976) and again between 2018 and 2022 using the same methods (Stevens 2025) we can see that as a group, negative indicator species (*Arrhenatherum elatius* (L.) P.Beauv. ex J.Presl & C.Presl*, C. arvense, Cirsium vulgare* (Savi) Ten.*, C. cristatus*, large docks, *Lolium perenne, Jacobaea vulgaris Gaertn., Rubus fruticosus* L.*, Urtica dioica, Pteridium aquilinum*) have increased in abundance in significantly more pavements than they decreased ($p<0.05$, paired t-test comparing the proportion of pavement units where species increased to the proportion of pavement units where species decreased (R CoreTeam 2022); Fig. 3). Problems with negative indicator species are identified above but even so, this is a worrying trend.

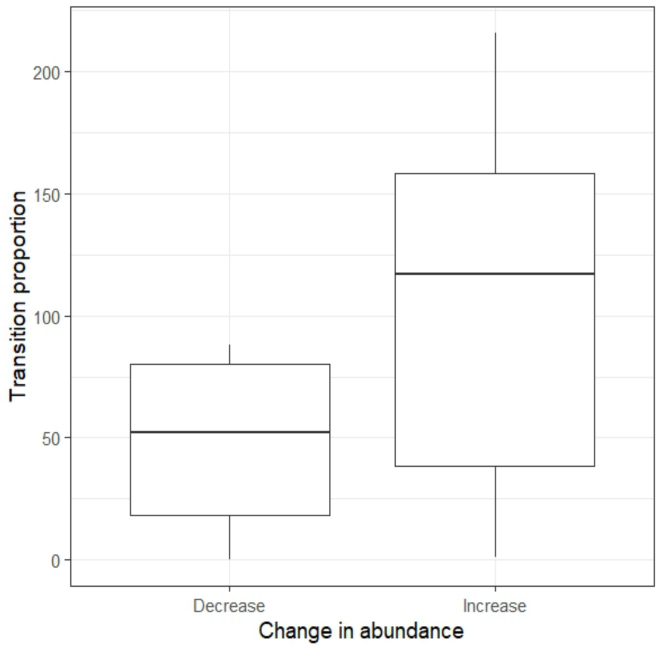

Figure 3. Number of Common Standards Monitoring negative indicator species (JNCC, 2009) which have increased and decreased between 1972 - 1976 and 2017 – 2022. The transition proportion describes the number of occurrences of the species which have changed. Data is presented as a box and whisker plot where the bold horizontal line is the median, the box limits show the 1st and 3rd quartiles and whiskers the minimum and maximum.

…and restoration guidance

Just as with management, there is no evidence base to support development of best practice for restoration. Large scale restoration projects have been undertaken in Sweden and Estonia in Alvar habitats (Rosén 2006; Rosén & van der Maarel 2000; EU Life 2014). While these projects have largely focussed on Alvar grasslands (grasslands on calcareous substrates with very shallow or no soils) they have also included some pavement habitats. However, in Great Britain no such information about best practice exists. Restoration efforts following over grazing have been attempted by fencing or switching from sheep to cattle grazing with mixed success, as have attempts at scrub or tree clearance. These efforts have had mixed success (Fig. 2b) and further research is needed to establish best practice. It is largely unknown whether passive or active restoration approaches (Rey Benayas *et al.* 2007) are needed in limestone pavements. Critically, very few attempts at habitat restoration have included monitoring of success and none have been published in academic journals.

Incentives for landowners

Another area where limestone pavements fall through the cracks is in incentives offered to land owners to manage their land for conservation. In order to further conservation of protected habitats and habitats of importance for conservation or landscape the UK government offers a range of Environmental Land Management schemes (ELMs). Countryside Stewardship (CS) Higher Tier scheme is designed to target priority habitats which require bespoke management. However, in England in particular, there are limited options available for limestone pavement above the moorland line (upland areas where vegetation is commonly semi-natural). UP3 'management of moorland' is the option most commonly available but this is targeted at typical moorland habitats rather than pavement, and its low financial value offers little incentive to landowners. Eligibility criteria for other potential options such as GS6 'Management or restoration of species rich grassland', GS7 'Restoration towards species rich grassland' or GS13 'Management of grassland for target features' often preclude limestone pavement because they limit areas of rock to less than 0.1ha. The more recent Sustainable Farming Incentive scheme (SFI) currently has few options for moorland although detail is yet to be released. Pavements typically sit within mosaics of upland calcareous grassland and often blanket bog, habitats of equal importance, all with bespoke and often conflicting management requirements, far more complex than a typical moorland.

Conclusions and Solutions

There is a clear need to build the evidence base and develop the tools available for those responsible for managing limestone pavements. There have been many initiatives in recent years to improve habitat condition of individual limestone pavements and a first step in addressing knowledge gaps is to ensure that monitoring is put in place and outcomes are widely shared when management changes are made. Publishing studies in academic journals is an important way of sharing evidence but freely available reports promoted through appropriate networks such as the Limestone Pavement Partnership (https://www.lancaster.ac.uk/lec/research/limestone-pavements-partnership/) are also an option. Work is clearly needed to ensure that tools such as the NVC and CSM are fit for purpose in limestone pavements.

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