Report Number
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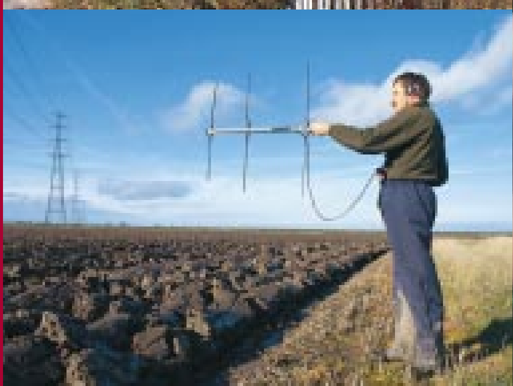
English Nature Research Reports



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1: Estimates of the areal extent of management burning in English Uplands

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Executive summary

The aim of this project was to conduct an assessment of the scale of current burning practice within the English Uplands, and to identify possible changes that might have occurred over recent periods. The vegetation cover categories considered for the assessment were based upon the broad habitats included in the Land Cover Map 2000 survey and identified as blanket bog, dry and wet heath, bracken, acid grass and montane communities. To achieve this the study acquired aerial photography for 2000 and the periods 1943-52 and 1965-80 and interpreted these with a view to identifying both the current and historical extent of burning practice by deriving estimates of burn parcel size, shape and return period.

Visible evidence of burning was only found in relation to *Calluna* dominated communities. For these sites where there is visible evidence of burning, the proportional area in management is 38%. This value is representative of the current scale of burning practice. A typical range encompassing 50% of the sites surveyed indicates a variation between 20% and 63%, although some sites exhibited higher levels of management. Typically, the area of individual burns range between 0.12ha and 0.55ha with a median value between 0.25 to 0.28ha. The range of burn parcel sizes therefore matches reasonably with the consensus on current advice for burn areas to fall within the range 0.3-0.5ha, but with a larger number of very small burns than expected. An estimate of the return period using historical photography has been made as described in 2.5 and is estimated at between 16-20 years. On average this is slightly longer than current guidance suggests, being typically of the order of 10-15 years. However, there are many areas where considerable shorter return periods are implied by the proportional areas of visible management. The results also provide some evidence that there was an increase in the level of management between the 1940s and the 1970s, but no change between the 1970s and currently.

From the assessments of the 2000 photography there were no unambiguous identifications of burning within any of the grassland areas. The practice is important regionally, but the scale is below that resolvable by the sample framework employed in this work to undertake a national assessment.

Contents

Erratum

At the request of the authors, Paragraph 5.4 has been amended to make the meaning clearer. The new text is provided below to assist those who may have an earlier version.

5.4 Summary of history of burning practice

The assessment of the history of burning practice at the level of the English uplands remains incomplete due to the problems noted earlier with the acquisition of historical imagery for a random subset of the original sample areas.

The inclusion of photography covering the English National Parks shows that a significant increase in class 1 (ie most recent burn) between 1970 and 2000 is apparent. This increase would be expected to produce a reduction in the estimated return period. It should be noted that these data are not expressible in terms of a national figure. However, they show evidence of changes for areas under at least nominal national park protection and, as such, there is little reason to assume they are not mirrored elsewhere in England.

1. Introduction

1.1 Background

As a consequence of variations in topography, management and edaphic factors the upland landscape comprises a dynamic continuum of intergrading mid-successional vegetation, eg the ecocline from blanket bog to upland heath priority habitats. In most areas of England, the species present, community structure and much of upland environment with which we are familiar today is only maintained through a variety of vegetation management practices including drainage, grazing, cutting and burning to satisfy (variously) farming, conservation, sporting and/or recreational interests. A key issue in such management is the burning of vegetation undertaken to provide differing aged stands of heather (mainly *Calluna*) for grouse, or to improve grazing for agricultural use.

A recent review by English Nature has raised concern about possible negative impacts on vegetation, invertebrates, soil structure/hydrology, water quality and carbon storage (Tucker 2003). This review however also identified an overall lack of objective data on the extent of current (*circa* 2000) burning practice within the English Uplands and any changes that might have occurred from previous decades.

This study has been under-taken to examine the scale of burning in the English Uplands and provide a baseline against which future burning practice can be assessed. It is not within the remit of this project to review the ecological consequences of either current or past burning practice as these are covered in Shaw and others. (1996) or Tucker (2003).

1.2 History, purpose and ecological effects of upland burning

1.2.1 History of upland burning

The influence of burning on the ecology of the UK landscape predates recorded history, with lightning almost certainly generating natural fires where local conditions could sustain them. Anthropogenic burning began around 5000 ago with the arrival of Neolithic people and clearance of wildwood expanded into upland regions during the Bronze Age (2400-750 BC). Although open areas may have always existed in north Scotland and a natural treeline may extend down to only a few hundred meters above sea level on the west coast of Scotland (SNH unpubl. data), it is unlikely any part of the English uplands is naturally free of trees (Dimbleby 1952). Hence the lack of woodland in upland England today results from the early development of shifting patterns of agriculture, and unrestricted grazing combined later, in some areas, with a demand for charcoal for use in iron smelting. The maintenance of the open landscape we see today is a direct result of continuing management, principally grazing and burning.

Moorland burning as a management tool can be traced back many centuries, at first in areas of southern Britain like Dartmoor, with areas of Scotland coming under regular management only as late as the eighteenth century when large scale sheep farming became widespread, replacing the earlier crofting way of life. At the beginning of the nineteenth century, increases in sheep grazing and, more importantly, grouse shooting led to an intensification of moorland management by fire. The result of widespread management of uplands for grouse led to the predominance of heather moor. As grouse shooting declined in the twentieth century, moorland burning also declined. Despite this general trend, over 50% of upland heath SSSIs in England are judged in poor condition as a consequence of too-frequent burning (EN SSSI condition report 2003).

1.2.2 Purpose of upland burning

The three main plant communities subject to burning in upland Britain are heather moorland (dwarf-shrub heath), bogs (ombrotrophic mires), and acid grassland, although it has to be acknowledged that these usually form an intergrading continuum.

Upland dwarf-shrub heath is usually found on relatively shallow peat, overlying stratified, freely-draining leached soils, although generation may also occur on de-graded or modified bog communities. It is generally dominated by heather, and the vegetation includes a range of other dwarf shrubs such as bilberries *Vaccinium spp*, crowberry *Empetrum nigrum*, bell heather *Erica cinerea* (in drier areas), cross-leaved heather *E. tetralix* (in wetter areas), western gorse *Ulex gallii* (in the south-west), and in northern areas, juniper, *Juniperus communis*, may be present.The purpose of heather moor burning, both for red grouse management and for livestock management, is to provide a continuous, plentiful supply of young-growth heather *Calluna vulgaris* for grazing. The growth of heather is typically defined by four stages, lasting around 30 years: 3 to 6 years as a pioneer, 10 in building, 10 in maturity, and 5 in degeneration. The mature and degenerate stages of heather offer little forage, so burning is used to prevent heather from reaching these stages. Burning has the effect of reversing a seral process that would eventually lead in most cases to the establishment of birch woodland, although the time taken for this to occur will depend on local circumstances such as available seed source. Heather regenerates vegetatively in the newly-burnt patches of moor, and with the use of a long-term (10-25 year) burning cycle, a regular age-structure of heather is maintained.

Bogs are peatlands which are, for the most part, ombrotrophic, ie they received the majority of their water and nutrients from precipitation, as opposed to minerotrophic peatlands which are also irrigated by the mineral ground water. Such rainwater fed ecosystems are very acidic and have low nutrient availability. On active bogs, dead organic matter accumulates at the soil surface and is gradually buried by new growth, eventually becoming peat. Bog vegetation can be diverse and is typically dominated by brophytes eg *Sphagnum* mosses together with vascular plants such *Calluna* and *Erica tetralix*. Bogs are burned for the same reasons as heather moor, for livestock forage and grouse rearing interests, although blanket bogs do not require a burning regime in order to be maintained. The effects of burning of bogs are different to the effects of burning heather moor, principally due to the fact that bogs are in a state of very slow change while heather moor is in a state of continuous succession. Far from simply halting or reversing successional processes, burning of bogs has more profound community impacts.

Acid grasslands are one of the most extensive semi-natural habitats in Britain, forming particularly large expanses in the uplands. In England most of this expanse has arisen as a consequence of grazing and burning management. These habitats typically have low biodiversity and occur in large uniform stretches, especially where overgrazing and frequent burning has occurred. On moderately acid, brown earth soils, the sward is dominated by sheep's fescue *Festuca ovina*, with common bent *Agrostis capillaris* a major component. Where soils are peaty, more poorly drained, the chief species is mat-grass *Nardus stricta*, with heath rush *Juncus squarrosus*. Because the diet of grouse is largely restricted to heather shoots, acid grassland is burned solely to produce new forage for livestock. Fibrous, dead material is removed, and some of the nutrients this contains is returned to the soil, encouraging a flush of growth.

1.2.3 Ecological impacts of burning

Calluna moor

The effect of burning on the communities of plants and animals present on moorland is complex. In general terms, burning prevents or reverses successional processes that would eventually result in reforestation of moorland, but the specific outcome of a burning regimen depends on many factors, notably the frequency and heat (intensity) of burning and the age of heather when it is burnt.

As noted above, heather passes through a series of growth phases over the course of thirty years or so. Vegetative regeneration of heather following burning declines in the mature phase of its growth and is absent in the degenerative phase, when regeneration is solely from seed. If vegetative regeneration of heather is vigorous, then the heather will quickly come to dominate burnt areas, while if it is weak or absent, these areas may become dominated by moor grass *Molinia caerulea* or bracken *Pteridium aquilinum* (Stevenson and others 1996). Too-frequent burning favours rapidly colonising, fire-resistant species like moor grass and bracken, and may result in conversion of dwarf-shrub heath to acid grassland or monocultures of bracken. In contrast, too-infrequent burning can also lead to the loss of the dwarf-shrub community where over-mature or degenerate stands of heather are burnt and regeneration is by seed.

The effects of burning are inextricably linked with those of grazing (Miles, 1988). Burning promotes young growth for grazing, but excessive grazing can eliminate regeneration completely, leading to the loss of dwarf-shrub heath and the spread of *Molinia* grassland. This is because heather regrowth on newly-opened habitat after a burn is preferentially chosen as food by grazing livestock. Heather that is regrowing from seed after over-mature stands have been burnt is unlikely to survive this selective grazing.

Acid grassland

The purpose of burning acid grassland is to remove litter and promote fresh growth for livestock forage. In contrast to the narrow 'strip' system of burning moorland, acid grassland tends to be burned in larger, less controlled fires. Tucker (2003), in a review of upland burning, found little research on the effect of burning regimes on acid grassland. However, it is known that different species of grass respond differently to burning. One of the species that is most resistant to burning is *Molinia*, the dense tufts of leaf-bases of which survive all but the hottest fires. Although *Molinia* is palatable to sheep, if insufficiently grazed, particularly following a large-scale fire, it quickly builds up into large tussocks that offer no fresh growth to feed on, which must be burnt again to make forage available. The fire-resistant and tussocky nature of *Molinia* may lead to it dominating the sward, at the expense of overall forage quality. Similarly, on drier sites, *Nardus stricta* may benefit from burning owing to its unpalatability and the ability of its rhizomes to survive fires. The effect of too much burning, therefore, is to increase the proportion of tussocky, unpalatable grasses, which is coupled with a loss of diversity in the sward.

Heavy grazing of acid grassland, coupled with burning, prevents re-establishment of heather and other dwarf shrubs, the young shoots of which are selectively taken by grazing livestock. Acid grasslands that have been created by overgrazing and too-frequent burning of bogs or moors can be restored by long-term reduction in grazing pressure and less-frequent burning.

Bogs

On heather moorland *Calluna* will, if unburned, proceed through the phases of pioneer, building, maturity and degeneration, which might ultimately lead to the succession of birch wood. In bogs, however, *Calluna* does not pass into the degenerate phase because of the continuous layering of the stems as they are buried under bog-moss. The immediate effect of burning bog vegetation is to destroy the above-ground woody tissues of the shrubs (*Calluna*, *Erica tetralix*, and others), the bog-moss surface, and any species sensitive to fire. Burning may also reduce or halt peat accumulation (Kuhry, 1994). One of the first species to recover is *Eriophorum vaginatum*, the new growth of which is useful forage. In contrast to the situation on heather moorland, it may take many years for *Calluna* to become the dominant species in the plant community after burning. Over time this may lead to a loss of diversity, with an increase of *Molinia* and *Juncus squarrosus* at the expense of other plants (Hobbs, 1984).

