NatureScot Scientific Advisory Committee Sub-Group Report on addressing the uncertainties in the evidence base on muirburn in developing a licensing approach

1. Chair's Introduction

The SAC Muirburn sub-group (sub-group) was formed at the request of NatureScot staff. The sub-group's Terms of Reference (see Annex 1) gave the purpose as 'to provide expert advice to support staff in addressing unclear elements of the evidence base, whilst minimising risks and applying the precautionary principle in developing a licensing approach to muirburn'.

The main tasks/specific points which the Terms of Reference and an accompanying paper identified it would be useful for the sub-group to consider were:

- Identify key points from the main findings of the NatureScot Research Report 1302 – 'Reviewing, assessing and critiquing the evidence base on the impacts of muirburn on wildfire prevention, carbon storage and biodiversity' which support evidence-based approaches to potential licensing of muirburn;
- Advise on key knowledge gaps outlined in the review, and others, which could be addressed through further work;
- Advise on further risks and benefits associated with muirburn as detailed in the review, and drawing on any other lines of available evidence;
- Support staff in developing the evidence base underpinning the application of the precautionary principle in relation to muirburn;
- Discuss and suggest ways to adopt a risk based approach in relation to muirburn;
- Discuss options to define 'peatlands' in relation to muirburn including any practical considerations (peat depth; vegetation type).

NatureScot published the Research Report 1302 (Holland *et al*., 2022), on its website on 19th October 2022. The purpose of the report was to help inform the development of a licensing approach to muirburn. The report was a focused assessment of the impacts of muirburn on carbon storage, net emissions and biodiversity and the relationship between wildfire and muirburn as they related to the development of a licensing approach. The main findings of the review indicated a lack of both studies and evidence on the impacts of muirburn in many areas; with some elements of the evidence base unclear or contested.

The sub-group acknowledged these significant gaps and have used this report to provide advice on how to approach the development of a licensing approach using principles and well defined approaches, including the precautionary principle and risk based approaches.

2. Executive Summary

Summarised below is the key advice from the sub-group on addressing the uncertainties in the evidence base in the development of a licensing approach.

2.1 General Advice

- *The evidence base on the benefits and 'costs' of muirburn is expanding, and the nature of impacts will become clearer over time which means that any guidance/policies and procedures adopted now will require to be monitored, reviewed and potentially updated in the future.*
- *An adaptive precautionary approach, which builds in transparent monitoring and review processes, (recognising that this will have significant financial and time implications and may not be feasible) should be taken in developing a licensing approach.*
- *The application of the Muirburn Code, with appropriate training, will provide a practical mechanism to implement a risk based approach.*
- *Keep abreast of new, relevant scientific developments and consider commissioning further focused pieces of work on specific aspects where the uncertainties are greatest or the scientific evidence most contested.*

2.2 Advice on Peatland

- *Maintaining the depth of 50 cm or more for the definition of peat enables outline desk-based assessments to be made as soil survey data is based on this definition.*
- *For the purposes of muirburn licensing, the subgroup advise using Class 1 & 2 in the Carbon & Peatland Map 2016 as the method of indicating areas of peatland.*
- *Site specific peat information could be provided as required using standard measurement protocols e.g. (https://www.iucn-uk-peatlandprogramme.org/sites/default/files/2019-07/PC_Field_Protocol_v1.1.pdf)*

2.3 Advice on Carbon

- *Where muirburn is licensed, provide clear guidance concerning the nature of the muirburn and under which conditions (temperature of fire, specific locations etc.) it is allowed to help mitigate the risk to carbon.*
- *Given the potential long term impacts on carbon storage, the subgroup recommend that NatureScot should commission a continuing review of the accumulating evidence to inform changes as required to licensing.*

2.4 Advice on Biodiversity

- *Within the Muirburn Code there are already good practice guidance and statutory restrictions for mitigating risk to protected species and nesting birds, and sensitive areas (Sections 4 and 5).*
- *NatureScot should undertake an assessment of the current legislation as it relates to muirburn and biodiversity to see if it is in keeping with recent scientific knowledge***.**
- *Future consideration should be given by NatureScot as to whether it is feasible to provide detailed habitat and or species mapping to help incorporate specific biodiversity objectives into muirburn planning.*

2.5 Advice on Wildfire

- *An exception to allow muirburn on peatlands to reduce wildfire risk would need additional evidence setting out why it is necessary to carry out muirburn and why burning is required rather than an alternative technique.*
- *Consideration should be given to (a) whether the existing Wildfire Risk Assessment template used in England is fit for purpose for use in Scotland and (b) whether any*

associated justification of muirburn as being the most relevant management practice requires the development of a full Wildfire Management Plan or simply a mapping process which indicates where on the site the fuel load in the existing habitats are best management by burning or cutting.

- *Where muirburn is to be implemented for wildfire control, adherence to the Muirburn Code (specifically section 7) should be recommended to minimize risk of escape fires.*
- *Where muirburn is implemented for experimental purposes, restoration or grass management the Muirburn Code should be followed, and any necessity for large fires should be implemented as a series of small contiguous fires as recommended in the Muirburn Code.*
- *Keep the work on developing a UK Fire Danger Rating System under review.*

2.6 Advice on Licensable Purposes

- *Exceptional licences on peatland, should require additional evidence than what is needed under a normal licensing process. This additional evidence should include why it is necessary to carry out muirburn, in preference to any other land management or risk reduction techniques.*
- *It would be helpful to identify if there are other processes whereby land managers ask for an exception on protected areas or similar which could be studied, both for the general process itself but also the weight of evidence and additional evidence that is required.*

2.7 Advice on what criteria should be included in a constraints map

- *The sub-group support the production of a constraints map – and that it should include conditions as outlined in the Muirburn Code, including appropriate timing.*

3. Structure of report

This report is structured around the following set of questions posed to the sub-group:

- How should peatlands be defined in relation to muirburn?
- How should muirburn manage the risks and take account of potential benefits to carbon storage?
- How should biodiversity be taken into account in determining where muirburn is appropriate?
- Can muirburn be used to address the risk of wildfire and if so in what circumstances?
- What should be taken into account to identify potential licensable purposes?
- What criteria should be included in a constraints map?

Each question has been assessed according to the summary of evidence and knowledge gaps and according to how a precautionary, risk based approach might be applied. The key advice has been summarised at the end of each question and collated in the Executive Summary in section 2.

4. Mode of operation

The sub-group was asked by NatureScot to produce a summary of their considered advice, setting out the rationale, including evidence or judgements drawn on and to include main discussion points highlighting any areas of consensus or divergence.

