The Bracken Control Group

EMERGENCY AUTHORISATION APPLICATION
FOR THE USE OF ASULAM

FOR THE CONTROL OF BRACKEN ON ROUGH GRAZING, MOORLAND, AMENITY GRASSLAND, FORESTRY AND THE HISTORIC ENVIRONMENT IN 2019.

SUPPORTING INFORMATION

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National Bracken Control Trials 2012-2018 - Tables

1 Introduction

1.1 This Supplementary Information is provided to support the application for an Emergency Authorisation to allow the continuing use of Asulam to control bracken in the UK.

1.2 This application is the latest in a series of applications, but the information has been reviewed and updated to include some preliminary information emerging from the National Bracken Control Trials (Appendix 1).

1.3 The Conservation Agencies in all the administrations have been asked for comment on this application and their responses have been reported in Section 1.

1.4 It is suggested that there is a strong case for the continued availability of Asulam and eventual registration of Asulam for bracken control under the current EU regulations.

2 Summary

2.1 A conservation agency view of bracken is summarised in Section 1. It is clear that uncontrolled bracken is perceived as a threat for many reasons.

2.2 The extent and nature of bracken control required locally depend on: the local nature conservation objectives, priorities for land management, access and landscape, and/or historic environment requirements.

2.3 The costs of bracken control are considered: for an 8-year control programme the costs are in the range £1,020 - £1,820 per hectare.

2.4 Many different methods can be used to control bracken and these can be placed into three main groups: physical, chemical and biological. The choice of method depends on the personal preference and the availability of resources and equipment. The most effective approach may be to use a combination of different techniques.

2.5 Appendix 1 provides a summary to date of the ongoing National Bracken Control Trials. The current conclusion is that Asulam is the safest and most effective product, but if licensed, some of the Sulphonyl Urea alternatives could have a role in specific circumstances.

SECTION 1 - NATURE CONSERVATION PERSPECTIVE

3 Designated Sites

3.1 Bracken can provide an important habitat for specific wildlife species. In some areas, there are positive associations with species such as fritillary butterflies. Bracken can provide a key habitat for upland margin birds, and in some habitats, it is an important component adding to structural diversity, especially in rough grassland on the upland margins.

3.2 However, high and dense bracken cover has serious negative impacts in some habitats and here it requires management. Bracken is often invasive and can dominate other vegetation, leading to changes in livestock grazing patterns (which may then interfere with the use of livestock for habitat management on a site); it can also out-compete other vegetation and result in direct loss of the interest feature for which a wildlife site is designated.

3.3 In England and Wales, 60% of moorland is designated for the quality of vegetation or the importance of the habitat to breeding birds (National Nature Reserves (NNR), Sites of Special Scientific Interest (SSSI), Special Areas of Conservation (SAC) and/or Special Protection Areas (SPA)). If the vegetation communities, which often form the basis of these designations, are invaded by bracken and out-competed, it may have an adverse effect on the conservation status of the designated areas.

3.4 70% of English grouse moors are within a National Park or Area of Outstanding Natural Beauty (AONB) and often their heather moorland is the key component of these treasured landscape designations.

3.5 Excessive bracken cover is also a concern in some lowland habitats, such as heathlands, which are also of national and international importance. In England, about 75% of lowland heathlands have statutory protection for their vegetation or the species they support. Many lowland heathlands are also Common Land with open public access.

3.6 Allowing the heath vegetation to be swamped by bracken compromises these designations.

4 Control of Bracken

4.1 Control of bracken is widely carried out for nature conservation purposes. Control where there is a problem with excessive cover is a requirement to maintain SSSIs currently achieving or recovering to favourable condition, and in restoring sites, which are not yet recovering. Bracken management continues to have a local role in helping to achieve Government commitments to SSSI targets, and for example in England, contributing to achievement of the objective to restore 200,000ha of priority habitat by 2020. Asulam is the only partially-selective herbicide available to control bracken on a large-scale. To achieve clearance of a particular patch of bracken may require a programme of treatment for up to 10 years.

4.2 Bracken can completely re-establish its dominance within about 3 years, so if treatment is not maintained, resources applied to control that bracken would have been wasted; the control programme would need to start again. Much of the cost of such programmes is covered by Government and/or European grants / public money and more still is invested by private individuals. The gains from the large amount of public funds, the resource and the effort that has been invested in bracken control management over the last 10 years will be put at risk if it is not possible to carry on using Asulam to maintain the selective, follow-up treatments on these areas. In addition, if there is a delay in the programme, and bracken is allowed to partly or fully recover its dominance, then it may require more intensive herbicide management to bring the matter under control at a later date. This would be both wasteful of resources and conflict with best practice.

4.3 Bracken control is a management requirement in SSSI management plans in some areas and agri-environment scheme options exist to facilitate this activity both within and outside SSSIs. Conservation agencies would generally consider alternative methods to herbicide use as a first option for bracken control, such as grazing, cutting, bruising or other mechanical control, and this decision process is set out in the revised "Herbicide Handbook" (Britt et al, 2003[1]). However, where access or terrain make mechanical or physical management difficult, dangerous or impossible (mechanical control is dangerous in MoD sites where ammunition may be a hazard), or where mechanical control is ineffective or poses a risk to other fragile habitats, ground nesting birds, reptiles or scheduled monuments, then chemical control is the only management option available.

4.4 In order to control bracken a systemic herbicide is needed (to kill the rhizomes). Asulam has this systemic property, as well as having less negative impact on non-target plants than other effective alternatives, although there is evidence that Asulam can cause damage to other fern, lower and vascular plant species. The conservation agencies have supported research into the risks of asulam to non-target plants (Sheffield et al 2003[2]) and a considerable body of evidence is available in order to enable judgements of risks through drift or overspray onto non-target areas. Such evidence has not been systematically collected for alternative selective herbicides with potential for bracken control, although early results from field studies of certain alternative herbicides are presented in Appendix 1.

4.5 Asulam is needed for bracken control on some lowland (especially heathland but also grassland) SSSIs. Inability to use herbicides for bracken control would risk areas of lowland heath SSSIs returning to unfavourable condition. Large blocks of bracken with a good heathland under-storey can be treated using Asulam and so effectively control the extent of bracken in an area, as long as follow up treatments are applied in subsequent years. Glyphosate cannot be used in the same way without risk of extensive mortality of non-target plants in the under-storey.

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[1] Britt. C, Mole A, Kirkham F and Terry A (2003) *The Herbicide Handbook*. Guidance on the Use of Herbicides on Nature Conservation Sites. English Nature Report under contract EIT 31-04-003. English Nature 2003. Updated by Natural England 2011.

[2] Sheffield E, Johns M, Rumsey FJ, and Rowntree JK (2003) *An investigation of the effects of low doses of Asulox on non-target species*. English Nature contracts EIT20-19-001 and EIT30-08-07. Peterborough. English Nature.

