Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	A and F

Study details	Authors	Adamson, JK and Kahl, J Changes in vegetation at Moor House within sheep exclosure plots established between 1953 and 1972 [Pt (summary) of long-term vegetation monitoring of the Hard Hill burning and grazing expt. At Moor House NNR all treated as one study.]
	Year	2003
	Aim of study	Monitor changes in vegetation within exclosure plots
	Study design	NRCT
	Quality score	1+ However, note evaluated with all other publications on the vegetation studies of the Hard Hill burning and grazing expt. at Moor House NNR and the study was classed overall as 1++. See the review report for more information on the other studies: Rawes & Williams (1973), Rawes & Hobbs (1979), Hobbs & Gimmingham (1980), Hobbs (1981), Hobbs (1984), Adamson & Kahl (2003)/Adamson pers. comm. (2004) to Stewart *et al*. (2004) and Lee *et al*. (2013).] [See also ET for Adamson & Kahl 2003.]
	External validity	EV+
Population and setting	Source population	North Pennines
	Eligible population	Range of upland vegetation types where the impact of removing grazing could be

		monitored. This included 4 blocks which were also subject to burning treatments
	Inclusion and exclusion criteria	Not stated
	Setting	Moor House National Nature Reserve
Methods of allocation to intervention/control	Methods of allocation	Not stated
	Intervention description	9 sites consisting of paired plots with one from the pair being fenced to exclude sheep and the other left open to allow free range grazing. I site consisting of four blocks containing paired plots, one fenced, one not and each sub divided to give 3 burn treatments
	Control/comparison description	Plots fenced to exclude any grazing
	Sample sizes	For burn plots, exclosures measures 90m x 30m, sub divided into 3, 30m x 30 m Other plots measured 30m x 30m , 21m x12m, 20m x 10m , 11m x 16m, 12m x 24m, 11m x 17m and 10m x 6 m
	Baseline comparisons	
	Study sufficiently powered	No statistic described in study, no power given, contributing studies referenced.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Full species list, number of hits on each species from pin frame, % of hits
	Secondary outcome	

	measures	
	Follow-up periods	Every few years-didnt state waht that was
	Methods of analysis	Not given in this report but contributing studies referenced
Results		Range of results to exclusion of grazing. High altitude deep peat sites showed largest response to exclusion with increased number of species, reduced bare ground and higher cover of some species compared with grazed plots.High altitude mineral sites saw an increase in *Deschampsia flexousa* in the fenced plots as is *Carex bigelowii* whilst *Festuca orvina* cover declined.
Notes	Limitations identified by author	The extent of reposnse to grazing pressure depends on intensity of grazing prior to exclusion. Caution required in interpretting results as only represent a comparison between adjacent plots as a single point in time.
	Limitations identified by review team	Differences in plot size.
	Evidence gaps and/or recommendations for further research	Paper identifies gaps and further research
	Sources of funding	

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	d) water quality/colouration.

Study details	Authors	ADAS [Also MAFF 2993.]
	Year	1997
	Aim of study	To map the extent of moorland burning in the North Peak ESA between 1988 and 1995 based on aerial photographic interpretation (API) as part of the ESA environmental monitoring programme. Mapping of the ‘core ESA’ was carried out by MAFF (1993) between 1988 and 1991 which was extended by ADAS (1997) between 1991 and 1995 within both the ‘core’ ESA and the 1993 extension areas. The accuracy assessment of the 1991–1995 API (ground-truthed for 230 burns at eight sites) revealed an overall mapping accuracy of 99%. Habitat maps were produced in 1988 and 1993 from a combination of API and ground checking. Overlaying maps of dry heath and ‘dry bog’ habitat and burning allowed examination of the pattern of burning in relation to habitat.
	Study design	2: aerial photographic interpretation of burning.

	Quality score	2++
	External validity	EV+
Population and setting	Source population	North Peak ESA
	Eligible population	Moorland in the North Peak ESA (census)
	Inclusion and exclusion criteria	NA
	Setting	North Peak ESA moorland (including 'dry bog' category)
Methods of allocation to intervention/control	Methods of allocation	NA
	Intervention description	Managed burning.
	Control/comparison description	NA, though unburnt areas included.
	Sample sizes	Census.
	Baseline comparisons	NA
	Study sufficiently powered	NA
Outcomes and methods of analysis (inc effect size, CIs for each outcome and	Primary outcome measures	Map of burning extent and distribution and summary statistics by broad habitat types.
	Secondary outcome measures	Accuracy assessment based on ground truthing a sample.

significance)	Follow-up periods	NA, though used 1988-95 aerial photos.
	Methods of analysis	Summary statistics.
Results		Within the original core ESA there was an increase in the number and area of burns and the proportion of 'heather moorland' burned annually (from 443 burns covering 179 ha in 1988/89 to 1,690 covering 490 ha between 1991 and 1995). Whilst the increase occurred on both ESA agreement land and non-agreement land, it was greatest on the former. Burning on the two heather-dominated habitat types, dry heath and 'dry bog' accounted for 93% of the total area of moorland burned from 1991 to 1995. Overall, similar proportions of dry bog (4%) and dry heath (3%) were burned annually (representing average rotations of 25 and 30 years including unburnt and unburnable areas).
Notes	Limitations identified by author	NR
	Limitations identified by review team	No data available post-1995.
	Evidence gaps and/or recommendations for further research	Repeat mapping to update change to cover more recent years.
	Sources of funding	MAFF

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	g) wildfire

Study details	Authors	Albertson *et al*.
	Year	2009/2010
	Aim of study	Albertson *et al*. (2009) developed a 'probit' model to assess the chance of wildfires at different times of yr, days of the week and under various weather conditions. Albertson *et al*. (2010) used the model to investigate the likely impact of climate change on the number of wildfires in the Peak District.
	Study design	2: model and correlation.
	Quality score	2+
	External validity	EV+
Population and setting	Source population	Peak District Moorland and weather records.
	Eligible population	NA
	Inclusion and exclusion criteria	NA
	Setting	Peak District moorland.

Methods of allocation to intervention/control	Methods of allocation	NA
	Intervention description	NA
	Control/comparison description	NA
	Sample sizes	Census
	Baseline comparisons	NA
	Study sufficiently powered	Census
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Frequency of wildfires in relation to weather scenarios.
	Secondary outcome measures	Frequency of wildfires in relation to broad moorland vegetation/habitat types taking into account area etc. Stakeholder opinion on wildfire frequency by vegetation type.
	Follow-up periods	NA. Future predictions.
	Methods of analysis	Probit model.
Results		The Peak District is expected to experience warmer, wetter winters and hotter dry summers. Simulations of likely future weather applied to the model suggest an overall increase in occurrence of summer wildfires. Little change in wildfire incidence was predicted in the near future, but as climate change intensifies, the danger of summer wildfires is projected to increase from 2070. Albertson *et al*. (2010) suggested, therefore, that fire risk management will be necessary in future. In addition, that "moorlands may have to be managed to reduce the chance of summer wildfires becoming catastrophic ... [and] management measures may include

		controlled burning, grazing or mowing to remove fuel." These studies include, but do not relate specifically to upland peatlands, nor does the model consider the effect of habitat/vegetation type and structure on fire risk/hazard and severity. Albertson *et al*. (2010) do, however, consider the effect of land management on vegetation and mention on the one hand the potential of managed burns to reduce fuel loading and on the other, the other the potential of reduced burning coupled with restoration such as rewetting to improve peatland resilience to wildfire.
Notes	Limitations identified by author	Lack of information on severity of wildfires (though suggested that area can be used as a proxy though not included in the study but could be modelled).
	Limitations identified by review team	Blanket bog with *Calluna* appears not to be separated from other 'heather moorland'. Results are for incidence of wildfire in relation to expected frequency by habitat. Although frequency is lower on heather moorland, which in the Peak District tends to be subject to managed burning, the direct relationship between managed burning (frequency, extent, burn types etc.) and associated activity (e.g. contributing to watching for and controlling wildfires) is beyond the scope of the study.
	Evidence gaps and/or recommendations for further research	See above.
	Sources of funding	Defra/EA/NW RDA.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	a) What are the effects of managed burning on the maintenance and restoration of the characteristic floristic composition, structure and function of upland peatland habitats? c) What are the effects of managed burning of upland peatlands on carbon sequestration and storage, either directly or indirectly through changes in vegetation composition and structure? d) What are the effects of managed burning of upland peatlands on water quality (including colouration, release of metals and other pollutants and aquatic biodiversity) and water flow (including downstream flood risk), either directly or indirectly through changes in vegetation composition and structure? e) How do differences in the intensity, frequency, scale, location and other characteristics of burns (including ‘cool burns’) affect upland peatland biodiversity and ecosystem services? N.B. This paper touches on elements of all these questions but is not a particularly good fit with any of them. It will provide partial answers

Study details	Authors	Allen S.E.
	Year	1964
	Aim of study	To look at what happens to nutrients found in heather during burning and how these are filtered through soils
	Study design	Lab study, case study?, review.

	Quality score	2++
	External validity	EV++
Population and setting	Source population	Kirkby Moor, near Ulverston and Moor House National Nature Reserve, Westmorland.
	Eligible population	Plant material from Kirkby Moor, near Ulverston and Moor House National Nature Reserve, Westmorland. Heather sampled from random positions (no explanation of how this was generated) within a circular area 400m in diameter at both sites Soils from Kirkby Moor, near Ulverston and Moor House National Nature Reserve, Westmorland, also a limestone wood near to Merlewood Research Station, Grange-over-Sands, Lancashire and agricultural land near Furness Abbey, Lancashire.
	Inclusion and exclusion criteria	Heather sampled from random positions (no explanation of how this was generated) within a circular area 400m in diameter at both sites Used heather only for burning, as '90% of the dry matter lost when most moors are burnt comes from heather'. Other studies show other species are similar to heather in chemical content.
	Setting	Upland moorland on clay mineral soils (<5cm peat), dominated by Calluna vulgaris, Nardus stricta and Vaccinium myrtillus (possible H12) and upland moorland on deep blanket peat dominated by Calluna vulgaris, Eriophorum vaginatum and Sphagnum spp (possible M19).
Methods of allocation to intervention/control	Methods of allocation	2 geographically distinct sites with differing soil profiles, mineral soil with a thin organic layer and on deep peat
	Intervention description	Nutrient content of Heather from heath vs bog

		Nutrient content of heather ash extracted using pure water vs rain water (mildly acidic) Comparison of nutrient content of heather ash burnt at 500°C vs 900°C Comparison of nutrient content of fresh heather, partially decomposed litter and fully decomposed litter Comparison of leaching rate of soils from Kirkby Moor and Moor House Comparison of nutrient content of leachates, having passed through the soil profile from Kirkby Moor and Moor House soils, also additional soils from limestone and sandstone. Comparison of amount of extractable nutrients at different depths in Kirkby Moor and Moor House soils
	Control/comparison description	?Controls would be unburnt heather?
	Sample sizes	samples of **200g fresh weight** heather : Extraction of nutrients from heather ash; nutrient release from fresh and decaying heather. Effect of burning at different temperatures (500°C or 900°C) on **25**g samples heather Known volumes of burnt or unburnt heather put on top of soil blocks, based on a maximum crop yield/unit area of 16000kg/ha Measured leachate from soil blocks of between 1000 ml and 5700 ml. Soil cores taken at 0-2cm, 2-4cm, 6-8cm and 15-18 cm
	Baseline comparisons	Comparisons are between burnt and unburnt heather
	Study sufficiently	Multiple replicates for all the various tests.

