Desk review of burning and other management options for the control for heather beetle (NEER009)

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Desk review of burning and other management options for the control for heather beetle

Pinder, A.C., Gillingham, P., Diaz, A. and Stillman, R

Bournemouth University

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Project manager

Adrian Pinder
1 Bournemouth University
Faculty of Science and Technology
Fern Barrow
Poole
Dorset
BH12 5BB
Tel: 01202 962574
www.bournemouth.ac.uk

Natural England contact

Evelyn Jack
Senior Adviser
Project Manager - Evidence Reviews
Natural England Mail Hub Block B
Whittington Road
Worcester
WR5 2LQ
evelyn.jack@naturalengland.org.uk

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Executive summary

The heather beetle *Lochmaea suturalis* is a naturally occurring species in the heather dominated landscapes of the United Kingdom. When the heather beetle population density increases dramatically it can cause significant damage to heather plants. It has been suggested that burning heather outside the permitted heather-burning season will promote the regeneration of heather following heather beetle damage. There is also some discussion as to whether burning outside the permitted season might also help control heather beetle. For these reasons Natural England regularly receives applications for licences to burn outside the permitted season. However, burning at this time of year may have effects on a wide range of biodiversity. Therefore, Natural England commissioned this report, and (NEER008 - *A desk review of the ecology of heather beetle)* to ensure the best available evidence is being used.

An extensive literature review was carried out to determine the effectiveness of burning and other management options in managing heather-dominated systems for the heather beetle *Lochmaea suturalis*. In general, the quantity of relevant studies was low, and the quality of most was also poor, with very low levels of replication and/or a lack of controls or comparators being very common. There are three potential ways that management could be used.

The first way is to reduce the likelihood of outbreaks. There is currently no evidence that burning is useful for this, due to a lack of relevant studies. Other management options that could be considered to achieve this are biological control and drainage of wetter areas, as well as general moorland management such as mowing, rotovating and sod cutting.

The second way that burning could be used is by burning infested areas to reduce the numbers of heather beetles present. There has been some discussion as to whether it would be necessary to do this outside the current burning season, but there is currently no reliable evidence available to show whether this is effective, nor a cost-benefit analysis to take account of the additional risks of burning during the summer months. This is again due to a total lack of relevant studies. Other management options at this stage are to use insecticides on the affected areas, but there are also risks associated with this and again there is a lack of evidence as to how effective it would be. The potential for biocontrol at this stage has also not yet been explored.

The third way is in encouraging regeneration of damaged areas. The available evidence for this is generally poor quality, and there is some suggestion that management techniques other than burning might be more effective at encouraging regrowth. In addition, some sites have been observed to regenerate naturally, in the absence of management, so there is a question as to whether management is necessary. Some trials are currently under way in Scotland and the Peak District with the aim of determining which management techniques are best for restoring damaged heather, but again the level of replication and lack of control areas appears to be a problem.

The following are recommended in order to be better able to advise managers in the future:

- Management actions should be carefully monitored so as to establish the effects of decisions (including whether to burn out of season or not). This monitoring should use properly designed experiments with adequate levels of replication and control plots. The effectiveness of management in controlling heather beetles and the effects on biodiversity as a whole and on ecosystem functioning should all be recorded.
- Further research should be undertaken into the relationship between the heather beetle and its natural enemies.
- Further research should be undertaken into the other factors that might affect the likelihood of outbreaks occurring.

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1 Introduction

Background

1.1 The heather beetle *Lochmaea suturalis* is a naturally occurring species in the heather dominated landscapes of the United Kingdom. It is recognised that population density can vary dramatically at the local level, giving rise to 'outbreaks' which can lead to damage to heather plants, with damage appearing in late June through to September.

1.2 Heather has been burned in rotation (to produce high densities of red grouse *Lagopus lagopus scoticus* since the first half of the 19th Century (Usher & Thompson 1993). Summer burning of heather was illegal as long ago as 1607 (Mowforth & Sydes 1989) and the current Heather and Grass Burning regulations (2007) stipulate that burning (in Upland areas) can only be undertaken between the 1st October and the 15th April, unless under licence from Natural England. In lowland habitats managed burning is permitted from the 1st November to the 31st March. Early authors on the subject (Morison 1938, Cameron *et al.* 1944) suggested that summer burning or potentially dusting with derris or pyrethrum during the early stages of an infestation might help control numbers. Natural England regularly receives applications for licences to burn outside the permitted season in order to promote effective regeneration of heather following heather beetle damage. There is also some discussion on whether summer burning might help 'control' heather beetle. However, advice on how to go about this legally is conflicting (MAFF 1999) and burning outside of the season may have impacts on wide range of biodiversity, such as breeding birds. Some managers consider heather beetle outbreaks to be an external factor outside immediate management control (Grant *et al.* 2012).

