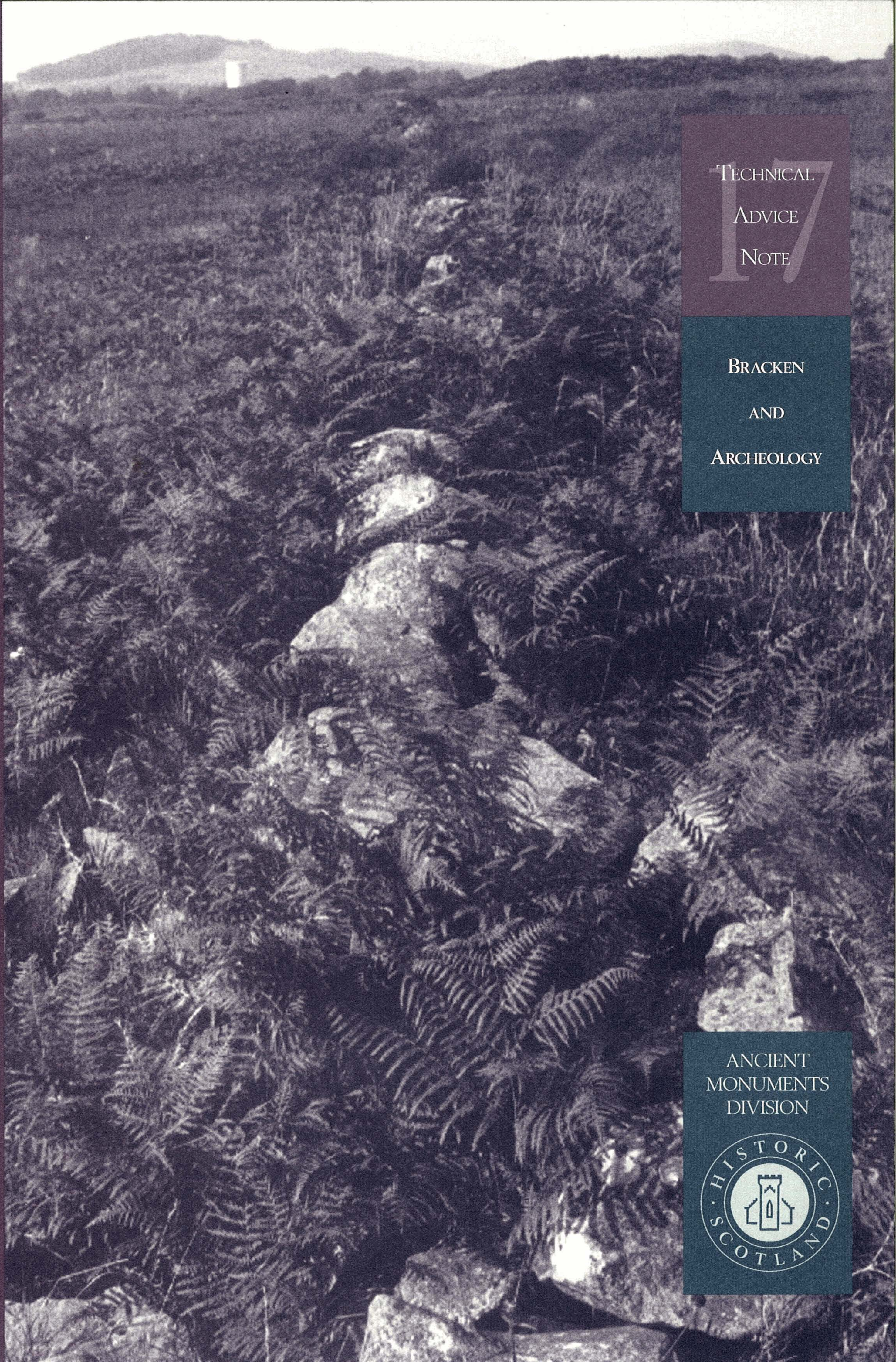
TAN 17

BRACKEN AND ARCHAEOLOGY



TECHNICAL ADVICE NOTE 17

BRACKEN AND ARCHEOLOGY

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Technical Advice Note 17

Bracken and Archaeology

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Published by
Historic Scotland