	powered	
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Measured K, Ca, Mg, P, in heather ash, comparing differences dissolved in pure water or rain water K, Ca, Mg, P and N in heather ash created at 500°C and 900°C K, Ca and P in fresh heather, partially decomposed litter and fully decomposed litter Rate of leaching ml/h through different soil types both burnt and unburnt. Amount of K, Ca, Mg and P left in leachate after moving through different soils again both burnt and unburnt Amount of extractable nutrients K, Ca, Mg, P, NH_4 and NO_3 at different depths of soil both burnt and unburnt Quantities of K, Ca, Mg and P retained by peat, clay, sandstone and limestone soils when treated with simulated ash extract Amount of K, Ca, Mg retained by fresh Sphagnum, heated Sphagnum and dead Sphagnum
	Secondary outcome measures	None
	Follow-up periods	None, N/A
	Methods of analysis	Standard deviations for individual values covering chemical, sampling and biological variation. These have not been published as tables would be too complex. All values claimed as real in text are significant with p=0.05 or less.
Results		In summary: mineral nutrients, particularly potassium, are readily dissolved from ash from burnt heather. The rate of solution is reduced if heather is burnt at a higher temperature. Soils tend to retain dissolved nutrients as rainwater leaches through, with

		organic and clay soils being more efficient than sandy soils. Sphagnum also retains dissolved nutrients. Over half the carbon, nitrogen and sulphur in heather is driven off in smoke. Any losses from the system can be restored from rainfall within a short period except on porous soils. Nitrogen may take longer, but microbial action might be important for this. • Potassium (K) is extracted from heather ash much more readily than other nutrients with 84% of K originally in heather taken up by rain water (Ca=29.6%, Mg=50.4% and P=54.4%). • All nitrogen is lost from heather burnt at either 500°C or 900°C. • For heather burnt at 500°C, most Ca, Mg and all K is retained in the ash. Burning at 900°C caused greater loss of nutrients except for Mg. • Partially decomposed heather releases nutrients (K and Ca) more quickly than either fresh or fully decomposed heather. • Addition of ash with large amounts of soluble nutrients did not generally cause significant increases in the amount of nutrients in leachate that had moved through the soil column. Burning did not appear to make much difference to the way nutrients were filtered through the soil. Fine ash washed into the top surface seemed to slow the movement of water. • Tests on soils showed that nutrients were held by litter and upper peat layers. Again there appeared to be no direct impact of burning on this. It appeared to be true for mineral soils with a thin organic layer and for deeper peats. Nutrients are held in the upper few centimetres of soil. • Burning raised the pH of soils both initially and after leaching with mildly acidic water.

		• Different soil types do appear to retain nutrients differently. Peat and clay soils retain nutrients. However sandstone soil lost K and did not gain Ca, Mg or P when treated with nutrient rich ash extract. Natural leaching following burning on sandy soil could lead to loss of nutrients. • Sphagnum was very efficient at retaining nutrients dissolved in water, with heated (up to 60°C) Sphagnum being nearly efficient as fresh Sphagnum. Dead Sphagnum was less efficient but did still hold nutrients. • Less than 1% of mineral elements appear to be lost in smoke, although burn temperature does have an impact with higher temperatures causing greater losses. However more volatile compounds carbon, nitrogen and sulphur are lost, again with greater losses at higher temperatures. Approx 70% of nitrogen is driven off and 50% of sulphur. 60.5% of carbon is lost in smoke from burning heather at 550-650°C and 67.5% of carbon is lost in smoke if burnt at 800-825°C. (It is not clear if this is a significant difference between these temperatures)
Notes	Limitations identified by author	Difficult to assess how much material e.g. in smoke would escape the moorland area in a natural burn. Wind strength and intense heat (from burn) which sets up ascending currents would contribute to this. Condensation in the vicinity of the fire is probable in field conditions. Most soils studied for this had high adsorption capacities, the results might vary more for soils of coarse structure.
	Limitations identified by review team	These are tightly controlled laboratory based results. Field based conditions and e.g. burn temperatures might be more variable. It seems unlikely that this would affect the overall results much.
	Evidence gaps and/or recommendations for further research	This is quite an old paper and therefore gaps may already have been addressed. Might be useful to look at what quantities of nutrients are actually removed in smoke, in field conditions. It seems likely that most are simply redistributed in the immediate

		vicinity? Might also be useful to look at how much microbial activity contributes to nitrogen input in a moorland system, presumably this will vary with different soil types.
	Sources of funding	Unclear, assumed funded by Nature Conservancy Council, although Hill Farming Research Organisation also provided advice and assistance with experimental work.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	b

Study details	Authors	Amar, Grant, Buchanan, Sim, Wilson, Pearce-higgins & Redpath
	Year	2009
	Aim of study	To explore whether changes in the abundance of five wader species in the uplands correlate with key hypotheses (including grouse moor management – incorporating burning) proposed for their declines
	Study design	Quantitative correlation
	Quality score	2++
	External validity	++
Population and setting	Source population	The paper categorises habitats as heather, bog, rough grass and acid grass, but the extent to which selected plot areas correspond with peat habitats rather than upland areas more widely is not reported.
	Eligible population	N/A
	Inclusion and exclusion criteria	Plots included in Sim et al (2005) study/presence of breeding waders

	Setting	Multiple geographic regions of UK – encompassing range of UK uplands
Methods of allocation to intervention/control	Methods of allocation	Data analysis undertaken on sub-set of plots used by Sim et al (2005) (N/R how subset selected)
	Intervention description	('grouse moor score' – extent of heather/grass burning)
	Control/comparison description	N/A
	Sample sizes	142 plots used in analysis (1,456km^2), distributed across 10 survey regions
	Baseline comparisons	Comparison of 1980-1993 wader survey data with 2000/2002 survey data
	Study sufficiently powered	Survey regions not randomly selected – chosen to represent widespread sample of upland Britain and most important areas for upland breeding waders
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	% per annum change in average number of species
	Secondary outcome measures	N/A
	Follow-up periods	Bird survey data originally surveyed 1980-1993 and resurveyed 2000/2002. Period between surveys 10-19 years
	Methods of analysis	Analysis at 2 spatial scales – to determine whether average per annum change on plots correlated with environmental covariates. Regional scale - Analysis using linear regression. Maximum sample size was 10, therefore no multiple regressions were possible and analyses were restricted to univariate tests. Plot scale – GLMM with 'region' as random term to incorporate lack of independence of varying plot numbers in different regions. This also aimed to control, to a degree, the difference in distance

		between transects and timespan.
Results		Regional scale analysis showed less intensive grouse moor management (decreased burn extent) was associated with greater declines in Lapwings at both the plot (*p=0.06*) and regional scale (near significant at *p=0.051*). However, a decline of 27% was still recorded in plots with the most intensive grouse moor management, suggesting this was not the sole variable contributing to the decline. Golden plover showed greater declines at the plot scale where grouse moor management was more intensive (in contrast to the predicted result).
Notes	Limitations identified by author	Current land use and habitat measures were used because measures over the period corresponding with bird data were unavailable Study considers a declining in grouse moor management, although acknowledges there have also been increases in some parts of northern England
	Limitations identified by review team	In the context of this review, the study considers grouse moor management as a whole, and does not separate the effect of burning from that of predator control Study identifies correlation, and not causality – eg confounding factors such as climate can not be excluded
	Evidence gaps and/or recommendations for further research	More detailed research into causality and mechanisms of wader decline
	Sources of funding	SNH

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	h) extent etc. of burning.

Study details	Authors	ANDERSON *et al*.
	Year	2009
	Aim of study	Development of models to test hypotheses about the factors influencing the distribution of a species of conservation importance, the hen harrier. As a minor part of this, they produced a 'burn intensity index' (as a measure of gamekeeper activity) and map based on the proportion of heather burnt within 10 km grid squares based on API mostly of 2005-2006 aerial photographic images (which is the only part directly relevant to the review).
	Study design	2: mapping burning intensity based on API.
	Quality score	2-
	External validity	EV+
Population and setting	Source population	UK moorland.
	Eligible population	UK moorland
	Inclusion and exclusion criteria	NA. Census at 10 km square level.

	Setting	UK moorland.
Methods of allocation to intervention/control	Methods of allocation	NA
	Intervention description	Burning identified on 2005-06 aerial photographic images.
	Control/comparison description	NA
	Sample sizes	Census
	Baseline comparisons	NA
	Study sufficiently powered	NR but census.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Burning intensity/extent as percentage of *Calluna*/10 km square in 5 classes.
	Secondary outcome measures	Map
	Follow-up periods	NA
	Methods of analysis	Mapped intensity/extent at 10 km square sscale.
Results		This indicated that in England, more intensive ‘strip burning’ of heather (on heath and bog) was largely restricted to the Pennines, Bowland, North York Moors and Northumberland, probably mainly on grouse moors.
Notes	Limitations identified by author	NR

	Limitations identified by review team	Resolution not very fine. Burn classes are not defined in terms of age since last burn and no information is given on any ground-truthing. Peatland not separated out from other ‘heather moorland’.
	Evidence gaps and/or recommendations for further research	
	Sources of funding	UK PopNet. Also used data from national hen harrier surveys (Country Conservation Agencies/RSPB).

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	**d)** What are the effects of managed burning of upland peatlands on **water quality** (including colouration, release of metals and other pollutants and aquatic biodiversity) and water flow (including downstream flood risk), either directly or indirectly through changes in vegetation composition and structure?

Study details	Authors	Armstrong, A., Holden, J. & Stevens, C. nd. The differential response of vegetation to gripblocking. Report to Noth Pennines AONB Partnership.
	Year	ND (2009)
	Aim of study	To determine some of the reasons for differences in revegetation so future grip blocking maximises vegetation growth, especially of peat-forming species. Included one (of seven) grips which had be burnt-over.
	Study design	Small-scale pilot correlation study. Reported to be "the first study which specifically examines, and attempts to explain, factors controlling vegetation response to blocking."
	Quality score	3-
	External validity	EV-
Population and setting	Source population	N Pennines blanket bog
	Eligible population	Allenheads grip-blocked blanket bog.

	Inclusion and exclusion criteria	One similar pair of grips with different response and five dissimilar grips in relation to size, vegetation and burning.
	Setting	Allenheads, N Pennines, England.
Methods of allocation to intervention/control	Methods of allocation	Blocked grips selected as above.
	Intervention description	Grip blocking.
	Control/comparison description	NA.
	Sample sizes	Seven blocked grips (only five in pt relevant to burning).
	Baseline comparisons	NR.
	Study sufficiently powered	NA.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Extent and composition of revegetation.
	Secondary outcome measures	Grip morphology and water geochemistry.
	Follow-up periods	NR.
	Methods of analysis	Simple summary statistics/box & whisker plots.
Results		"Recent burning notably influences geochemistry within the grip." The lowest pH and highest conductivity, DOC and colour were found in the burnt grip. "There is a positive relationship between DOC concentration and slope for all data, except grip 4 which was

		recently burnt. The same pattern is also reflected in the water colour data at all absorbances measured ...”
Notes	Limitations identified by author	Small sample size on one N Pennines blanket bog site.
	Limitations identified by review team	NR.
	Evidence gaps and/or recommendations for further research	NR. Repeat study at other sites esp. in relation to burning.
	Sources of funding	N Pennines AONB Partnership

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	d) water quality; and b) fauna.

Study details	Authors	ASPRAY
	Year	2012
	Aim of study	A PhD study of macroinvertebrate communities and ecosystem functioning in *peatland* streams. The overarching aim was to improve understanding surrounding the impacts of stressors to peatland streams and to contextualise this research with an improved knowledge of the dynamics of intact peatland streams. This included assessing the impacts of two catchment-scale drivers of change in peatland habitats (rotational heather burning and erosion) on stream ecosystems, examining physicochemistry, macroinvertebrates and ecosystem functioning across fifteen streams and examining gradients of sedimentation associated with environmental change and land management using streamside mesocosm and reach experiments.
	Study design	2: correlation studies.
	Quality score	2++
	External validity	EV+
Population and setting	Source population	The Pennines upland peatlands.