4.6 As examples of the scale of implication for heathland sites, the majority of the unfavourable Dorset heathland units have a bracken control requirement and there has been heavy reliance on Asulam in heathland restoration projects, for example in the Thames Basin Heaths area, where there has been a major effort to expand heathland following conifer removal.

4.7 In both the uplands and the lowlands, there are a number of SSSIs where herbicidal control of bracken is carried out for biodiversity conservation purposes. Herbicides are used in the preparation of ground for establishment of woodland for biodiversity and its use is of major importance for the protection of archaeological sites many of which are scheduled monuments. In both cases it is important to minimise any effects on non-target plants to maximise re-establishment of ground flora. The extensive use of Asulam in the uplands for agricultural and sporting purposes has often prevented bracken becoming a specific conservation issue in such areas, and inability in the future to carry out selective herbicidal control is likely to result in an impact on favourable habitat condition in such areas.

4.8 In general, a programme of herbicide use is needed over a number of years to achieve complete control as bracken vigour is progressively reduced over a number of seasons of control. This programme is still underway in many SSSIs and under agri-environment scheme agreements. Where completion of a control programme cannot be achieved, there is likely to be rapid reversion to bracken dominance and loss of the gains made in preceding treatment years.

5 Cutting of Bracken

5.1 Cutting is often not a practicable alternative to chemical control with a selective herbicide like Asulam in heather moorland areas. Experiments on the North York Moors have shown that cutting cannot achieve clearance unless it is done at least three or four times per growing season, to a very low level below the height of surrounding vegetation and for at least three or four years consecutively. Labour costs make this impracticable in many situations. It is not possible to cut bracken with machinery low enough without risking damage to other vegetation and/or causing damage to surface peat that can lead to an erosion risk. Furthermore, mechanical cutting may cause damage to known and unknown archaeological interest preserved in the peat.

SECTION 2 – AGENCY PERSPECTIVES

6 Natural England

6.1 Whilst bracken can provide an important habitat for wildlife, it also has serious negative impacts in some habitats and here it requires management. The key habitats on which bracken can have a major negative impact are locally in drier upland peat moorland, upland wet/dry heath habitats and in lowland heath. Dense bracken cover remains the reason why some lowland heathlands in SSSIs are assessed as being in unfavourable condition and is a cause of unfavourable condition or a threat to several upland SSSIs. Dense bracken outcompetes typical heathland species and destroys or obscures valuable features such as bare ground or short vegetation that is important for many heathland species. Other effects include the negative impact on both natural regeneration and new planting in woodlands, whilst bracken rhizome damage to historic and archaeological features has become a major issue.

6.2 Control programmes are in place to attempt to halt and reverse this process on many SSSIs. Schemes exist to help fund farmers and land managers carrying out bracken control measures for nature conservation and historic heritage purposes under various agricultural support programmes associated with Rural Development Programmes in Britain. In England, almost 25,000ha received payments for bracken control (all methods) in 2016, whilst in excess of 2,200ha of SSSI were treated with asulam by aerial application (based on consultations received from aerial spray operators). The continuing importance and ability to manage bracken in schemes, where there is public funding, is a priority.

6.3 The British Isles contain a major part of the world resource of managed heather dominated habitat and England in particular accounts for 23% of the total drier upland heather-dominated phase. In 2008, it was estimated that almost 35% of this drier moorland/heathland area was degraded and/or at risk of bracken encroachment. By 2011, this had reduced to 24% largely as a result of Environmental Stewardship Schemes. By 2015, the figure came down to 19% and this should reduce further if bracken control is successfully maintained through grant aided operations. Over 850ha of former bracken dominated land has been fully regenerated to dwarf shrub (ericaceous and other species) 2010-2016 in the North York Moors alone, and in this period the combined figure for Northumberland / Durham, the Yorkshire Dales, Peak District and the rest of North Yorkshire/South Cumbria came to over 1,250ha.

6.4 Although at some sites bracken control can be achieved to a degree by mechanical cutting or other non-chemical control techniques, it is not always possible. For example, if the site is too steep or the terrain too uneven or rocky, mechanical control is not possible and chemical control is the best option. At present asulam, under the current Emergency Authorisation, provides the systemic action needed to kill bracken rhizomes, whilst having lower risk to non-target plants than other effective alternatives.

6.5 Following its withdrawal of approval, and alongside the manufacturer's application for full re-authorisation of asulam, the conservation agencies, with other partners including Historic England and members of the bracken control industry, have supported field trials to investigate the relative efficacy of Asulam against two potential alternative (Sulphonyl Urea) herbicides as bracken control agents. The trials are reported in Section 2, below.

7 Historic England

7.1 Historic England is fully supportive of the application for an Emergency Authorisation, as the importance of Asulam is recognised. A key feature for Historic England is the ability of Asulam to provide a method of controlling bracken in very sensitive / unstable areas with minimal negative heritage and ecological impact.

7.2 Historic England has devoted resources to a three-year programme (2017 - 2019) to examine the efficacy and impact of physical against chemical control methods on two major historic environment / Scheduled Ancient Monument areas in England.

7.2.1 Concern over the impact of bracken on the historic environment and 'soft' monuments in particular underpins Historic England's concern and the support for bracken control.

7.2.2 Early results from this work are favouring chemical control and the use Asulam, in particular.

7.3 Historic England has established an internal Bracken Management Group consisting of various specialists. This group is reviewing the progress of the above programme with a view to implementing the best bracken control protocol on other Historic England sites affected by bracken encroachment.

8 Scottish Natural Heritage

8.1 The Scottish Government continues to support bracken control through the Agri-Environment and Climate Scheme of the Scottish Rural Development Plan. In 2017, the level of support was:

Option	**ha**	**£**
Primary treatment of bracken – manual	163	24,456
Primary treatment of bracken – mechanised or chemical	2,013	452,873
Follow-up treatment of bracken – mechanised or chemical	4,275	384,745
Totals	**6,451**	**862,074**

8.2 Bracken is a native plant and a natural component of many woodlands. It can provide a valuable habitat, particularly if the canopy is relatively open, so it is not viewed as such a threat as an invasive non-native species.

8.3 Bracken is a successful coloniser and can encroach on other habitats, often as a result of poor management of that habitat. SNH supports the control of bracken in such circumstances.

8.4 Aerial spraying will be undertaken on large steep sites for primary control where other control options appear to be impractical or are unsafe. The perception is that this represents a significant proportion of places where bracken needs to be controlled in Scotland, but we have no figure to provide in support of this.