ISBN 1 900168 618

Edinburgh 1999

Commissioned by
ANCIENT MONUMENTS DIVISION

HISTORIC · SCOTLAND ·

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ACKNOWLEDGEMENTS

AOC Archaeology prepared this Note under a contract from Historic Scotland. Deirdre Cameron and Sally Foster managed the main stages of the project for Historic Scotland, with Noel Fojut managing its completion. The project managers acknowledge the advice and input of many present and former colleagues, especially Olwyn Owen and also Ian Armit, Patrick Ashmore, Gordon Barclay, Richard Hingley, Lesley Macinnes and Andrea Smith.

The project's origins lie in a 1992 internal report by Olwyn Owen of Historic Scotland, with contributions from Jerry O'Sullivan and Coralie Mills. This focussed on the impact of bracken on the archaeology of areas near Lairg that had been excavated under the direction of Rod McCullagh in advance of road improvements.

Historic Scotland acknowledges assistance and advice received during various stages of this project from, amongst many others, John Henderson and Tony Clay of the Scottish Executive Rural Affairs Department, David Miller of the Macaulay Land Research Institute, James Fenton and Robin Turner of the National Trust for Scotland, Jonathan Wordsworth of the Council for Scottish Archaeology and Tim Yarnell of the Forestry Commission. The authors particularly wish to thank Rod McCullagh and Murray Cook of AOC Archaeology for their assistance, encouragement and support, Rhône-Poulenc for advice and technical literature, and Scottish Executive Rural Affairs Department for consent to use information derived from monitoring of the Environmentally Sensitive Area Scheme.

The assistance of Ian Shepherd and Moira Greig of Aberdeenshire Council's Archaeology Service is gratefully acknowledged, both in identifying sites for field study and for permission to use Figure 10, which remains the Council's copyright. All other illustrations are Crown Copyright, either created for this Note or derived from other projects undertaken by AOC Archaeology and sponsored by Historic Scotland.

PREFACE

Bracken is a familiar problem for field archaeologists, as anyone who has undertaken field survey can testify. After mid-June each year, a large part of our rural archaeological heritage disappears under a blanket of waving green fronds, only to re-emerge in the late autumn, even then remaining cloaked in dry brown stems until mid-winter. The frustration of criss-crossing a steep hillside in vain search of a favourite site, thigh-deep or eye-deep in bracken and plagued by insects, is sufficient to burn the bracken fern into any archaeologist's consciousness.

The cloaking effect of bracken was what primarily concerned archaeologists until recently. It concealed unrecorded sites from recognition and study, requiring much field survey to take place in the early months of the year, when poorer weather lowered productivity and motivation. More seriously, it concealed recorded sites from forestry workers or construction engineers, leading to inadvertent destruction. We had the impression that bracken was spreading more widely, and were aware that the agricultural community was developing techniques to control it, because of its toxic effects on livestock. But in the main, bracken was something archaeologists lived with.

Public consciousness has focussed on bracken more recently, when research began to suggest it might have carcinogenic properties. Concern rose for the health of those who suffered regular exposure to bracken, especially when its spores were active. This news reached the archaeological community, but did little more than raise mild concern – although any excuse to avoid bracken was always welcome.

About the same time, field archaeologists working on a number of sites in the Highlands, who were collaborating increasingly with soil scientists, noted that bracken appeared to be associated with soils that had lost their structure. This observation caused little surprise, for we had long recognised the surface link between bracken and former human cultivation or habitation sites – indeed it was quite useful in the field, and many of us had followed the maxim of "start at the bracken patches and work out". If bracken indicated de-structured soils, this was useful knowledge, because such soils would have poorer or absent stratigraphy, and would therefore be less informative about early farming or other activities. Logic dictated that sites, or areas of sites, that were free of bracken should be excavated in preference to those with bracken. But how were we to establish whether or not bracken was mobile: were present-day bracken-free areas truly unaffected, or were they simply passing through a bracken-free phase in a cycle of repeated colonisation and retreat?