The extremely low nutrient status of bogs raises questions about the long-term outcome of a burning regime. Whilst on dry dwarf shrub heath burning results in a flush of nutritious young growth, burning of bog vegetation has a less beneficial outcome because the growth of *Calluna* would not have been impeded by degeneration of individual plants, and so would not respond positively to burning. In other words, burning may not generate any more young growth of heather than would be present under a *laissez-faire* regime, so this kind of management is probably of little or no benefit for grouse (Hobbs 1984). Edible species like *Eriophorum* may temporarily replace *Calluna* after burning, providing forage for sheep. It is generally accepted that burning has a negative impact on species of *Sphagnum* moss (Tucker, 2003), although direct evidence is lacking, frequently because degradation of bogs is caused by grazing and draining at the same time as burning. Pearsall (1950) noted that bogs in good condition may have more than 12 species of plant per square metre, while degraded, *Eriophorum* dominated bogs may have only 3-4 species per square metre. Detailed information on the effect of burning on bog vegetation is provided by Shaw and others (1996).

Animal communities

Moorland, whilst low in plant diversity, supports a large community of invertebrates. Usher & Thompson (1993) quantify this for the North York Moors, which have 2.2% of British vascular plant species, but 15% of carabid beetle species and 20% of spider species. The diversity of these polyphagous predators depends on the mosaic structure of upland heathland, and simplification due to large-scale burning and heavy grazing will inevitably lead to a loss of species. Medium-rotation, small-scale burning therefore favours generalist invertebrate predators because it maintains the complex mosaic of different-aged stands of heather.

The problem of too-frequent burning and heavy grazing converting dwarf-shrub heath and bog into acid grassland also impacts on phytophagous insects. Many more species of phytophagous insect are associated with the woody plants of moorland and bog than with the grasses, sedges, and rushes of moorland and acid grassland. Around 100 species of phytophagous insect have been recorded from each of *Calluna vulgaris*, *Vaccinium* species and *Erica* species. In contrast, plants like *Eriophorum* spp., *Nardus*, and *Molinia* are extremely species-poor, with around 10 species of phytophagous insect found on each. Only two phytophagous insects have been recorded from *Juncus squarrosus*, both of which are polyphagous. The shift from shrubs to grass-like plants caused by a combination of heavy grazing and burning therefore leads to an inevitable loss of invertebrate diversity. Some moorland insects are associated only with mature or degenerate heather plants, and for this reason Usher & Thompson recommend that some areas of dwarf-shrub heath are left permanently unburnt.

Although the principal purpose of burning on grouse moors is to increase the population density of red grouse via the increased availability of high-quality forage, other species of birds might benefit similarly. These include curlew, golden plover and lapwing (Tharme and others 2001). Relaxation of burning regimes may have a beneficial effect on densities of meadow pipit, and in turn, hen harriers (Smith and others 2001).

The mountain hare may benefit from moorland management by burning in its stronghold of north east Scotland. Although heather forms a large part of the hare's diet, it may benefit more from the presence of gamekeepers and the consequent low density of predators rather than because of the improved quality of the heather (Hudson 1992, cited in Tucker 2003).

1.2.4 Summary

Burning, especially when coupled with overgrazing, has had drastic impacts on upland habitats. Overgrazed and too-frequently burned moorland and bogs have been converted to acid grassland, with a general loss of plant diversity. Used correctly, burning could maintain a *status quo* on dry heathland, preventing degradation of grazing quality or succession of the plant community. Burning of bog vegetation seems to have little positive benefit for grazing of either livestock or grouse, but has great costs in terms of loss of plant biodiversity. Burning of acid grassland alone probably has little detrimental effect, but linked to excessive grazing it can result in species-poor, unpalatable swards over large areas.

The above provides an important context within which it is clear that burning remains a significant management practice within the English Uplands that can have both beneficial and sometimes adverse effects. However, there remains a paucity of data detailing how burning practice occurs currently and how it might have changed over last 4-5 decades. This report details the results of an investigation based on interpretation of aerial photography that aims to provide such data.

1.3 Objective

The objective of this work was to provide an analysis and review of the history and scale of past and present burning in the English uplands.

2. Data sources and mapping protocol

2.1 Target classes

English Nature identified blanket bog, dry and wet heath, bracken, acid grass and montane communities as the target classes for this assessment of burning practice within the English Uplands.

2.2 Sample design

A detailed mapping of burning covering all the target classes and the entirety of the English Uplands was beyond the scope of the current project. Therefore it was decided that estimates of burning practice were to be based on an area frame sample. This entails locating a spatially distributed sample of areas, where each sample is of a fixed size. Mapping of burning practice is undertaken only for the sample of areas via interpretation of an appropriate source of remote sensing imagery.

To ensure that an unbiased national estimate of the current scale of burning in the English Uplands could be made from the sample data, the sample design followed a random systematic protocol. To achieve this, the study area is sub-divided into blocks of sampling units. (eg blocks of 10 by 10 1km^2 sampling units). A sample unit is chosen randomly within a block. The systematic random sample is created by selecting sampling units at the equivalent locations in each of the blocks covering the study area. The sampling fraction can be adjusted by changing the block size and/or adding a replicate in each block (ie selecting another sampling unit randomly within each block).

The area of the English Uplands was delineated initially on the basis of the Environmental Zones dataset (Environmental Zone 3 – Uplands) developed as part of the Countryside Survey 2000 (Haines-Young and others 2000). The zones are based on combinations of the underlying sampling units, or land classes, used for the CS2000 field survey. Using these data the English Uplands represent a total area of 15688 km^2. From past experience in the UK undertaking surveys in rural landscapes and the methodology used for the Countryside Survey 2000, 1km^2 sample sites have proven to give a good balance between the amount of information each site contains and the number of sites to be surveyed.

For this work the Upland Environmental Zone was used to define the study area and an initial sample. There are no clear guidelines for setting the size of the sample other than using the experience of other surveys. Similar work by the United States Department of Agriculture has shown that sample sizes of 2% were more than adequate to produce acceptable results when the data were the sole source of information used to estimate areas of landscape features (Hanuschak and others 1979). The Monitoring Landscape Change Project (Hunting Technical Services 1986) also successfully used a 2% sample.

In the context of this project and the data available to define the area of the English Uplands, a reasonable compromise is to begin with an initial 1% sample fraction applied to the area defined by Environmental Zone 3. This results in around 157 sites. However, it was recognised that the initial sample will include a number of sites which will not be under burning management, since the definition of the Environmental Zone does not precisely define the location of the vegetation types of interest.

To improve the efficiency of the survey, ancillary data sets can be used to stratify the study area. The Land Cover Map 2000 1km data are available from the Centre for Ecology and Hydrology and provides summaries of the broad habitats of the UK. These data were used to refine the area to be studied by discarding 1km squares from the Uplands with no significant presence of the target vegetation types (eg acid grasslands, bog and dwarf shrub heath). However, there are uncertainties in these data. For example, according to the CEH website (http://www.ceh.ac.uk/data/lcm/ lcmleaflet2000/leaflet5.pdf) blanket bog is comparatively under-estimated by LCM2000; and heath and moor are accordingly over-represented; similarly, semi-natural grasslands are over-estimated by LCM2000.

An initial 1% sample of sites was therefore identified following the sampling protocol described above. These sites were assessed visually using low resolution quick look aerial photography which is available on the GetMapping Plc web site. This procedure was used to define a target class threshold of % cover of a 1km segment provided by the LCM2000 data. The aim in identifying this threshold was to avoid the selection of sample sites within which very small areas of the target classes occur at the boundary of the sample area thereby making the mapping of burning practice unreliable. The threshold value could then be applied to the LCM2000 data and used to define the final stratification of the English Uplands (ie only those areas where the target class % exceeded 5% were included in the sampling). The selected threshold value was 5% and this defined a total study area of 10360km^2 (Figure 2.2.1). A 2% systematic sample (1 site selected for every 50) was drawn from the total 10360 squares resulting in 208 sites identified for the assessment of the current burning practice.

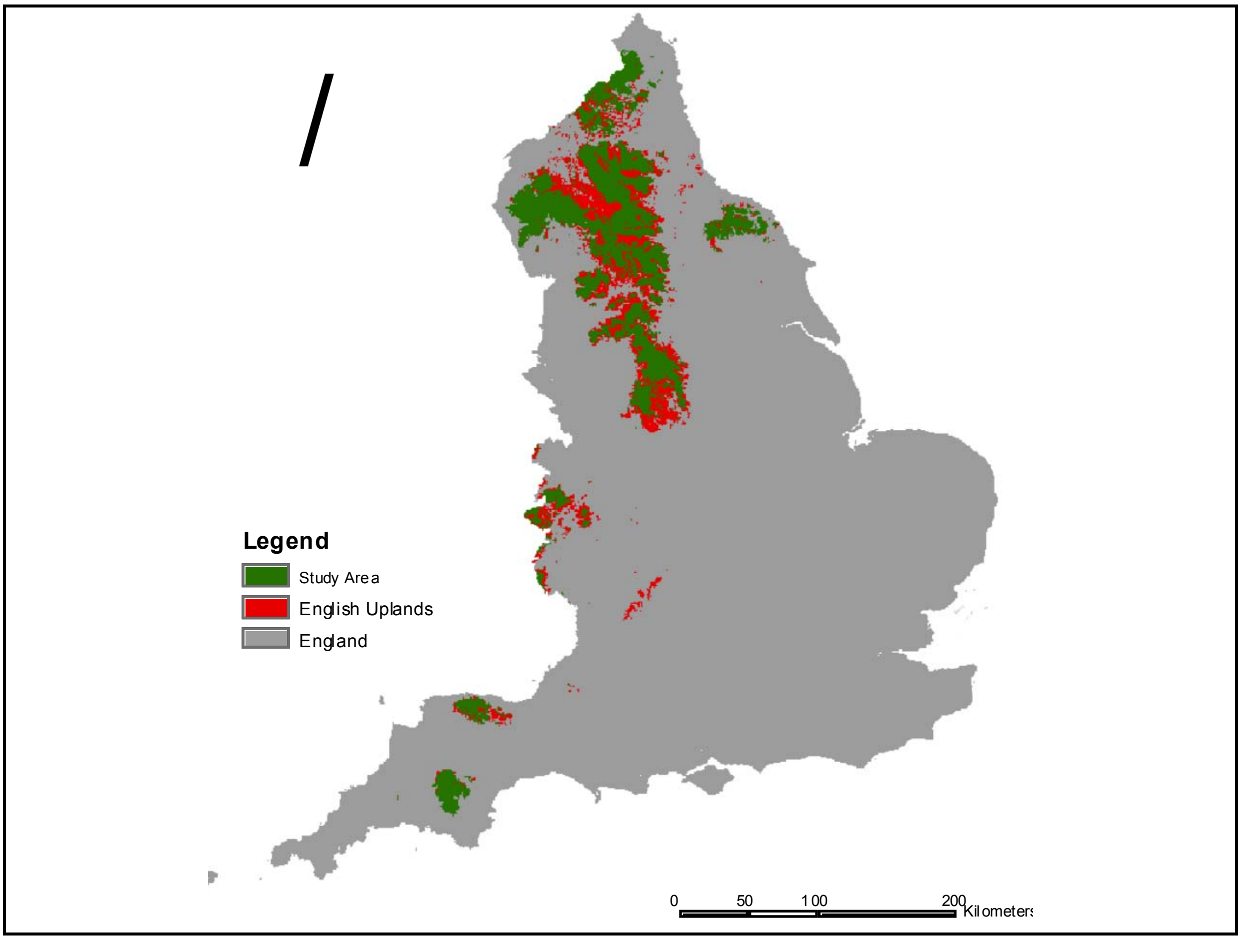


Figure 2.2.1 Location of study area for the history of burning in the English Uplands as defined by the sum of target classes from the LCM2000 data set