8.5 Bracken control effort has prevented the area of bracken cover in the UK increasing rapidly. This suggests that bracken control, largely by spraying, is working. A single aerial application cannot eradicate bracken and it is suggested that much chemical bracken control has been ineffective because aerial spraying has not always been followed up properly with subsequent ground-based mechanical or chemical treatments. Besides, there are areas where other options could be used, and would be more effective (e.g. smaller buffers are required for non-aerial methods, meaning a higher proportion of the bracken can be treated), but aerial application is used on convenience and cost grounds.

9 Natural Resources Wales

9.1 Bracken can provide valuable habitat, but in some situations, it does require control. For example, bracken continues to provide serious competition for the establishment of young trees, and if left unmanaged, it can result in unsuccessful forest regeneration.

9.2 The application of asulam by hand held equipment is currently not practicable on the Welsh Government Woodland Estate, due to the prohibitive high volumes of water required by the current authorisation. In limited situations, where there are no other options, NRW supports the use of Asulam for bracken control in management agreements for SSSIs and on NNRs. The aerial application of Asulam is generally considered not to be viable, in terms of coupe scale and constraints, for use on the Welsh Government Woodland Estate. However, aerial application is used within NNR and SSSI management agreements.

9.3 In the wider context, the interests of NRW, in respect of the use of Asulam on the Welsh Government Woodland Estate, are represented by Ian Willoughby, through the Bracken Control Group. Ian Willoughby is also part of the State Sector Forest Management Officers group, along with NRW, and as a member of this group, NRW is supportive of current research into alternative chemicals.

10 Department of Agriculture, Environment and Rural Affairs, Northern Ireland

10.1 The spread of bracken in Northern Ireland is becoming a major concern throughout the country, and a similar trend is developing through Southern Ireland. Some of the areas with high bracken cover are designated as Areas of Special Scientific Interest (ASSI), SPA etc. In some cases, these sites are designated due to the underlying habitat, which the bracken is destroying. Both government and non-government bodies are now recognising this and, in some cases, have applied for consent to the NI Environment Agency to control the bracken.

10.2 Liaison with Southern Ireland

10.2.1 There is ongoing work with University College Dublin to investigate the toxins released by bracken.

10.2.2 A link has been established to a landowners' group in the Cooley mountains area that is seeking to control bracken.

10.2.3 Discussion has taken place with Teagasc[3] advisors about bracken management in the upland areas.

10.3 In 2014, the College of Agriculture, Food and Rural enterprise (CAFRE) established four bracken control demonstration sites, located across NI.

10.3.1 Each site is subdivided into five plots as follows: control plot, cut only plot, roll only, weed wipe with Glyphosate and spray with Asulam.

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[3] Teagasc is the semi-state authority in the Republic of Ireland responsible for research and development, training and advisory services in the agri-food sector.

10.3.2 Findings to date:

- Asulam has reduced bracken cover by up to 95%. Little bracken regrowth has been observed.
- Rolling only twice each year has shown limited success - up to 30% reduction.
- Cutting only - limited reduction. Timing of cutting is key.
- Weed wiping with glyphosate - reduced bracken cover by up to 50%. Ragwort and briars seem to develop in these areas in the year following application.

10.3.3 Asulam is certainly showing the best results with no damage being caused to the underlying habitat.

10.4 No aerial spraying of bracken has taken place in NI since 2012. In April 2016, an aerial spraying contractor from Scotland attended an aerial spraying workshop, organised by CAFRE. This generated considerable interest in aerial control of bracken, but unfortunately, the contractor was not able to carry out any work and this caused frustration amongst farmers and landowners.

10.5 It is estimated that in Northern Ireland an area of 2,000 acres is available for aerial spraying. Ulster Farmers Union Hill Farming Committee and CAFRE have been trying to arrange for some aerial spraying to take place.

10.6 There is interest in applying Asulam from a drone and CAFRE would be willing to demonstrate this, if permission were granted.

SECTION 3 – THE CASE FOR BRACKEN CONTROL

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11 Bracken cover: advantages and disadvantages (Table 11.1)

11.1 **Table 11.1** contains an assessment of the advantages and disadvantages associated with the presence of bracken and some of the issues associated with control techniques.

11.2 There are many more negatives than positives. Whilst bracken beds are important ecological and landscape features in some locations, encroachment into more sensitive habitats and heritage environments as well as land of direct commercial value and negative impacts on water resources and health make continued control a high priority for economic and conservation reasons.

11.3 It appears that the total area of bracken is still increasing and more importantly, due to policy developments (and physical factors such as climate change), new areas and habitats are being colonised for the first time.

Table 11.1: An Assessment of the advantages and disadvantages associated with bracken and its control

Advantage	Disadvantage
1 Wildlife and Habitat Conservation	
1.1 Canopy Bracken produces a substitute woodland canopy which encourages woodland floor flora and fauna.	Dense canopies generally have a poor ground flora and much bracken litter. Diversity is generally uniform and low across the UK (Environment Agency, 2000).
1.2 Small Mammals Bracken stands, especially on the edge of moorland at the junction with in-bye grazing fields, can encourage small mammal (for example: Wood Mouse *Apodemus sylvaticus)* population movement and increases in density.	Bracken invades and degrades or replaces moorland, heath and grassland habitats with consequent decreases in small mammal diversity and activity.
1.3 Larger mammals. Where bracken is dominant, and trees / scrub are absent, larger mammals, such as Red Deer *Cervus elaphus,* may be attracted (Jinger Tan, 2012).	Poor vegetation cover may discourage other herbivores thus decreasing grazing quality and quantity. The habitat encourages the Sheep Tick life cycle, which benefits from the presence of some of their principal hosts.

1.4 Bird Habitats Bracken beds, in association with trees, are important as bird habitats for species such as Stonechat.	Some bird species such as Merlin, Twite and Skylark are displaced when bracken encroaches, especially into dwarf shrub communities.
1.5 Reptiles Reptiles, especially Adders and Common Lizard, may hibernate or shelter in dense bracken litter.	The lack of open ground for basking and mating reduces reptile activity generally.
1.6 Invertebrates About 40 species of invertebrates live and feed on bracken, with 11 being specific to it but none are Red Data Book species.	The invertebrate diversity associated with bracken beds is lower than on the habitats it tends to replace such as heath / moor, bog and species rich grassland (Brown, 2018a).
1.7 Woodland Bracken can act as a nursery crop for certain trees.	Bracken can improve soil fertility which retards the redevelopment of encroached habitats (for example: grasses replace ericaceous plants).
1.8 Tree regeneration Bracken can prevent spontaneous tree regeneration giving advantage to other species.	Competition from bracken can suppress planted tree growth/ and desirable natural regeneration.
1.9 Habitat re-stabilisation	Rapid recolonization after fire or disturbance can prevent habitat re-stabilisation.
1.10 Threat to sensitive habitats	Bracken poses a severe threat to key, sensitive habitat types, such as dry heath, bog, dune systems and 'lazy beds' on the west coast of Scotland (Brown, 2018b).
2 Heritage Impacts	
2.1 Scheduled Ancient Monuments Dense cover can protect sensitive SAMs and high value features such as carved stones[4] and 'soft' surface or near surface structure by litter build up and stock exclusion.	Historic England Surveys have shown that the biggest single threat to SAMs and other heritage features in the rural landscape is the encroachment of bracken rhizomes, litter and canopy cover (Historic England, 2013) by causing direct physical/chemical damage and loss of visibility of smaller features.