The sub-group met four times from December 2022 to February 2023. The sub- group focused on the NatureScot report (Holland *et al*., 2022), and the evidence provided therein relevant to the specific questions. The group recognised that new information and knowledge is continually becoming available, and that given the very focused time request, the group was unable to undertake any additional evidence review**.**

5. Risk based management and the precautionary principle

5.1 Introduction

The precautionary principle helps policy and decision makers accommodate a degree of uncertainty. The precautionary principle states "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (UNEP 1992). "The precautionary principle enables decision-makers to adopt precautionary measures when scientific evidence about an environmental or human health hazard is uncertain and the stakes are high. The precautionary principle is closely linked to governance. This has three aspects: risk governance (risk assessment, management and communication), science-policy interfaces and the link between precaution and innovation." (European Parliament, downloaded 2023)

The precautionary principle can be applied in two ways, either by preventing the activity or development (strict precaution) or allowing the process to continue with adaptations (adaptive precaution). In practice, strict precaution is not often applied as practical steps may be taken to reduce uncertainty and the extent of the potential hazard, and any decision may therefore be subsequently reviewed; this is adaptive precaution and is akin to risk management.

There remains considerable uncertainty around the evidence base on muirburn and where there is scientific evidence, in many cases, it is contradictory. This has led to the proposal to apply the precautionary principle in developing a licensing approach.

5.2 Adaptive management

At the base of any decision making process should be sound scientific information and its evaluation must be the basis for applying precaution. However, it is important to recognise that the scientific information base may shift as knowledge evolves and so management should also be adaptive. Adaptive management is a systematic approach to proactively monitor the results of actions and use these to inform future actions. Adaptive management acknowledges risk, and the need to be precautionary and is a common regulatory risk management tool. Adaptive management may also aid in the identification and filling of knowledge gaps by linking the future results of ongoing experimentation and monitoring to changes in management. Ongoing monitoring is already integrated into many

regulatory areas. Key to the success of such a strategy is the need for management practices to be responsive to changing conditions and knowledge over time.

Application of an Adaptive management approach means that mechanisms should exist for re-evaluating the basis for decisions and that such mechanisms should be transparent. In the application of the precautionary principle, a high degree of transparency, clear accountability and meaningful public involvement are appropriate.

Given the high degree of uncertainty in the current evidence base, it is recommended that the precautionary principle it is applied with respect to:
- Helping mitigate any potential adverse impacts of muirburn on carbon and biodiversity in situations where muirburn continues to occur;
- Seeking to reduce any increase in wildfire risk in situations where there may be concern that the removal of muirburn may increase fuel load or where muirburn initiates a wildfire escape and thereby increases such a risk

Advice: *An adaptive precautionary approach, which builds in transparent monitoring and review processes, (recognising that this will have significant financial and time implications and may not be feasible) should be taken in developing a licensing approach.*

Scientific advice would be that, subject to resource constraints and feasibility, such monitoring and review should be used to:

(a) Develop understanding of the impact of licensed activities
- Seek to ensure that carbon and/or biodiversity are not being adversely impacted in situations where muirburn continues to occur
- Seek to ensure that carbon, biodiversity and/or wildfire risk are not being adversely impacted in situations where muirburn has been prevented

(b) Take into account scientific evidence
- Allow the application of the precautionary principle and the adaptive management approach to be reviewed and adapted, where necessary, in the light of additional scientific evidence becoming available.

6 Questions addressed in the report

The remainder of the report is structured around the questions set out in Section 3. The sub-group recognised that the evidence base for the individual questions is uncertain (and sometimes contradictory) and evolving, with new scientific evidence being added to constantly. As well, the subgroup recognised that the impacts being investigated may operate over quite different timescales

6.1 How should peatlands be defined in relation to muirburn?

6.1.1 Key points on evidence and gaps

The soil survey data for Scotland, in relation to peat, is based on a definition of peat at a depth of 50 cm or more. The sub-group did not identify additional evidence around the impacts of muirburn on different depths of peat.

6.1.2 Advice on how to take a risk based precautionary approach

The sub-group noted it would be time-consuming and costly to re-survey Scotland using a different peatland depth definition. The sub-group noted that the Carbon and Peatland Map 2016 is a useful source of data and that to establish new national peat maps at a new depth would take significant resources. However the sub-group did note that if more detailed information is needed a wide variety of techniques exist which could be used, including newer technologies, such as drones or satellites, and that these could be applied in specific areas if required.

The sub-group suggest an alternative strategy, of using Class 1 & 2 in the Carbon & Peatland Map 2016. Class 1 is peat according to the definition of a depth of 50 cm or over and Class 2 is dominated by peat but with some peaty soils. Using these two classes would refine areas which have high restoration potential in relation to carbon storage and thus could be used in any licensing decisions concerning muirburn.

As part of the monitoring and review features of adaptive management, the sub-group noted that a GIS exercise could be undertaken to provide an indicative peat map for landowners. This could be backed up with targeted and proportionate on the ground surveys by the applicant. Guidance and protocols could be produced to provide details on how to carry out a peatland survey. This could draw on existing guidance e.g. Peatland Action. Any procedures could include specific guidance about how the results of surveys should be reported and what the minimum requirements are.

Any monitoring and review guidance/protocol should clarify when additional surveys on the ground will be required and at what scale. The data collated can help to build knowledge of peat depths across the areas covered by a licence.

There may be specific applications where the use of other approaches will be important (e.g. gamma rays and other techniques set out in the NatureScot evidence review), but for a general coverage, technology which is usable by a wider community should be used i.e. peat probes.

Advice: *Maintaining the depth of 50 cm or more for the definition of peat enables outline desk- based assessments to be made as soil survey data is based on this definition.*

Advice: *For the purposes of muirburn licensing, the subgroup advice using Class 1 & 2 in the Carbon & Peatland Map 2016 as the method of indicating areas of peatland.*

Advice: *Site specific peat information could be provided as required using standard measurement protocols e.g. (https://www.iucn-uk-peatlandprogramme.org/sites/default/files/2019-07/PC_Field_Protocol_v1.1.pdf)*

6.2 How to manage the risks and take account of potential benefits of muirburn to carbon storage?

6.2.1 Advice sought on carbon

In the absence of a clear understanding of the impact of muirburn on carbon budgets, consideration of how the risks to carbon storage from muirburn should be assessed and when muirburn could be used as a management technique on heath (dry and wet) and acid grasslands. In particular it would help to focus on:

- Impacts of muirburn on degraded and/or modified peatlands and moorland habitats, many of which we seek to restore.
- Impacts of muirburn in areas with carbon rich soils undergoing and with potential to undergo habitat management that will restore healthy carbon functions.
- Impacts on peatlands of variable depth (<10cm, <30cm, <40cm).

6.2.2 Key points on evidence and gaps

There is limited evidence in the literature with regard to the risks of muirburn to carbon storage. However the sub-group did note that what evidence there is indicates that some impacts may operate over long time periods (e.g. decades). The evidence on the impacts of muirburn on carbon stores shows some contradictions in terms of both benefits and disadvantages. The situation is complex as carbon accumulation is influenced by many interacting factors, and fire, which itself is variable in character, may influence carbon storage in many ways. This makes it difficult to predict the impact of individual muirburn events on carbon storage of individual sites.