1.3 In order to inform their advice and decision-making on this issue, Natural England commissioned this review to ensure they are drawing on the best available evidence.

Aims and objectives

1.4 The initial aim of this review was to assess evidence to address the question:

- "Is burning an effective management technique for heather beetle?"

1.5 A secondary aim was to assess evidence to address the question:

- "Is out-of-season (summer) burning a more effective management tool for controlling heather beetle outbreaks than within season (autumn/spring) burning?"

1.6 An additional aim was to consider other management options and assess the evidence for their efficacy compared to burning, whether in or out of season. Lastly, where evidence is lacking, we aimed to highlight these knowledge gaps and make recommendations for further research.

Methods

1.7 Literature from the systematic review completed for NEER008 - *Desk review of the ecology of heather beetle* was screened for relevance for this review by considering the summaries written for NEER008. Literature found during the first systematic review but not selected for inclusion in NEER008 was additionally screened for relevance for this review by the lead author at title level. Papers were rejected if the title was clearly not relevant, or if the source was clearly not reliable (ie a press release or news source) and if there was any uncertainty then the paper was passed along to the next step. The remaining papers were then screened at abstract level and if still unclear, a full text search was performed to determine relevance.

1.8 Additional searches were made in Google Scholar using the search terms in Table 1. These searches were not performed in mySearch (Bournemouth library services database) as the terms “Heather Beetle” and “*Lochmaea suturalis*” had already been explored in full during the literature search for the first review, so no additional material would have been found. The outcomes of these additional searches (inclusion, rejection and at which stage, along with availability) were recorded in a spreadsheet, with 4 being rejects at the title level, 9 being rejected at the abstract level and 9 being rejected after a full text search (see Appendix 1 for rejected papers, Appendix 2 for papers that were not available and Appendix 3 for all papers selected for inclusion). We additionally searched the bibliographies of all selected texts and searched for all literature that appeared relevant at title level or by description in the text. The chosen papers were then read in more detail and synthesised to produce this review. Originally we had intended to extract data from each paper, and rate each for quality based on the number of replicates and relevance of the trial to the aim of this review, however all the papers we found would have been considered low quality and relevance given these criteria, so we have instead ranked sources for quality of the study performed and included an additional rank for relevance to the questions of interest (see Appendix 3).

Table 1 Additional searches performed in Google Scholar to generate further source articles for this review

Date	Search String	No. of results	No. of new results[1]
14/01/14	“Lochmaea suturalis” AND “*burn*”	56	7 (3)
14/01/14	“Lochmaea suturalis” AND “*manage*”	228	33 (11)

[1] Number in brackets refers to the number of these references that were included in this review.

2 Results

Overview of literature selected

2.1 Many of the field experiments conducted by scientists occurred on the same few sites and management for heather beetle was very rarely found to be a primary objective of the study. Questionnaire approaches undertaken in Scotland (Pakeman *et al.* 2002) and England and Wales (Newton *et al.* 2009) cover larger geographical areas, but are necessarily mostly based on the opinions of land managers, and do not define a timescale for, or what is meant by, 'success' when managing heather. In addition, the latter does not consider heather beetle, and found that the opinions of land managers was at odds with the available evidence from scientific experiments. One potentially useful paper was only available in German, with an abstract in English (Goldammer *et al.* 2009), however it appears to be largely anecdotal in nature and there was only one mention of *Lochmaea suturalis*, the remainder is a general overview of German land managers experiences of the use of prescribed fire since the 1990s.