2.3 Imagery requirements

Previous work undertaken as part of the Monitoring Landscape Change in the National Parks project (Bird and others 2000), showed that multi-spectral image classification was unsuitable for mapping of detailed upland cover types and of limited value for mapping broader classes. More recent work undertaken by the authors on the mapping of burning practice in Yorkshire using both satellite and aerial photographs demonstrates that resolutions of better than 5m are required to provide an adequate basis for mapping recent patterns of burning practice. For example, Figure 2.3.1 shows a catchment in Yorkshire with recent burning in 2000 both from a satellite image (15 m pixels) and aerial photography (25cm pixels), together with the results of a visual interpretation of the aerial photography. Historical satellite imagery available for the mid-1970s and mid-1980s only has pixel sizes of 80m to 30m. For this study, therefore, aerial photograph data are preferred

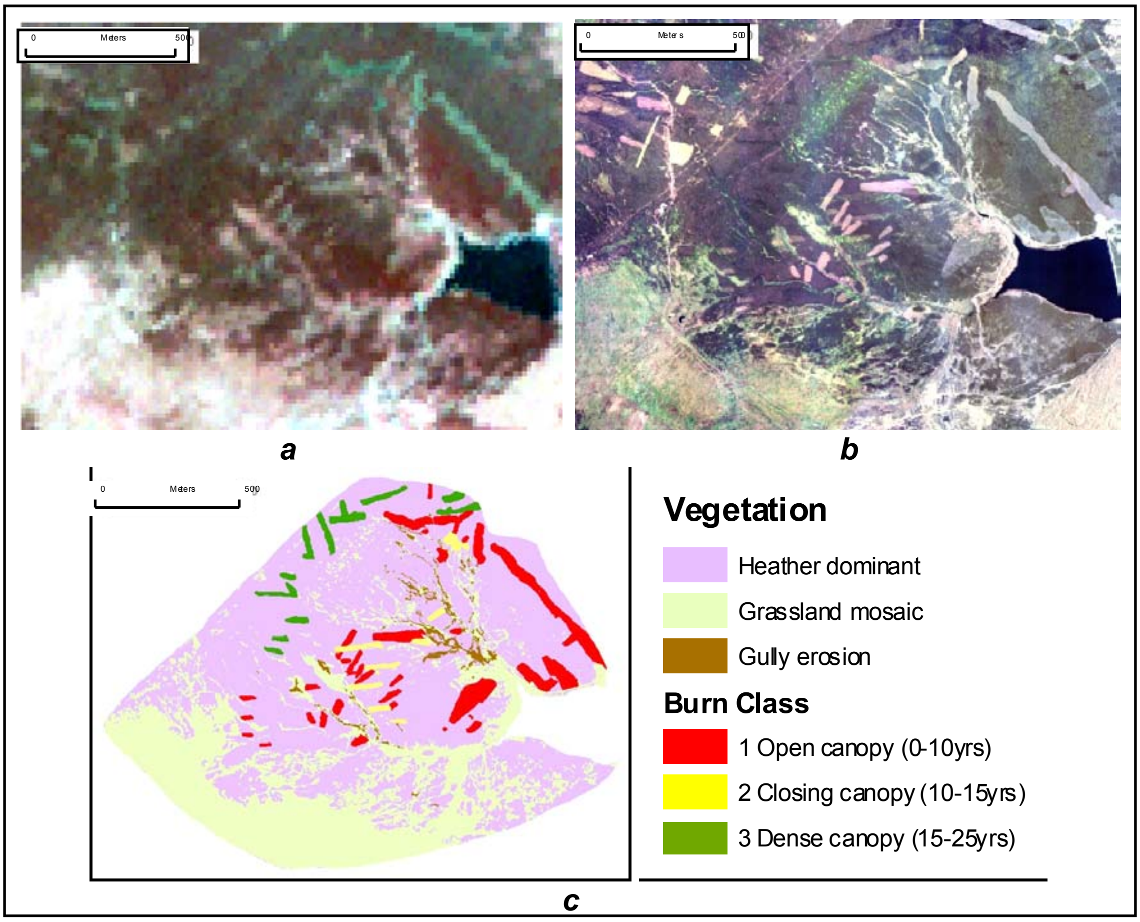


Figure 2.3.1 Keighley Moor catchment area: (a) Aster false colour composite (b) aerial photograph mosaic (c) Visual interpretation of aerial photograph mosaic

2.3.1 Contemporary photography

At the time this work was undertaken the only source of photography completely covering the English Uplands and acquired around the year 2000 was the ortho-corrected and geo-referenced digital aerial photography from GetMapping Plc. The 2m resolution imagery product was selected in place of 25cm full resolution product as this provides a more cost effective solution and past experience has shown that it contains adequate spatial detail to map areas of burn within dwarf heath shrub and would likely contain sufficient detail to map burns occurring in grassland areas, since these are typically much larger. Digitisation of burn extent within each sample image was under-taken on-screen with an estimated accuracy +/- 1.5 metres for boundary position.

2.3.2 National historical photography

The National Monument Records Office was selected as the source for acquiring historical photography since initial contact with staff indicated a high probability of obtaining sufficient coverage using the archive of the RAF and Ordnance Survey aerial photographs which, together, offered up to 4-5 dates with coverage back to the 1950s. It was recognised that the National Parks also retain important archives of aerial photography, but initially this assessment required access to a source of photography covering the whole of the English Uplands.

The time available for this project and the costs of acquiring aerial photography meant it was not possible to make an assessment of burning practice for all 208 sites using the historical photography. Rather a 10% sub-sample of the 208 sites was identified as the basis for carrying out the historical analysis. In addition, the timing of the project coincided with a period of reduced service at the NMR Offices and it was necessary to make a rapid selection of sites for the historical assessment in advance of completing the interpretation of the contemporary photography. A list of the 40 sites with the highest % of the target classes was therefore forwarded to the NMR Offices. The resultant database listing of available photography was reviewed and 23 sites identified with aerial photograph coverage that offered the best compromise in terms of consistent time period, scale and quality of photography. A subsequent visit was then made to identify the specific sites from the actual hard copy photographs available at NMR.

From the review of the photography the most consistent periods of time ensuring reasonable coverage were 1943-1952 and 1965-1980. These periods also ensured that burns undertaken at an earlier period would not still be evident in the later period photography. For the 1943-1952 period the quality of photography was insufficient for the purposes of mapping burning for 5 of the sites. The photography was initially screened using a visual assessment for the presence of burning. For 1943-52 9 sites possessed no visible evidence of burning and for 1965-80 14 sites had no visible evidence of burning. This compares with 11 sites for the 2000 photography. Table 2.3.1 lists the sites, photography dates and an indication of whether burning was visible evident in the photographs.

Following this review, laser copies of the photographs were obtained and a visual assessment of burning practice made on acetate overlays. To allow mapping of burn parcels from the hard-copy photographs, a number (typically 3-5) of control points were identified on each overlay by comparison with available map sheets and the digital photography for 2000. The interpretations were scanned, and geo-referenced in the GIS using the control points and the areas of burn re-digitised.

Table 2.3.1 Distribution of national historical photography sample sites and indicator of presence of burning practice

SQ ID	NMR Ref	Site Name	Period 1 1943-52	Period 2 1965-1980	Period 3 1999-2000
1	A	Goathland Moor	N 1945	Y 1973	Y
3	C	Brown Haw	NA	Y 1973	Y
5	E	Bink Moss	N 1946	N 1972	Y
12	K	Starling Dodd	NA	N 1973	N
13	L	Amicombe Hill	N 1947	N 1962	N
14	M	Greenup Edge	N 1946	N 1971	N
17	O	Allendale	Y 1951	Y 1977	Y
19	Q	Knock Fell	NA	N 1971	N
23	U	Egglestone Common	Y 1946	Y 1965	Y
25	W	Low Moor	Y 1952	Y 1973	Y
26	X	Fairfield	NA	N 1973	N
28	Y	Cut-Thorn Hill	N 1948	N 1970	N
29	Z	Easington High Moor	N 1946	N 1972	Y
30	AA	Hallam Moors	Y 1945	Y 1975	Y
31	BB	Hen Tor	N 1946	N 1965	N
32	CC	Scafell Pike	NA	N 1972	N
34	EE	Greenhow Moor	Y 1946	Y 1976	Y
36	GG	Darnbrook Fell	Y 1946	N 1974	N
37	HH	Smittergill Head	Y 1948	Y 1971	Y
38	II	Great Moor	N 1946	Y 1980	Y
39	JJ	Birker Fell	Y 1946	N 1972	N
98	MM	Withypool Common	N 1947	N 1976	Y
135	NN	Cannon Hill	Y 1946	N 1976	N

2.3.3 National Parks photography

After the historical photography arrived and was being interpreted the results of the interpretation of the contemporary photography indicated that visible evidence of burning was restricted to *Calluna* dominated moor. The sample of historical photography acquired from NMR was selected as being representative of the English Uplands and therefore included a number of sites where the proportion of *Calluna* was low, in addition to sites where burning was absent. This resulted in fewer sample sites with visible evidence of burning than originally envisaged.

To provide additional information on historical burning practice, an archive of 1970s photography held by Cranfield University and covering the majority of the National Parks in England was utilised, although data were not available for Cumbria and Dartmoor National Parks. No visible evidence of burning was found in any of the assessment of the sample sites using the 2000 photography. However, it must be noted that the sample is representative of the English uplands and not designed to provide statistics for any specific location. Therefore it should not be concluded that burning does not occur in these areas.

The sampling procedure employed was to first identify those sites occurring within the national parks with more than 30% of the target class dwarf shrub heath from the original 208 1km^2 sample sites. This resulted in 24 sites for analysis.

2.4 Interpretation methodology

As with all aerial photographic interpretation the only evidence for estimating the approximate extent and age of a burn in any imagery is the textural, spectral, and contextual information it contains. For evidence of burn to be visible some characteristic signature that separates burned from unburned areas has to be manifest in the image. How quickly this signature disappears from the landscape, relative to the frequency of aerial imagery acquisition, as the burned community recovers is clearly an important factor controlling the ability to detect and assess burn extent using this technique. Of the vegetation classes identified by English Nature to be examined the generally quick regeneration of many monocotyledons, for example *Poaceae*, relative to *Calluna* would be expected to create potential difficulties in this respect.

Even where patches of burn are readily apparent within aerial imagery characterisation of burn history within a sample segment is not in fact a trivial problem. Almost all large blocks of *Calluna*, for example, will at some stage have been managed so the simple question 'how much has been burned' will return a value of 100% for almost all *Calluna* in an image. This will apply similarly for areas of grassland under burn management. Many previous studies simply report an areal extent of 'burn'. It is apparent these reported 'burns' would be recognised as lighter features, with distinctive regular boundaries, within a matrix of darker mature *Calluna*. However, in reality these areas probably really represent newer burn within areas of older burn, hence should more correctly be identified as 'visible burn' or 'recent burn'.

Previous work undertaken by Cranfield University has demonstrated that it is possible to extract more information than simple burn extent from 25cm resolution colour imagery. Within single images a number of factors can be used to estimate the time since each block was burned.

The texture and colour of *Calluna* regrowth together with the pattern of overlying burns allows a good estimate of at least the sequence of burns on a site. However, comparison between sites requires rather more stability than such an approach generates. It has been found that generally four classes of *Calluna* re-growth relative to burn can be identified consistently across most colour high resolution mages. The features of these classes are presented in Table 2.4.1 below.