The effect of burning on carbon storage will depend on the characteristics of the fire. Fire intensity and severity are influenced by topography, weather during burning, and by vegetation composition, fuel load, and fuel moisture content, which in turn is influenced by weather in the days prior to burning and local hydrology. The amounts of carbon released in combustion, and left as litter and char, will depend on the nature of the fire. Fire characteristics will also influence subsequent ecosystem respiration and photosynthesis, and possibly methane (CH_4) emissions and Dissolved Organic Carbon (DOC) loss. Where the soil/peat is very wet, gaseous losses of carbon can occur as methane, an even more potent greenhouse gas than CO_2. However, the few studies of effects of burning on CH_4 flux show inconsistent responses. All carbon fluxes will change as the vegetation regenerates following burning, with rate of regeneration and initial composition of the community also being influenced by the intensity and severity of the fire.

Carbon storage is the net outcome of carbon inputs and outputs over the longer term (e.g. decades or management cycle duration). So the response of carbon storage to burning depends on all the factors which influence fire, which are highly heterogeneous spatially and/or temporally (Holland *et al*., 2022).

Another facet of the carbon debate is the potential for char/charcoal created by muirburn to increase carbon storage, primarily due to its recalcitrance. The nature of the char depends on the fire conditions; the hotter the fire, the more resistant the char is to decomposition, but also the more likely there will be negative impacts. The effect of char on carbon accumulation will depend on the balance between carbon lost in combustion and the amount of char produced, between the long-term decomposition rates of litter and char, and between positive and negative priming effects of char on soil microbial activity. Peat can accumulate on peatlands that have undergone prescribed burning as evidenced by measurements of carbon accumulation rates over the past 300 years (Heinemeyer *et al*.

2018). These measurements of carbon accumulation include the char itself (which may be important in explaining apparent differences in burning impacts on peat carbon accumulation rates between studies measuring carbon fluxes or stocks). One study suggests that hot fast burns are beneficial for carbon accumulation in char (Worrall *et al*. 2013). However, the situation is complex, and the conditions required for prescribed burning to promote char production, and generate long term net carbon gain through char, are not yet clear. Ignition of peat would likely negate any benefit of char (Clay and Worrall, 2011) and benefits have not been proposed for slopes on which fire may result in erosion (Heinemeyer *et al.* 2018).

6.2.3 Advice on how to take a risk based, precautionary approach

It is the view of the sub-group that at this time, NatureScot would not be in a position to judge an individual application on the basis of its risks to carbon storage because the information that currently exists in the scientific literature suggests that the risk to carbon storage is moderated by a very large number of contextual factors that almost certainly would not be included in the licensing application. It would not be practicable for a landowner or NatureScot to predict the effect of burning on the long-term carbon budget of a particular site. The sub-group noted that a precautionary approach is implicit in developing a licensing approach as it will, in and of itself expand the area that would, on the face of it, not be able to be burnt. The sub-group noted that the Muirburn Code provides guidance and statutory requirements to minimise the risks in general.

The main remit of the Muirburn Code is to ensure that muirburn is done,

- In the right place and season of the year,
- with sufficient staff (and backups) along with adequate fire control equipment,
- under appropriate weather conditions,
- avoiding damage to sensitive habitats and ecosystem services, and
- ensuring the prescribed fire doesn't lead to a wildfire.

Essentially, safety, risk assessment, complying with statutory requirements (including protection of sensitive species and habitats) underpin the Muirburn Code.

The maximum fire area is not defined in the Muirburn Code but it implies (and good practice dictates) that the aim should be to have relatively small fires. Low severity (or cool burn) fires are mentioned briefly, the sub-group consider that more nuance should be used in introducing and explaining what is meant by a cool burn and the potential risk mitigation benefits that would ensue from more widespread use of cool burns.

Advice**:** *Where muirburn is licensed, clear guidance concerning the nature of the muirburn and under which conditions (temperature of fire, specific locations etc.) it is allowed, would mitigate the risk to carbon.*

Advice**:** *Given the potential long term impacts on carbon storage, the subgroup recommend that NatureScot should commission a continuing review of the accumulating evidence to inform changes as required to licensing.*

6.3 How should biodiversity be taken into account in determining where muirburn is appropriate?

6.3.1 Advice sought on biodiversity

With a mixed picture in relation to impacts on bird species, a lack of evidence on small mammals, invertebrates and reptiles and a lack of evidence on grasslands and other habitats, what approach is advised to help balance the risks and benefits to biodiversity to ensure that a muirburn licence will support the new Scottish Biodiversity Strategy? In particular it would help to focus on:

- Identifying potential risks and benefits to specific assemblages and habitats.
- Highlighting any approaches to help understand and balance these risks and benefits.

6.3.2 Key points on evidence and gaps

(Holland *et al*., 2022) found evidence that indicates that burning results in a change in plant species composition and structure, but that this change is not always consistent and is dependent on a wide variety of other factors. It also found evidence of species specific effects for birds, no evidence could be found for small mammals, reptiles and amphibians (identified as a research gap) and that the evidence base was too limited to conclude on effects on invertebrates. This was in line with previous work ""Conservation outcomes from muirburn depend heavily on the interactions between burning rotation length, patch size, edaphic conditions, other anthropogenic pressures (grazing, drainage and atmospheric deposition), and the timescales over which these interactions are measured" (Werritty et al., 2015).

6.3.3 Advice on how to take a risk based, precautionary approach

The sub-group reflected that taking into account the effects of muirburn on different species is challenging due to a number of factors including the nature of the muirburn, the vegetation and habitat, the species mobility, the dynamic nature of their presence and that there is less quantitative understanding of their spatial distribution, in comparison with the maps of peat and peaty soils. The sub-group did note that there is a legal requirement for land managers not to destroy, damage or disturb certain protected species, whether by muirburn or any other activity and that at designated sites there already exist protective measures such that burning is allowed only under exception and that the Muirburn Code is followed. The Muirburn Code (sections 4 and 5) offers guidance and specific requirements regarding biodiversity**.**The sub-group also noted that some burning is carried out for conservation reasons e.g. to protect Arctostaphylos Heath.

It was noted that the overarching principle of not burning on peat will protect blanket bog habitats and species that thrive in such habitats.

The sub-group considered that the first step would be to identify whether any protected species exist at any site for which a muirburn licence is sought. The sub-group noted that constraints on when and where burning can take place should be informed by (our sometimes limited) knowledge on wider biodiversity within the landscape. More generally however, the sub-group noted that the uncertainty is considerable and while there are vegetation, habitat and some species maps there would still remain considerable uncertainty about the presence of any given species at any given location. The sub-group

noted that knowledge of the location and presence of, for instance upland ground nesting birds e.g. snipe and golden plover may not always be available.

The sub-group noted that for specific species, which may be limited to specific habitats, and which may only be present at specific periods of time, the advice should concern setting a particular period within which prescribed burning should not happen, particularly if that particular habitat falls within an area that has been identified as an area to potentially carry out muirburn. The sub-group also noted that another consideration in defining muirburn conditions should be patch size. If the muirburn only covers a small patch, there is a high chance of recolonization of mobile species after the burn.

Considering the previous points made concerning carbon and other considerations, the sub-group would advise that NatureScot give some consideration to creating a general constraints map, which would include a peat/soil map overlaid by a layer describing a vegetation and finally species maps (if such exist). Such a multi-layer map would provide an initial spatial constraint map, identifying areas to be considered for licensed muirburn. Such a constraints map is in keeping with the Muirburn Code and specifically the general considerations for muirburn planning (section 6).