2.2 There are three possible ways that burning might be expected to be beneficial when managing heather beetles. The first is in prevention of outbreaks in the first place. This might be expected if heather beetle outbreaks are only found on older heather, as some authors have contended (Richards 1926, Marrs 1986, see paragraph 2.3). The second is in killing off individuals during an outbreak, so that less damage is caused (see paragraph 2.4). Thirdly, burning might encourage regeneration of damaged heather after an outbreak (see paragraph 2.5). There are also risks and disadvantages associated with burning (see paragraph 2.7) that have led some managers to consider other management methods to prevent scrub encroachment, and some of these might usefully be considered for management of heather beetle at some of the stages covered in paragraphs 2.3 to 2.7 (see 2.8 -). In addition, if the negative effects of climate change operate mostly through the increased availability of nutrients via increased nitrogen mineralisation and nitrification (Wessel *et al.* 2004), management that removes these nutrients might be expected to both mitigate the impacts of increased nitrogen availability both directly and via the indirect effect on heather beetles (see Evidence Review NEER008 *Desk review of the ecology of heather beetle*). In the debate surrounding the usefulness of burning in the early 1990s, objections to the practise centred around the removal of nutrients from the system (Usher & Thompson 1993), which may actually be useful under climate change either to prevent heather beetle attack or prevent encroachment by grasses following an outbreak (see Evidence Review NEER008).

Effectiveness of heather burning to prevent outbreaks of heather beetle

2.3 Currently, burning occurs on a cycle anywhere between less than ten and over 25 years (Usher & Thompson 1993), with geographical variation in the frequency of burn events. The Moorland Association and the Heather Trust both assert that carefully managed moors with appropriate burning and grazing will suffer less damage (The Heather Trust 2008, **http://www.moorlandassociation.org/heather_beetle.asp** [Accessed April 2014]), based on the idea that seedlings and older heather are more vulnerable to attack and that degenerate areas take longer to recover as germination from seed must occur. However, most of the evidence for or against the effectiveness of burning in preventing outbreaks is circumstantial, and we have already seen that there is no real evidence for damage being worse on plants of different ages (see Evidence Review NEER008). Damgaard *et al.* (2013) found that burning did not prevent a heather beetle outbreak occurring on their experimental site in Denmark, 7 years after the burn had taken place. However, they did not consider unburned areas within their study, so it is not clear whether the outbreak was more or less severe on the burned plot. Mowforth and Sydes (1989) state that infestations are noticeably

restricted to neglected (ie unmanaged) heather, but do not give any evidence to support this statement. Terry *et al.* (2004) used a model parameterised with data on heather beetle outbreak frequency from the Netherlands to investigate the likely impacts of nitrogen deposition. They found no effect of burn frequency on which plant was predicted to be dominant *(Molinia* or *Calluna*) in the UK uplands.

Effect of heather burning on population density of heather beetle

2.4 We did not find a single reliable source of information dealing with the relative effectiveness of summer burning in controlling heather beetle numbers. Staley (2001) pointed out that Grimshaw (1911) and Morison (1963) both called for out-of-season burns as this is when the larvae are expected to be vulnerable. Once the beetle reaches the pupal stage it is in the soil layer. However, Staley (2001) always found pupae on the soil rather than below it (adults were found in the soil) and argues that the beetles are susceptible to low humidity during the pupal stage (with no evidence to support this), thus burning would be expected to have a negative effect on pupal survival. However, examination of the life cycle (see Evidence Review NEER008) reveals that the pupal stage also occurs whilst burning is forbidden and studies show that the temperature just 1 cm below the soil surface can be much lower than that experienced above it (Gimingham 1972), so it is unclear whether burning would control numbers at this stage. Cameron *et al.* (1944) stated that summer burning is effective in controlling larvae, but this source was only available as an abstract (the full book is out of print and has been for some time) and so the experimental work leading to this conclusion has not been assessed for quality in this review.

Effectiveness of heather burning to encourage heather regeneration

2.5 MacGillivray (2004) found that across four estates that had experienced heather beetle infestations in Scotland, recovery was more prominent in areas where burning took place. However, the study was unbalanced, with different treatments occurring on the different estates so that site specific differences cannot be separated from those caused by management. In addition, the site with grazing was disregarded because regeneration began before the study started (but after the outbreak), which may well mean that regeneration was in fact quickest on this site. Burning of heather does not always result in regeneration; Lippe *et al.* (1985) reported that a spring burn of 200 hectares of beetle-damaged heather in the Netherlands failed to result in re-establishment. They attributed this to a drought that occurred in the summer of 1959, although they did not carry out any experimental work (such as watering some areas) to confirm this. The burned area remained bare and the organic layer subsequently eroded. Nilsen (2004, Nilsen *et al.* 2005) found that shorter burning intervals resulted in more vigorous regeneration (from seed), with no vegetative regeneration at all. Burns where the temperature reaches a maximum of 400 °C are likely to be more successful as the stem bases of heather plants will not be killed, allowing vegetative regeneration (Gimingham 1972). Using a questionnaire approach, Pakeman *et al.* (2002) discovered that moorland managers reported success when using burning as a technique to enhance recovery of heath following damage by heather beetles in two out of 24 cases prior to 1997, and 14 of 52 cases after this. However, they did not define what was to be considered 'successful' (this was left up to the respondents to decide) and the mangers questioned had not included control areas (that had been damaged by beetles but left unburned). The ability of heather to resprout from the base of an otherwise dead stem declines with age (Gimingham 1972, Pakeman *et al.* 2002), so only younger heather would be expected to recover well after burning (although this may partly be due to the higher temperatures experienced when burning older heather, Gimingham 1972). One of the major problems in this area is a general lack of high quality monitoring data; for example, Prentice *et al.* (1987) report a management burn being undertaken to rejuvenate heath in the Netherlands following