	Eligible population	Pennines blanket bog with rotational burning and erosion issues.
	Inclusion and exclusion criteria	Headwater streams were selected and catchments were classified as: (i) *intact* catchments, (ii) *eroded* catchments that are not actively managed, and (iii) catchments *burnt* by rotational heather burning.
	Setting	Fifteen Pennine study sites located across the North Pennines, Yorkshire Dales and the Peak Distinct.
Methods of allocation to intervention/control	Methods of allocation	As above: headwater streams were selected and catchments were classified as: (i) *intact* catchments, (ii) *eroded* catchments that are not actively managed, and (iii) catchments *burnt* by rotational heather burning (in yr prior to sampling).
	Intervention description	Burning (as part of the study relevant to the review).
	Control/comparison description	Intact catchments.
	Sample sizes	15 Pennine catchments. At each sampling reach bankfull width was measured at 10 evenly spaced cross sections along the reach length and depth measured at five intervals at each cross section.
	Baseline comparisons	NA
	Study sufficiently powered	NR. Relatively large sample of catchments with wide geographic distribution, though concentrated in the Peak District and North Pennines.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Benthic macroinvertebrate samples, where possible identified to species. Metabolism, re-aeration, primary production and decomposition.
	Secondary outcome measures	Contextual physiochemical variables: reach velocity, electrical conductivity, time of travel, average reach slope, water temperature, pH, median grain size, dissolved metals, major anions, nutrients, DOC and total organic carbon (TOC).

	Follow-up periods	
	Methods of analysis	Effects of the three catchment types on stream ecosystems were assessed using nested mixed effect general linear models (GLM). Analysis was completed using backward stepwise deletion to find the most parsimonious model. Species-habitat relationships were examined using multivariate ordination in CANOCO. A one way analysis of similarity (ANOSIM) test was also completed on transformed macroinvertebrate data to test the null hypothesis that differences in macroinvertebrate taxa between catchment classifications were not different to those within types. Relationships between species, functioning, and environmental variables were further considered with correlations between, macroinvertebrate community metrics, metabolism, algal biomass rates and decomposition rates (dependant variables) and environmental variables (independent) using Pearson's correlation coefficient. In addition, multiple linear regressions models were completed to consider overall relationships across sites regardless-of-catchment classification. For these models, contextual environmental variables were divided into five groups: catchment characteristics, organic matter, nutrient chemistry, major ions, and solutes, these were tested against dependent factors and only significant results are presented.
Results		Erosion, and to some degree rotational heather burning, were found to impact physicochemical variables, with total oxidised nitrogen (TON) and SSC displaying increased concentrations in impacted catchments. Associated shifts were found in macroinvertebrate communities, with amplified abundance in eroded catchments driven by increases in more sediment tolerate taxa, such as Chironomidae and Oligochaeta. Streams draining eroded and burnt catchments also displayed lower numbers of sensitive Ephemeroptera, Plecoptera and Trichoptera taxa. Functional parameters did not reflect these changes in chemistry and biota, but there were clear differences between the fifteen individual streams. It was concluded that "this body of research highlights peatland streams as unique and heterogenic systems but also as

		systems that are sensitive to anthropogenic stressors at both the catchment and reach scale. These habitats have intrinsic importance, supporting diverse macroinvertebrate communities, are significant for the modulation of carbon and are good indicators of the condition of the surrounding catchment. Thus, this work emphasises the need for restorative measures and sustainable management in peatland habitats that considers the streams they support. In addition, this work furthers knowledge of the baseline conditions in these systems and increases understanding of the use of functional processes as ecological indicators in peatland streams."
Notes	Limitations identified by author	
	Limitations identified by review team	
	Evidence gaps and/or recommendations for further research	
	Sources of funding	University of Leeds

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	d) water quality.

Study details	Authors	Beharry-Borg *et al*.
	Year	2009
	Aim of study	To report to Yorkshire Water on the socioeconomic implications of different land management policies in YW's catchments. The overall aim of the work package was to develop a land use decision model that helps better understand decisions of tenant and non-tenant farmers, and to model how alternative land use decisions affect water quality. Ultimately it will show the best ways to work with land managers in order to implement best practice. This included repeatedly surveying 27 stream sites across the Upper Nidderdale region in Yorkshire over a 12-month period.
	Study design	2: correlation study
	Quality score	2+
	External validity	EV-
Population and setting	Source population	Upper Nidderdale area, Yorkshire.
	Eligible population	Upper Nidderdale catchment.

	Inclusion and exclusion criteria	NR
	Setting	Upper Nidderdale catchment.
Methods of allocation to intervention/control	Methods of allocation	
	Intervention description	NA, study concentrated on the relationship with broad vegetation types (which are indirectly related to burning management).
	Control/comparison description	NA
	Sample sizes	27 sub-catchment sample points.
	Baseline comparisons	NA
	Study sufficiently powered	NR, but small sample size.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Water colouration and DOC.
	Secondary outcome measures	Concentrations of chemical solutes, soil types, landcover/vegetation and management by area.
	Follow-up periods	Survey over 12-month period, from 27 sub-catchment sample points.
	Methods of analysis	Median, mean, minimum and maximum concentrations/values for all chemical solutes were calculated for all the stream waters sampled over the course of the study. In addition median and mean values of all chemical solutes were calculated for each catchment. Prior to statistical analyses, all chemical response variables (DOC, C:C ratio, SUVA, NO3-N and PO4-P) were tested for normality and equality of variance. To explore

		the impact of soil types and land cover on DOC, C:C ratio, SUVA, NO3-N and PO4-P and SO4 concentrations in the Nidderdale AONB, multi linear regression (MLR) models were used. To obtain the simplest significant models for all chemical data, model reduction was achieved by stepwise regression. Moreover, stepwise regression was used to obtain the simplest model explaining DOC, C:C ratio, SUVA, NO3-N, PO4-P, and SO4. This was carried out for the vegetation characteristics and soil characteristics, separately. The relationship between physical catchment characteristics and catchment chemical characteristics within the Nidderdale AONB, the river Nidd, and the river Washburn has been analysed using Pearson (r) correlation.
Results		A significant positive relationship between the proportion of *Calluna* cover and DOC. The proportion of the catchment area burnt was associated with a change in the composition of DOC (reported as SUVA and also as a colour to DOC ratio). It was suggested that burning is associated with an effect on DOC.
Notes	Limitations identified by author	As there is a strong relationship between dwarf shrub vegetation and burning, it is difficult to disentangle which is having the largest influence on the composition (as indicted by the C:C ratio and SUVA) of DOC. Thus further process based research is required that investigates the relative importance of burning versus vegetation cover on the concentration and composition of DOC. Further work is also required to look at the impact of burning and drain blocking on DOC concentration and composition at the catchment scale.
	Limitations identified by review team	Small sample size.
	Evidence gaps and/or recommendations for further research	Extension of similar studies to other sites and further investigation of the relationship between dwarf shrub cover and burning on water colouration/DOC.
	Sources of funding	Yorkshire Water Ltd.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	

Study details	Authors	Benscoter *et al*.
	Year	2011
	Aim of study	Experimental alteration of soil moisture profiles of peat monoliths and laboratory burn tests to examine the effects of fuel type and depth-dependent variation in bulk density and moisture on depth of fuel consumption.
	Study design	1: lab study using peat monoliths. Including modelling.
	Quality score	1+
	External validity	EV-
Population and setting	Source population	A bog/fen site in Alberta, Canada.
	Eligible population	The study site.
	Inclusion and exclusion criteria	NR
	Setting	Athabasca Bog, Alberta, Canada. Suggested to be representative of ombrotrophic bogs

		of the region.
Methods of allocation to intervention/control	Methods of allocation	NR
	Intervention description	Ignition of sample peat 'pedons' (see below).
	Control/comparison description	Fuel condition compared to unburned horizons.
	Sample sizes	18 'pedons' (of surface peat c.60 x 40 cm and 20-30 cm deep), six of each of the three main vegetation types, extracted from the site. Two pedons of each type were assigned to each of three fuel moisture (drying) treatments.
	Baseline comparisons	NA
	Study sufficiently powered	NR
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Depth of burn.
	Secondary outcome measures	Effects of bulk density, soil moisture content and their interaction on peat combustion. Thermal diffusivity (rate of heat movement through the fuel horizon) calculated.
	Follow-up periods	
	Methods of analysis	Regression analysis. Thermodynamic fuel consumption model.
Results		Mean depth of burn varied across the three moisture treatments ($p = 0.003$), with the air-dried and oven-dried samples burning to a greater depth than the field sample. Depth of burn was not significantly different ($p = 0.05$) among fuel types. Ignition at the soil surface showed no significant difference ($p = 0.05$) in bulk density between successful and unsuccessful ignitions.

		Average surface volumetric water content for successful ignitions was significantly less than for unburnt samples ($p = 0.03$).
Notes	Limitations identified by author	NR
	Limitations identified by review team	
	Evidence gaps and/or recommendations for further research	
	Sources of funding	National Aeronautics and Space Administration (NASA) and Natural Sciences and Engineering Research Council of Canada (NSERC).

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	What are the effects of managed burning of upland peatlands on water quality (including colouration, release of metals and other pollutants and biodiversity) and water flow (including downstream flood risk), either directly or indirectly through changes in vegetation composition and structure?

Study details	Authors	Brown, L. Holden, J., Ramchunder, S. & Langton, R.
	Year	2009
	Aim of study	To compare aquatic invertebrate communities in headwater streams from an unmanaged catchment with those where controlled burning is used.
	Study design	Observational (correlation?)
	Quality score	2-
	External validity	EV-
Population and setting	Source population	Upland moorland headwater streams
	Eligible population	North Pennines AONB (1 site just outside boundary)
	Inclusion and exclusion criteria	Streams within catchments subject to managed burning, or within catchment with minimal grazing management and no burning

	Setting	Moor House NNR for unmanaged catchment, 3 sites within or on the edge of the North Pennines AONB
Methods of allocation to intervention/control	Methods of allocation	Streams of orders 1-4 within Moor House NNR; 2nd order streams for burnt sites but other selection criteria not specified.
	Intervention description	Managed burning – no details of intensity, elapse time, return time, burn area or proximity to streams, vegetation composition etc..
	Control/comparison description	Streams within the Moor House NNR where sheep grazing is limited to 0.6-1/ha and removed during winter. Report does not specify whether only data from 2nd order streams were used in this pilot study comparison but this is presumed to be the case.
	Sample sizes	3 x burn sites
	Baseline comparisons	Not specified for control sites. Either 3 x 2nd order streams or 10 streams of orders 1-4: presumed to be the former.
	Study sufficiently powered	No. Pilot study only.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Total abundance of invertebrates No. of taxa No. of individuals per taxon
	Secondary outcome measures	No.s of EPT taxa Berger-Parker index Relative abundance of individual taxa
	Follow-up periods	Single sample comparison – N/A

	Methods of analysis	Graphical output for each outcome as bar charts with 1 x SE bar provided – pilot study only
Results		Preliminary study: possible trends only: No difference between burnt & unburnt sites in total invertebrate abundance or taxonomic richness Significant differences in the abundance of individual species, with the following much less abundant in burnt sites: *Ecdyonurus dispar* (Mayfly), *Isoperla grammatica* & *Perlodes microcephala* (Stoneflies). Chironomidae & Simuliidae show a trend towards greater abundance
Notes	Limitations identified by author	None
	Limitations identified by review team	Pilot study with insufficient explanation of site selection criteria: the results are highly likely to be confounded by a range of unknown factors. Physical and management characteristics of burnt catchments are not defined at all and require careful standardisation to create a robust comparison.
	Evidence gaps and/or recommendations for further research	Include more comparable headwater streams in catchments with burning. Provide accurate multivariate data to characterise the physical and management characteristics of treatment sites (including soil types, i.e. are they all on primarily peat soils?), including as far as possible historic data on burning, spatial pattern of burning, burn characteristics, general vegetation characteristics (including bare peat), grazing regime etc. Published studies suggest that changes in hydrological flow paths in catchments with intensive burning may cause sediment changes to the stream bed – providing physical characterisation of this as part of the multivariate environmental data would enhance

		the explanatory power of the study. Sample on more than one occasion.
	Sources of funding	North Pennines AONB Peatscapes Partnership

As part of a larger project, Brown et al. (2009) undertook a pilot study to compare the aquatic invertebrate communities of three 2nd order streams in upland moorland catchments subject to controlled burning with those of the Moor House NNR catchment, which has minimal grazing management and no burning. Five quantitative samples were taken in September 2007 at each location. Data were pooled to provide estimates of total invertebrate abundance, taxonomic richness and the relative abundance of individual taxa, which were identified to species-level as far as possible. Identification was validated externally.