[4] Example: Allan Heads, North York Moors - on the current trial sites prehistoric markings and stone features described in the late 19th Century but then covered by bracken litter have started to reappear for the first time in living memory as the litter disintegrates after bracken control.

2.2 Archaeological features	The presence of archaeological features can be completely obscured visually by bracken cover.
3 Human Health	
3.1 Sheep Ticks	Bracken provides a habitat which encourages both sheep ticks and their larger hosts thereby strengthening the cycle for the transmission of pathogens which cause Tick Borne Diseases (TBDs) such as Lyme Disease and Anaplasmosis. (See the Supplementary Information to the BCG's 2017 EA application[5]). Bracken is the most important habitat for tick activity on open moor, heath and encroached grasslands.
3.2 Toxicity	Bracken is highly toxic and there are strong links to certain types of human (and mammalian) cancers.
3.3 Health Risk	Specific occupational groups as well as walkers, runners, cyclists and horse riders are at high risk of exposure to toxic substances and ticks in and around dense bracken beds.
4 Landscape and Recreation	
4.1 Visual Feature The golden autumn colour of senescing bracken fronds gives a valued visual landscape feature and texture, especially where woodlands are absent.	Extensive beds of bracken reduce landscape diversity.
4.2 Access Bracken beds can deter access by both people and animals encouraging landscape 'remoteness' and protecting against erosion.	Paths are obscured and both people and grazing animals are concentrated into specific areas, potentially causing erosion and making animal management (especially sheep) difficult.
5 Agriculture and Land Use	

[5] The large-scale bracken reduction programme in the Quantock Hills in Somerset with the subsequent reduction in tick activity and human tick borne disease between 2008 and 2016 is a good illustration of the health problems bracken can generate and the clear cut impact of actually reducing the risk by effective control (Brown, BCG 2017).

5.1 Agriculture Historically, Bracken has been important as animal bedding, for packing (especially soft fruits due to the biocidal effects), as thatch, and for potash and even primitive glass production. Bracken can improve soil quality for agricultural or forestry purposes.	Bracken reduces both the quantity and quality of grazing land; poisoning livestock and causing oncogenesis; acting as a reservoir for tick-borne diseases; increases veterinary costs.
5.2 Alternative Uses Bracken can be to be used as a biofuel, source of bioplastic.	
5.3 **Sporting**	Replacement of dwarf shrub habitats by bracken reduces grouse habitat and tick activity can increase grouse mortality as well as that of other ground nesting birds.
6 Hydrology and Environmental Quality	
6.1 Stabilisation Bracken rhizomes/roots, litter and canopy cover stabilise soil, especially on slopes and can also reduce runoff.	Mechanical methods of bracken control can cause disruption of soil structure and result in erosion.
6.2 Impact on Water Transfer	Bracken can intercept precipitation and increase evapotranspiration from the canopy and litter can impact on water transfers and storage.
6.3 Impact of control Herbicides	Control herbicides, especially glyphosate and some sulphonyl ureas can have a very strong impact on non-target plant and animal species and sensitive habitats and result in loss of vegetation ground cover as well as diversity (Brown, Daligan and Roe, 2018). This again can lead to soil instability on slopes >8 degrees with subsequent erosion and accelerated runoff, especially damaging on deeper, dry organic soils.
6.4 Soil Accumulation	The use of herbicides (viz the current Asulam registration situation) can lead to accumulation in the soil with biocidal impacts and the EC Drinking Water Directive 80/778/EEC MAC (maximum admissible concentration) being exceeded (Environment Agency 2000).

12 Cost of Bracken Control

12.1 An assessment of control costs indicates that they range from £1,020 to £1,820 per hectare over an 8-year programme with a variable outcome and impact on non-target features depending on the methods used (see below and Alday *et al*, 2016).

12.2 Veterinary and medical costs associated with bracken are difficult to quantify. There is a consensus that grazing loss due to bracken encroachment is costing the agricultural industry around £8 million a year, with veterinary bills exceeding £1.8 million on top.

12.3 Damage to heritage features, key habitat loss or degradation and human health costs cannot be quantified but are thought to be substantial (as shown by the Quantock Hills Study).

12.4 With current control costs and land prices a conversion rate purely in terms of grazing gain of one unit of cost for bracken control to 10 units of grazing/stock value is widely accepted as a minimum benefit (Varvarigos and Lawton 1990, updated 2015).

SECTION 4 - BRACKEN CONTROL

13 Methods of Bracken Control

13.1 Generally, speaking bracken control outside improved or semi improved grazing land, forestry or woodland and specialist horticultural environments involves areas where there is high habitat, plant/animal species or archaeological/heritage interest.

13.2 In the UK, there are 19 key habitats which are susceptible to loss or negative change as a result of bracken encroachment (Brown 2018).

13.3 The threat from bracken and control techniques to water supplies and human and animal health is relevant in all areas.

13.4 For these reasons methods of control must not only be effective on the bracken but must have a minimal impact on all non-target and heritage attributes as well as not compromising water resources.

13.5 The different bracken control techniques can be considered in three groups:

13.5.1 Physical Control
13.5.2 Herbicide Control
13.5.3 Biological

14 Physical Control Techniques

14.1 Ploughing

14.1.1 Outside the improved agricultural, forestry and horticultural areas this technique is unacceptable because it completely denatures the habitat and soil structure and will damage archaeological features. Even on grazing land there is potential for nesting bird mortality, damage to the understory and increased risk of soil erosion and water contamination.

14.2 Cutting, Swiping and Whipping

14.2.1 There are various reviews of the detailed methods of 'cutting' bracken available (Alday et al, 2016).

14.2.2 Regular severing of the fronds in the annual growth cycle prevents the movement of photosynthates to the rhizome system and releases the dormancy of buds resulting in the reduction in the number available to produce fronds in subsequent years.

14.2.3 Cutting two or three times a year has successfully achieved total control of bracken within 6 to 12 years in some areas, but there are examples where this technique has not worked.

14.2.4 Although cutting can be effective, there is still the issue of non-selective damage to other plant species and ground nesting birds may be at risk. If mechanised techniques with large vehicles are used, the impact on the ground can be significant. This is of particular concern on archaeological / heritage 'soft sites' (Historic England 2013, Scottish Natural Heritage 2014). There is also increased risk of damage/erosion on wetter sites and deeper dry peats.