Table 2.4.1 Classes of *Calluna* re-growth recognisable during API of high resolution colour aerial imagery and their main visual characteristics

Class	Represents	Characteristics
1	Open, sparse, or nonexistent *Calluna* canopy **new burn**	colour varies according to substrate and sward mix - ie presence of fast regenerating grasses and presence or absence of visible burned remains texture varies with age of *Calluna* burned
2	Partial and closing *Calluna* canopy **recent burn**	presence of darker patches of regenerating heather
3	Dense even canopy - mature **mid-aged burn**	complete dark and visibly smooth canopy

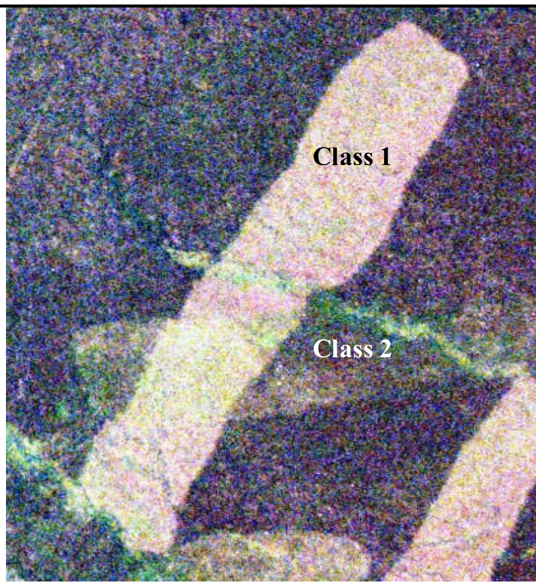
Class	Represents	Characteristics
4	Uneven canopy - degeneration phase **old burn or unmanaged**	complete canopy, looks both slightly lighter than 3 owing to presence of visible lighter stem material and has distinctive 'lumpy' texture no relic burns patterns are visible within this class - hence it is impossible to distinguish whether class 4 represent areas of old burn or unmanaged *Calluna*

Although there is much variation in both texture and colour of these classes resulting from both the age of *Calluna* when last burned and the abundance of other faster recovering vegetation such as *Poaceae* these are consistently identifiable in aerial imagery with a 25cm resolution.

However, reconstruction of the boundaries of overlap areas, especially where class 3 has been extensively re-burned can still be problematic. Examples of each class are shown in Figure 2.4.1.

Areas of Class 1 (diagonal) overlying area of Class 2. The smooth texture and light colouration of a burn patch with no apparent *Calluna* regeneration defines Class 1.

The apparent, but incomplete, canopy of regenerating *Calluna* shown in the near horizontal patches define Class 2.



Two strips of Class 3 lying within a matrix of Class 4. The darker and smoother textured nature of a dense canopy of regenerating *Calluna* is clearly visible.

Once the late mature and degeneration stage of *Calluna* growth is reached the texture become noticeably 'lumpy' and the area lightens as stem and ground becomes visible.

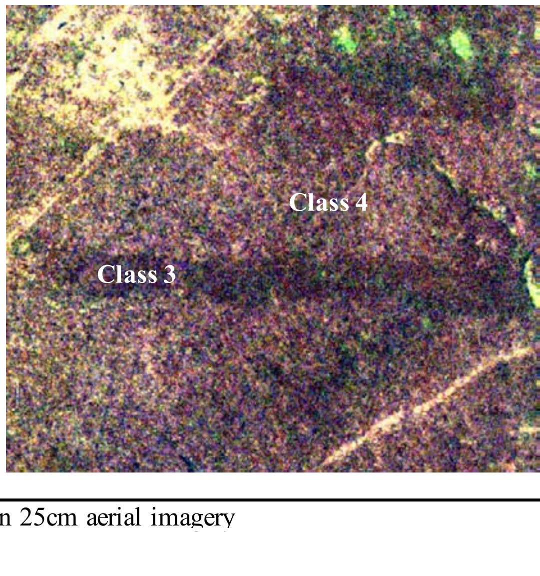
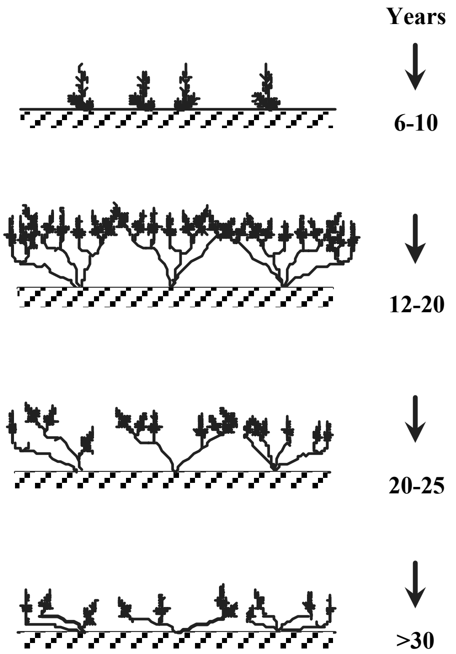


Figure 2.4.1 Examples of appearance of burn classes in 25cm aerial imagery

While interpretation into these categories is consistently applicable the actual age or time since burn that each class represents is rather 'fuzzier' and varies according to the rapidity of *Calluna* regeneration. Although undoubtedly a simplification of very wide range of responses, especially resulting from meteorological and soil conditions, consideration of the suggestions by Gimingham (1959) allows a possible framework for interpreting growth classes into approximate age for *Calluna* re-growth, see Figure 2.4.2 *below.* Note however these are very approximate and in places sufficient regrowth to allow a reburn may occur in 6 years.



Pioneer
seedling establishment to development of plant fully into a bush - long/short shoot differentiation

Building
from above until the plant is typically 15years old - the bush-like form grows to cover larger area

Mature
lasts until plant is typically 25 years old growth continues but less - centre of the bush thins and many shoots prostrate

Degenerate
growth declines much further - bush very ‘thin’ all shoots prostrate - ultimately death

Figure 2.4.2 Suggestions of growth phase and age in *Calluna vulgaris* after Gimingham (1959)

Class 1 represents part of the early pioneer stage before plant size and density makes them readily visible within the image. As such it most likely covers the period immediately after a burn to around 5 or 6 years following it. While re-growth from the burning of some stands of vigorous, healthy *Calluna* can be fast, older over-mature stands often recover slowly and, in some case where the peat surface is burned little growth may be apparent even many years after a burn. Class 2 represents a period between late pioneer and early building phases and probably covers years 4 to 12 since burning, again depending on *Calluna* response and vigour. Class 3 represents the mid to late building phase and into early mature, ie perhaps 10 - 25 years. The smooth texture of this class identify it as being terminated by the change in appearance as stem length reaches the stage where central gaps begin to appear in the foliage of each plant. This textural change is readily apparent in 25cm imagery and defines class 4, which can be taken to cover perhaps the period of 22 years and onwards since burn. No upper age limit is placed on class 4 and, although it might perhaps be possible to deduce from the homogeneity of the stand whether it has been managed over a longer period, this has not been attempted. It is sometimes possible to distinguish within these four classes, for example a very new burn (1-2 years) from those of perhaps 3 and 4 years.

2.5 Estimation of return period or repeat time

Repeat time or return period is simply an estimate of the time taken for an entire area to be burnt, ie if 1/20th (5%) of the area in question is burnt, on average, each year repeat time is 20 years. Few previous studies using API have attempted to estimate the time since each parcel was burned. As a consequence return times are usually derived from a single combined extent figure for all burns, divided by an estimate of the maximum age that burns remain visible, to give an annual figure. Such single estimates answer few questions regarding changes in practice over time.

The ability to distinguish more than one age class presents the opportunity to derive a better estimate for a return period for each examined image than the use of a single class or 'burn'. More importantly it allows the exclusion of sites that have only recently (last 5- 8yr) been returned to management. These are characterised by overall small areas of burning within a matrix of mature, and over-mature *Calluna*, and their inclusion will inflate overall estimates of a burn return period. As return period is a crucial component in assessing the sustainability of a burning regime this revised method will enable more accurate assessments to be made.

Repeat time can be derived by using any proportion of burn for which a maximum age can be estimated. To eliminate the bias arising from including areas with recently changed management only sample segments with both class 1 and class 2 burn segments were included in this analysis.

Where both class 1 and class 2 are apparent in a sample segment, a return period is derived from each class independently using a maximum age estimate for each class. Following this an area weighted mean of both values are calculated to give an upper and lower estimate of the return period using the following model.

Assumptions

Only the aggregated class 3 and 4 (mature/degenerate) are subject to burning. The estimates of current and recent burning practices are made by reference to classes I-2. Classes have an age range that is subject to uncertainty. The age structure within each class is equal.

Model

The proportion of heather in class i is X_i.
The start year of class i is S_i.
The end year of class i is E_i.

The mean length of class i is L_i, which is estimated by the following equation:

$$L_i = ((E_i - S_{i+1})/2) - ((S_i + E_{i-1})/2) \qquad \text{(assumes } S_1 = 0 \text{ and } E_0 = 0\text{).}$$

The best estimate of current repeat time is:

$$T = L_i / X_i.$$

The range in which the repeat time must fall is given by:

$$T_{min} = (S_2 - E_0)/X_1 \quad \textit{and}$$
$$T_{max} = (E_1 - S_1)/X_1.$$

The above equations are valid descriptions of the current return time, but do not take into account variability in management over time. By incorporating the proportion of heather in class two, it is possible to take an overall view of management practices over the last decade or so, removing short-term temporal variation in management. The best estimate of return time becomes:

$$T = (L_1 + L_2)/(X_1 + X_2)$$

This measure provides a better estimate of return times provided management over the duration of class one and two has been consistent. Any bias arising when an area has just come into, or has fallen out of, management in the last decade is corrected by removing samples that have X_1 or $X_2 = 0$.

3. Scale of current burning practice in the English uplands

3.1 Target class distribution within sample segments

The distribution of the target classes with the sample segments is described in Table 3.1.1. As noted previously, the sample of segments was drawn from a total study area that was determined on the basis of the target classes exceeding a threshold of 5%. This equates to an area of 10360km^2. In terms of spatial coverage, heath and acid grass were the most dominant classes and occurred in 79% and 76% of the segments and had a similar distribution in terms of proportion per segment. Bracken (42%) and bog (34%) were less extensive but bog showed the highest median value in terms of proportional cover.

Table 3.1.1 Distribution of target classes (%) within the sample sites

	Segments	Min	Lower Quartile	Median	Upper Quartile	Max
Bog	71 (34%)	0.2	6.4	23.9	49.3	98.9
Heath	165 (79%)	0.1	3.8	15.8	37.6	100.0
Bracken	88 (42%)	0.1	2.1	6.6	25.0	78.8
Acid Grass	159 (76%)	0.1	7.3	15.2	33.1	100.0
Montane	0 (0%)	-	-	-	-	-
Target	208 (100%)	5.1	20.2	51.8	88.1	100.0

3.2 Extent of burning

3.2.1 Grassland and bog

The detection of burn on acid grassland is more problematic than for other target classes, since the signature of the burn is not as long lived as for dwarf shrub heath environments. From the assessments off the 2000 photography there were no unambiguous identifications of burning within any of the grassland areas. However, one sample segment located within

Dartmoor National Park showed some possible evidence of previous management. This was investigated in the field survey and direct evidence of burning found in the form of a sparse distribution of *Calluna* stems. The condition of the stems suggested the burn probably took place more than 5 years previously. To confirm that the resolution properties of the photography were not preventing identification of burn parcels, data were acquired from the Exmoor National Park Authority. These data represent field mapping of burn parcels and are available for the years 1997-2000 inclusive and 2001. Upon combining these data with the segment data, one burn parcel mapped in 1997 intersected with the sample segments. However, upon closer inspection there was no readily identifiable signature of the burn remaining in the photography, which was dated 18 June 2000.

3.2.2 Dwarf shrub heath

Visible evidence of burning was found consistently within the dwarf shrub heath class, or more specifically within stands dominated by *Calluna*. Of the 208 sample segments, 102 (49%) had no *Calluna* present. Of the remaining 106 sites where *Calluna* was evident, 75 sites (71%) possessed visible evidence of burning. Table 3.2.1 contains data on the proportions in the interpreted classes and estimates of the areas covered within the complete study area.

Table 3.2.1 Area of heather burning within the English Uplands

	Interpreted Class				
	Calluna	***Calluna* *(Class 1)***	***Calluna* *(Class 2)***	***Calluna* *(Class 3&4)***	**No *Calluna***
Proportion (%)	24	4	3	17	76
Area (km^2)	2526	437	328	1761	7834
CI 95%	446	121	99	385	446

The values in Table 3.2.1 are expressed as proportions for the complete study area of 10360km^2. *Calluna* covers 24% of the study area with *Calluna* in visible management equating to 7% and the presence of *Calluna* without visible evidence of management equating to 17% of the study area.