Results are presented as a series of bar charts with standard errors. There is preliminary evidence that although burning does not appear to affect the total abundance of invertebrates or their taxonomic richness it may be detrimental to some species; this is exemplified by the scarcity of the Mayfly *Ecdyonurus dispar* and the Stoneflies *Isoperlodes grammatica* and *Perlodes microcephala* in streams from catchments with controlled burning.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	What are the effects of managed burning on the maintenance and restoration of the characteristics floristic composition, structure and function of upland peatland habitats?

Study details	Authors	Burch, J.
	Year	2008
	Aim of study	To identify a simple & reliable indicator as to when the optimum balance between moorland regeneration and biomass accumulation has been reached as a trigger for optimal burn management, using bryophyte regeneration as the indicator of habitat recovery.
	Study design	Correlation
	Quality score	2-
	External validity	EV-
Population and setting	Source population	North Yorkshire Moors upland moorland
	Eligible population	NVC types H12a (dry heath) and M16d (wet heath)
	Inclusion and exclusion criteria	Sites chosen for their equivalent slope, altitude and aspect and with Calluna of different ages in close proximity (no details provided of any of the criteria for inclusion). Areas

		with degenerate Calluna excluded. One wet site had two very different stands types, both of which were typical and therefore included. Plots were chosen from sites burnt 1, 3, 5, 7, 10, 15, 20 and 25+ years ago (no details on source of burn dates).
	Setting	Spaunton Moor. NVC types H12a (4 sites) & M16d (3 sites).
Methods of allocation to intervention/control	Methods of allocation	Sites selected for comparability of slope, altitude and aspect (no details provided) NVC stands chosen as 'typical' but appropriateness of this to the site not discussed. Burn ages presumed to provide the best range available but no details provided regarding source of dating. No rationale or method provided for selecting locations of plots for quantitative sampling. All quantitative samples located systematically within the same $4m^2$. Transects for community description located to avoid edge effects but no details of rationale/method provided
	Intervention description	Aka burns of differing ages, allocation rationale not provided.
	Control/comparison description	Comparative response of dry heath (H12a) versus wet heath (M16d) in the following measures: Density of bryophyte shoots (selected species) in relation to canopy height across burn types Canopy height among burn classes Bryophyte community composition – as defined by NVC type and/or burn class
	Sample sizes	4 replicates for H12a for 8 burn age classes 3 replicates for M16d burn classes 3, 7 & 25+ yrs; 2 replicates for 5, 15 & 20 yrs; 1

		replicate of 10yr burn 8 quantitative samples from each plot (replicate area) from 1 x 4m^2 area 3 transects for species data per plot
	Baseline comparisons	N/A
	Study sufficiently powered	Low replication and missing burn category reduces power of the analysis substantially. No power analysis as such. Poor description of analytical approach undermines the value of the results section.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Density of bryophyte shoots Canopy height (needs clarifying - vascular canopy or specifically Calluna?).
	Secondary outcome measures	Classification of bryophyte communities.
	Follow-up periods	N/A
	Methods of analysis	Spearman's rank correlation Friedman's test of medians TWINSPAN for species composition data
Results		Strong -ive correlation for canopy height with *Camplyopus introflexus* and *Sphagnum* spp. up to 25 & 30cm on dry and wet heath, respectively. Strong +ve correlation for canopy height with *Hypnum jutlandicum* to ca. 50cm There is moderate evidence that the bryoflora is mature when the canopy is 41-54cm. There is moderate evidence that canopy height represents a wide range of ages and

		developmental stages of Calluna.
Notes	Limitations identified by author	None
	Limitations identified by review team	This study if fraught with sampling problems none of which are tackled adequately. Multiple issues regarding a lack of justification/rational for site selection, choice of NVC types and relevance; biased plot & transect selection; confounding historic and current management factors (e.g. grazing); potential sources or error in the data; suitability and limitations of the analyses; limitations to the interpretation of data. Assumes that bryophytes are an adequate surrogate for the entire floristic community Too many sources of subjectivity make this a weak study.
	Evidence gaps and/or recommendations for further research	Study may have wider application but would have to be repeated using a well-justified sampling methodology and statistically rigorous design which would enable a much more powerful analysis to elucidate the validity of the biometric/structural surrogate for biomass accumulation.
	Sources of funding	NE?

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	

Study details	Authors	Chambers *et al*.
	Year	2007
	Aim of study	To chronicle the palaeoecology of *degraded blanket mire* in Wales to provide an understanding of various factors in mire degradation and the implications for conservation management.
	Study design	3: paleological case-studies.
	Quality score	3+
	External validity	EV+
Population and setting	Source population	Peatland sites with previous palaeoecological studies in Wales.
	Eligible population	Two upland, modified peatland study sites.
	Inclusion and exclusion criteria	Criteria for sample location within sites: peat profile of at least 0.25 m depth; reasonably flat ground; and vegetation exhibiting degradation manifested by one or more of: high predominance of graminoids, poor representation of ericoid sub-shrubs, and low bryophyte (especially *Sphagnum*) cover.

	Setting	Hirwaun Common, NW of Aberdare, S Wales and Mynydd Langatwg, N of Brynmawr, mid-Wales. One an NVC community M25 *Molinia* mire on relatively shallow (<50 cm) peat and the other M18 *Calluna-Eriophorum* blanket mire. It was noted that many European blanket mires are degraded and contain few Sphagna with more than half exhibiting symptoms of degradation in Wales.
Methods of allocation to intervention/control	Methods of allocation	NA. See above re sample selection criteria.
	Intervention description	NA
	Control/comparison description	NA
	Sample sizes	1-3 monoliths/site.
	Baseline comparisons	NA
	Study sufficiently powered	NR, but case-studies.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Pollen diagrams, macrofossil zone diagrams/tables.
	Secondary outcome measures	
	Follow-up periods	NA.
	Methods of analysis	Descriptive diagrams, tables and text based on range of palaeoecological techniques comprising plant macrofossil analysis, charcoal analysis, spheroidal carbonaceous particle (formed from high-temperature combustion of fossil fuels) analysis, pollen analysis, radiocarbon dating and

		determination of peat humification. No statistical testing.
Results		The data collected suggested a major vegetation change which post-dated the start of the industrial revolution. There was evidence for increased burning activity, but as this was not evident in all profiles it was suggested that this was unlikely that fire was the principle or sole agent in vegetation change. Rather, increased atmospheric input, plus a change in grazing pressure, may have been responsible. The overwhelming dominance of *Molinia* at one site and local dominance of *Calluna* at the other was considered unprecedented. Millennial-scale dominance of Autin's bog-moss *Sphagnum austinii (imbricatum)* characterises the earlier record with its demise and that of round-leaved sundew *Drosera intermedia* took place in historical times. Thus, both sites show floristic impoverishment within the 20th Century, with recent single species dominance. The authors, therefore, suggested that conservation management to reduce the current pre-eminence of *Molinia* would not run counter to long-established dominance, so in cultural and historical terms can be fully justified. Potential intensive restoration techniques include use of herbicides, mechanised destruction of long-established *Molinia* tussocks, and re-seeding with *Calluna vulgaris* (Anderson *et al*. 2006, above). It was suggested that the best prospects for wider success in South Wales would involve modifying grazing regimes to reduce the prevalence and intensity of sheep grazing, and encourage instead lighter grazing by cattle; reducing burning and atmospheric pollution; and combating gullying to maintain hydrological integrity.
Notes	Limitations identified by author	NR
	Limitations identified by review team	Data restricted to two sites in Wales (although similar data is available more widely in the GB uplands, but often is not interpreted in the context of current management issues.
	Evidence gaps and/or recommendations for	Perhaps the collation of data from similar studies more widely in the GB uplands.

	further research	
	Sources of funding	CCW.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	How does the interaction of managed burning and grazing affect upland peatland diversity and ecosystem services?

Study details	Authors	Chapman, D.S., Termansen, M., Quinn, C.H., Jin, N., Bonn, A., Cornell, S.J., Fraser, E.D.G., Hubacek, K., Kunin,W.E. & Reed, M.S.
	Year	2009
	Aim of study	To design and apply a model incorporating reciprocal feedback between ecology and management as a means of exploring the response of upland vegetation to external policy and climate change
	Study design	Correlation - modelling
	Quality score	2-
	External validity	EV-
Population and setting	Source population	Peak District National Park unenclosed upland moorland
	Eligible population	71 management units (MUs) representing 40% of eligible area
	Inclusion and exclusion criteria	Availability of management data resulting from a structured questionnaire.

	Setting	Dark and South-West Peak District, mostly ESA
Methods of allocation to intervention/control	Methods of allocation	MUs divided into contiguous 100x100m cells within which empirical data are available for vegetation & environment. Each MU has a management strategy associated with it, defined by sheep grazing regime, burning management and labour costs.
	Intervention description	Dwarf shrub component of the vegetation is burnt when sufficient cover present. Dwarf shrub age stage is defined by time since burn. Grazing impact varies according to vegetation composition, stock density, and by application of the Hill Grazing Management model to dwarf shrub utilisation. Vegetation dynamics are affected by suitability of the local environment (cell-by-cell basis), the growth phase of Calluna, and relative inter-specific competitiveness. Management is constrained to strategies in place in 2005 and applied probabilistically. Stochasticity is incorporated.
	Control/comparison description	- Fixed grazing in summer or winter, with all other management strategies (burning, other grazing regimes) equally available. - Managed burning or no burning (all grazing regimes permitted alongside) - Fixed or flexible management strategy imposed - Fixed incremental increases to temperature up to the current maximum (to keep variables within reliable ranges), which modifies vegetation dynamics.
	Sample sizes	10 x 500yr simulations per comparison
	Baseline comparisons	Outcome from 500yr run using current management strategies only
	Study sufficiently powered	Assumed so from evidence presented. Statistical comparisons of selected outcome presented.

Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Area of dwarf shrub, bracken, graminoids and bare peat (at specific time). Relative abundance of dwarf shrub growth phases Density of sheep grazing in winter & summer Area of dwarf shrub burnt per annum Proportion of productivity grazed
	Secondary outcome measures	Sensitivity of different vegetation types & bare peat to model parameters Relationship between annual change in dwarf shrub area and the proportion of productivity biomass grazed (U) for different dwarf shrub habitat qualities (Q) Contour plot showing threshold U above which dwarf shrub cover declines for different Q and proportion of bracken (at pre-set inter-specific competitiveness) Time trend and equilibrium community composition under specific simulation scenarios Changes in the cover of individual vegetation types & bare peat with increasing temperature.
	Follow-up periods	All simulations run to 500 yrs
	Methods of analysis	Sensitivity analysis for cover of vegetation types and bare peat to model parameters ($P < 0.05$ for 2/32) Means and ranges illustrated graphically for the response of area of each vegetation type & bare peat to temperature increases, contrasting burn strategies with fixed or flexible management.
Results		Current management strategies will enable dwarf shrub cover to increase to 110% of 2005 after ca. 100yrs. Approx. 5.6km^2 of dwarf shrub will be burnt annually favouring the building phase of

		Calluna. The model was most sensitive to: the max. increase in cover from dwarf shrub with no grazing; susceptibility to grazing; competitiveness of bracken; noise; and the vigour of degenerate dwarf shrub. Dwarf shrub is sensitive to over grazing and management adapts to this Dwarf shrub is most favoured by longer-term management Warmer temperatures are likely to reduce dwarf shrub cover and increase bracken. Responses are non-linear for graminoids and bare peat, with the biggest expansion occurring at high temps. If burning is banned (but irrespective of fixed or flexible management). Dwarf shrub cover is maximised with burning and management fixed to the current strategies. Even if burning is not banned the loss of dwarf shrub at higher temperatures causes a reduction in burning intensity such that most dwarf shrub is in the degenerate phase. The interactions between management and vegetation dynamics have an important influence on the cultural landscape.
Notes	Limitations identified by author	Relative simplicity of some aspects of the model such as: movement behaviour of sheep; absence of plant physiological responses; social factors; effects of habitat on dwarf shrub ageing; short term nature of management data. Model does not account for other potentially important allogenic factors influencing upland moorland change such as N-deposition, wild fire, gully blocking.
	Limitations identified by review team	Failure of vegetation categories to discriminate ‘white moor’ among non-peatland graminoid vegetation cover, dwarf shrub is equated entirely to Calluna: these two factors limit more direct application to the south west in particular.

		all vegetation types with significant dwarf shrub are assumed to behave in the same way in terms of the model parameters. Limited to sheep grazed areas unless adequate data are available for more complex multi-species grazing scenarios.
	Evidence gaps and/or recommendations for further research	Modifications to the model to incorporate cattle, ponies and potential combinations of grazers; substitution of sub-classes for graminoid cover to enable the model to be applied to Molinia grassland, with some consideration of burning strategy for this. Exploration of the 'maximising utility' scenario.
	Sources of funding	Rural Economy and Land Use Programme research project.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	d) water quality/colouration.

Study details	Authors	Chapman *et al*.
	Year	2010, 2011
	Aim of study	A comparsion the spatial and temporal variability of water colouration for fifteen watercourses in the How Stean catchment in Upper Nidderdale, in the Yorkshire Dales, in 1986 and 2006/7. A small part of the study considered the impact of burning.
	Study design	2: correlation study (burning only a part of the overall study). Burning determined by API expressed as a percentage of each i km square burnt.
	Quality score	2-
	External validity	EV-
Population and setting	Source population	How Stean catchment, Upper Nidderdale, Yorkshire.
	Eligible population	How Stean catchment.
	Inclusion and exclusion criteria	NR
	Setting	How Stean catchment, Upper Nidderdale, Yorkshire.

Methods of allocation to intervention/control	Methods of allocation	NA
	Intervention description	Burning etc.
	Control/comparison description	NA
	Sample sizes	In 1986, stream water samples were collected approximately every 2 weeks between 1st March and 24th November from the 15 How Stean subcatchments (and the catchwater aqueduct inflow to Scar House reservoir). In 2006/2007, the How Stean sub-catchments and the Scar inflow were sampled monthly between May 2006 and April 2007. In addition, samples were collected on two occasions in October in an attempt to determine peak water colour.
	Baseline comparisons	NA
	Study sufficiently powered	?
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Water colouration/DOC
	Secondary outcome measures	pH
	Follow-up periods	1986, 2006-07.
	Methods of analysis	Similarities in water colour between individual sub-catchments in 1986 were explored by correlation analysis. The results of these correlations indicated two distinct groups of sub-catchments and subsequently repeated measures ANOVA was used to determine whether there was a statistically significant effect of catchment type on mean monthly water colour in both years of sampling. Relationships between mean annual water colour in 2006 and catchment attributes were examined by correlation analysis.

Results		Water colour increased in all sub-catchments between 1986 and 2006/07, but there was considerable variability in the increase, which ranged from 22 to 155%. Although the study did not set out to investigate the effect of burning (Holden *et al*. 2012), six of the sub-catchments were intensively managed by burning in both 1986 and 2006, five were not burnt over the twenty year period and four were not managed for grouse in 1986 but had very small (<4%) areas of burning occurring post-2000. Despite this variation in burn management, no relationship between burning management and increase in water colour was apparent. However, the method used to determine the extent of burning and the fact that it did not separate out recent burning was critisised by Yallop *et al*. (2011; also see Chapman *et al*. 2011 in response). For the catchments that were not managed by burning over the 20-year period, water colour increased between 22 and 117%, whereas for the catchments that were consistently managed by burning, water colour increased by 37-123%. Hence both types of catchments displayed a wide variation in the increase in water colour over the 20 yr suggesting that factors other than burning, such as interactions of decreases in sulphate deposition with different soil types were more important in controlling the variability in water colour increase in these catchments.
Notes	Limitations identified by author	In many upland catchments in the UK, peat dominates the upper plateaus whereas organo-mineral soils predominate on the slopes. These organo-mineral soils are likely to have a large influence on the amount and composition of DOC reaching UK upland surface waters and, therefore, warrant further investigation given that the results from this study suggest that it is the catchments with a larger proportion of flow coming from the mineral horizons that have shown the largest increase in water colour over the last 20 years. Without a better understanding of the processes controlling DOC retention and release within organo-mineral soils, it is not possible to predict or model the future trajectory of DOC change and hence water colour, and its subsequent impact on drinking water treatment and quality, freshwater biota and the carbon cycle.

	Limitations identified by review team	However, the method used to determine the extent of burning and the fact that it did not separate out recent burning was critisised by Yallop *et al*. (2011).
	Evidence gaps and/or recommendations for further research	Extension of similar studies to organo-mineral soils.
	Sources of funding	Yorkshire Water Ltd, NERC, RELU.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	b) What are the effects of managed burning on the maintenance and enhancement of the characteristic fauna of upland peatlands either directly or indirectly through changes in vegetation composition and structure? c) What are the effects of managed burning of upland peatlands on carbon sequestration and storage, either directly or indirectly through changes in vegetation composition and structure?

Study details	Authors	Chen Y., McNamara N.P., Dumont M.G., Bodrossy L., Stralis-Pavese N., Murrell J.C.
	Year	2008
	Aim of study	To compare the impact of regular, frequent burning and non-burning, and removal of Calluna vulgaris on the diversity and activity of methanotrophs (methane metabolising bacteria).
	Study design	Case control trial?
	Quality score	2++
	External validity	EV+
Population and setting	Source population	Moor House National Nature Reserve, North Pennines, England
	Eligible population	Known burn history either unburnt since 1954, or burnt frequently 1954, 1964, 1974,

		1984, 1994 and 2006, from replicate blocks (A-D), four soil samples from each of four replicate blocks.
	Inclusion and exclusion criteria	Sampled within 30mx30m exclosures either unburnt since 1954, or burnt approximately every 10 years since 1954
	Setting	Upland blanket peat (up to 4m depth) on gentle eastern slopes.
Methods of allocation to intervention/control	Methods of allocation	Samples from plots with well documented management history either unburned for more than 50 years or burned approximately every 10 years for 50 years.
	Intervention description	Frequent, regular burning compared to unburnt Calluna dominated vegetation over soils, compared to soils where Calluna was completely removed, roots and all, described as 'barren'
	Control/comparison description	Differences in methanotroph diversity and activity in unburnt or frequently burnt soils , also vegetated or unvegetated soils
	Sample sizes	Four replicate plots for both burnt and unburnt x 4 soil cores (5cm x 5cm x 30cm depth). Soil cores divided into 5cm depths. 4 samples, per block, per depth. Soils from same depth combined and homogenized. Also 10 soil monoliths (25cm width, 50 cm length, 30cm depth) from unburnt area. 5 had all Calluna removed, including roots. Soil cores as above taken from each monolith. Soils from each treatment, for each 5cm depth combined.
	Baseline comparisons	None
	Study sufficiently	At least 16 replicates of each treatment burned or unburned.

	powered	
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Tested for pH and water content on all soils Tested the potential CH_4 oxidation capacity of the different soils at different depths. Methanotroph community structure was measured Total bacterial diversity was also measured
	Secondary outcome measures	None
	Follow-up periods	None
	Methods of analysis	Soil moisture measured by incubating 5-g soil samples at 85°C until constant weight observed. Soil pH measured by mixing 1g soil with 10ml of distilled water. CH_4 oxidation potential measured by incubating 5g soil from each depth with 1%(v/v) CH_4 in 120 ml serum vials (performed in triplicate). Disappearance of methane was followed by measuring its concentration by gas chromatography using flame ionization detector every 6-13 hours over 5 days DNA extracted with FastDNA SPIN kit for soil. DNA extracted in duplicate from homogenized soil, eluted with 100-µl elution buffer, pooled (200µl) and kept at -80°C 341f_GC/907r primers used to amplify bacterial 16S rRNA genes for analysis by denaturing gradient gel electrophoresis (DGGE). DGGE performed using Bio-Rad D-Code system with 6% (w/v) polyacrylamide gels containing 40-70% denaturant gradient. After electrophoresis gels were stained with SYBR Green for 60 min before photographing, DGGE fingerprints were compared using the GelCompar II programme.

		pmoA microarray analyses looks at encoding the potential active site of particulated methane monooxygenase (pMMO). Real-time PCR quantification of pmoA genes from Methylocystis/Methylosinus group was carried on an ABI 7000 real-time PCR system. **Potential CH_4 oxidation activity and pmoA copy numbers for vegetation and unvegetated soils were subjects to statistical analyses. Test of mean (Student's t-test) and variance (F-test) were performed using Excel.**
Results		The pH and water content of the soils whether burnt, unburnt, vegetated or barren were found to be broadly similar. The most active region for CH_4 oxidation capacity for most soils was 5-10cm depth. 2 of the 4 unburnt samples were most active at 10-15cm depth. The measured CH_4 oxidation potential was ~25µmol g^{-1} day^{-1}. No differences found between burnt or unburnt treatments. Type II methanotrophs were most abundant in all soil samples, however using a variety of tests showed that relative abundance of certain type I methanotrophs was higher in unburned treatments. Total bacterial diversity is similar in all soils, however there was some separation of burned and unburned treatments. This was also compared with nearby grass dominated soils and this suggested a correlation between bacterial community profile and plant cover. Removal of Calluna vegetation decreased the CH_4 uptake potential. Potential CH_4 oxidation activity of soil with Calluna was significantly (α=0.01) higher than when

		Calluna had been removed. Vegetated soil had about 5 times higher bacteria/methanotroph than non-vegetated soil. Both vegetated and non-vegetated soils had similar community make –up of methantrophs, again dominated by type II methanotrophs.
Notes	Limitations identified by author	Further work to look at the niche occupied by Type I methanotroph species in the soils which are highly dominated by Type II methanotroph species could be investigated using more sensitive methods. Primers used in real-time PCR which only target a subset of type I methanotrophs may underestimate the total diversity and mask subtle differences present between treatments. Further work may be needed to determine the exact role of Calluna in CH_4 oxidation.
	Limitations identified by review team	A strength might be the known history of the burnt sites, but this frequency of burning, every 10 years on deep peat seems quite harsh. It would be interesting to look at the methanotroph diversity under burns of different ages, although it might be harder to establish the long term history on the site, as is available here. I am not quite sure what they have proved by removing all Calluna roots and all. This does not seem to equate to anything that might be likely in real life. Even if all Calluna is removed from the system it would normally be replaced by something?
	Evidence gaps and/or recommendations for further research	Further detailed analyses with more sensitive techniques are needed to identify the subtle changes caused by frequent burning management. More systematic sampling to investigate the seasonal effects on methane oxidation of soils after burning. Investigate potential effect of burning on methanogen populations and the associated effects on methane production.