As work continued, the possibility emerged that bracken, rather than simply colonising disturbed soils, might actually be the principal agent of this de-structuring. For the first time we saw bracken as an active cause of damage to sites, rather than as a passive problem. If it is truly the case that bracken de-structures soils, then we were watching the archaeological value of sites being destroyed before our eyes. From being an inevitable nuisance, bracken had moved to being a positive threat, and potentially one on the same scale as rabbit burrowing or coastal erosion.

With this perception of threat came a need for systematic study. Excavators were tasked to keep records of bracken and the extent of its effects on stratigraphy. Major excavations, for example at Lairg, found themselves turning into de facto bracken research projects. Sister disciplines were approached for relevant research. We needed to understand the problem and to prove the causal links, so that we could argue for control measures, either funded directly from archaeology budgets or through agri-environment schemes or forestry estate management. And we needed to identify control measures that were effective while avoiding incidental damage to the archaeology. We needed to know whether it was more cost-effective to concentrate on controlling and eradicating bracken on sites where it was present, or preventing it spreading to unaffected sites.

Many research avenues are still open, but the time has arrived to provide an interim statement on many of the key matters. This Note draws together what archaeologists who are not intimately familiar with "the bracken question" need to know to understand the plant, its interaction with archaeology, and the measures available for its control. It also seeks to provide an understanding of the archaeological issues for those already familiar with bracken matters through work in, for example, agriculture and forestry.

Bracken is a shared problem for all who manage Scotland's rural land, for production, pleasure and conservation. The way forward must be to build understanding of the scope of the problem from our different perspectives and to exchange information about possible solutions. This Note represents an interim contribution to that process. It does not contain the answers, if indeed there are full answers, but it is an important marker on the way. I commend it to all land managers who care about their heritage, and to all archaeologists who care about what is happening within the sites and landscapes we study.

David J Breeze
Chief Inspector of Ancient Monuments
November 1999

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1 INTRODUCTION

Bracken is a management issue on archaeological and historic sites as it is an aggressive coloniser, which has a vigorous and destructive rhizome system:

- it destroys and reduces the significance of sub-surface archaeological evidence, including the ability to reconstruct past environments;
- it obscures sites, reducing their accessibility and making them more vulnerable to inadvertent damage.

Where bracken is a threat for either reason, a long-term management plan to control or eradicate the infestation is appropriate.

Any management assessment should be undertaken within the broader framework of maintaining and enhancing the natural heritage value of the site. In particular bracken control measures may have a negative impact on valued natural heritage features such as other ferns and ground-nesting birds.

This paper considers the evidence for the impact of bracken and other ferns on the archaeological resource and aims to raise awareness of the issues. Written as a practical guide, it also includes discussion of the ecology of bracken (as a basis for understanding its impact on archaeology); how the condition of sites should be assessed; when control is appropriate; and how it can most effectively be delivered. Information is provided on grant aid as well as sources of further information and advice.

2 AN INTRODUCTION TO THE BOTANY AND ECOLOGY OF BRACKEN AND FERNS

Bracken (*Pteridium aquilinum* (L.) Kuhn) is just one of a large number of species of fern found in Britain. Like flowering plants, ferns have well-developed leaves (called fronds) and conductive and supporting tissues, but they differ in their means of reproduction. Instead of flowers and seeds, the ferns form spores, microscopic reproductive bodies which can be disseminated widely. Under favourable conditions, a spore germinates into a simple organism called a prothallus which usually bears both male and female sex organs. Fertilisation of an egg cell from the female organ by a sperm cell from the male organ results in formation of a zygote which grows into a young fern plant.

Unlike most other ferns, bracken is an aggressive coloniser and has become a very serious weed in recent times. This paper concentrates on bracken as a management issue for archaeological sites.