***Advice**: Within the Muirburn Code there are already good practice guidance and statutory restrictions for mitigating risk to protected species and nesting birds, and sensitive areas (Sections 4 and 5).*

Advice:** NatureScot should undertake an assessment of the current legislation as it relates to muirburn and biodiversity to see if it is fit for purpose in terms of both the licensing authority and the land manager and in keeping with any recent scientific knowledge**.

***Advice:** Future consideration should be given by NatureScot as to whether it is feasible to provide detailed habitat and or species mapping to help incorporate specific biodiversity objectives into muirburn planning.*

6.4 Can muirburn be used to address the risk of wildfire and if so in what circumstances?

6.4.1 Advice sought on wildfires

With a lack of clear evidence on the relationship between muirburn and wildfire (both in terms of its role in causing wildfire and in its role in reducing the risk of wildfire) how should we identify the range and levels of risk? In particular it would help to focus on:

- What factors need to be considered in assessing whether muirburn has a role in reducing the risk of wildfire, and if it does what is this role and in what circumstances should it apply?

6.4.2 Key points on evidence and gaps

There are two issues associated with the relationship between muirburn and wildfire, a negative and a positive one.

(a) Negative effect

Some muirburn fires escape and get out of control and this leads to an unintended fire outwith the intended burn area. The recording of such fires is often via the Scottish Fire and Rescue Service (SFRS) and often relates to callouts (although not all wildfires result in call outs). Some of these are genuine and some are callouts by the general public to genuine muirburn fires that are not out of control. An analysis of SFRS records suggests that escaped muirburn may have caused 60% of wildfires, a similar estimate to that from a questionnaire study of 41 estates, showing 53% of wildfires started by muirburn (Luxmoore 2018, Legg et al 2006; both cited in Holland et al., 2022)

There is no doubt that muirburn can, on occasions, get out of control and develop into a wildfire. This is a risk implicit every time a fire is lit. However, if the Muirburn Code is followed this risk should be minimised, specifically having trained practitioners identifying when and where to burn and having sufficient trained practitioners and equipment to control the fire (Section 4.2).

Moreover, if there is good planning and liaison with SFRS there should be a reduction in false recording of well-managed muirburn as wildfires. Irrespective, there is a need for a good, national recording system for wildfires.

(b) Positive effect

All vegetation and peat will burn if they are dry enough and there is an ignition source. The ignition source of most wildfires in the UK is usually from accidental fires from barbecues/campfires etc. There is also the possibility of fires from lightning, sunlight via glass, discarded cigarettes, plane crashes and sparks from industrial units (welders etc.). Muirburn will not on its own affect whether a wildfire starts under these situations but the vegetation mosaic might lead to a better chance of reducing the intensity and severity of the fire (sensu Keeley, 2009) by reducing the overall vegetation biomass on the ground – the fuel load. Moreover, it also allows easier movement across the landscape of firefighters hence aiding the chances of putting the fires out quickly. Although it should be noted that Holland *et al*., 2022 concluded in their review that 'the evidence base relating to the role of muirburn in controlling fire intensity and fire severity was too limited to draw firm conclusions'.

Having said this, the evidence for muirburn mitigating some of the risks of wildfires is weak in Britain. Part of the reason for this is that wildfires are sporadic and it is difficult to study them unless the wildfire runs across land for which there is existing data. Wildfire mitigation is also not generally the primary purpose for carrying out muirburn. This has, in part, resulted in a lack of clear understanding of the effectiveness of muirburn as a wildfire management strategy at a landscape scale. However, if the international literature is considered all the evidence suggests that the fuel load is always an important variable in wildfire damage. In the British Isles, muirburn has been shown to reduce fuel load and, hence it is likely to help mitigate the potential speed with which a wildfire could spread and reduce its intensity. A project conducted by the James Hutton Institute and Edinburgh University looked to 'establish a robust approach for adapting the Canadian Fire Weather Index (a forest fire danger rating system) to

Scottish moorland vegetation types'[1]. The project concluded that 'There are no appropriate fuel models within the Canadian Fire Weather Index System that match the fuel structure of heather moorland and adequately capture the fire spread drivers in these systems'. Manchester University with funding from Defra is currently looking at developing this work further.

Although wildfires are deemed currently not to be a major issue within Scotland, they do occur occasionally with considerable damage to habitats. Their frequency of occurrence, size and increase in burn temperatures may become an increasing issue within Scotland if climate change produces warmer and especially drier springs and summers.

6.4.2 Advice on how to take a risk-based, precautionary approach

It is recognised that there may be situations where an applicant wishes to use muirburn to seek to reduce wildfire risk, i.e. the primary rationale for the muirburn would be to reduce fuel load and thereby reduce the intensity/severity/impact of any wildfire that happens to occur. As indicated above, the application of the precautionary principle to the muirburn licencing process should – until further evidence is available as to whether muirburn does or does not reduce wildfire risk - allow for such an exception to be applied for. However, the application process should also require an applicant to provide evidence that the wildfire risk is unacceptably high and – if that is the case – that muirburn is the most relevant management practice to reduce the fuel load. This justification and explanation should be laid out in a plan demonstrating how the muirburn will be planned to protect an area or asset from wildfire. Muirburn should reduce the fuel load and thus mitigate the potential speed with which a wildfire could spread and reduce its intensity. In addition, it provides a mosaic of patches, some with parts with a lower vegetation height allowing easier access for fire fighters.

The sub-group advise that an exception to allow applicants to apply to carry out muirburn specifically to reduce the risk associated with any wildfire which might occur, should be supported by a set of criteria to justify why they think the fuel load is high, and why wildfire risk is unacceptably high. The sub-group advises however, that where prescribed burning is to be implemented for wildfire control, adherence to the Muirburn Code (specifically section 7) is recommended to minimise risk of escape fires.

In England, any request to conduct muirburn on deep peat within areas designated for their nature conservation value currently requires the applicant to conduct a Wildfire Risk Assessment and – on the basis of the risks identified – develop a Wildfire Management Plan [for more details see: https://www.uplandsmanagement.co.uk/wildfire].

The sub-group advise that consideration be given to (a) whether this existing Wildfire Risk Assessment template is fit for purpose for use in Scotland and (b) whether any associated justification of muirburn as being the most relevant management practice requires the development of a full Wildfire Management Plan or simply a mapping process which

[1] Taylor AFS, Bruce M, Britton AJ, Owen IJ, Gagkas Z, Pohle I, Fielding D, Hadden R (2021). Fire Danger Rating System (FDRS) Report. James Hutton Institute. https://www.hutton.ac.uk/sites/default/files/files/publications/SFDRS-Research-Report-Final-15-2-2022.pdf

indicates where on the site the fuel load in the existing habitats is best managed by burning or cutting.

The sub-group suggested that where muirburn is implemented for experimental purposes, restoration or grass management the Muirburn Code should be followed, and any necessity for large fires should be implemented as a series of small contiguous fires as recommended in the Muirburn Code. In addition this may minimise the risk of escape fires.