an attack by heather beetles, but the success or otherwise of this was not measured, and there do not appear to have been any control areas that were not burned, to determine whether recovery would have occurred in the absence of fire.

Effect of season on burning effectiveness

2.6 Cameron *et al.* (1944, only abstract available so studies not checked for quality) stated that summer burning is effective in controlling larvae, but that spring burning did not control adult numbers. There is some evidence that heather regeneration is more vigorous after autumn burning than spring burning (Miller & Miles 1970), which may be because heather tends to be fairly dormant in the autumn, whereas it is just beginning to grow in March-April (Miller *et al.* 1984), so spring burning would be expected to cause more physiological damage to plants.

Potential risks of burning

2.7 Burning, if undertaken inappropriately (ie too frequently) has been linked to declines in the sand lizard and in butterflies and moths in the New Forest (Newton 2013). On drier sites, time since last burn affects the species of carabid beetles and spiders that are likely to be present (Usher & Thompson 1993). Whilst large numbers of these invertebrates can be found on burned heath within a short time of the fire, it is unclear how many are resident and to what extent these high numbers are caused by the relative ease of movement (and thus higher likelihood of encountering a trap) in such open habitats. Poor burning practises have also been linked to heather decline and erosion, particularly if the burn was either too hot or too cold, on wetter ground, over too large an area, on a steep slope or where grazing pressure is high (Bunce 1989). High temperature burns (as might be encountered in accidental burns or on older heather) have been linked to a higher likelihood of invasion by *Deschampsia flexuosa* (Power *et al.* 2001, Price 2003). The risks of fire are expected to be higher outside the permitted burn season, since drier soils are more likely to catch fire or to erode if left bare. Maximum burn temperatures are also higher on older heather than on younger stands, and these higher temperatures also last for longer on older heather (Gimingham 1972), probably because there is more biomass available to burn.

Potential management alternatives

2.8 Some authors have raised the possibility of using insecticide to control beetle outbreaks in progress (for example, Morison 1938, Cameron *et al.* 1944, Miller *et al.* 1984). This is apparently effective against larvae in early August, but less effective against adults in May and June (Cameron *et al.* 1944, only the abstract was available, so studies have not been checked for quality). However, as the Sports Turf Research Institute (**http://www.stri.co.uk/golf/heather-beetles/**) point out, this might eradicate other invertebrates that inhabit heaths. There have not been any trials conducted to determine either the efficacy of this approach or the impact on non-target invertebrates, some of which are natural enemies of *Lochmaea suturalis* (see NEER008). Treatment with insecticide might therefore be counter-productive, although it is currently uncertain to what extent natural enemies control the size of heather beetle populations, or the extent to which this control could be utilised in an outbreak situation. Biological control has been raised as a possibility for controlling heather beetle population sizes (Waloff 1987), but currently it is not possible to secure the more promising natural enemies on a commercial basis in sufficient quantities to have an impact. Another possibility is to mow the dead heather left after an outbreak and scarify the ground, which has apparently resulted in successful regeneration of heather following an infestation at Formby Golf Club (Simpson *et al.* 2001). However, few details were given, the study appears to include no replication, there do not appear to have been any control plots left unmanaged, and ‘success’ of regeneration was not defined or measured in any meaningful way.