14.2.5 If bracken is cut and the residue removed for other purposes, as in the past for bedding, potash etc, the system is depleted and the bracken is weakened, if not eradicated from specific sites. However, if it is simply cut and the residue allowed to accumulate the litter build up is much more rapid than on the normal annual cycle or after effective herbicide control. This build up not only inhibits re-colonisation by other ground cover, but it creates an environment which creates favourable conditions for ecdysis[6] in the Sheep Tick population (Brown 1997, Jinger Tan 2012, Brown 2016).

14.3 Rolling and Bruising

14.3.1 Rolling and bruising works in the same way as cutting, but as fronds are only partially damaged, the impact on dormant buds is less marked. If heavy rollers are used there needs to be vehicle access and more frequent treatments, all resulting in the potential for a greater amount of physical

[6] Ecdysis - the process of shedding the old skin (in reptiles) or casting off the outer cuticle (in insects and other arthropods)

damage (including soil erosion) and continuing accumulation of litter. Again, there is potential for nesting bird mortalities and wider damage to the understorey.

14.4 Burning

14.4.1 In spite of its advocates, burning is not considered to be a valid bracken control technique on its own. Bracken is a fire adapted species and the potash released from burning the fronds favours bracken spore germination and survival. Studies by Brown and Tollhurst (1990) have shown that frond density and production increase dramatically in the first two years after burning.

14.4.2 If used as a preparatory technique to remove bracken litter, prior to chemical control, burning has a role to play in bracken control programmes, especially on the leading edges of bracken beds.

14.4.3 Burning can have an impact on ground nesting birds, small mammals and reptiles as well as damaging the understorey and increasing the risk of soil erosion. There are different dates for the designated burning season in parts of the UK, but generally burning is only permitted during the winter months, when the impact is likely to be lowest.

14.5 Grazing

14.5.1 Animal activity can have an impact on bracken beds in two ways.

14.5.2 The impact of trampling / digging.

- Cattle have more impact than sheep.
- Rabbit warrens have a damaging impact on bracken stands but are destructive to soils and provide a potential starting point for erosion (Glen Clova - Brown, 2017).

14.5.3 Young bracken croziers and growing frond tips are toxic to stock and there are many poisoning and associated diseases for both sheep and cattle (for example: Bright Blindness).

14.5.4 As long as their diet is supplemented with vitamin B12 to prevent internal bleeding, Pigs can make huge impacts on bracken stands, including the rhizomes, but the soil and habitat destruction is also great.

14.5.5 Animal activity should not be regarded as a significant bracken control option on a large scale. Animals damage non-target ground storey species and habitats, they can initiate and accelerate soil erosion and water run-off, damage archaeological/heritage features and greatly increase the risk of livestock poisoning and exposure to ticks and TBDs is great.

14.6 Forestry

14.6.1 Both the processes of planting and felling can have a major impact on bracken.

14.6.2 When the tree canopy has closed after planting, bracken is shaded out.

14.6.3 Clear felling can allow extensive bracken re-colonisation, especially if there is no replanting or accelerated natural tree regeneration in place (Dumfries and North York Moors – Brown, 2017).

- Bracken on such areas is often very difficult to control because of access restrictions and the debris left by the forestry activity;
- Aerial herbicide application is often the only realistic option.

15 Herbicide Control

15.1 The most widely used herbicides are Glyphosate and Asulam. Glyphosate can only be applied from the ground, while Asulam can be applied from both ground and aerial sources.

15.2 Sulphonyl Ureas are used for bracken control in Australia and New Zealand for bracken control. Ongoing trials in the UK are exploring the use of the Sulphonyl Ureas, Amidosulfuron and Metsulfuron methyl individually and in combinations in the ground-based control of bracken (see Appendix 1).

16 Biological Control

16.1 In the 1970s, Lawton explored the use of non-native herbivorous insects, which feed on bracken, but for biological security reasons this approach was abandoned. There has been ongoing consideration of Myco-herbicides (biocides) but success has been limited. The same post-treatment issues of soil and water runoff outlined above apply would apply although water quality might be less of an issue.

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There are numerous other relevant publications and sources particularly those produced by Professors Marrs and Pakeman and their associated colleagues and teams, but the references here are confined to specific points and data sets mentioned in the text.

APPENDIX 1

NATIONAL BRACKEN CONTROL TRIALS 2012-2018

Interim Summary Report

1 Introduction

1.1 This trial work, which will be completed during 2018, is being carried out by Professor Roy Brown, who drafted this summary.

1.2 A summary of the information collected to date is provided to demonstrate the scale of the work taking place to confirm that Asulam is the most effective chemical for the control of bracken.

1.3 Some additional data may be included in the final report from the trials.

2 Purpose of the Trials

2.1 To evaluate the relative efficacy of Asulam against two alternative Sulphonyl Urea chemicals as bracken control agents over a period of 6 years (2012 to 2018).

2.2 To investigate the overall impact of these chemicals on non-target species (NTS) and on the target habitat and/or heritage features as a whole.

2.3 To evaluate the relative efficacy and impact on NTS of aerial as opposed to ground-based application.

3 Summary of the trial - bracken control efficacy and impact on NTS (Table 1)

3.1 **Table 1** summarises the results expressing the efficacy as a percentage of the pre- control bracken frond and rhizome standing crop in late July each year for years 3 and 5 after treatment with no follow up. It compares aerial and ground-based application (some applications, for example Glyphosate and lower active ingredient Amidosulfuron sites were only treated on the ground).

3.2 **Table 1** provides an overall qualitative ranking for the impact of the herbicides on non-target plants in years 3 and 5 after control. Figures for years 1, 2, 4 are available, but the year 3 and year 5 represent the first and latest time that follow up treatment would normally be considered. Deliberately, all of these trials have not been followed up. Figures will also be added following the final survey of the sites in 2018.

3.3 As a general comment the impact of all treatments is greater as a result of ground application in terms of frond control but is less marked in relation to rhizome response, and the difference is insignificant on non-target species.

3.4 **Asulam.** In both years (and indeed all other years) the impact on NTS was at the lowest rating of any chemical used and, although not reflected in the table, there was no sign of ongoing chemical activity from year 2 onwards. Details of ongoing chemical activity evaluation are discussed in the 'Goathland Bracken Report 2017'. The details of the NTS response are discussed further around **Table 2**.

3.5 It is important to stress that Asulam comes out as the best control agent with the least negative environmental impact of any treatment physical or chemical because of its high efficacy rating, minimum NTS impact and lowest impact on soil structure.

3.6 **Amidosulfuron 1N** applied from the ground has shown the highest frond control of herbicide in the trials. It is unclear why frond recovery has been so strong when so much damage has been done to the rhizomes. Like Asulam, the impact on plant NTS has been extremely low, but there is evidence of ongoing chemical activity to year 3 at least. Details of NTS response are discussed below.