The sub-group noted that in Holland *et al*., 2022 an estimate of the proportion of wildfires that result from managed burning, lay in the range of 15%-60%, but based on limited evidence base and with a number of caveats. The review concluded that there is evidence that muirburn directly causes a proportion of wildfires that occur, but that there remains uncertainty regarding this proportion. The subgroup advises that to minimize the risk of a muirburn escaping, it has to be well-managed and controlled and that training can help impart knowledge of the necessary skills and knowledge (included in the Muirburn Code, Section 3.3).

The sub-group noted the work by the James Hutton Institute and the ongoing work on the development of Wildfire Prediction and Warning Systems at Manchester University[2] . This may provide key input into the provision of times when wildfires are likely and appropriate management can be put in place to minimize risks. The subgroup recommends that NatureScot should keep this matter under review.

Advice: *An exception to allow applicants to apply to carry out muirburn specifically to reduce the risk associated with any wildfire which might occur, should be supported by a set of criteria to justify why they think the fuel load is high, and why wildfire risk is unacceptably high.*

Advice: *Where muirburn is to be implemented for wildfire control, adherence to the Muirburn Code (specifically section 7) should be recommended to minimize risk of escape fires.*

Advice: *Consideration should be given to (a) whether the Wildfire Risk Assessment developed in England is fit for purpose for use in Scotland and (b) whether any associated justification of muirburn as being the most relevant management practice requires the development of a full Wildfire Management Plan or simply a mapping process which indicates where on the site the fuel load in the existing habitats is best managed by burning or cutting.*

Advice: *Where muirburn is implemented for experimental purposes, restoration or grass management the Muirburn Code should be followed, and any necessity for large fires should be implemented as a series of small contiguous fires as recommended in the Muirburn Code.*

Advice*: Continue the work on developing a UK Fire Danger Rating System under review.*

[2] Toward a UK Fire Danger Rating System: Working towards a tailored UK fire danger rating system https://ukfdrs.com/

6.5 What should be taken into account to identify potential licensable purposes?

6.5.1. Licensable purposes outwith peatland

In order to issue a licence there will need to be sufficient confidence that a licensable purpose will be met. Currently muirburn can take place within the muirburn season (1st October – 15th April in Scotland) without a licence. This period can be extended to 30th April with the permission of the landowner.
The reasons for which muirburn are currently undertaken are broadly to:

- Conserve, restore, enhance or managing the natural environment
- Conduct research;
- Protect public safety;
- Grazing for livestock and game management;
- Create firebreaks and/or reduce the fuel load to manage the risks associated with wildfire causing damage to habitats, forestry, woodlands or property.

The sub-group agreed that the licensable purposes as identified above were appropriate in principle. The sub-group noted that reference to public safety is in relation to wildfire. No other potential licensable purposes were identified by the sub-group.

6.5.2 In what circumstances should burning be permitted on peatlands?

The Wildlife Management & Muirburn (Scotland) Bill 2023 proposes to introduce a statutory ban on burning on peatlands and includes suggestions on the circumstances in which burning could be permitted on peatlands. These are:

- Restoring the natural environment;
- Preventing, or reducing the risk of, wildfires causing damage to habitats;
- Preventing, or reducing the risk of, wildfires causing harm to people or damage to property;
- Research.

It is proposed that there will be a provision for issuing exceptional licences to allow burning on peatland.

Advice: *Exceptional licences on peatland, should require additional evidence than is needed under a normal licensing process. This additional evidence should include why it is necessary to carry out muirburn, in preference to any other land management or risk reduction techniques.*

Advice: *It would be helpful to identify if there are other processes whereby land managers ask for an exception on protected areas or similar which could be studied, both for the general process itself but also the weight of evidence and additional evidence that is required.*

6.5.3 Exceptional wildfire situations

Muirburn, and indeed other techniques of vegetation management (e.g. cutting, rotavating, ploughing or bulldozing), may need to be permitted in exceptional situations if large

wildfires break out, when near properties and especially if the fire approaches national/international infrastructure. Here the management needs to be implemented in advance of the approaching wildfire to stop its further spread. When this is needed, speed in decision-making will undoubtedly be of the essence and decision-making must either have a rapid response or be delegated to SFRS.

6.6 What criteria should be included in a constraints map?

The sub-group were asked to summarise the proposal for a licence application to be accompanied by a constraints map, showing where and where not it would be appropriate to burn according to criteria prescribed through a licensing approach. In particular the sub-group were asked to summarise advice on what data could be used to create a map and a rationale for the different criteria which should be taken into account.

The sub-group noted that the general conditions already outlined in the Muirburn Code would provide the criteria for a constraints map (these include features and assets, protected and sensitive areas etc.). The constraints should also include reference to the appropriate timing of burning. The sub-group noted that the burning season dates of 1st October to 15th April could still be applicable but anything outwith these dates would require an out of season licence. The sub-group also suggested that a base constraints map should include peat/soil information, a vegetation layer including trees and information concerning species distributions. These latter layers may prove challenging (time and resource constrained) so may not be fully implementable at this time.

Advice: *The sub-group support that a constraints map be produced – and that it should include conditions as outlined in the Muirburn Code. A further relevant constraint as outlined in the Muirburn Code is also timing.*

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Annex 1 Terms of Reference

SAC Muirburn sub-group

Terms of Reference

1 Aim

To bring together a small sub-group of the SAC to support staff in advising on science and technical matters related to: a) the 2022 review of muirburn published by NatureScot; b) gaps in knowledge and evidence; and ensuing work in developing a muirburn licensing approach.

2 Background

The Scottish Government committed, through the current Programme for Government, to introduce a new Wildlife Management (Grouse) Bill in 2022-'23. The Bill will introduce two new licences; one for grouse moor management, and one for muirburn.

The muirburn licence will apply to all muirburn and not just that which takes place on grouse moors; it will apply to hill farmers and crofters as well as grouse moor managers. The muirburn licence was recommended through the Werritty Report and will result in muirburn being 'unlawful unless carried out under licence'.

NatureScot is working closely with the Scottish Government to develop options for a licensing approach. The first stage has been a review of the evidence base. A final report has concluded, broadly, that some elements of the evidence base are unclear or contested in relation to impacts on carbon sequestration, wildfire incidence and containment, and biodiversity.

3 Scope

The purpose of the muirburn licence is to 'minimise the risk of damaging effects on environmental interests and address potential benefits such as the reduction of fuel loads'. The purpose of the SAC muirburn subgroup will be to provide expert advice to support staff in addressing unclear elements of the evidence base, whilst minimising risks and applying the precautionary principle in developing a licensing approach to muirburn. This will contribute to the development of policy (the sub-group will not be involved in policy development).

4 Main tasks/specific points it would be useful to consider

- Identify key points from the main findings of the NatureScot review report which support evidence based approaches to potential licensing of muirburn;
- Advise on key knowledge gaps outlined in the review, and others, which could be addressed through further work;

• Advise on further risks and benefits associated with muirburn as detailed in the review, and drawing on any other lines of available evidence;
• Support staff in developing the evidence base underpinning the application of the precautionary principle in relation to muirburn.