2.9 There is some evidence of a link between nitrogen deposition and heather beetle growth rates (see Evidence Review NEER008) and a possibility that outbreaks might be more likely or frequent in areas with high deposition. In addition, nitrogen deposition might lead to a higher likelihood of invasion by grasses once the heather canopy has been opened by a heather beetle outbreak (see Evidence Review NEER008). Therefore, managing the nutrient budget might be expected to both decrease the chances of an attack and to encourage heather regeneration after an attack. In a simple model, Britton *et al.* (2001) predicted vegetation dynamics under a range of scenarios of rainfall and nitrogen deposition, with management by cutting or rotovating compared to none at all. They did not explicitly consider heather beetle outbreaks, made many untested assumptions and did not ground truth their output with real data, but their conclusions were that management by cutting or rotovating would be expected to result in more stable *Calluna* stands, with slower expansion of *Deschampsia flexuosa*. To achieve this, cutting needed to be more frequent when rainfall was low or nitrogen deposition was high. Härdtle *et al.* (2006) compared the effects of mowing, burning and sod-cutting on heathland nutrient budgets in North-West Germany, and found that sod-cutting removed the most nutrients. Cutting and burning only removed five years-worth of atmospheric deposition at current levels, so heaths managed using these practises would accumulate nitrogen in the long term, although more frequent burning could be more effective in keeping nutrient levels low (Niemeyer *et al.* 2005). Power *et al.* (1998) similarly found that cutting and removal of above-ground plant material would not stop nitrogen accumulation at a site in Southern England.

2.10 Where *Calluna* has been replaced by grass species such as *Deschampsia flexuosa*, *Nardus stricta* or *Molinia caerulea* (possibly following a heather beetle outbreak, see Evidence Review NEER008) managers might desire to restore the area. One potential way of doing this would be to treat the vegetation with herbicides to allow *Calluna* to reinvade. Milligan *et al.* (2003) found that the herbicides most effective at controlling *Molinia* (glyphosate and cycloxydim) also reduced the cover of live *Calluna*. Two other herbicides had a short-term effect on *Molinia* but did not affect *Calluna*. They hypothesised that the use of some graminicides predisposed *Calluna* to attack by heather beetles, but despite such an outbreak occurring during their trial, they did not record the relative severity of damage on the different treatments. Another hypothesis that has been put forward based on field observations and unbalanced experiments with low levels of replication is that grazing and gap-creation by cattle favours *Calluna* establishment and recovery (Bokdam 2001), although experimental work by Bokdam and Gleichman (2000) found that grazing by cattle (despite their preferential use of grasses) did not reduce grass invasion in heather or reduce grass cover in grass heath. In addition, five years after a heather beetle outbreak, DEFRA (2005) found no evidence of any difference in rates of recovery of heather under different stocking rates on organic and conventional farm units. This has not stopped some authors (Buchanan *et al.* 2006) from claiming that cattle grazing leads to more rapid recovery of heather following an outbreak of *Lochmaea suturalis*. Further techniques that have been tested to restore *Calluna* cover in grass heath (in Breckland, dominated by *Deschampsia flexuosa*) include cutting, turf stripping and rotovating, with rotovating being recommended based on a combination of effectiveness and practicalities (Britton *et al.* 2000).

2.11 There may be interactions between management and other factors. Britton *et al.* (2007) conducted a relatively well-replicated (6 blocks) experiment in Scotland to determine the impacts of grazing and nitrogen deposition on burned and unburned heather. Each block was divided into two sub-blocks, one of which experienced a single burn event. Within these sub-blocks, combinations of simulated grazing and nitrogen deposition were performed. They found that in general, burned plots had lower (but increasing) species richness for the first three years after the burn event. The level of nitrogen deposition had no impact on burned plots, but on unburned plots there was reduced species diversity after just one year with the highest treatment, and after 5 years (when the report was produced) with the lowest treatment. Therefore, burning might be expected to decrease the impacts of nitrogen deposition, although longer term experiments would be needed to state this for sure. Damgaard *et al.* (2013) conducted an experiment to determine the impacts of grazing by

sheep on burned heather (they did not include unburned controls). They found that grazing on burned areas had a positive effect on species richness, but a negative effect on dwarf shrubs. Their plots were attacked by heather beetles, but they do not appear to have recorded whether this was more severe on grazed or ungrazed plots, which would have been useful information for this review. They state that grazed plots had less heather, which may have been due to heather beetle attack. This implies that the outbreak was more severe on grazed plots, but this is not absolutely certain. Helsper *et al.* (1983) found that a single nitrogen fertilisation enhanced the rate of *Calluna* regeneration after sod-cutting, whereas repeated fertilisation inhibited *Calluna* but enhanced bryophytes. In common with many of the sources summarised here, their experiment did not include a non-cut control, and replication levels were low with just 3 plots of each treatment.