		Possibly look at how methanotroph communities vary in deep peat under different vegetation types. Is there a difference between dry modified bog dominated by Calluna, a wetter bog with abundant Sphagnum and a bog dominated by Eriophorum? Possibly even the community on deep peat in the lowlands that is now being used for intensive agriculture?
	Sources of funding	Funding from: Centre for Ecology and Hydrology Q1 Carbon Catchment Research Programme, and Dorothy Hodgkin Postgraduate Award through University of Warwick.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	What are the effects of managed burning of upland peatlands on carbon sequestration and storage, either directly or indirectly through changes in vegetation composition and structure?

Study details	Authors	Clay, G.D. & Worrall, F.
	Year	2011
	Aim of study	To investigate the biomass and carbon losses during a moorland wildfire.
	Study design	Observational
	Quality score	2+
	External validity	EV+
Population and setting	Source population	Peak District
	Eligible population	Moorland near Edale, Peak District. Study site = burnt area of 10 ha and surrounding unburnt vegetation. Vegetation dominated by heather, bilberry, and cotton grasses with area of *Sphagnum* spp, on **peat** soils.
	Inclusion and exclusion criteria	None
	Setting	Moorland near Edale, Peak District.

Methods of allocation to intervention/control	Methods of allocation	None
	Intervention description	Wildfire – burnt for 3 days covering 10ha.
	Control/comparison description	Control was surrounding vegetation – no area defined.
	Sample sizes	65 quadrats (42 burnt, 23 unburnt)
	Baseline comparisons	N/A
	Study sufficiently powered	Only data from one wildfire reported.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Pre- and post-burn biomass and carbon. Black carbon production
	Secondary outcome measures	None
	Follow-up periods	Data collection carried out three weeks after the fire.
	Methods of analysis	N/A as no analysis.
Results		Shrubs and grasses occupied c. 46% and 33% respectively in unburnt sections. Similar areas were occupied by char and exposed soil in burnt sections. Moss (including Sphagnum) occupied similar % of area (c. 5%) in both burnt and unburnt areas – suggesting little affected by fire (suggests in low temp fires it merely dries out rather than burning). Carbon concentrations for different vegetation types are given.

		Mean pre-burn biomass was 344 +/- 189g m^{-2} and pre-burn carbon was 170+/-96 gC m^{-2}. Approx 86% of biomass and carbon lost as a result of the fire (range 100% - 53% depending on how severe burn was). In some areas up to 50% of biomass survived (unburnt or slightly charred). Mean black carbon production (BC/CC) was 4.3+/-2.3% gC m^{-2}. Includes analysis of wildfire size distribution in National Park between 1976 and 2004. Mean wildlife size = 670m^2 (range 1m^2 – 5.5km^2). Average area burnt in wildfires each year = 1.2km^2. 9.3-18.6km^2 burnt each year in total (managed and wildfire).
Notes	Limitations identified by author	Since this study considered effects of a wildfire, the location could not be predicted and therefore it was not possible to have baseline pre-burn biomass and carbon levels; instead the study had to rely on values from non-burnt vegetation nearby.
	Limitations identified by review team	
	Evidence gaps and/or recommendations for further research	Need to understand the spatial variability of fire severity/intensity, to understand effects on char production and on seed banks (and thus need for targeted regeneration work), and to understand more about the factors that influence the fire severity.
	Sources of funding	

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	What are the effects of managed burning on upland peatlands on carbon sequestration and storage, either directly or indirectly through changes in vegetation composition and structure?

Study details	Authors	Clay, GD, Worrall, F and Rose, R
	Year	(2010)
	Aim of study	To measure or estimate all the carbon pathways for areas under managed burning and grazing to make estimates of carbon budgets under burning and grazing regimes.
	Study design	Modelling using Moor House data including from the Hard Hill expt (RCT)
	Quality score	2++
	External validity	+
Population and setting	Source population	Blanket bog at Moor House National Nature Reserve.
	Eligible population	Hard Hill experimental plots
	Inclusion and exclusion criteria	Utilised factorial experimental plots subject to a range of grazing and burning treatments since 1954.

	Setting	Upland blanket bog in a North Pennines NNR. Vegetation type M19b.
Methods of allocation to intervention/control	Methods of allocation	Factorial experiment design laid out in 1954.
	Intervention description	This experiment utilised unburned (since 1954), 10yr and 20yr burn for both grazed and ungrazed (since 1954) plots.
	Control/comparison description	No burning since 1954, no grazing since 1954, no burning or grazing since 1954.
	Sample sizes	Management combinations duplicated. 3 dipwells in each plot sampled monthly for 33 months for unburned and 20 yr burn treatment. 10 yr burn treatment sampled 1 yr before and after burning in February 2007. CO_2 measured in gas collars x2 per plot October 2006 then x3 per plot from Spring 2007.
	Baseline comparisons	n/a – no data about pre 1954 conditions (but reference to source paper).
	Study sufficiently powered	n/a
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Depth to water table in dip wells (monthly readings) CO_2 concentration in gas collars (minimum readings monthly) DOC concentration Environmental Change Network data (Trout Beck catchment) gave discharge, air and soil temperature, rainfall, solar radiation.
	Secondary outcome measures	Particulate Organic Matter (estimated from companion study) Dissolved CO_2 Surface exchange of CO_2

		Respiration Primary Productivity Rainfall Carbon Methane Carbon Budget
	Follow-up periods	n/a
	Methods of analysis	Method of carbon budget calculation described in paper.
Results		All treatments were net sources of carbon ranging from 62 to 206 gC m^{-2} yr^{-1}. Unburned sites were on average a source of 156.7 gC compared to sources of 109.6 and 125.9 gC m^{-2} yr^{-1} on the 10 and 20 yr burn plots. As CO2 equivalents the sites a sources of up to 585 gC m^{-2} yr^{-1}. ANOVA results show burning and grazing were significant factors in the total carbon budgets. Interannual variation accounted for 19% of the variation, grazing 23% of the variation. Grazed sites were smaller sources than ungrazed sites (112.5 vs 149 gC m^{-2} yr^{-1}). Burning accounted for the largest source of variance (26%) – the presence of burning rather than a specific regime led to smaller sources. DOC fluxes based on soil water concentrations and flow at the catchment outlet were estimated to vary between 48 and 80 gC m^{-2} yr^{-1}. Net ecosystem respiration varied across treatments from 136.6 to 258.7 gC m^{-2} yr^{-1} and primary productivity ranged between 109.3 and 198.7 gC m^{-2} yr^{-1}. Methane fluxes were calculated to be5.25 – 6.86 gC m2 yr.

Notes	O	Carbon budget scaled from plot sample measures. Difficulty of extrapolating findings to peat sites elsewhere. 3 yr study may not reflect the longer term peat forming timescale. Some carbon flux pathways estimated from best available data but not measured directly on site.
	Limitations identified by review team	Grazed plots – no account of carbon off-take in sheep? Results for the 10 yr plot sampled before and after burning do not seem to be reported.
	Evidence gaps and/or recommendations for further research	Rationalisation of these findings with other studies e.g. EMBER where findings appear to be contradictory.
	Sources of funding	DEFRA / SEERAD Rural Economy and Land Use Programme, Natural England

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	What are the effects of managed burning of upland peatlands on water quality (including colouration, release of metals and other pollutants and biodiversity) and water flow (including downstream flood risk), either directly or indirectly through changes in vegetation composition and structure?

Study details	Authors	Clay, G.D., Worrall, F., & Aebischer, N.J.
	Year	2012
	Aim of study	To examine the effect of managed burning on DOC concentrations in soil and runoff waters.
	Study design	Correlation using chronosequence
	Quality score	2+
	External validity	EV+
Population and setting	Source population	Upland peatland, Northumberland
	Eligible population	Presumed as *Calluna-Eriophorum* blanket mire with 50cm+ peat depth:
	Inclusion and exclusion criteria	Managed burns of specified mean dimensions and known elapse time drawn from 2 sites (unbalanced design). 3 x control plots per site in proximity to burn plots.

	Setting	Managed grouse moorland in Northumberland at 2 x sites 23km apart – Emblehope & Ray Demesne Moors
Methods of allocation to intervention/control	Methods of allocation	No details/rationale regarding location of field infrastructure or reliability of aging burn sequence: may be available elsewhere (e.g. PhD thesis).
	Intervention description	Managed burning of grouse moor with no penetration of litter/soil
	Control/comparison description	Plots at local steady-state vegetation. May have been burnt previously but not within the 10yr period covered by the study.
	Sample sizes	8 x burn ages – 3 drawn from Ray Demesne, 5 from Emblehope. 14 x monthly samples, consecutive bar 1 month interruption period (severe weather Jan 2010)
	Baseline comparisons	2 x sites x 3 controls 14 x monthly samples as above
	Study sufficiently powered	Yes, authors base assumption on power calculation for analogous study.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Water depth, pH, conductivity, Absorbance at 400, 465 & 665nm, DOC concentration (colourimetric method)
	Secondary outcome measures	Specific absorbance (colour:carbon ratio) E4/E6 (ratio of absorbance at 465nm & 665nm) - measure of humification of DOC
	Follow-up periods	10 yr chronosequence Sampled over 15 month period commencing Dec 2009 (newest burn 7 months elapse

		time maximum).
	Methods of analysis	Blocked ANOVA with general linear modelling Post hoc testing of factors using Tukey test Loge transformation of data sets with heterogeneous variance (from Levene test) Normalisation of data based on monthly average of 6 x control plots ANOVA with and without covariates: magnitude of effects of each significant factor and interaction provided. Such analysis can distinguish all attributable sources of variation caused by e.g. differing peat depths among sampling plots.
Results		Significant differences in water table depth among burn years ($P < 0.001$), explaining 14.5% of variance. Up to 4 yrs elapse time, the most recent burns had the shallowest water tables & these were significantly shallower than older burns ($P < 0.05$) – attributed to the effect of vegetation draw down during post burn regeneration. Runoff and Interstitial waters are hydrologically distinct: runoff waters were more dilute, with median DOC of 71mg/l compared to 97mg/l. For normalised data, specific absorbance of soil water was highest in newest burns becoming similar to controls with increasing elapse time. Without covariates burn year explained most (18%) of variation in Abs400. With covariates burn year was still a significant factor explaining normalised Abs400, with differences attributable to old versus new burns (mid-age burns excluded). For runoff water, trends among burns were only interpretable for Abs400, which were highest in the newest burn: burn age was a significant factor for normalised Abs400 data and explained 9% of variance with and without covariates. Behaviour of DOC in runoff & soil water is not systematic over time: large values occur in a range of burn years. Trends and significances elucidated by the analysis are

		numerous and complex, and thus not catalogued fully herein. General trend is for most recent burns to have higher colour and older burns to have lower colour: DOC does not mirror this and thus colour:carbon ratios are highest in recent burns but they return to control levels in older burns. The impact on hydrology of ecosystem characteristics during burn revegetation and community maturation are used to explain water colour changes.
Notes	Limitations identified by author	None
	Limitations identified by review team	No recognition of grazing impact: are these moors grazed and, if so, is grazing pressure equivalent? In the absence of details regarding initial field set-up and rationale it is difficult to identify potential limitations. No indication of the relative location of sampling plots within the catchment and whether this may be a potential factor affecting the behaviour of soil and runoff water in burns (it is recognised that the analysis allows for burn effects to be discerned from other sources of variation).
	Evidence gaps and/or recommendations for further research	How might grazers affect the responses detected in the study? How are these responses affected by relative position within the catchment? How can plot- and catchment-scale responses be reconciled?
	Sources of funding	Game and Wildlife Conservation Trust

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	What are the effects of managed burning of upland peatlands on water quality (including colouration, release of metals and other pollutants and aquatic biodiversity) and water flow (including downstream food risk), either directly or indirectly through changes in vegetation composition and structure?