5 Duration of group/frequency of meetings

This will be a time bound task and finish group. We anticipate that the group will meet two to three times, once in late- November, once in December and potentially once more in January. Advice will be sought through correspondence as well as in meetings.

SUMMARY OF IMPLICATIONS OF UPDATED KNOWLEDGE OF THE RELATIONSHIP BETWEEN WILDFIRES, MUIRBURN AND PEATLANDS IN RELATION TO THE 2023 ADVICE FROM THE SAC MUIRBURN SUB-GROUP

Key Summary:

This updated advice from NatureScot SAC strengthens the conclusions stated in its previous 2023 report. Specifically:

- *that the evidence remains contested*
- *that the adaptive precautionary approach is critical in that context*
- *that the existing licensable purposes and revised Muirburn Code together are vital components in managing the risks of furthering carbon losses on peatlands.*

HEADLINE POINTS

- **Compliance with the Muirburn Code and training is the best way to reduce the risks and uncertainties associated with muirburn. Licensing is the best way to secure compliance with the Code.**
- **Muirburn for wildfire prevention is different from muirburn for habitat management: the former requires targeted and strategic placing of firebreaks and strategic reduction of fuel load.**
- **Evidence suggests climate change will increase the risk of wildfires in coming years.**
- **A high proportion (approx. 80%) of peatland in Scotland is degraded and at higher risk of damage from burning.**
- **The original advice in the 2023 SAC muirburn sub-group report to adopt an adaptive precautionary approach remains valid.**

PEATLANDS AS CARBON STORES

- ***Peatlands play a crucial role in reaching net zero*** and addressing the climate crisis by storing carbon when in good condition. Significant public investment is being directed at restoring peatlands. Degraded peatlands are carbon emitters.

EVIDENCE BASE & PRECAUTIONARY APPROACH

- Some new evidence has emerged since 2023 but the overall picture is ***still of an unclear evidence base*** on the impacts (long-term) of muirburn on peatlands, including other climate risks (such as pests, pathogens and disease) that could affect habitat quality and carbon storage.
- Taking an ***adaptive precautionary approach remains the best way to ensure muirburn can be used appropriately and safely***, particularly in relation to protecting peatlands and addressing wildfire risks, at least in the short term.

REGULATION

- ***Four out of the ten licensable purposes*** in the Wildlife Management and Muirburn Act ***are to prevent or reduce the risks of wildfire***
- The aim of the ***regulation is to ensure that muirburn is carried out safely and appropriately*** – this still stands

- ***Compliance with the Muirburn Code and training is currently the best way to reduce the risks*** and uncertainties associated with muirburn and the best way to ***secure compliance is through licensing***
- ***The evidence of a relationship between muirburn and wildfire is uncertain*** e.g. work by Fielding et al 2024 indicates that muirburn and wildfires tend not to be co-located but recent experience at Dava-Carrbridge indicates some overlap and previous evidence[1] suggested that muirburn causes a proportion of wildfires that occur on moorland, noting that there remains uncertainty regarding this proportion.
- ***All licences and guidance are subject to regular review***. This adaptive approach allows new evidence and knowledge to inform future iterations.

REDUCING WILDFIRE RISKS

- **Muirburn for wildfire prevention is different from muirburn for habitat management;** wildfire prevention requires targeted and strategic placing of firebreaks and targeted and strategic reduction of fuel load and leads to a different pattern of burning/cutting and habitat renewal across landscapes.
- Integrated fire management is being suggested for wildfires – emphasising fire prevention and preparedness for a range of climate risks, both acute and chronic. ***Muirburn would be part of this management strategy but not the sole component.*** There needs to be a more holistic approach to wildfires
- The recent World Bank European review[2] suggests promotion of more ***nature based and sustainable land use practice for fire risk management***.

1 INTRODUCTION, BACKGROUND AND CONTEXT

1.1 Climate change & wildfires

Our changing climate, with hotter temperatures, storms and droughts is increasing the risks of wildfires (classified as 'large, uncontrolled outdoor fires exceeding 1,000 square meters of burned area on appropriate land types'[3]). In Scotland wildfire risks can affect the uplands and lowlands, including peatlands. Scotland experienced its largest wildfire on record in June 2025 (Dava Carrbridge estimated to have covered approximately 10,000 ha). The fire was reported widely in the media and social media and led to several high-level debates, including a joint Ministerial Wildfire Summit held in October 2025. In Scotland, most wildfires are caused by people with ignited fires resulting in wildfires depending on conducive conditions (e.g. fuel load, moisture, weather conditions etc.).

[1] https://www.nature.scot/doc/naturescot-research-report-1302-reviewing-assessing-and-critiquing-evidence-base-impacts-muirburn
[2] https://documents1.worldbank.org/curated/en/099092925035521062/pdf/P178843-1338e9a8-b919-4ec6-9e2d-27763da28cd8.pdf
[3] Scottish Fire and Rescue Service - https://www.firescotland.gov.uk/outdoors/wildfires/understanding-wildfires-in-scotland/

1.2 Muirburn licence

The muirburn licence, was introduced by the Wildlife Management and Muirburn (Scotland) 2024, to help ensure that all muirburn was carried out appropriately and safely. The licence distinguishes between peatland and non-peatland and includes ten licensable purposes, four of which relate to reducing wildfire risks. It was due to come into effect on 1st January 2026 but was delayed to allow further consideration on the role of muirburn in reducing the risks of wildfire.

1.3 Evidence base

The evidence base on the impacts of muirburn is unclear. This lack of clarity led to a sub-group of NatureScot's Scientific Advisory Committee being set up in October 2022 to provide advice to NatureScot staff on how to apply the precautionary approach and adopt a risk-based approach to developing a licencing regime for muirburn. This advice focused on impacts of muirburn on peatlands, carbon stores, biodiversity and relationship to wildfires. The group produced a short report setting out their advice in early 2023 (key findings are set out in Annex 1).

1.4 Policy intent of muirburn regulation in relation to peatlands

The muirburn licence distinguishes between peatland and non-peatland, with early thinking referring to a 'ban' on burning on peatlands. This was driven by the role of peatlands in achieving net zero and the potential negative impacts of burning on peatlands for carbon storage. There are four licensable purposes for carrying out muirburn on peatlands, of which two relate to reducing wildfire risks. The WM&M Act stipulates that muirburn on peatlands must be 'necessary' and that 'no other method of vegetation control is practicable'.

2 WHAT WAS THE KEY ADVICE IN THE 2023 REPORT?

The key advice set out in the SAC muirburn sub-group's 2023 report included:

- NatureScot should ***adopt an adaptive precautionary approach*** to developing the licensing approach to allow new learning and understanding to feed into future iterations of the licence and guidance
- An exception to allow muirburn on ***peatlands to reduce wildfire risk*** would need ***additional evidence*** setting out why it is ***necessary*** to carry out muirburn and why burning is required rather than an alternative technique.
- Compliance with ***the Muirburn Code and training will help to implement a risk-based approach*** to muirburn
- Given the potential ***long-term impacts on carbon storage***, the subgroup recommend that NatureScot should commission a ***continuing review of the accumulating evidence*** to inform changes as required to licensing.