2.12 There is very little information available concerning the relative effectiveness of different management techniques at all, let alone with respect to managing for heather beetles. Newton *et al.* (2009) undertook a systematic literature review to compare the efficacy of grazing, burning and cutting as management techniques for lowland heath. Of 269 references that they examined, only 13 had appropriate comparators to quantify the impact of management on the heath and only three of these dealt with grazing and cutting or burning in combination. Many studies lacked statistical significance due to a combination of large variance and small sample size. The only conclusion they were able to draw was that grazing increased the cover of grasses and decreased the cover of ericoid shrubs.

2.13 Not included in that review, Terry *et al.* (2004)'s modelling exercise predicted that heather beetle outbreaks would be less frequent in the lowlands with high intensity mowing compared to low intensity mowing, and that sod cutting would be more effective than mowing at retaining *Calluna* dominance under high nitrogen deposition. However, they did not compare these techniques to burning, which they only modelled in the uplands. Not all modelling exercises are so helpful: Bakema *et al.* (1994), despite including heather beetle outbreaks and management by sod cutting, grazing, mowing and burning, did not present any results comparing predictions using different management scenarios. In addition, their model may have been based on incorrect assumptions, as they only included the possibility of outbreaks on heather stands aged over five years, whilst we know from Pakeman *et al.* (2002) and others that infestations have been detected on stands younger than this. In a similar modelling exercise also including heather beetle outbreaks, Ashmore and Terry (2007) found that management history (including cutting and burning) was more important than historical nitrogen deposition in determining the balance of heather and grass species, but did not provide predictions for the relative effectiveness of different management techniques.

2.14 Power *et al.* (2001) found (after undertaking a small experimental study with relatively low levels of replication on a heath in Surrey) that low intensity mowing was less likely to result in invasion by *Deschampsia flexuosa* than high intensity mowing, low or high temperature burns. A further study with low levels of replication found that scarification resulted in more heather seedlings germinating than burning or rotovation (Taylor 1995, see Figure 1 below).

A trial was carried out on St. Ives golf course in West Yorkshire on two blocks, one dominated by Calluna and the other by *Molinia caerulea* and *Nardus stricta* (Taylor 1995). Each block was subdivided into three plots, one of which was subjected to scarification, the second to burning (using a blow torch at 400 °C) and the third to rotovation to a depth of 100 mm. Each of the three plots was then further subdivided into four restoration treatments, either being left bare, having heather brash added, having heather capsules (seed heads) added or having capsules added along with a nurse grass mixture. On both blocks, more heather seedlings were found (after 1-1.5 years) on the plots that had undergone scarification than on the rotovated or burned plots. Across the plots, leaving the ground bare resulted in more heather seedlings, and on the grass block there was an increase in the amount of coarse grass, particularly on the burned plot. This study typifies the sort of information available in that there is a lack of replication (only 1 true replicate of each treatment combination) and in this case the author has carried out statistical analysis despite this limitation. Therefore, it is difficult to say whether the patterns observed are as a result of the management undertaken or some other, unmeasured factors.

Figure 1 Comparing heather regeneration from seed after three different treatments

2.15 There are other ways of considering the relative benefits of different management techniques; burning is weather dependent and runs the risk of spreading out of control, whilst cutting (mowing) is not. However, cutting costs around three times the amount that burning does, and its use is limited to areas with suitable terrain (Thompson *et al.* 1998). Burning is only allowed under a specific set of circumstances (MAFF 1999) and other management techniques will have to be considered in areas not suitable for burning.

2.16 Some sources advocate the 'do nothing' approach to controlling heather beetle populations (Laurie 2013, based on anecdotal evidence only), as successful management in the short term might lead to further outbreaks on regenerating heather, necessitating further management that would result in exhaustion of the seed bank. This 'do nothing' approach would certainly be the cheapest option. There have been many observations of damaged heather recovering after several years (for example, Berendse *et al.* 1994, Wilson 2003). Indeed, Rogers (1996) found that defoliation of *Calluna* (simulating an outbreak of heather beetles) resulted in an abundance of new seedlings as well as resprouting from root crowns.