Study details	Authors	B. Clutterbuck and A.R. Yallop
	Year	2010
	Aim of study	To investigate the relationship between DOC concentration in surface waters from upland peat catchments and changes in meteorological, atmospheric deposition and land use/management factors in 6 Pennine catchments over the last 40 years.
	Study design	Correlation study
	Quality score	2++
	External validity	++
Population and setting	Source population	Moorland in N England
	Eligible population	Six discrete upland areas of England – one in the North Pennines and 5 sites in the mod and southern Pennine chain.
	Inclusion and exclusion	Catchments selected as having good archive of historical aerial imagery or extensive

	criteria	records of land use. DOC or historical water colour data are available. Catchments have substantial cover of blanket peat.
	Setting	Upland blanket bog in the Pennines.
Methods of allocation to intervention/control	Methods of allocation	Catchments chosen as having suitable land cover and for data availability.
	Intervention description	n/a
	Control/comparison description	n/a
	Sample sizes	Six catchments
	Baseline comparisons	n/a
	Study sufficiently powered	Large data sets from 6 catchments with sufficient variation in local factors to demonstrate the significance of local factors over the regional scale effects.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	DOC concentrations measured weekly at Troutbeck. Hazen measures of water colour from WTW for the 5 southern catchments - converted to DOC by standard methods. Periods of data availability vary. Climate data. Acid deposition data from UK Air Quality Archive. Land cover and soil distribution from air photography where available 1966 – 2005.
	Secondary outcome measures	n/a
	Follow-up periods	n/a

	Methods of analysis	Non-parametric tests used to test for change/trend in discrete (annual) data. Relationships and interactions were analysed in forward-entry stepwise regression.
Results		Significant increases in DOC were found in 4 catchments for the period 1990 – 2005 of the order of 53-92% of 1990-1994 means. Lower (10 -18%) but significant increases were found in the remaining 2 catchments. Longer term data also showed significant increases in the four catchments (1975 –1989) but at a lower rate than the later period. No significant trends in annual rainfall were found but mean monthly temperature increased by 0.05 – 0.07 ^{0}C ($p<0.01$) between 1990 – 2005. No significant temperature trends were noted in long-term data sets. Decreasing trends for sulphate were found for all sites for 1990 – 2005, representing 45 -53%. Land use in all catchments was stable but extent of burning increased in 4 catchments by 4.8 – 12.2% The only variable related to change in DOC was change in new burn on blanket peat as a % of the catchment. (r^2=0.76, $p<0.015$). DOC production was also shown to be related to annual temperature.
Notes	Limitations identified by author	None.
	Limitations identified by review team	Data do not fully explain the influence of Sulphate.
	Evidence gaps and/or recommendations for further research	Extension to wider area to test if effects are apparent across UK uplands – where there are a wider range of climatic and other conditions. Is the increase in DOC due to burning applicable at the first burn – or does the effects persist with subsequent fires?
	Sources of funding	Yorkshire Water Services Limited

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	? Not really directly applicable to any question What are the effects of managed burning on the maintenance and restoration of the characteristic floristic composition, structure and function of upland peatland habitats?

Study details	Authors	Cotton, D.E. & Hale, W.H.G (also Hale, W.H.G. & Cotton, D.E. 1988 summarised at end)
	Year	1994
	Aim of study	To assess the effectiveness of two cutting treatments as alternatives to traditional moorland burning practice, using an experimental field trial on Ilkley Moor.
	Study design	Experimental
	Quality score	1-
	External validity	EV-
Population and setting	Source population	Upland heather-dominated moor
	Eligible population	Degenerate heathland requiring management where traditional moorland burning is not acceptable.
	Inclusion and exclusion criteria	None

	Setting	Upland heathland at c. 380m, comprising *Calluna vulgaris*, *Empetrum nigrum* and *Vaccinium myrtillus* on c 10cm deep peat, at Ilkley Moor.
Methods of allocation to intervention/control	Methods of allocation	15 plots each assigned to one treatment – no details of method of allocation
	Intervention description	Burning (using a flame-thrower), flailing (above ground vegetation was smashed with a mechanical flail and the resulting litter left on the soil surface) and rolling back the vegetation (by using spades to cut major stems and above-ground material, which was then manually rolled to the sides of the plot).
	Control/comparison description	Plots compared with adjacent areas of similar vegetation left undisturbed
	Sample sizes	15 plots, 20 quadrats from each plot sampled for vegetation.
	Baseline comparisons	None.
	Study sufficiently powered	Yes.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	% top cover of *Calluna* and *Empetrum* and bare ground
	Secondary outcome measures	None
	Follow-up periods	10 years
	Methods of analysis	ANOVA
Results		Percentage top cover of *Calluna* increased in all three treatments over time (P<0.01-

		0.001). Bare ground decreased in all three treatments over time (P<0.001). No change in percentage top cover of *Empetrum* over time. *Calluna* is more abundant in burned and flailed plots than in rolled ones (P<0.01). Bare ground is more abundant in rolled plots than burned or flailed plots (P<0.001).
Notes	Limitations identified by author	Burning using flame-thrower may not simulate standard burning practice. Study didn't evaluate whether leaving litter on the soil surface might have long-term effects due to nutrient enrichment.
	Limitations identified by review team	No baseline vegetation data collected prior to treatment so it is not clear whether plots were comparable prior to treatment.
	Evidence gaps and/or recommendations for further research	Impacts on other elements of the community, such as lichens and invertebrates – the leaf litter created by flailing may prevent re-colonisation by lichen and/or germination of seed of other species.
	Sources of funding	

Hale, W.H.G. & Cotton, D.E. (1988) The management of vegetation change on Ilkley Moor. Aspects of Applied Biology 16: 311-316

This paper is a previous report of the same experiment – reporting on four years of the study (management carried out in 1983, and surveys carried out in 1987).

In the introduction the paper notes that the vegetation of Ilkley Moor has changed since the 1900s with bracken and crowberry increasing at the expense of heather. This was considered to result primarily from excessive sheep grazing.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	b) fauna

Study details	Authors	COULSON, J.C. 1988. [+ related studies: BUTTEREFIELD & COULSON 1983, 1985, COULSON & BUTTEREFIELD, 1986.]
	Year	1988 (The structure and importance of invertebrate communities on peatlands and moorlands, and effects of environmental and management changes. *Special Publication of the British Ecological Society,* 7.)
	Aim of study	To study the structure and importance of moorland and peatland invertebrate communities and consider the effects of management.
	Study design	2: correlation study.
	Quality score	2-
	External validity	2+
Population and setting	Source population	Invertebrates on moorland and peatland in northern England.
	Eligible population	Invertebrates liable to be captured by pitfall trapping and extraction of soil samples in samples on moorland and peatland sites in northern England.
	Inclusion and exclusion criteria	NA

	Setting	Range of moorland habitats and peatlands in northern England.
Methods of allocation to intervention/control	Methods of allocation	NA. No direct measure of intervention (burning) but correlation between species/communities/assemblages and habitats and associated environmental and management variables.
	Intervention description	NA
	Control/comparison description	NA
	Sample sizes	Large, e.g. 29,000 individuals of 168 species of spiders, 13,498 individuals of 66 species of Carabids, from 42 sites (33 on peat) with minimum of eight soil samples.
	Baseline comparisons	NA
	Study sufficiently powered	No data given.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Individuals by species.
	Secondary outcome measures	Species richness/diversity, density/standing crop, assemblage (similarity from cluster analysis)
	Follow-up periods	NA
	Methods of analysis	Cluster analysis (average linking) to determine similarity of species composition, Similarity Index (modified Sorensen's Index) using pseudo-species for differing abundance classes.

Results		Five main communities were identified including high and lower altitude blanket bog, edge peat and mixed moor (wet/dry bog/heath). Although similar numbers of species were found across the habitats, the mixed moor had the highest diversity in terms of number of species and individuals, although the numbers of individuals caught on the moorland habitats was greater than in lowland mires. The data were further investigated including the effects of environmental and management changes. Standing crop showed marked differences between communities. The species of the blanket bog community were typical of those found in sub-arctic regions of Scandinavia and have a northern European distribution. It was suggested that the mobility of most invertebrates and the relatively small plots which are burnt at any one time raises no major problems for recolonisation for invertebrates. However, it is difficult to separate the direct effects of burning from those associated with the loss of food for invertebrates. Large and extensive burning of a moor, as occurred in the North York Moors in 1976, has had more pronounced effects on the whole ecosystem because of the much larger areas involved, the major effects of the hot fire on the vegetation and burning of peat for many days.
Notes	Limitations identified by author	Difficult to separate the direct effects of burning from those associated with loss of food for invertebrates.
	Limitations identified by review team	The direct relationship between burning and invertebrate assemblages or indirect effects on vegetation structure and composition were not investigated. Little information given on how environmental and management factors were classified and taken into account.
	Evidence gaps and/or recommendations for further research	See above. It would be informative to more clearly classify management and especially burning and ideally sample within such management classes.
	Sources of funding	NCC, NERC, Manpower Services Commission.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	c

Study details	Authors	Couwenberg, Thiele, Tanneberger, Augustin, Barisch, Dubovik, Liashchynskaya, Michaelis, Minke, Skuratovich & Joosten
	Year	2011
	Aim of study	To outline a methodology to assess emissions and emission reductions from peatland rewetting projects, using vegetation as a proxy
	Study design	Quantitative observational
	Quality score	2-
	External validity	-
Population and setting	Source population	Raised bog habitats
	Eligible population	701ha. C. Vulgaris, E. vaginatum, Polytrichum strictum occurred with high frequency. Sphagnum spp in wetter areas. Betula spp present
	Inclusion and exclusion criteria	-

	Setting	Ostrovskoe, Belarus
Methods of allocation to intervention/control	Methods of allocation	N/A
	Intervention description	Rewetting peatland/creation of alternative vegetation type
	Control/comparison description	Comparison scenarios (vegetation types) - Baseline – expansion of birch trees favoured by presence of E. vaginatum tussocks, largely covered by 'forested bog heath' Rewetting (project scenario) – wet sphagnum communities expand at expense of bog heath. Growth of dwarf shrub and trees will be impaired
	Sample sizes	N/A
	Baseline comparisons	Current vegetation types - C. Vulgaris, E. vaginatum, Polytrichum strictum at high frequency. Sphagnum spp in wetter areas, Drosera rotundifolia, Betula spp present.
	Study sufficiently powered	N/A
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	GHG flux (CH_4, N_2O and CO_2)
	Secondary outcome measures	N/A
	Follow-up periods	Based on 30 year scenario
	Methods of analysis	GHG flux values were assigned to vegetation types following a standardised protocol and using published emission values from plots with similar vegetation and water level in regions with similar climate and flora.