3 WHAT HAS CHANGED SINCE 2023?

The advice in the 2023 report predated the passing of the WM&M Act and the increase in awareness of wildfire risks, especially following the Dava Carrbridge fire. The following highlights the main changes in policy development, knowledge and evidence in relation to peatlands and climate change which are relevant to Scotland (note research from beyond

Scotland has been included e.g. Natural England updated literature review and publications by Heinemeyer).

Peatland policies

- Continued significant public investment in peatlands in recognition of their role in achieving net zero and climate change targets (£35.5 million in peatland restoration in 2025-26[4])
- New targets for peatland restoration in the Draft Climate Change Plan (400ha by 2040)
- Publication of first in a series of rolling Peatland ACTION Five-Year Partnership Plans (published December 15th 2025)
- DEFRA extension of regulation on grass and heather burning in England[5] (peat at depth of 30cm and extended to Less Favoured Areas)

Relationship between wildfires and peatlands - new and developing knowledge relevant to Scotland (see Annex 2)

- New research publications and position statements indicating positive impacts of muirburn generally, not just in relation to wildfire prevention (e.g. research comparing burning, cutting and no management which suggests burning is the best technique for carbon storage) and negative impacts (e.g. IUCN Peatland Programme position statement on burning on peatlands)
- Updated evidence review on managed burning by Natural England confirmed their earlier evidence review that managed burning can lead to changes in vegetation and hydrology of peatlands.
- New data sets (e.g. SFRS incident reports for 2025 and NatureScot's summary of wildfire and muirburn extent derived from satellite imagery 2023/'24). SFRS 2025 data indicates significant increase in wildfires from previous 2 years.
- NatureScot's report on predicted increase in droughts – predicted to be 1 in 3 year events by 2040 and affect east more that west of Scotland
- Developing Climate Change Risk Assessment 4 confirms that wildfires are likely to continue to be a risk, and, current drafts emphasise the importance of stochastic aspects of climate change (extreme events and unusual weather patterns of weather) and multiple cascading risks.
- Wildfire as a theme in the Scottish Government's Strategic Research Programme – new research being considered on what fire resilient landscapes look like

Development of licence/Muirburn Code

- An outline licence application has been developed and a revised Muirburn Code with input from stakeholders
- Carrying out muirburn to alleviate wildfire risk requires a different approach to carrying out muirburn to manage habitats. The focus should be on targeted and strategic reduction of fuel loads and creation of fire breaks.
- Guidance on how to apply for a muirburn licence for the purpose of reducing wildfire risk on peatlands has been developed – this focuses on a risk-based approach and

[4] https://www.nature.scot/sites/default/files/2025-06/peatland-action-annual-review-2024-25.pdf
[5] https://www.gov.uk/guidance/heather-and-grass-burning-apply-for-a-licence

requires details on ignition risks and what is at risk and confirmation that muirburn will be carried out in a strategic and targeted way to address these specific risks.
- All licences and guidance are subject to regular revision and iterations, taking on board any new and emerging evidence.

4 WHAT IS THE GROUP'S UPDATED ADVICE IN THE FACE OF THESE CHANGES?

We have undertaken this review within a very tight timescale but are confident that we have captured the main changes since 2023.

The following summarises our updated advice:

- ***Peatlands –*** The condition of the peatland and hydrology (moisture) should be considered in understanding impacts of muirburn. Drained peatlands, low water, or those with substantive erosion are likely to be more vulnerable to peat burning. There is some research evidence outside the UK that degraded/drained peatlands are more likely to burn and wet ones are less likely to burn compared to other habitats. Such evidence is needed in the UK/Scottish context. We know that it is estimated that over 80% of Scotland's peatlands are degraded.

- ***Uncertain evidence base –*** The evidence base remains unclear. Examples of where more evidence is needed include:
    - The impact of alternative vegetation control methods, e.g. cutting - some evidence (Heinemeyer) suggests that cutting results in higher C losses due to slower heather regrowth.
    - There is a need for long-term studies on the impacts of wildfires and muirburn on carbon storage as well as more on cutting vs burning.
    - Need to be clearer on the risks of 'business as usual' and the consequences of more complex habitat mosaics in (parts of) the uplands.
    - More work is also required on the impacts of muirburn on amphibians and reptiles.
    - Recovery after wildfires is poorly studied. The recovery rate of different habitats, particularly in response to restoration needs further study.
    - Rates of spread are a key research gap for different habitat types - and with an increasing urgency given many afforested/naturally tree regenerating landscape

- ***Integrated wildfire management –*** wildfire management plans are starting to emerge, for instance the Cairngorms National Park have created an integrated wildfire management plan - https://cairngorms.co.uk/our-work/wildfire-management - this could be used as a benchmark for other collective regional plans. Integrated fire management is being suggested more generally for wildfires, so muirburn would be part of this management but not the sole component. The recent World Bank European review suggests promotion of more nature based and sustainable land use practice for fire risk management, again which might also reflect on changes in muirburn.

5 NEXT STEPS

We propose to convene a small, focused group of researchers and scientists from across the UK to address the unclear and contested evidence base around muirburn and wildfires. The group will highlight the key science and evidence and gaps and routes to address these gaps and ways to deal with the increasingly unpredictable impacts of climate risks - acute and chronic. This will help ensure up to date science and knowledge underpins the development of a Scottish wide integrated and strategic approach to wildfires and informs our approach to muirburn. We will aim to initiate this review by early summer.

Annex 1 Executive Summary in 2023 Report

Summarised below is the key advice from the sub-group on addressing the uncertainties in the evidence base in the development of a licensing approach.

2.1 General Advice

- *The evidence base on the benefits and 'costs' of muirburn is expanding, and the nature of impacts will become clearer over time which means that any guidance/policies and procedures adopted now will require to be monitored, reviewed and potentially updated in the future.*
- *An adaptive precautionary approach, which builds in transparent monitoring and review processes, (recognising that this will have significant financial and time implications and may not be feasible) should be taken in developing a licensing approach.*
- *The application of the Muirburn Code, with appropriate training, will provide a practical mechanism to implement a risk based approach.*
- *Keep abreast of new, relevant scientific developments and consider commissioning further focused pieces of work on specific aspects where the uncertainties are greatest or the scientific evidence most contested.*

2.2 Advice on Peatland

- *Maintaining the depth of 50 cm or more for the definition of peat enables outline desk-based assessments to be made as soil survey data is based on this definition.*
- *For the purposes of muirburn licensing, the subgroup advise using Class 1 & 2 in the Carbon & Peatland Map 2016 as the method of indicating areas of peatland.*
- *Site specific peat information could be provided as required using standard measurement protocols e.g. (https://www.iucn-uk-peatlandprogramme.org/sites/default/files/2019-07/PC_Field_Protocol_v1.1.pdf)*

2.3 Advice on Carbon

- *Where muirburn is licensed, provide clear guidance concerning the nature of the muirburn and under which conditions (temperature of fire, specific locations etc.) it is allowed to help mitigate the risk to carbon.*
- *Given the potential long term impacts on carbon storage, the subgroup recommend that NatureScot should commission a continuing review of the accumulating evidence to inform changes as required to licensing.*

2.4 Advice on Biodiversity

- *Within the Muirburn Code there are already good practice guidance and statutory restrictions for mitigating risk to protected species and nesting birds, and sensitive areas (Sections 4 and 5).*
- *NatureScot should undertake an assessment of the current legislation as it relates to muirburn and biodiversity to see if it is in keeping with recent scientific knowledge*.