Other factors affecting heather re-establishment

2.17 There has been some mention of seasonality already in relation to burning such that burning in autumn is more effective than in spring, but Miller and Miles (1970) also found the opposite for cutting, such that regeneration of heather was more vigorous after a spring cut than an autumn one. Hobbs and Legg (1984) hypothesised that the floristic composition of vegetation colonising the bare ground available immediately after burning determines post-fire development of heathland vegetation. Nilsen (2004) found that in central Norway (where heather beetle outbreaks have not yet been reported), soil variables such as peat depth and pH (rather than whether they were grazed or not) explained most of the variation in vegetation between sites in the initial years after a management burn. Nilsen *et al.* (2005), working in the same area, also found that there was a higher frequency of *Calluna* seedlings following a burn on dry heath compared to wetter sites. In Denmark, Riis-Nielsen (1997) observed that germination of new *Calluna* plants was extensive in the spring following an outbreak, but this occurred almost exclusively in the gaps between bushes. Drought may also play a part; Nielsen *et al.* (2000) found that regrowth of heather from seeds or stem bases following an outbreak in Denmark failed in large parts of their study site, which they attributed to extreme drought in the following two seasons. They did not however gather evidence for this by

watering any of the plots in question. The Heather Trust (2013) observed that the density of young plants appears to be higher in areas that have received seed and in wheel tracks, but there is no scientific basis for this as yet.

2.18 There seems to be some controversy regarding the effect of nitrogen on heather regeneration. Evans *et al.* (2006) found that *Calluna* growth following a heather beetle outbreak was suppressed on plots fertilised with a high level of nitrogen. Similarly (in an experiment with relatively low levels of replication), Riis-Nielsen (1997) observed that regeneration of *Calluna* by both seedlings and branches seemed to be higher at lower levels of nitrogen deposition. Conversely, Lee and Caporn (1998) found that nitrogen addition in the range of 0-20 g N m-2 yr-1 resulted in increased growth of *Calluna* and a decline in some other species, at least initially. Uren *et al.* (1997) similarly found large positive effects of low levels of nitrogen application on the growth and flowering of *Calluna* in the short term. However, nitrogen has been found to have no effect on heather germination (Britton *et al.* 2003).

3 Knowledge gaps

3.1 Although large scale studies of damage caused by heather beetle have occasionally been carried out (for example, MacGillivray 2004, O'Hanrahan 2005), these are usually very simple and the data gathered are not suitable for use in statistical analyses. The use of management burns to try to regenerate areas damaged by heather beetle is largely based on the opinions and previous experience of managers (Pakeman *et al.* 2002) rather than any scientific evidence for its effectiveness; most studies that do consider the effectiveness of burning (for example in regenerating heather) do not explicitly consider effectiveness in relation to heather beetles. In addition, the effectiveness of summer burning or of cutting accompanied by vegetation removal on controlling numbers is largely unknown and considerable research would be required to develop an evidence base for either (Rosenburgh & Marrs 2010). Once damage has occurred, it would be useful to know whether it is better to manage (whether by burning or other means) as soon as possible, or to continue to follow the usual management plan (The Heather Trust 2012).

3.2 Many potentially fruitful avenues for further research have already been identified by other authors. Pakeman *et al.* (2002) recommended the development of remote-sensing techniques to monitor outbreaks and further research into heather beetle ecology, particularly regarding dispersal behaviour and the factors affecting the relationship between *Lochmaea suturalis* and its natural enemies. They also recommended further monitoring of damaged areas to determine the factors influencing recovery, and experimental assessment of different management techniques to enhance recovery. Many of these recommendations were echoed in 2010 by Rosenbugh *et al*. The state of our knowledge has not advanced much since, and we would add that a good geographic spread would be needed of such studies, in order to determine the generality of results.

3.3 There are some trials currently taking place on Langholm Moor in Dumfriesshire and work began at two sites in the Peak District in 2013 (The Heather Trust 2012, 2013) so there is the potential for more information to become available in the next few years. These trials have the advantage of being on land that has recently been infested, rather than just being general management trials and they include control (unmanaged) areas. However, the descriptions of these trials (The Heather Trust 2013) imply that there is just one plot per site for each treatment, which is not enough data to carry out statistical testing and any results will be observations rather than proper tests. In addition, the managed plots have been sprayed with glyphosate and cycloxydim, which have been found to have negative effects on *Calluna* cover (Milligan *et al.* 2003), so other management possibilities still need to be investigated outside these trials. Moors for the Future are currently setting up a project to investigate the effects of conservation land management on the economic benefits of ecosystem services provided by grouse moors, and this could be a potential site for further research (part-funded by Natural England, Sarah Proctor, pers. comm.).