3.7 **Metsulfuron 1N** ground applied shows a reasonable level of frond control after 3 years but the results at year 5 were one of the poorest levels of control in both ground and aerial treatment. Overall the level of control is good but the impact on NTS is the joint worst with Glyphosate with a damage rating of five in year 3 only improving to four by year 5. There is also clear evidence of ongoing chemical activity and the strongest negative impact on both plant and animal NTS as Tables 2 and 3 demonstrate. There is concern over the biological impact on freshwater.

3.8 **Amidosulfuron 1N + Metsulfuron 0.5N** the ground-based application of this mix gave a good but not exceptional level of frond control in year 3. Ground based rhizome impact was moderate in year 3 but relatively lower by year 5. Reasonable level of control, but very high NTS damage with a score of four in year 3 and three in year 5. Again, some evidence of ongoing chemical action in year 3 and probably year 5. Similar though less strong environmental impact to Metsulfuron 1N and Amidosulfuron 1N + Metsulfuron 1N below.

3.9 **Amidosulfuron 1N + Metsulfuron 1N** the ground-based application of this very high level of active ingredient mix gave a good level of frond control in year 3 Neither the frond nor the rhizome results were exceptional for the level of active ingredient involved. There was a high level of NTS damage with a score of four in year 3 and four in year 5. Definite ongoing chemical activity in year 5.

3.10 **Glyphosate** was only used as a ground-based treatment. Rhizome control was the weakest of any treatment. There were very high, negative impacts on NTS with a rating of five in year 3 and four in year 5. Overall recovery of the trial plots was very slow. In these trials, this treatment came through as a moderate control agent only but it appeared to inflict the greatest and most persistent damage on non-target attributes.

3.11 **Amidosulfuron 0.5N** was used as part of a programme to explore possible lower active ingredient levels as the non-target impacts of this herbicide were low. The was a good level of frond control in year 3 dropped in year 5 giving a higher level of efficacy than Amidosulfuron 1N at that stage. Very low level of NTS impact.

3.12 **Amidosulfuron 0.25N** had a low level of frond control with an equally modest rhizome response. Very low level of NTS impact. Both this and the 0.5N trials might be encouraging for specific uses in the future. A further line of investigation is underway into an earlier application timing for Amidosulfuron as the mode of action is slightly different to Asulam and there is evidence from work in New Zealand that treatment can be successfully carried out earlier in the growing cycle rather than waiting for full canopy maturity as with Asulam. However, whilst there may be some niche opportunities for the use of Amidosulfuron in bracken control the costs and longevity of activity preclude this as the primary herbicide for bracken management in the long term and on a large scale.

4 Detail of the impact of herbicides on Non-Target Species (Table 2)

4.1 **Table 2** summarises the number of NTS plant groups / species affected by the various chemical treatments and methods of application in years 3 and 5 post spraying. It then summarises the percentages affected each year based on numbers of species present involved. This does not cover the physical area of damage within the trial plots and this is discussed in the context of the individual treatments below.

4.2 In interpreting the percentage figures, it is important to note that the control plots all recorded a 2% damage level caused by background, non-treatment related, factors and this should be considered in interpreting the figures on the treated plots.

4.3 **Asulam**. In year 3, both aerial and ground-based trial areas had 46 NTS present. By year 5 these figures had risen to 49 and 48 respectively against pre-spray 48 species. In year 3 some 6% of species in the aerial plots showed damage, dropping to 4% by year 5. In year 3 ground-based damage affected 11% of species, declining to 6% in year 5. These are very low figures and the mean physical area of damaged vegetation within the plots was 6% for aerial in year 3 and 11% for ground based with year 5 recording 4% and 6% respectively. These are all very low values.

4.4 **Amidosulfuron 1N**. In year 3, both application methods were carrying 47 NTS and in year 3 this figure rose to 48. 8% of aerial NTS and 13% of ground based showed damage dropping to 4% and 8% respectively in year 5. Both aerial and ground-based plots recorded about 13% by area showing damage in year 3 and about 11% in year 5. These figures are again low.

4.5 **Metsulfuron 1N**. In year 3, only 38 of the original 48 NTS were present in the aerial plots and 36 in the ground based. In year 5 the aerial rose slightly to 40, but the ground based was static/declining at 35. In year 3 some 34% of NTS had damage on the aerial plots with 52% on the ground-based plots. In year 5 this had dropped to 25% and 37% respectively, which is extremely high. Coupled with damaged areas of 18% and 14% on both application types in years 3 and 5 respectively. This is a very damaging herbicide to NTS plants.

4.6 **Amidosulfuron 0.5N + Metsulfuron 0.5N.** Aerial plots recorded 44 NTS in year 3 and 46 NTS in year 5. Ground based figures were 43 and 44 respectively. Percentage of species showing damage was again high with 20% and 15% respectively on the aerial plots in years 3 and 5 with the corresponding figures for ground-based plots at 25 and 13% respectively. It is interesting that the differences between ground and aerial application are much less marked with this combination. Both applications recorded about 14% of area damaged in year 3 and 12% in year 5. High level of NTS damage overall.

4.7 **Amidosulfuron 1N + Metsulfuron 1N**. This very high active ingredient mixture had only a slightly greater effect that the 0.5N mixture. On the aerial plots there were 43 NTS in year 3 and 44 in year 5 with the corresponding figures on ground based at 40 and 42. Percentage of species damaged was again very high at 32% in year 3 and 20% in year 5 on aerial plots and 50% and 24% respectively on ground based. Both application methods recorded area damage levels of 16% in year 3 and 12% in year 5. Again, an extremely damaging combination.

4.8 **Glyphosate**. It was only possible to carry out ground-based trials with 35 of the original 48 plant NTS present in year 3 and 39 in year 5. Percentages of species showing damage were extremely high at 88% in year 3 and 59% in year 5. Area of damage was 53% in year 3 and 18% in year 5. The most damaging of any herbicide sprayed in these trials. Trials elsewhere have shown that use in a weed wipe gives a good level of bracken control with a lesser, but still marked, negative impact on NTS.

4.9 **Control plot**. There was no variation in species diversity, but 2% damage was recorded across the board on each sample check relating to non-treatment impacts (above).

4.10 **Asulam** clearly has the minimum impact on diversity over time, with Amidosulfuron close behind but all other treatments caused extensive NTS damage.

5 Invertebrate surface fauna under bracken, bracken-controlled areas and heather dominated moorland (Table 3)

5.1 The first section of **Table 3** compares unsprayed bracken sites with sites 1 year after spraying and 4 years after spraying. Eight Invertebrate groups/orders with their number of species are recorded under Asulam, Amidosulfuron and Metsulfuron treatments. The figures for dry *Calluna* heath at various points have been included in the second part of the table but this is not discussed further here.