As noted above defining the area of study based on a 5% threshold of the target classes results in a total study area of 10360km^2. Summing the target class areas from the LCM2000 dataset for all the 1km squares in the study area, produces a total of 5528km^2 which is 53% of the study area as defined based on a single threshold. This indicates that the study area is rather fragmented. This study has estimated an area of *Calluna* cover from photo-interpretation of the aerial photograph data of 2526±446ha. The total area of *Calluna* (ie class 9 and 10, dense and open dwarf shrub heath), obtained using the LCM2000 dataset is 2087 km^2. The LCM2000 estimate is within the lower limit of the 95% confidence interval of the study estimate and indicates a relatively good agreement between the two sets of data.

The above figures represent the importance of burning as a management practice at the level of the English Uplands. However, the target classes represent only 53% of the total study area, and burning has only been found in relation to the presence of *Calluna*. Considering all the 106 sites with *Calluna* present the average proportion of the heather area present in the sample sites that showed visible evidence of burning is estimated at 27%. Further restricting the estimate to those sites where there is visible evidence of recent management, the average proportion of the heather area in management increases to 38%.

These figures represent an average that is representative of *Calluna* dominant sites within the English Uplands. However, burning practice exhibits considerable variation across the study area in terms of the proportional area of *Calluna* in visible management. Table 3.2.2 provides summary statistics relating to the proportion of the sample segments with identifiable burning and Figure 3.2.1 shows two locations with varying levels of management.

Table 3.2.2 Statistics on proportion of area burnt

	Minimum	Lower Quartile	Median	Upper Quartile	Maximum
% visibly managed	0.6	20	31	63	100

Figure 3.2.1 shows an example of sample segments with ~30% of the *Calluna* burnt and area where the proportion burnt is much higher.

In summary, it is evident that burning as a management practice within the English Uplands is dominated by the burning of dwarf shrub heath. Furthermore, for a typical area of *Calluna* in management, the proportion of *Calluna* that would show visible evidence of burning is nearly 40%. The presence of grassland burning is a much less significant feature of the English Uplands overall and the presence and scale cannot be accurately estimated from the sample size and stratification employed within this project.

Figure 3.2.1 Sample segments showing example areal extents of *Calluna* burn ***(top: ≈30%, below: >70%)***

3.3 Area of Burn Parcels

An estimate of the typical size and shape of burn parcels in classes 1 and 2 has been undertaken. As noted previously, in relation to heather burning for grouse management the area of a burn parcel would be expected to fall within the range 0.3 - 0.5ha (Tucker, 2003), exceeding the earliest recommendations on burn size proposed by Lovat (1911) of 0.05 – 0.10 ha. The typical advice for burning is given in relation to the width of the burn, being of the order of 30 – 50m wide and as long as practicable. This latter element will be constrained by the size of the management area and any natural environmental or non-natural administrative boundaries present locally.

Obtaining the burn parcel area from the digitised parcels is very straightforward within a GIS as long as the burn parcel is entirely within the sample $1km^2$ site being assessed. However, in reality many burn parcels are truncated by the boundary of the sample site and therefore will not give a true measure of the parcel area. One of the considerations in selecting a sample site area of $1km^2$ not was to ensure that the majority of the burn parcels being mapped would fall within the boundary. However, necessarily some burn parcels will cross the boundary and leaves the problem of whether to include or discard these from the analysis. Using all burn parcels will likely increase the proportion of mid-size parcels occurring as large parcels that cross the sample boundary become truncated. Restricting the analysis to only those parcels contained completely within the sample segment will lead to a bias towards smaller burn parcels, since larger parcels are more likely to cross the boundary.

To obtain some idea of the importance of boundary effects Table 3.3.1 presents results for both cases. The mean parcel area ranges from 0.64ha based on all the mapped parcels to 0.47ha for those that are completely contained within the sample segments, and the maximum parcel area reduced from 32.75 ha to 12.05ha. The median value ranges between 0.28 and 0.25 respectively and is a more robust estimate of the typical burn parcel size. These data suggest that most burns (ie approximately 50%) cover areas between 0.12ha and 0.55ha.

Table 3.3.1 Statistics of burn parcel size (ha)

	Parcels	Min	Low Quartile	Median	Up Quartile	Max
All parcels	2342	0.01	0.13	0.28	0.62	32.75
Not touching boundary	1733	0.01	0.12	0.25	0.51	12.05

Clearly statistics on the maximum size of area burnt are less reliable based on an aggregated assessment of the raw data. There were 12 burn parcels mapped that exceeded 10ha and the largest burn parcel was mapped at 32.75ha. The latter burn did intersect the segment boundary but only by a relatively small proportion.

3.4 Shape of burn parcels

The shape of burn parcels is considerably more difficult to quantify than area, since the latter parameter is available as a standard calculation within any GIS for a mapped polygon. A simple shape index has been used to provide a method of describing the range of burning practice with the aim of separating the more “traditional” burning practice of long thin burns and combining this with the burn parcel area. The shape index used is based on a ratio of the area of the burn parcel (multiplied by 4π) by the square of the perimeter. This results in a scaled value with an upper limit of 1.0 indicative of a circle. A square shape has a value of 0.79, while rectangles with a length that is 2, 3, 4 and 5 times the width have shape index values of 0.70, 0.59, 0.50, 0.44 respectively.

Using the data on parcel area restricted to those parcels that are completely contained within the area of the sample site, Table 3.4.1 provides a categorisation of all the parcels in terms of their shape and area. The selection of area classes included the ranges noted previously as consistent with historical and recent guidance. On this basis the majority of burn parcels occur within the intermediate size range of 0.1ha - 0.3ha. When considering shape, most parcels are rectangular in shape with the length of the burnt parcel typically exceeding 3 times the width. Figure 3.4.1 shows an example of a site where a more traditional form of management is being conducted. The establishment of burning regimes characterised by a mosaic of square parcels is not the normal adopted practice. However, Figure 3.4.1 shows a sample site where this practice does occur alongside a more traditional style of management.

Table 3.4.1 Shape and size distribution of burn parcels

Shape class	**Size class (ha)**					
	1 (>0.5)	**2 (0.3-0.5)**	**3 (0.1-0.3)**	**4 (0.05-0.1)**	**5 (<0.05)**	**Total**
1 (≥0.79)	12	18	36	18	2	86
2 (0.70-0.78)	22	20	135	54	8	239
3 (0.59-0.69)	47	50	164	57	22	340
4 (0.50-0.58)	52	58	145	49	13	317
5 (<0.50)	324	146	218	49	14	751
Total	457	292	698	227	59	1733

Shape class	**Size class (ha)**					
	1 (>0.5)	**2 (0.3-0.5)**	**3 (0.1-0.3)**	**4 (0.05-0.1)**	**5 (<0.05)**	**Total**
1 (≥0.79)	0.7%	1.0%	2.1%	1.0%	0.1%	5.0%
2 (0.70-0.78)	1.3%	1.2%	7.8%	3.1%	0.5%	13.8%
3 (0.59-0.69)	2.7%	2.9%	9.5%	3.3%	1.3%	19.6%
4 (0.50-0.58)	3.0%	3.3%	8.4%	2.8%	0.8%	18.3%
5 (<0.50)	18.7%	8.4%	12.6%	2.8%	0.8%	43.3%
Total	26.4%	16.8%	40.3%	13.1%	3.4%	100%

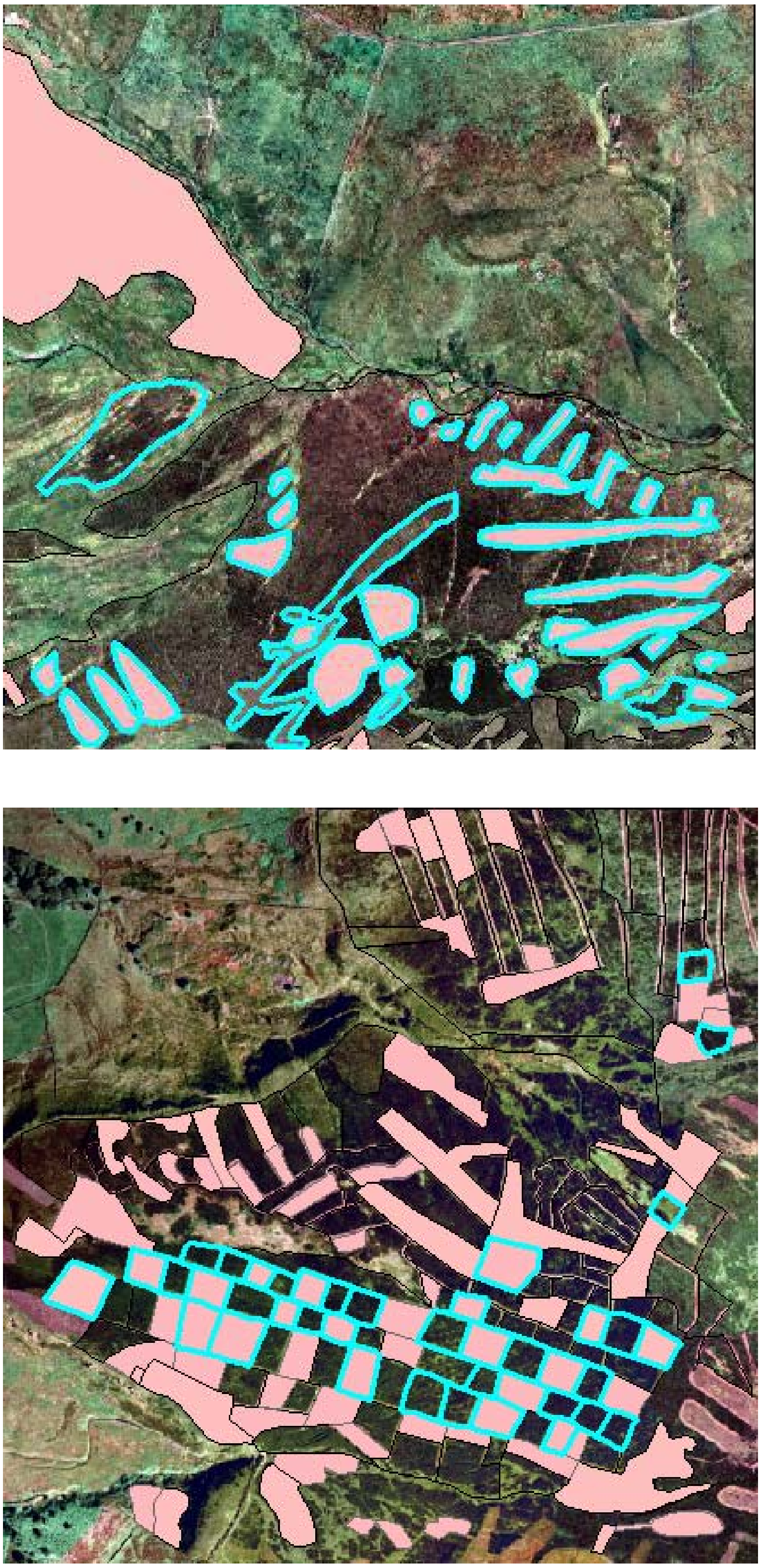


Figure 3.4.1 Examples of management practice
(top: traditional form below: non-traditional with mechanically cut firebreaks)

3.5 Estimates of return period for consistently managed *Calluna* blocks

Estimated return periods are summarised in Table 3.5.1 and Figure 3.5.1. The most frequent class has a return estimated at between 16-20 years and this probably represents a good return period for continuously managed *Calluna*. However, the proportion of management with a shorter return period could be considered worthy of concern as repeat burning at this frequency is associated with poor condition assessments (English Nature 2003). Of equal note is the long tail of return periods suggesting that in a large majority of places over-mature heather is part of the management programme.