Recommendations for further research

- Properly replicated studies comparing the effectiveness of burning, compared to other management options and to control plots, in a) preventing beetle outbreaks, b) managing outbreaks in progress and c) regenerating damaged heather. A range of studies across a wide geographic area would generate the most reliable information.
- Further research into the general ecology of heather beetles, including factors affecting dispersal and the relationship between population size and the density of natural enemies.
- Cost-benefit analysis of different management options, taking into account a) the effectiveness of management and b) the impact on other species.

4 Management recommendations

4.1 Given the paucity of information on the effectiveness of burning to a) prevent heather beetle outbreaks, b) control heather beetle numbers during an outbreak or c) encourage heather regeneration after an outbreak, it is difficult to make management recommendations. Likewise, information on the effectiveness of burning at different times, and of other potential management techniques (including cutting at different intensities, grazing and herbicide use) is also lacking, and comparisons between different management techniques have rarely been made. There is no evidence that summer burning helps heather to regenerate after an infestation. There is also no evidence that summer burning helps to control beetle numbers during an attack, because suitable studies have not been done. We therefore recommend that any licences granted to allow burning out-of-season are accompanied by a requirement to undertake proper monitoring of the recovery, or otherwise, of heather for several (ie at least 5) years subsequent to the burn taking place. There would need to be a clear statement of the aim (ie regeneration of damaged heather or control of beetle numbers) of the burn, as well as a clear definition of success. Ideally this would be done in conjunction with academics or others with knowledge of experimental design, to ensure that any data collected would be useful to inform management decisions in the future. Some land managers already monitor permanent quadrats on their sites (Newton *et al.* 2009) and managers such as these would benefit from contact with academics as to how to best design a monitoring programme.

4.2 In the case of burning for control of heather beetles, variables monitored would need to include the cover and condition of regenerating heather as well as the impact on other species using the habitat. Out-of-season burning on areas damaged by heather beetle would need to be compared as a minimum to within season burning (preferably separating spring and autumn burns into different treatments) as well as control areas where no burning was undertaken. For the results to be scientifically worthwhile, several replicates of each treatment would be needed.

4.3 Current advice to practitioners on managing for heather beetle centres around preventative management of moors by following a carefully designed regime of cutting or burning (**http://www.stri.co.uk/golf/heather-beetles/**, [Accessed April 2014] **http://www.moorlandassociation.org/heather_beetle.asp** [Accessed April 2014]) and it would be useful to implement a monitoring regime to determine the success or otherwise of this approach. Where outbreaks do occur, the advice that has been given is to wait a full growing season to determine whether heather will regenerate without intervention before cutting and removing dead heather. This appears to be a relatively sensible approach, particularly in the absence of better scientific evidence for other approaches.

4.4 Recommendations for upland management (in particular for breeding birds, ground beetles and spiders) have previously been made (Usher & Thompson 1993). Of particular relevance to this review, they recommend conserving and where possible re-creating wet flushes, as several characteristic species are reliant upon them. In terms of controlling heather beetle, some authors (Cameron *et al.* 1944, The Heather Trust 2008) have suggested draining wetter areas, in order to reduce the locations for egg-laying of *Lochmaea suturalis*. It is clear that before such drainage could occur, the potential gains achieved by reducing heather beetle numbers should be carefully balanced against the losses of species that would accompany any drainage operations. In addition, sites that have been re-wetted should be monitored (preferably in conjunction with control sites that have not been managed in such a way) for heather beetle outbreaks.

Summary of management recommendations

- Damaged areas should be left for a full growing season to determine whether heather will regenerate without intervention.
- Any licences to burn out-of-season should be accompanied by a requirement to undertake well-replicated monitoring of the effectiveness of this course of action compared to out-of-season burning and to control areas (ie areas with no management).
- Brash used in moorland restoration should be screened for larval infestation before use.
- The effects of any draining or re-wetting of peat should be carefully monitored, again with the inclusion of control plots and a reasonable level of replication.

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Appendices 1 - 3 Outcome (inclusion, rejection and at which stage) and availability of the papers chosen for inclusion in the study

Appendices 1 - 3 are available in the form of an excel spreadsheet and supplement this report.

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