5.2 Pre-spray 35 invertebrate species were recorded from the eight groups under the unsprayed bracken. One year after spraying, there were 30 species on the Asulam plots, rising to 45 at 4 years after spraying which is a significant increase. At one year there were 27 species on the Amidosulfuron plots increasing to 42 at the 4-year point. Metsulfuron showed the greatest losses with 16 species at 1 year rising to 29 at 4 years. The negative impact is marked.

5.3 *Coleoptera:* 9 species recorded pre-control, rising to 18 at year 1 and 19 at year 4 under Asulam, a result closely mirrored by Amidosulfuron with 16 and 18 species respectively but much less marked with Metsulfuron with 9 species at 1 year and 14 species at 4 reflecting the advantages of clearing bracken by whatever means.

5.4 *Opiliones* species increased from three under bracken to four at year 1 and 5 at year 4, four and five under Amidosulfuron but remained at two in year 1 and three in year 4 under Metsulfuron. *Hymenoptera* were significantly reduced from six species pre-spray to one under all three herbicides, at year 1, but then recovering to eight under Asulam, six under Amidosulfuron and four under Metsulfuron.

5.5 *Araneida:* 2 species recorded pre-spray, but none were recorded under any of the treatments in either year 1 or 4. Interestingly, three species have been recorded under Asulam and two under Amidosulfuron in year 6 (2018).

5.6 *Acari:* recorded three species pre-spray, including Sheep Tick *Ixodes ricinus*, with no return under any treatment up to year 4 under any herbicide.

5.7 *Diptera* are an important group under intact bracken cover, often having high densities, as well as relatively high densities (two of which are bracken specific).

5.8 *Myriapoda* were not recorded under the unsprayed bracken canopy, but one species was recorded under both Asulam and Amidosulfuron treatments at year 1 rising to three at year 4 and one under Metsulfuron at year 4.

5.9 *Collembola:* three species recorded pre-spray with two under Asulam and Amidosulfuron at year 1 and one under Metsulfuron. By year 4, there were four species under Asulam and Amidosulfuron and two under Metsulfuron. By year 5, when significant alternative cover was developing, the number of species had risen to seven where Asulam had been used, five under Amidosulfuron but still only three under Metsulfuron.

5.10 Overall, Asulam has had the lowest initial impact and seen the greatest increases in diversity and density post herbicide control.

6 Optimum Asulam application rates and methods of application

6.1 There have been many studies over the years, a number of the key ones are cited in the Bibliography; two examples, aerial and ground-based regimes, are used to illustrate the main points.

7 Aerial Regimes, a comparison 1993 to 1999 (Table 4)

7.1 These trials were carried out on moorland areas within the North York Moors prior to the designation of the moors as Sites of Special Scientific Interest (SSSI) and European Habitats Directives in the late 1990s and early 2000s. The objective was to establish the best regime for aerial bracken control using Asulam in sensitive areas where conservation objectives are high priority. All trials used Delevan 2 Raindrop nozzles on booms attached to R44 helicopters flying at standard speed/height (Brown, Goathland Report 2018).

7.2 This regime involved a **standard single pass** applying 11 l/ha of Asulam with no subsequent follow up. In year 1 canopy cover was down to 5% of pre-spray with stipe (frond) density down to 3%. By year 7, the cover increased to 68% of the original and stipe density up to 78%. This result is predictable. Follow up herbicide application in year 2-3 and possibly 4-5 would be essential to achieve effective long-term control.

7.3 **Double pass 14 days apart**. 1N Asulam used each time. No follow up. In year 1 canopy cover was 0% of pre-spray, as was stipe density. In year 7, cover was at 10% and 21% of the pre-treatment level. This is a very good result which, if coupled with alternative ground cover regeneration, would not require further herbicide input to achieve total control.

7.4 **Double pass at right angles within 15 minutes**. Each pass applying 5.5 l/ha. No follow up. In year 1, canopy cover was 0% of pre-spray and stipe density 3%. By year 7, canopy cover was at 38% and stipe density at 23%. Although there is significant recovery at year 7, the level of control is good for the amount of active ingredient used. Again, this method gives a long period of low recovery which, if coupled with active habitat restoration, would preclude further herbicide input. It is not suggested that this regime should be routinely adopted in preference to active follow up interventions at appropriate points after initial control.

7.5 **Single pass 11l/ha application followed up in year 3** with a further single 11 l/ha pass. First year cover reduction to 5% with stipe density at 3%. By year 3, prior to respray, canopy cover was at 25% and stipe density 52% of pre-spray. In year 7, frond cover was at 4% and stipe density 3%. Effective, but expensive application involving two full 1N applications and two separate helicopter inputs.

7.6 On balance the right-angled, double 0.5N active ingredient passes proved to be the most effective compromise in terms of the cost/efficacy balance.

8 Ground based regimes (Table 5)

8.1 There have been numerous studies (for example Alday *et al* 2016) and this note summarises the key points from the amalgamated studies where multiple replicates are available (n ranges from 16 to 32 replicates of treatment sites). Individual, non-replicated sites have not been included and practices which totally disrupt / destroy vegetation and soil profiles (for example pig activity) have not been considered.

8.2 **Table 5** ranks seven treatments (three physical and four herbicide) qualitatively but with percentage impact summary figures to back up the rankings.

8.3 Consistently, the three **Asulam** treatments occupied most of the 1, 2 and 3 positions in terms of the rhizome and frond reductions. The only exception was the tied third place between lance applied Asulam and x2 Annual cutting with sheep grazing on the front cover in year 5. **Glyphosate** applied by a weedwiper scored three in year 1 in the frond response table confirming that it can be a very effective control mechanism in the short term as far as above ground performance is concerned. However, after 5 years it was the least effective and in both the short and long term it had the lowest impact on rhizome response by a considerable margin. The three **Physical Control** regimes occupied the lower score slots, although x2 cut + sheep grazing gave a consistently good level of control.

8.4 Despite lower efficacy over a 5-year period, physical control can be delivered as part of routine land management with the use of stock (both cattle and horses can have a major impact but have not been included here due to a lack of replicated studies) and cutting equipment at a relatively low cost. However, it is very rare for physical methods to achieve permanent removal of the bracken, whereas that is always the objective in larger scale herbicide input.

8.5 In delicate habitats / heritage environments, the footprint of the equipment involved and the impact of the cutting / crushing / trampling input can cause a great deal of damage, undermining the gain of removing the bracken in terms of negative environmental impact.

8.6 Asulam scores at the highest level on the efficacy, minimal environmental / non-target impact and potentially safety scales. However, its potential as a selective herbicide and conservation management tool, is being severely limiting by the restrictions on the types of ground-based equipment that can be used, and the requirement to use high dilution rates in hand-held equipment.