Table 3.5.1 Estimated return periods for consistently managed sites

	Low range (T_{min})	Mid range (T)	High range (T_{max})
Minimum	10	11	12
Median	26	28	30
Maximum	213	234	255

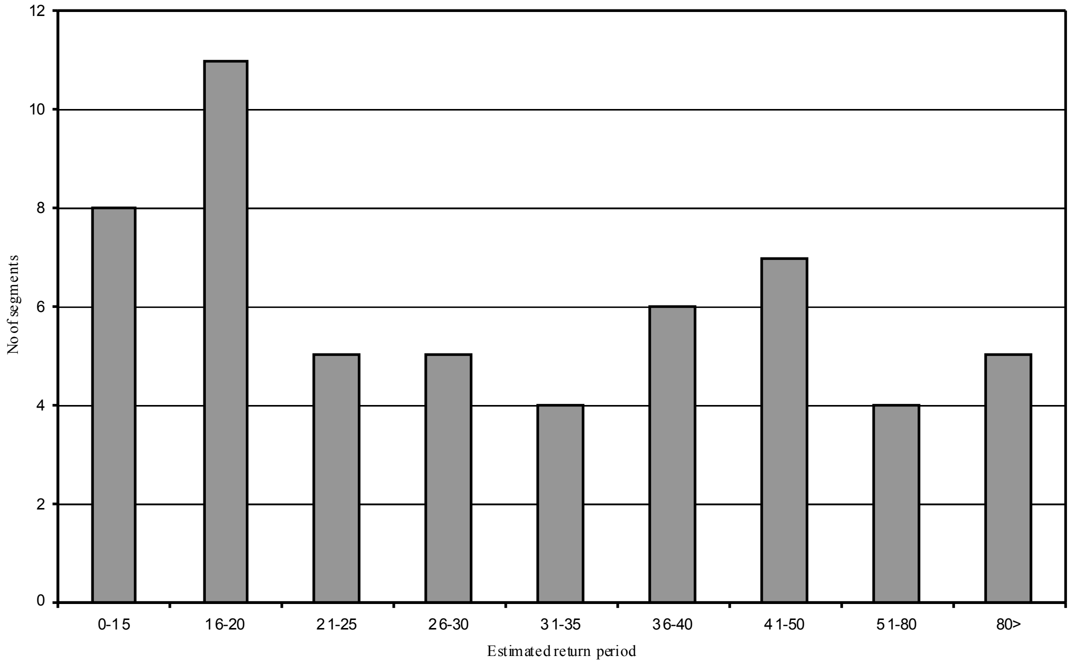


Figure 3.5.1 Frequency distribution of estimated return times for continuously managed areas (T) (*n=48. class duration: 1 = 0-6; 2 = 5-12; 3 = 10-22; 4 > 20)*

4. History of burning practice in the English uplands

4.1 National historical photography

4.1.1 Changes in burning practice

The restricted number of sample sites available from the NMR photography limits the type of assessment that can be undertaken. It is not possible to adequately determine the proportion of burning by date, nor the typical return period. Rather emphasis is given to determining the relative change between periods in burning parcel size and shape.

Tables 4.1.1 and 4.1.2 present the proportion of burn parcels in each of the size and shape classes used earlier. Given that relative change is being assessed the tables are constructed using all parcels mapped as having visible evidence of burning. For comparison, Table 4.1.3 presents the distribution for the contemporary photography but restricted to the NMR sites where burning was identified.

Table 4.1.1 Shape and size distribution of burn parcels for period 1945-1952

Shape class	Size class (ha)					
	1 (>0.5)	2 (0.3-0.5)	3 (0.1-0.3)	4 (0.05-0.1)	5 (<0.05)	Total
1	0.0%	3.2%	1.6%	0.0%	1.6%	6.5%
2	0.0%	0.0%	0.0%	0.0%	1.6%	1.6%
3	4.8%	1.6%	6.5%	0.0%	0.0%	12.9%
4	11.3%	1.6%	4.8%	0.0%	1.6%	19.4%
5	50.0%	3.2%	4.8%	0.0%	1.6%	59.7%
Total	66.1%	9.7%	17.7%	0.0%	6.5%	100%

Table 4.1.2 Shape and size distribution of burn parcels for period 1965-1980

Shape class	Size class (ha)					
	1 (>0.5)	2 (0.3-0.5)	3 (0.1-0.3)	4 (0.05-0.1)	5 (<0.05)	Total
1	1.7%	0.9%	0.9%	0.0%	0.0%	3.4%
2	3.4%	0.0%	3.4%	0.9%	0.0%	7.7%
3	6.0%	5.1%	2.6%	1.7%	0.9%	16.2%
4	9.4%	2.6%	3.4%	0.0%	0.0%	15.4%
5	48.7%	7.7%	0.9%	0.0%	0.0%	57.3%
Total	69.2%	16.2%	11.1%	2.6%	0.9%	100%

Table 4.1.3 Shape and size distribution of burn parcels for period 1999-2000

Shape class	Size class (ha)					
	1 (>0.5)	2 (0.3-0.5)	3 (0.1-0.3)	4 (0.05-0.1)	5 (<0.05)	Total
1	0.4%	0.8%	1.1%	0.6%	0.2%	3.2%
2	1.3%	1.9%	4.9%	1.5%	0.0%	9.5%
3	3.4%	4.4%	8.0%	3.0%	0.6%	19.4%
4	4.6%	3.4%	9.1%	1.9%	0.4%	19.4%
5	22.4%	10.1%	12.7%	2.5%	0.8%	48.5%
Total	32.1%	20.7%	35.7%	9.5%	2.1%	100%

As expected compared to the data derived for the English Uplands based on 208 sample sites, the use of all burn parcels rather than those completely contained within the boundaries of the sample segments for the smaller number of historical sites has lead to an increase in the proportion of parcels in size classes 1 (+5.7%) and 2 (3.9%) and a reduction in the proportion of parcels in size classes 3 (-4.6%), 4 (-3.6%) and 5 (-1.3%). However, overall the pattern presented remains the same (with size class 3 (0.1-0.3ha) being the most frequently represented, followed by size class 1 (>0.5ha)) and although this bias will also be present in the data for the two historical periods, relative change can still be identified.

From these data the most notable difference is in respect to the size distribution of the burning parcels. Historically burning parcels were larger on average than currently, and this appears consistent between the periods 1945-1952 and 1965-1980. A summary of the statistics of the actual burn parcel sizes for each period is presented below and confirms the change noted above.

Table 4.1.4 Statistics of burn parcel size (ha)

Period	Minimum	Lower Quartile	Median	Upper Quartile	Maximum
45-52	0.05	0.30	0.77	1.67	48.14
65-80	0.03	0.39	1.03	2.79	22.28
99-00	0.01	0.17	0.33	0.63	32.75

Due to the issues of sample selection indicated earlier, the number of sample sites for which estimates of proportional area burnt are too few to produce a statistical assessment of for each period and therefore a precise estimate of any historical change. Only 9 of the original 23 sites possessed burning in at least one of the periods 1945-1952, 1965-1980 and 1999-2000. However, using these data the average change in proportion under visible management from *circa* 1940s to *circa* 1970s was +12% and from *circa* 1970s to currently was -0.3%.

4.2 National Parks photography

4.2.1 Changes in burning practice: areal extent and return period

The interpreted samples from the National Historical photography and the National Park photography that had dates in the 1970s were combined to generate an increased sample size to allow for statistical testing of temporal change to be undertaken. However, as these samples were not part of a random countrywide sample, it should be noted that country-wide assessment of change should not extrapolated from them. Also a wider range of individual dates were involved with the 1970s photographs than the current photography.

From Table 4.2.1.1 the area of *Calluna* remained unchanged within the sample sites between the two time periods. There was a significant increase in the area of burn class 1 (areas most recently burnt) in the 2000 imagery when compared to imagery representative of the mid 1970s. There is a corresponding significant decline in Class 3, showing this as the main class contributing to the increase. However, although not significant the 5% decline in Class is indicative of new areas coming into management.

Table 4.2.1.1 Summary changes in burning recorded in paired 1km^2 samples between 1970 and 2000.

Area %	1970's mean		2000 mean		
DSH	62.7	*(5.7)*	62.6		*(5.3)*
Class 1	15.1	*(2.3)*	29.7	**	*(3.8)*
Class 2	18.9	*(2.8)*	18.9		*(3.2)*
Class 1 & 2 *combined*	34.0	*(4.1)*	48.6	*	*(4.8)*
Class 3	25.7	*(5.4)*	15.8	*	*(3.3)*
Class 4	40.3	*(6.4)*	35.7		*(5.6)*
*s.e. of mean show in italics * P <0.05 ** P<0.001: paired t-test, data arcsin transformed prior to analysis. d.f. = 22 n.b. owing to spatial bias in sampling these cannot be used for national estimates.*					

Estimates of the mean return period shows a reduction from 33.7 years in 1970 to 26.4 years in 2000, however this change is not statistically significant. The protocol used for determining return period, ie the use of only samples with both class 1 and 2 present in the sample area reduces the sample size available and this may influence significance in this case.

5. Conclusions and recommendations

5.1 Review of aim and methodology

The aim of this project was to conduct an assessment of the scale of current burning practice within the English Uplands, and to identify possible changes that might have occurred over recent periods. The vegetation cover categories considered for the assessment were based upon the broad habitats included in the Land Cover Map 2000 survey and identified as bog, heath, bracken, acid grass and montane communities. To achieve this the study acquired aerial photography and interpreted these with a view to identifying both the contemporary and historical extent of burning practice by deriving estimates of burn parcel size, shape and return period.

The geographical limits of the study area were defined based upon the Environmental Zone 3 Uplands dataset developed as part of the Countryside Survey 2000 and modified using the broad habitat summaries of the LCM 2000 data, which are available at a spatial resolution of 1km^2. This resulted in a final study area of 10360km^2. Within the constraints of time and resources, a sample survey was designed based upon a distribution of areas of fixed 1km^2 size. A total of 208 sample sites were selected based upon a random sampling and represents 2% of the study area. Using aerial photography that was acquired around 2000 all 208 sites were photo-interpreted for visible evidence of burning in the target classes. Subsequently, sub-samples of these 208 sites were identified as the basis for undertaking assessments of burning practice using historical photography representative of the periods 1943-52 and 1965-80. In the sample methodology emphasis was given to estimating the current scale of burning practice, since these results would provide important information to allow targeting of future monitoring programmes.

5.2 Visible evidence of burning within the target classes

With respect to the identified target classes, montane was not represented in the study area according to the LCM 2000 broad habitats data. All other classes were present within the 208 sample sites analysed for the contemporary assessment. However, visible evidence of burning was only identified with respect to the heath class, or more specifically within *Calluna* dominated stands. The lack of burning of bog is expected, however, it is known that burning of acid grass is undertaken for agricultural purposes and mainly within the southern central and south west upland regions.

Since grassland burns are expected to exceed the typical size of heath burns, there was some concern that the size of the sample sites might be smaller than the typical area burnt and therefore mask any visible evidence of burning. Additionally the signature of burning in grass dominated environments would not be expected to last beyond perhaps 2 to 3 years. Data provided by Dartmoor National Park Authority confirmed an absence of burning within the sample sites for the period of 2-3 years of the photography and therefore it was concluded that the lack of visible evidence of burning was a true indication that grass burning is not a significant practice at the level of the English Uplands. The practice is important regionally, but the scale is below that resolvable by a sample framework defined for the development of national estimates.

5.3 Summary of current scale of burning practice

For *Calluna* dominated sites where there is visible evidence of burning, the proportional area in management is 38%. This value is representative of the current scale of burning practice. A typical range encompassing 50% of the sites surveyed indicates a variation between 20% and 63%, although some sites exhibited higher levels of management.

Typically, the area of individual burns range between 0.12ha and 0.55ha with a median value between 0.25 to 0.28ha. The range of burn parcel sizes therefore matches reasonably with the consensus on current advice for burn areas to fall within the range 0.3-0.5ha, but with a larger number of very small burns than expected. However, the guidance provided do not take account of the local administrative and environmental boundaries encountered nor the total size of the areas being managed. These locally specific factors can result in much smaller parcels being burnt.

An estimate of the return period using historical photography has been made as described in 2.5 and is estimated at between 16-20 years. On average this is slightly longer than current guidance suggests, being typically of the order of 10-15 years. However, there are many areas where considerable shorter return periods are implied by the proportional areas of visible management.

The survey revealed a number of sites where management appears very intense and the adoption of mechanised cutting of firebreaks has replaced more traditional methods of burn control. In some areas these appear to represent a significant change to recent management practice. It is possible these represent a drive to conform to Tier 1C Moorland ESA payments although other 'drivers' may be operating.

5.4 Summary of history of burning practice

The assessment of the history of burning practice at the level of the English uplands remains incomplete due to the problems noted earlier with the acquisition of historical imagery for a random subset of the original sample areas.

The inclusion of photography covering the English National Parks shows that a significant increase in class 1 (ie most recent burn) between 1970 and 2000 is apparent. This increase would be expected to produce a reduction in the estimated return period. It should be noted that these data are not expressible in terms of a national figure. However, they show evidence of changes for areas under at least nominal national park protection and, as such, there is little reason to assume they are not mirrored elsewhere in England.