Results		Current GHG fluxes 5,471t /yr CO_2-eq. (average 7.8 t/ha/yr). 5,527 t/year (7.9 t/ha/yr) = baseline scenario without rewetting 2,403 t/year (3.4t/ha/yr) = project scenario with rewetting Estimated emission reduction = 3,124t/yr (4.5t/ha/yr) in 2039
Notes	Limitations identified by author	Reliable data for GHG flux is limited and available publications are poor in the description of site conditions Emissions related to wind/water erosion may be significant but are difficult to assess and were excluded from the research Various limitations of using vegetation as proxy for GHG fluxes, particularly – vegetation reacts slowly to environmental changes and may take several years for vegetation composition to reflect site changes Assumptions made in study may significantly alter outcomes (eg assumptions made on extent of trees may have a disproportionately large effect on the predicted net result)
	Limitations identified by review team	-
	Evidence gaps and/or recommendations for further research	Integration of more site specific data into models to allow identification of most realistic outcomes
	Sources of funding	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Centre for International Migration and Development, RSPB, Ministry of Agriculture, the Environment and Consumer Protection of Mecklenburg-Vorpommern

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	h)

Study details	Authors	Critchley
	Year	2011a (b also covered by this same ET: a = blanket bog and b = upland heathland inc. wet heath using same methods/field teams)
	Aim of study	To provide information on the condition of blanket bog [and upland heathland] priority habitat in England based on a representative sample using the Common Standards Monitoring (CSM) methodology (JNCC 2009).
	Study design	2: sample survey
	Quality score	2++
	External validity	EV++
Population and setting	Source population	English blanket bog and upland heathland (from NE Priority Habitat Inventories)
	Eligible population	Natural England blanket bog and upland heathland Priority Habitat Inventory polygons stratified by designated site and agri-environment (AE) agreement status.
	Inclusion and exclusion criteria	NA

	Setting	English blanket bog/wet heath
Methods of allocation to intervention/control	Methods of allocation	NA
	Intervention description	NA, though burning evidence and impacts recorded by some variables ('attributes')
	Control/comparison description	NA
	Sample sizes	97 blanket bog habitat polygons and 99 upland heathland polygons (88 with wet heath) with c.50 per SSSI/non-SSSI, AE agreement/non agreement strata.
	Baseline comparisons	NA
	Study sufficiently powered	Relatively large sample size.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Burning into moss, liverwort or lichen layer and burning 'sensitive areas'.
	Secondary outcome measures	NA
	Follow-up periods	As recordable on survey, i.e. recent.
	Methods of analysis	Samples split into all vegetated and blanket bog (deep(er) peat, >30 cm) and all vegetated and dwarf-shrub heath (with wet heath assessed separately) and analysed separately. Each sample point assessed as either passing or failing 14 CSM attribute targets and polygons were then assessed as either passing or failing the favourable condition threshold (all 14 targets met at 90% or more of sample points) and data given for percentage pass rates for individual attributes with 95% CI. Differences in pass rates by SSSI and AES status of sites

		were analysed for individual targets using Log-linear analysis for multidimensional contingency tables.
Results		No sites were in favourable condition. The burning into bryophyte and lichen layer attribute (Target 10) was failed in 21% of sites and burning in sensitive areas (Target 11) in 15% (based on blanket bog samples and threshold for passing = 90% of samples). Overall, 11% of samples failed the burning into bryophyte and lichen layer. Failure rates were significantly higher for SSSI than non-SSSI (41% and 4% for T10 and 33% and 2% for T11, both $P<0.001$) though slightly lower for AE agreements than non-agreements (19% and 23% for T10 and 12% and 21% for T11, both ns). The failure rate was lower for SSSI sites under AE agreements than not ($P<0.001$). Although lower than failure rates than some other attributes (e.g. no sites passed the cover of indicator species target), they are relatively high given that when bog it is burnt, it would only be expected that a proportion would be burnt each year (say typically 6.7% based on a 15 year rotation) and that the 'cool burns' normally advocated (e.g. in the Heather and Grass Burning Code and normally in SSSI consents and AE agreements) should not burn into the bryophyte and lichen layer. Similar results for wet heath: None of the 99 heathland sample sites were in favourable condition overall (wet and dry heath combined), nor the 88 with separate wet heath assessments. The burning into the bryophyte and lichen layer attribute was not met in 31% of sites and the burning in sensitive areas attribute in 12% (based on the CSM threshold for a site/feature passing being 90% of samples passing all the targets). Overall, 17% of the 927 wet heath samples across sites did not meet the burning into bryophyte and lichen layer target. The SSSI and AE agreement status of sites had no significant effect on the pass rate for the burning in to the bryophyte and lichen layer target, but the pass rate for SSSI sites was significantly higher than for non-designated sites and there was a significant interaction with AE agreements (both $p<0.05$).

Notes	Limitations identified by author	One, perhaps two attributes could not be fully addressed as Sphagnum fallax not recorded separately from other Sphagnum spp.
	Limitations identified by review team	Only single survey of condition at one point in time. Length of time under agreement not given or taken into account in analyses. Errors in PHI used as sample frame (though addressed to some extent by analysis on blanket bog subset of samples). Sensitive areas determined in field rather than prior mapping.
	Evidence gaps and/or recommendations for further research	Repeat survey to identify change over time esp. on AE agreement c.f. non-agreement sites. Comparison with Natural England's own condition assessment results overall and for the individual sites.
	Sources of funding	Natural England/Defra (as part of ES monitoring programme).

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	a) flora

Study details	Authors	CURRALL, J.E.P. [Also published abstract: CURRALL 1989.]
	Year	1981
	Aim of study	Currall (1981, 1989) in a wide-ranging PhD ,studied the effect of management burning on wet heath vegetation on the island of Skye in western Scotland in 1977-78, principally by a post-burn chronosequence across 53 stands of varying ages after burns up to a >20 yr category. In addition, the effects of grazing, clipping and raking were investigated using grazing exclosures, burn temperatures were measured and the effects of burning on vegetation, including individual species' responses, were more generally reviewed. The objectives were to study the use and control of fire; vegetation responses to fire; interactions of grazing and burning; and alternative methods to achieve the objectives of burning.
	Study design	2: chronosequence and some permanent plots. Survey/monitoring. Also some experimental manipulation of management in plots including grazing, clipping and ranking.

	Quality score	2+
	External validity	EV+
Population and setting	Source population	Wet heath on the island of Skye in western Scotland.
	Eligible population	Burn patches by age classes.
	Inclusion and exclusion criteria	Burn patches of know age; other factors including management relatively constant.
	Setting	Wet heath burn patches of different age classes on the island of Skye in western Scotland.
Methods of allocation to intervention/control	Methods of allocation	Selected based on age class.
	Intervention description	Managed burning.
	Control/comparison description	
	Sample sizes	Post-burn chronosequence including 460 quadrats across 53 stands and additional permanent plots of varying ages after burns up to a >20 yr category on a single Scottish island.
	Baseline comparisons	
	Study sufficiently powered	NR
Outcomes and methods of analysis (inc effect size, CIs for each outcome and	Primary outcome measures	Species frequency and cover abundance.
	Secondary outcome measures	Species-richness, water table depth and burn temperatures.

significance)	Follow-up periods	Up to 26+ months in permanent quadrats and >20 yr post-burn in chronosequence stands.
	Methods of analysis	Summary statistics with some significance testing. PCA. A polythetic, non-hierarchical, agglomerative, clustering procedure was used (TABORD, designed to construct phytosociological tables) was used to cluster similar vegetation samples.
Results		The author suggested that post fire successions in wet heath in NW Scotland typically follows three phases. Firstly, there is a graminoid phase, which is dominated by species that are able to rapidly recover or colonise bare ground after fires. The actual species present depends on the pre-fire community composition, but ericoids, mat-grass *Nardus* and total bryophytes decline significantly, though species-richness increases initially then gradually declines. The second phase is a 'dense graminoid phase' and results from the establishment of dense growth of *Molinia* or *Trichophorum cespitosum* and a reduction in bare ground, though *Erica tetralix* may peak in this phase. This seems to be characteristic of wet heath, not normally being seen in dry heath successions. The phase may last 8-12 yr. *Calluna* and other ericoids tend to become dominant in the third phase, typically *c*.15 yr after the fire, while graminoids decline, and bryophytes develop under the canopy. With further time, species such as *Potentilla erecta* and *Eriophorum vaginatum* may reappear as gaps occur in the heather canopy. It was suggested that burning on short rotations and/or heavy grazing after burning can lead to maintenance of the dense graminoid phase and hence dominance of *Molinia* and *Trichophorum* and reduction in *Calluna*.
Notes	Limitations identified by author	NR
	Limitations identified by review team	Post-burn (and grazing etc.) monitoring in permanent plots only over a short period (up to 26 months). Chronosequence approach has been criticised in general (although author briefly argues that an attempt was made to reduce variation in other factors across a large sample of quadrats/plots/stands).
	Evidence gaps and/or recommendations for	Extension of monitoring of post burn response to other wet heathland sites.

	further research	
	Sources of funding	NERC and University of Aberdeen.

Evidence Table

Name of Evidence Review:	Natural England Uplands Evidence Review
Name of Review Topic:	What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity and the provision of ecosystem services?
Review Question(s)	b) What are the effects of managed burning on the maintenance and enhancement of the characteristic fauna of upland peatlands either directly or indirectly through changes in vegetation composition and structure?

Study details	Authors	CURTIS, D. J. & CORRIGAN, H.
	Year	1990
	Aim of study	To investigate the relationship between diversity and composition of spider fauna and land management/vegetation of blanket bog/wet heath peatlands.
	Study design	2. Quantitative observation/correlation: correlation study.
	Quality score	2-
	External validity	EV-
Population and setting	Source population	Islay
	Eligible population	Six ‘sites’.
	Inclusion and exclusion criteria	NR

	Setting	?
Methods of allocation to intervention/control	Methods of allocation	Sites under different management regimes (esp. grazing and burning) and hnec vegetation composition/structure sampled. No direct 'treatments'.
	Intervention description	See above.
	Control/comparison description	NA
	Sample sizes	6 sites, mean 26 pitfall traps/site, c.9,200 individuals caught.
	Baseline comparisons	It was a baseline survey/study.
	Study sufficiently powered	NR, but probably low power.
Outcomes and methods of analysis (inc effect size, CIs for each outcome and significance)	Primary outcome measures	Numbers of spider individuals/species.
	Secondary outcome measures	Spp diversity and richness.
	Follow-up periods	Sampled over 1 year.
	Methods of analysis	ANOVA of spp diversity and richness by site and DCA ordination of 'spider data' (type NR) by sites. Summary statistics for basic site attributes (altitude, soil moisture and veg. ht and spp. diversity).
Results		"Differences in spider community assemblages" [species diversity and richness and species/species groups] are "attributed to changes in the vegetation [composition] microtopography [/structure] produced by direct or indirect management practices."

		Shorter swards resulting from burning and grazing were associated with relatively high species richness, but low species diversity reflecting increased numbers of surface-active *Lycosids* but declines in numbers of web-spinning *Linyphids.*
Notes	Limitations identified by author	None.
	Limitations identified by review team	Site selection and sample location is not described so could be affected by bias and/or not be representative of the island or habitats within it. Site (or sample) attributes are not included in the analyses. Thus, clear differences in spider assemblages between sites are only interpreted as reflecting site attributes, particularly vegetation and soil moisture and indirectly management Some of the differences may reflect inherent differences in the veg. types/structure and their extent between sites rather than just the impact of management on them.
	Evidence gaps and/or recommendations for further research	NR. More detailed studies looking at relationship between spider communities and vegetation type/structure and other environmental variables and management including burning.
	Sources of funding	NR