Chemical Bracken Control Efficacy and Non Target Species Impact Summary at 3 and 5 years
(Based on National Trials Programme 2012 to 2017, where n = 18 in all sample categories)

Treatment	**Ground Application** Frond		Rhizome		**Aerial Application** Frond		Rhizome		**NTS rating ***	
	Year 3	Year 5	Year 3	Year 5	Year 3	Year 5	Year 3	Year 5	Year 3	Year 5
Asulox	82%	71%	66%	57%	76%	58%	62%	52%	one	one
Amidosulfuron 1N	93%	41%	79%	68%	62%	28%	75%	65%	one	one
Metsulfuron 1N	80%	70%	62%	44%	74%	61%	58%	38%	five	four
Amid. + Met.0.5N	86%	65%	72%	56%	65%	48%	68%	50%	four	three
Amid. + Met. 1N	82%	68%	60%	49%	74%	59%	60%	49%	four	three
Glyphosate	76%	62%	58%	38%	NA	NA	NA	NA	five	four
Amidosulfuron 0.5N	82%	61%	65%	54%	NA	NA	NA	NA	one	one
Amidosulfuron 0.25N	70%	50%	60%	50%	NA	NA	NA	NA	one	one

* NTS rating. One = little or no damage and 5 = extensive and sustained damage, often with species losses.

Impact of Bracken Control Chemicals on Non-Target Species (NTS)

Figures are number of species showing moderate/severe impact in years 3 and 5

NB. Pre treatment there were 48 NTS present in all categories

Treatment	Dwarf Shrub		Grasses/Sedges/ Rushes		Herbs		Bryophytes		Total NTS present			% NTS damaged	
	Year3	Year 5	Year 3	Year 5	Year 3	Year 5	Year 3	Year 5	Year 3	Year 5		Year 3	Year 5
Asulox													
Aerial	1	1	2	0	1	0	2	1	46	49		6%	4%
Ground	2	1	3	1	3	1	3	1	46	48		11%	6%
Amidosulfuron													
Aerial	1	0	1	0	1	1	0	1	47	48		8%	4%
Ground	1	1	2	1	2	1	1	1	47	48		13%	8%
Metsulfuron													
Aerial	4	3	3	2	4	3	2	2	38	40		34%	25%
Ground	5	3	4	3	5	4	5	3	36	35		52%	37%
Amid+Met.0.5N													
Aerial	2	2	1	1	1	1	5	3	44	46		20%	15%
Ground	3	2	3	1	3	1	2	2	43	44		25%	13%
Amid+Met.1N													
Aerial	5	3	3	2	3	2	3	2	43	44		32%	20%
Ground	6	2	5	2	4	3	5	3	40	42		50%	24%
Glyphosate													
Ground	6	5	8	6	9	6	8	6	35	39		88%	59%
Control													
Aerial	1	1	0	0	0	0	0	0	48	48		2%	2%
Ground	1	1	0	0	0	0	0	0	48	48		2%	2%

Comparison of Moorland Surface Invertebrate Fauna in Bracken and Heather

(After Brown 1986, Pakeman and Marrs 1991, Brown 2011 and Brown 2017 - excludes Lepidoptera)

Invertebrate Group or Order	Vegetation and Management											
	Unsprayed Bracken	Sprayed Bracken (n = 26)						Dry Calluna Heath (n = 32)				
		Year 1			Year 4							
		Asulox	Amido'	Metsulf'	Asulox	Amido'	Metsulf'	New Burn	4 year regrowth	10 year regrowth	20 year+ regrowth	Total Heather Species
Coleoptera (Beetles)	9	18	16	9	19	18	14	19	40	40	22	43
Opiliones (Harvestmen)	3	4	4	2	5	5	3	4	6	6	7	16
Hymenoptera (Bees,Wasps and Ants)	6	1	1	1	8	6	4	0	1	0	1	1
Araneida (Spiders and Mites)	2	0	0	0	0	0	0	7	9	9	6	9
Acari (Ticks)	3	0	0	0	0	0	0	0	1	1	1	1
Diptera (True Flies)	9	4	3	3	6	6	4	3	7	5	3	8
Myriapoda (Centipedes and Millepedes)	0	1	1	0	3	3	2	0	2	2	0	2
Collembola (Springtails)	3	2	2	1	4	4	2	3	6	12	7	13
Totals	35	30	27	16	45	42	29	36	72	75	47	93

NB There are no Red Data species in the unsprayed bracken fauna, but 5 in the regenerated bracken areas (cover mainly Grasses, Calluna and Vaccinium) and 9 in the Heather Sites

A comparison of four Aerial primary Asulox control regimes on the North York Moors National Park 1993 to 1999.

Treatments replicated 4 times.

Control Regime	% canopy cover	stipe density m^2
1. Single Raindrop nozzle pass with 1N Asulox (11l ha) in early August No follow up.		
a. Spray year immediately prior to treatment	99	28
b. First year after treatment	5	1
c. Year seven	68	22
2. Double pass Raindrop nozzle 14 days apart. Each application 1N Asulox (11l ha) in early/mid August. No follow up.		
a. Spray year immediately prior to treatment	98	28
b. First year after treatment	0	0
c. Year seven	10	6
3. Double pass at right angles Raindrop nozzle within 15 minutes. Each pass applying 0.5N (5.5l ha). No follow up.		
a. Spray year immediately prior to treatment	97	30
b. First year after treatment	0	1
c. Year seven	38	7
4. Single pass Raindrop 1N Asulox (11l ha) followed three years later by a further single pass at 1N rate.		
a. Spray year immediately prior to treatment	98	31
b. First year after treatment	5	1
c. Year three, full respray	25	16
d. Year seven	<5	1

Note: applications to GEP standards, verified.

Ranking of Ground Based Bracken Control Treatments based on Trials carried out between 1986 and 2017 (ongoing)

Treatment	Indicator							
	Rhizome mass				Fronds (cover, height and stipe density)			
	Initial (yr1)		Long Term (yr 5)		Initial (yr 1)		Long Term (yr 5)	
PHYSICAL								
Cut x 2 a year	4=	49%	5	42%	4=	94%	4	78%
Crush x 2 a year	5	44%	6	38%	6	90%	5	73%
Cut + Sheep	4 =	49%	4	47%	5	92%	3=	86%
HERBICIDE								
Ulva (Asulox)	2	53%	1	52%	1	100%	2	90%
Lance (Asulox)	3	52%	3	49%	4=	94%	3=	86%
Tractor Boom (Asu)	1	58%	2	51%	2	98%	1	92%
Weedwipe (Glyp.)	6	39%	7	31%	3	96%	6	66%

Notes:
Ranking of the 7 treatments based on efficacy of control, not selectivity to non target attributes
1 is most effective and 7 is least effective
% reductions are given next to rankings