5.5 Recommendations

The starting point for the current study was an assessment of burning practice across the whole of the English Uplands and encompassing 5 priority habitats (bog, heath, bracken, acid grass and montane communities), although only heath and grass habitats were likely to have significant levels of burning. An intended use of the results of the study is initiation of baseline monitoring on a selection of sites. The data derived for this study do provide a suitable basis for identification of sites with varying levels of contemporary management of heath.

An outcome of the study has been that nationally burning for management of heather is much more significant than burning of grass. As a consequence of this, and limited signature for grass burns, the national sampling protocol has not produced sufficient local data to allow extraction of reliable estimates of the extent of grass burning where it occurs. In this respect therefore it might be thought necessary to undertake further work to assess the scale of current grass burning practice. This should be undertaken in co-operation with staff at the Exmoor and Dartmoor National Parks, since these bodies hold considerable archive material and data on current burning practice are also routinely acquired. In addition, Exmoor National Park possesses archives of colour infrared photography and the characteristics of the photography, together with their availability for the whole area are more suited to the identification of burning than standard colour photography. Oral evidence gathered in the South West leads us to suggest that managed *Molinia* burning in the Dartmoor and Exmoor national parks appears to be reducing, and results from both English Nature and National Park pressure. It is therefore suggested that a thorough review of, not only past change, but of the potential consequences of future change is undertaken and that in particular the recent wide-spread discontinuation of an age-old management practice is thoroughly monitored.

In areas of *Calluna* heath the recent observed adoption of mechanical methods of fire control and the concomitant increases in the overall extent of areas in burn class 1 (no visible *Calluna* regeneration) in a number of areas should be of further investigated. The factors driving this change and the ecological and hydrological consequences of its continuation, merit further investigation.

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Appendix 1. Location of sample squares and API estimates. England Survey 2000

Location of 1km sample sites and API estimates of *Calluna* and burn class extent: 2000.
see 2.4 for descriptions of cover classes
note figures are corrected to 1km^2 -
max overall sample correction applied <1%

Country/UA	OS grid ref		SQID	*Calluna* cover class (m^2)				
	east	north		0	1	2	3	4
Blackburn with Darwen UA	367500	416500	154	1000000	0	0	0	0
Cheshire	395500	366500	143	1000000	0	0	0	0
Cheshire	393500	367500	163	970248	0	0	0	29752
Cheshire & Derbyshire border	400500	369500	28	625874	0	189552	0	184574
County of Herefordshire UA	327500	233500	161	1000000	0	0	0	0
Cumbria	374500	533500	8	0	6070	0	0	993930
Cumbria	368500	544500	9	296012	216405	295440	125345	66798
Cumbria	335500	521500	11	448081	0	0	0	551919
Cumbria	314500	515500	12	496855	0	0	0	503145
Cumbria	328500	511500	14	1000000	0	0	0	0
Cumbria	323500	509500	15	1000000	0	0	0	0
Cumbria	314500	510500	16	1000000	0	0	0	0
Cumbria	373500	530500	19	477980	0	0	0	522020
Cumbria	366500	541500	21	539256	47912	89456	25209	298167
Cumbria	330500	529500	24	1000000	0	0	0	0
Cumbria	335500	515500	26	1000000	0	0	0	0
Cumbria	320500	507500	32	1000000	0	0	0	0
Cumbria	368500	539500	37	376836	216501	184859	95076	126729
Cumbria	317500	498500	39	1000000	0	0	0	0
Cumbria	325500	512500	42	1000000	0	0	0	0
Cumbria	316500	515500	43	834297	0	0	0	165703
Cumbria	358500	502500	45	1000000	0	0	0	0
Cumbria	366500	499500	50	1000000	0	0	0	0
Cumbria	322500	494500	54	1000000	0	0	0	0
Cumbria	319500	524500	57	695572	0	0	0	304428
Cumbria	344500	517500	61	1000000	0	0	0	0
Cumbria	357500	502500	66	1000000	0	0	0	0
Cumbria	319500	514500	67	1000000	0	0	0	0
Cumbria	313500	483500	75	1000000	0	0	0	0
Cumbria	364500	545500	77	584973	0	0	0	415027
Cumbria	321500	497500	82	1000000	0	0	0	0
Cumbria	371500	501500	85	1000000	0	0	0	0
Cumbria	347500	505500	86	1000000	0	0	0	0
Cumbria	349500	501500	90	35026	191430	0	0	773544
Cumbria	334500	508500	100	1000000	0	0	0	0
Cumbria	305500	512500	112	1000000	0	0	0	0
Cumbria	386500	511500	113	915557	15323	0	0	69120
Cumbria	316500	516500	115	680923	0	0	0	319077
Cumbria	364500	480500	116	627339	78349	24392	86784	183137
Cumbria	325500	517500	117	1000000	0	0	0	0
Cumbria	352500	540500	121	1000000	0	0	0	0

Country/UA	OS grid ref		SQ ID	*Calluna* cover class (m^2)				
	east	north		0	1	2	3	4
Cumbria	318500	491500	128	663021	0	0	0	336979
Cumbria	366500	575500	131	1000000	0	0	0	0
Cumbria	316500	518500	136	1000000	0	0	0	0
Cumbria	347500	513500	137	1000000	0	0	0	0
Cumbria	358500	573500	140	1000000	0	0	0	0
Cumbria	373500	540500	142	40274	53391	160843	16327	729164
Cumbria	363500	572500	149	1000000	0	0	0	0
Cumbria	316500	496500	152	1000000	0	0	0	0
Cumbria	363500	488500	156	1000000	0	0	0	0
Cumbria	340500	524500	158	935857	0	0	0	64143
Cumbria	342500	502500	160	1000000	0	0	0	0
Cumbria	353500	514500	165	1000000	0	0	0	0
Cumbria	375500	493500	177	1000000	0	0	0	0
Cumbria	385500	511500	184	485114	0	0	0	514886
Cumbria	378500	507500	190	1000000	0	0	0	0
Cumbria	329500	542500	193	1000000	0	0	0	0
Cumbria	367500	512500	201	1000000	0	0	0	0
Cumbria	373500	545500	202	1000000	0	0	0	0
Cumbria	360500	494500	204	700371	0	0	0	299629
Cumbria	368500	505500	205	948519	0	0	0	51481
Cumbria	355500	587500	206	1000000	0	0	0	0
Cumbria & North'land border	374500	549500	71	850066	79464	20541	49929	0
Cumbria & North'land border	367500	576500	96	1000000	0	0	0	0
Derbyshire	408500	403500	20	1000000	0	0	0	0
Derbyshire	405500	377500	44	253300	146913	90829	50549	458409
Derbyshire	417500	385500	101	565720	129663	38628	230185	35804
Derbyshire	421500	379500	138	1000000	0	0	0	0
Derbyshire	417500	388500	172	1000000	0	0	0	0
Derbyshire	413500	373500	179	1000000	0	0	0	0
Derbyshire	401500	387500	192	927107	0	0	0	72893
Devon	257500	84500	13	559859	0	0	0	440141
Devon	257500	73500	27	1000000	0	0	0	0
Devon	259500	65500	31	1000000	0	0	0	0
Devon	265500	87500	47	1000000	0	0	0	0
Devon	264500	63500	48	833521	0	0	0	166479
Devon	260500	70500	59	1000000	0	0	0	0
Devon	263500	62500	64	1000000	0	0	0	0
Devon	263500	87500	93	1000000	0	0	0	0
Devon	270500	144500	135	564887	0	0	0	435113
Devon	269500	144500	148	1000000	0	0	0	0
Durham	387500	524500	5	0	124043	174553	127488	573916
Durham	380500	532500	7	1000000	0	0	0	0
Durham	400500	528500	23	0	343544	49642	176796	430017
Durham	399500	544500	33	16018	215723	89494	140801	537963
Durham	382500	528500	40	398294	32126	0	0	569580
Durham	384500	528500	46	33556	228452	132457	56931	548603
Durham	401500	532500	51	0	347115	167706	195774	289405
Durham	381500	524500	52	1000000	0	0	0	0
Durham	404500	531500	76	292857	185860	100719	64004	356560
Durham	401500	549500	126	744814	0	255186	0	0
Durham	407500	540500	130	689147	81849	56710	22987	149307
Durham	405500	508500	132	643943	5492	0	0	350565

Country/UA	OS grid ref		SQ ID	*Calluna* cover class (m^2)				
	east	north		0	1	2	3	4
Durham	409500	541500	147	673515	37237	3433	53713	232102
Durham	412500	553500	207	1000000	0	0	0	0
Durham & Cumbria border	383500	520500	6	354048	62310	157981	213993	211668
Durham & North'land border	391500	548500	22	45664	75154	82013	38284	758884
Greater Manchester	365500	412500	110	742602	0	0	0	257398
Greater Manchester	378500	416500	200	1000000	0	0	0	0
Lancashire	362500	458500	10	35653	76456	29716	40143	818033
Lancashire	379500	440500	53	1000000	0	0	0	0
Lancashire	394500	437500	63	630956	16111	0	0	352933
Lancashire	385500	427500	125	1000000	0	0	0	0
Lancashire	367500	447500	139	794563	0	0	0	205437
Lancashire	373500	458500	169	1000000	0	0	0	0
Lancashire	369500	446500	187	779664	0	0	0	220336
Lancashire	353500	451500	191	784624	0	0	0	215376
Lancashire	368500	447500	196	850724	0	0	0	149276
North Yorkshire	487500	499500	1	0	111470	159198	202051	527280
North Yorkshire	407500	467500	2	138866	138196	168518	23715	530704
North Yorkshire	399500	479500	3	644234	35149	51717	48224	220676
North Yorkshire	391500	504500	18	78902	51493	0	24773	844832
North Yorkshire	411500	457500	25	92874	194132	52261	109745	550988
North Yorkshire	474500	511500	29	279920	93641	252059	25920	348461
North Yorkshire	461500	502500	34	0	346424	226276	150621	276679
North Yorkshire	395500	494500	35	46719	146017	78029	147817	581417
North Yorkshire	388500	472500	36	1000000	0	0	0	0
North Yorkshire	399500	458500	49	184506	185707	63388	352187	214212
North Yorkshire	384500	496500	55	951129	0	0	0	48871
North Yorkshire	467500	510500	58	591144	239494	51491	1963	115907
North Yorkshire	461500	494500	72	249820	373888	116244	151725	108324
North Yorkshire	454500	498500	73	409580	31770	22559	109107	426984
North Yorkshire	399500	474500	78	1000000	0	0	0	0
North Yorkshire	397500	507500	80	312946	260938	50938	65788	309389
North Yorkshire	459500	511500	83	629701	34315	242380	73374	20229
North Yorkshire	386500	481500	97	1000000	0	0	0	0
North Yorkshire	404500	455500	99	899084	8712	15661	0	76542
North Yorkshire	400500	497500	102	475111	121361	0	0	403528
North Yorkshire	396500	478500	103	1000000	0	0	0	0
North Yorkshire	400500	473500	104	1000000	0	0	0	0
North Yorkshire	415500	482500	106	411778	196450	212163	49783	129827
North Yorkshire	410500	453500	107	301959	211657	56585	81506	348293
North Yorkshire	406500	477500	108	727226	57984	0	0	214790
North Yorkshire	477500	496500	109	527954	349924	106793	0	15328
North Yorkshire	399500	482500	111	498601	63800	228966	0	208634
North Yorkshire	418500	472500	118	525060	13358	8911	0	452671
North Yorkshire	416500	482500	122	622827	174505	147352	42707	12609
North Yorkshire	369500	476500	123	1000000	0	0	0	0
North Yorkshire	451500	499500	124	681342	103515	107913	15778	91452
North Yorkshire	398500	474500	127	1000000	0	0	0	0
North Yorkshire	388500	503500	129	191589	0	0	0	808411
North Yorkshire	387500	504500	134	1000000	0	0	0	0
North Yorkshire	381500	488500	144	784665	0	0	0	215335
North Yorkshire	497500	500500	146	856396	6347	37039	9021	91197
North Yorkshire	480500	496500	157	897927	70183	6706	3735	21450