- *Future consideration should be given by NatureScot as to whether it is feasible to provide detailed habitat and or species mapping to help incorporate specific biodiversity objectives into muirburn planning.*

2.5 Advice on Wildfire

- *An exception to allow muirburn on peatlands to reduce wildfire risk would need additional evidence setting out why it is necessary to carry out muirburn and why burning is required rather than an alternative technique.*
- *Consideration should be given to (a) whether the existing Wildfire Risk Assessment template used in England is fit for purpose for use in Scotland and (b) whether any associated justification of muirburn as being the most relevant management practice requires the development of a full Wildfire Management Plan or simply a mapping process which indicates where on the site the fuel load in the existing habitats are best management by burning or cutting.*
- *Where muirburn is to be implemented for wildfire control, adherence to the Muirburn Code (specifically section 7) should be recommended to minimize risk of escape fires.*
- *Where muirburn is implemented for experimental purposes, restoration or grass management the Muirburn Code should be followed, and any necessity for large fires should be implemented as a series of small contiguous fires as recommended in the Muirburn Code.*
- *Keep the work on developing a UK Fire Danger Rating System under review.*

2.6 Advice on Licensable Purposes

- *Exceptional licences on peatland, should require additional evidence than what is needed under a normal licensing process. This additional evidence should include why it is necessary to carry out muirburn, in preference to any other land management or risk reduction techniques.*
- *It would be helpful to identify if there are other processes whereby land managers ask for an exception on protected areas or similar which could be studied, both for the general process itself but also the weight of evidence and additional evidence that is required.*

2.7 Advice on what criteria should be included in a constraints map

- *The sub-group support the production of a constraints map – and that it should include conditions as outlined in the Muirburn Code, including appropriate timing.*

Annex 2 Additional relevant research reports, data and policy statements (this list is not exhaustive and are the key ones identified in the time given)

Published reports

- Alastair J Crawford, Claire M Belcher, James I L Morison, Stefan H Doerr, Nicholas Kettridge, Gareth D Clay, **Fuel moisture and flammability of leaf litter in British forest plantations and their implications for wildfire risk**, *Forestry: An International Journal of Forest Research*, 2025;, cpaf029, https://doi.org/10.1093/forestry/cpaf029

- Clay G and Worrall F (2011). **Charcoal production in a UK moorland wildfire--how important is it?** J Environ Management 92(3):676-82.

- Fielding, D., Newey, S., Pakeman, R.J., Miller, D., Gagkas, Z., Matthews, K. and Smith, S.W., 2024. **Limited spatial co-occurrence of wildfire and prescribed burning on moorlands in Scotland.** *Biological Conservation*, *296*, p.110700. https://www.sciencedirect.com/science/article/pii/S0006320724002623

- Fielding, D., Pakeman, R. J., Newey, S., & Smith, S. W. (2025). **The impact of moorland cutting and prescribed burning on early changes in above-ground carbon stocks, plant litter decomposition and soil properties**. *Ecological Solutions and Evidence*, 6, e70112. **https://doi.org/10.1002/2688-8319.70112**

- Heinemeyer, A. (2023). **Protecting our peatlands. A summary of ten years studying moorland management as part of Peatland-ES-UK: Heather burning compared to mowing or uncut approaches.**

- Heinemeyer, A., Morton, P.A., David, T., Holmes, T. Jones, A.L., Liu, B. (2025) **Ecological implications of changes in vegetation elemental composition under different heather (*Calluna vulgaris*) managements on British blanket bog**. *Journal of Environmental Management* **392,** 126720. [Available online at: https://doi.org/10.1016/j.jenvman.2025.126720].

- Heinemeyer, A., Ashby, M.A., Liu, B., Mycroft, A., Burn, W.L., Holmes, T., Jones, A. L., Andrews, L.O. (2025) **Prescribed Heather Burning on Peatlands: A Review of Ten Key Claims Made About Heather Management Impacts and Implications for Future UK Policy.** *Mires and Peat* 32, 12. [Available online at: https://doi.org/10.19189/001c.143335].

- Marrs, R. H., Marsland, E. L., Lingard, R., Appleby, P. G., Piliposyan, G. T., Rose, R. J., O'Reilly, J., Milligan, G., Allen, K. A., Alday, J. G., Santana, V., Lee, H., Halsall, K., & Chiverrell, R. C. (2019). **Experimental evidence for sustained carbon sequestration in**

fire-managed, peat moorlands. *Nature Geoscience*, **12**, 108–112. **https://doi.org/10.1038/s41561-018-0266-6**

- Naszarkowski, N. A. L., S. J. Woodin, L. C. Ross, A. J. Hester, and R. J. Pakeman. 2025. " **Fire Severity and Habitat Type Determine Vegetation Change and Regeneration Time Following Wildfires in Scottish Uplands.**" *Ecology and Evolution* 15, no. 7: e71791. **https://doi.org/10.1002/ece3.71791**.

- Simpson, K. J., C. M. Belcher, and S. J. Baker. 2025. **Adaptive plant traits under anthropogenic burning regimes: a database for UK heath and mire plant species.** *American Journal of Botany* 112(10): e70090. **https://doi.org/10.1002/ajb2.70090**

- Spracklen, B. D., & Spracklen, D. V. (2023). **Assessment of peatland burning in Scotland during 1985–2022 using Landsat imagery**. *Ecological Solutions and Evidence*, 4, e12296. **https://doi.org/10.1002/2688-8319.12296**

- Integrated fire management as an adaptation and mitigation strategy to altered fire regimes | Communications Earth & Environment

- Management of Wildfire Risk in the European Union | GFDRR

- UHI – Wildfire and degradation accelerate northern peatland carbon release

- UHI – Blanket bog vegetation response to wildfire and drainage suggests resilience to low severity, infrequent burning

- NatureScot Research Report 1228 - Anticipating and mitigating projected climate-driven increases in extreme drought in Scotland, 2021-2040

Critiques of other reports

- Prescribed Fire in UK Heather-Dominated Blanket Bog Peatlands: A Critical Review of "Carbon Storage and Sequestration by Habitat: A Review of the Evidence (Second Edition)" by Gregg et al., 2021

Literature Reviews

- Natural England - An evidence review update on the effects of managed burning on upland peatland biodiversity, carbon and water (NEER155)

Policy Statements

- IUCN Position Statement: Burning on Peatlands (updated April 2025)

Data and statistics on wildfires in Scotland

- Scottish Fire & Rescue Service 2025 Wildfires - reported incidents 2025-12-08 https://naturescot.nexus.objective.co.uk/documents/A5636550/details

- NatureScot dashboard based on data from Sentinel 2 satellite imagery - Wildfire and muirburn extents in Scotland