Country/UA	OS grid ref		SQ ID	*Calluna* cover class (m^2)				
	east	north		0	1	2	3	4
North Yorkshire	380500	486500	159	1000000	0	0	0	0
North Yorkshire	455500	498500	166	951874	0	0	0	48126
North Yorkshire	397500	455500	167	1000000	0	0	0	0
North Yorkshire	396500	482500	168	1000000	0	0	0	0
North Yorkshire	412500	504500	171	855549	24292	0	0	120160
North Yorkshire	390500	501500	174	692524	0	0	0	307476
North Yorkshire	394500	477500	182	1000000	0	0	0	0
North Yorkshire	489500	496500	183	1000000	0	0	0	0
North Yorkshire	415500	478500	185	1000000	0	0	0	0
North Yorkshire	481500	495500	188	1000000	0	0	0	0
North Yorkshire	412500	465500	189	691689	13964	0	0	294348
North Yorkshire	414500	481500	195	957240	4192	4526	6876	27167
North Yorkshire	462500	490500	203	1000000	0	0	0	0
North Yorkshire & Cumbria border	379500	486500	119	0	0	0	0	1000000
North Yorkshire & Lancashire border	369500	479500	141	1000000	0	0	0	0
Northumberland	391500	618500	4	680910	0	3946	0	315144
Northumberland	386500	551500	17	5471	115600	102510	136574	639845
Northumberland	394500	625500	38	380873	53207	69289	160955	335676
Northumberland	381500	602500	41	1000000	0	0	0	0
Northumberland	403500	596500	56	230595	432408	158556	84675	93765
Northumberland	386500	626500	60	974029	5869	0	20102	0
Northumberland	387500	602500	62	910673	52884	14477	21966	0
Northumberland	393500	610500	70	1000000	0	0	0	0
Northumberland	376500	553500	81	390927	438985	0	132551	37536
Northumberland	369500	606500	89	735079	95189	169732	0	0
Northumberland	385500	628500	92	1000000	0	0	0	0
Northumberland	407500	605500	95	100189	172409	498592	134542	94268
Northumberland	388500	628500	133	1000000	0	0	0	0
Northumberland	401500	593500	145	1000000	0	0	0	0
Northumberland	398500	554500	150	754588	42293	14358	0	188761
Northumberland	378500	571500	164	1000000	0	0	0	0
Northumberland	369500	585500	170	1000000	0	0	0	0
Northumberland	404500	599500	173	1000000	0	0	0	0
Northumberland	375500	570500	175	1000000	0	0	0	0
Northumberland	366500	558500	176	722228	122887	57586	39482	57817
Northumberland	361500	598500	180	1000000	0	0	0	0
Northumberland	370500	590500	186	1000000	0	0	0	0
Northumberland	360500	593500	194	1000000	0	0	0	0
Northumberland	361500	585500	199	1000000	0	0	0	0
Shropshire	342500	291500	105	873906	0	0	0	126094
Shropshire	333500	294500	120	719318	17319	17546	103056	142762
Shropshire	326500	277500	162	1000000	0	0	0	0
Shropshire	321500	281500	197	1000000	0	0	0	0
Shropshire	332500	279500	198	1000000	0	0	0	0
Shropshire	326500	281500	208	1000000	0	0	0	0
Somerset	279500	142500	69	1000000	0	0	0	0
Somerset	274500	141500	74	1000000	0	0	0	0
Somerset	281500	135500	98	510688	0	303678	0	185634
Somerset	295500	128500	114	577986	23917	0	29882	368216
Somerset	283500	137500	151	1000000	0	0	0	0
Somerset	281500	139500	155	769077	0	0	0	230923
Somerset	288500	130500	178	1000000	0	0	0	0

Country/UA	OS grid ref		SQID	*Calluna* cover class (m^2)				
	east	north		0	1	2	3	4
South Yorkshire	425500	387500	88	569975	123767	112440	173895	19922
South Yorkshire	425500	392500	181	1000000	0	0	0	0
South Yorkshire & Derbyshire border	423500	387500	30	372375	135783	76139	282362	133341
West Yorkshire	404500	432500	65	557860	23917	0	0	418223
West Yorkshire	397500	421500	68	1000000	0	0	0	0
West Yorkshire	394500	433500	79	513938	214218	124464	142747	4633
West Yorkshire	401500	413500	84	1000000	0	0	0	0
West Yorkshire	393500	420500	91	1000000	0	0	0	0
West Yorkshire	400500	438500	94	512506	29968	0	58258	399268
West Yorkshire	401500	417500	153	815133	0	0	0	184867
West Yorkshire & Lancashire border	389500	423500	87	1000000	0	0	0	0

Appendix 2. Location of sample squares and API estimates. Historical imagery

Location of 1km sample sites and API estimates of *Calluna* and burn class extent: Historical imagery
See 2.4 for descriptions of cover classes Source 1= NRMC 2 = CCGIM Nat. Park archive
.n.b: figures corrected to 1km^{2} - max sample correction applied <1%

Country/UA	OS grid ref		SQ ID	source	Year		*Calluna* cover class (m^2)				
	east	north					0	1	2	3	4
Cumbria	368500	539500	37	1	1971		156959	0	106363	374568	362110
Cumbria	368500	539500	37	1	1948		155128	0	0	208227	636645
Cumbria	317500	498500	39	1	1972	*	984430	0	0	0	0
Cumbria	317500	498500	39	1	1945	*	719973	4118	0	0	204328
Cumbria & North'land border	367500	576500	96	2	1975		1000000	0	0	0	0
Derbyshire	405500	377500	44	2	1972		430627	46548	2850	0	519975
Derbyshire	417500	385500	101	2	1976		543735	34605	0	328666	92994
Durham	387500	524500	5	1	1972		0	0	0	1000000	0
Durham	387500	524500	5	1	1946	*	0	0	0	755710	0
Durham	400500	528500	23	1	1965	*	0	146178	245906	176992	109152
Durham	400500	528500	23	1	1946	*	72349	8525	94849	0	554486
North Yorkshire	487500	499500	1	1	1973	*	0	10402	442777	0	95616
North Yorkshire	487500	499500	1	2	1972		0	142139	245229	92073	520560
North Yorkshire	399500	479500	3	1	1971		751672	0	140889	57828	49611
North Yorkshire	391500	504500	18	2	1975	*	560100	0	0	0	352507
North Yorkshire	411500	457500	25	1	1973	*	1440	13844	73869	416860	6599
North Yorkshire	411500	457500	25	2	1974		122399	131562	116289	27288	602462
North Yorkshire	411500	457500	25	1	1952	*	59925	370272	89114	238911	220709
North Yorkshire	474500	511500	29	1	1972		335491	74604	198074	87072	304759
North Yorkshire	474500	511500	29	1	1946		249337	0	0	0	750663
North Yorkshire	461500	502500	34	1	1976		1227	189764	277081	207972	323955
North Yorkshire	461500	502500	34	1	1946	*	1305	0	99781	691907	0
North Yorkshire	388500	472500	36	1	1974		434053	0	0	0	565947
North Yorkshire	388500	472500	36	1	1946		487899	36983	0	0	475118
North Yorkshire	399500	458500	49	2	1974		174696	95985	0	109933	619386
North Yorkshire	467500	510500	58	2	1972		187154	81050	87168	67963	576664
North Yorkshire	461500	494500	72	2	1972		167311	220184	297824	261958	52723
North Yorkshire	459500	511500	83	2	1972		506408	41743	143780	308069	0
North Yorkshire	400500	497500	102	2	1975		656402	66939	116916	77545	82199
North Yorkshire	410500	453500	107	2	1974		366237	59245	92622	165860	316036
North Yorkshire	406500	477500	108	2	1975		746576	46989	69360	28445	108630
North Yorkshire	477500	496500	109	2	1972		533182	139745	44520	0	282553
North Yorkshire	399500	482500	111	2	1975		545758	8207	79151	11605	355279
North Yorkshire	451500	499500	124	2	1972		792999	76284	79211	36762	14744
Northumberland	391500	618500	4	2	1975	*	527922	0	0	0	221842

Country/UA	OS grid ref		SQ ID	source	Year		*Calluna* cover class (m^2)				
	east	north					0	1	2	3	4
Northumberland	386500	551500	17	1	1977	*	0	165488	241447	128345	28645
Northumberland	386500	551500	17	1	1951		84252	90069	588128	81011	156540
Northumberland	394500	625500	38	1	1980		443769	11512	337066	21575	186078
Northumberland	381500	602500	41	2	1975	*	757942	0	0	0	204565
Northumberland	403500	596500	56	2	1975		23735	344870	359328	217456	54611
Northumberland	387500	602500	62	2	1975		888652	31965	21080	19234	39069
South Yorkshire	425500	387500	88	2	1976		531699	70523	157957	215941	23881
South Yorkshire & Derbyshire border	423500	387500	30	1	1975		238665	166394	149094	349033	96814
South Yorkshire & Derbyshire border	423500	387500	30	1	1945	*	74343	7782	82677	69310	153736

* incomplete segments owing to some cloud cover: n.b. these are excluded from analysis in Table 4.2.1.1

ENGLISH NATURE

Research Information Note

English Nature Research Reports, No. 667

A history of burning as a management tool in the English uplands
1: Estimates of the areal extent of management burning in the English uplands

Report Authors: Dr Adrian R Yallop, Dr Graham Thomas Dr Jonathan Thacker, Mr Tim Brewer, and Dr Christophe Sannie

Introduction

Fire is regularly used as a management tool as a means of encouraging fresh growth of vegetation for livestock or red grouse. The practice is centuries old and comprises burning patches of vegetation during the autumn, late winter or early spring. The burns carried out as part of red grouse management are generally small and this is based upon grouse feeding and sheltering preferences. By contrast, agricultural burns tend to be much larger, sometimes several hectares in extent.

The vegetation that is subject to regular burning in the English uplands includes, grassland, heathland and blanket bog.

In recent years, concern has been raised over the influence that regular burning has upon vegetation, invertebrates, soil structure and hydrology, water quality and carbon storage. Many of the sites that are currently affected by burning are designated as being of international importance for nature conservation.

English Nature has been seeking to assess the impacts of burning management upon the English uplands. To date, a review of the existing literature relating to burning impacts has been completed and this project is intended to be the first of several that will begin to look in more detail at the relationship between burning and its impacts upon the English uplands.

What was done

A contract was let to determine whether aerial photography could be used to assess the scale and intensity of burning within the English uplands.

Results and conclusions

The study used aerial photographs from the periods 1943-52 and 1965-80 and for 2000. The study found:

- Visible evidence of burning was only found in relation to *Calluna* dominated communities.
- For the sites where there is visible evidence of burning, the proportional area in management is 38%.
- A typical range encompassing 50% of the sites surveyed indicates a variation between 20% and 63% although some sites exhibited higher levels of management.
- The typical area of burns range between 0.12 ha and 0.55 ha with a median value between 0.25 ha to 0.28 ha.
- The estimate of a return period using the historical photography is estimated at 16-20 years. However, there are many areas where considerably shorter return periods are implied by the proportional areas of visible management.
- The inclusion of photography covering the English National Parks shows that a significant increase in class 1 (ie most recent burn) between 1970 and 2000 is apparent within these areas.
- Burning of grassland was identified as being of regional importance but the scale is below that resolvable by a sample framework defined for the development of national estimates.

English Nature's viewpoint

Regular burning, whether part of grouse moor management or as part of livestock production, has shaped the open landscape typical of much of upland England and English Nature recognises the value of sympathetic burning regimes.

As the report states, certain difficulties arose during the investigation of the work that means the assessment of the history of burning practice at the level of the English uplands remains incomplete. As such, this work should be seen as a contribution to our knowledge rather than the definitive work and those with an interest in the subject matter are urged to explore these matters further.

Further information

English Nature Research Reports and their *Research Information Notes* are available to download from our website: www.english-nature.org.uk

For a printed copy of the full report, or for information on other publications on this subject, please contact the Enquiry Service on 01733 455100/101/102 or e-mail enquiries@english-nature.org.uk

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Front cover photographs:
Top left: Using a home-made moth trap.
Peter Wakely/English Nature 17,396
Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
Paul Glendell/English Nature 23,020
Main: Identifying moths caught in a moth trap at Ham Wall NNR, Somerset.
Paul Glendell/English Nature 24,888

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