2.1 Bracken (*Pteridium aquilinum*)

2.1.1 Differentiating bracken from other ferns

Bracken is a large fern, with established plants growing up to 2m or more in height. It is able to spread vegetatively, through its extensive underground rhizome system, and so, unlike other British ferns, bracken is usually found in colonies rather than as isolated plants. For absolutely certain identification, a good field guide should be used, for example Page (1982), but bracken is not too difficult to identify:

1 when mature, it has very large, triangular, compound, leathery fronds which curve markedly so that they are mostly in the horizontal plane;

2 emerging young fronds are crozier-shaped and, unlike other ferns, the first pair of pinnae (leaf-blades) unfurl rapidly while the rest of the frond is still coiled;

3 bracken lends a distinctive series of colours to the land, being light green in spring, dark green in summer and yellow-green to brown in autumn. This is linked to the seasonal life cycle of the plant, with fronds lasting for a season and then dying back quickly with the first hard frosts of the autumn.

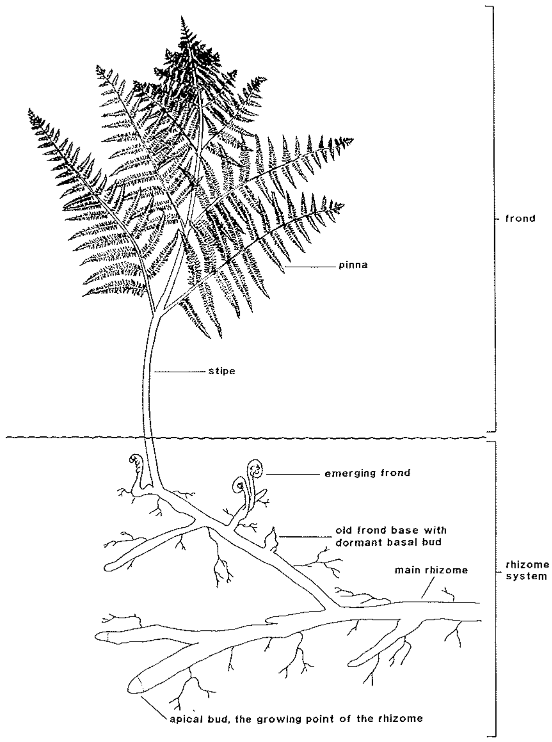

Figure 1. Botanical illustration of the bracken plant

2.1.2 Ecology and life-cycle

It is important to understand the ecology and life cycle of bracken if it is to be controlled effectively. (See Mitchell (1973), Watt (1976) and Pakeman *et al* (1994) for detailed technical accounts).

The ability of bracken to spread vegetatively from its underground rhizome system is what makes it such a problematic land management issue. In comparison, establishment of new plants from spores is a relatively rare occurrence and is not considered significant in terms of bracken management on archaeological sites.

A single bracken plant consists essentially of a major rhizome, with many secondary off-shoots, and of above-ground fronds which are made up of pinnae borne on a stem or stipe. The main rhizome is more or less horizontal and grows at one end while dying off at the other. It bears off-shoots which, for convenience, can be classified as two types; short-shoots which grow upwards and bear fronds, and long-shoots which do not have fronds and which grow in any direction. In fact, one type of shoot can change into the other, altering direction accordingly.

In the late spring, new fronds develop from buds on the short-shoots of the rhizome system. The growth of the new fronds depletes the stored carbohydrate reserves in the rhizome system. The emerging fronds unfurl to allow the pinnae to expand and to photosynthesise. Fronds begin to mature in about July, becoming darker-green and harder, and their photosynthesis replenishes the carbohydrate stores in the rhizomes for use in the following growing season. The fronds die off in August to October, depending on the timing of the first frosts, and collapse soon after. The plant then remains dormant, over-wintering as an underground rhizome system, until spring heralds the growth of new fronds once again.

Usually, each of the short-shoots produces one frond annually, but sometimes two or none. Additional frond buds are produced elsewhere on the rhizomes, usually at the base of previous years' fronds, and while they normally remain dormant, if the emerging frond is damaged then a dormant bud can quickly grow to replace it. These reserve buds, together with the extensive, perennial rhizome and its food-reserves, make bracken very resilient to damage and resistant to control procedures.

There are longer cycles at work in bracken colonies than just the annual cycle. The factors affecting these are complex, and not yet fully understood, but essentially the result is that, while the vegetative spread of bracken tends to concentrate along an advancing front of dense growth, behind this front the oldest areas of the colony can become degenerate and their growth more sparse. Colonies experience cycles of expansion and decline, over a period in the order of 100 years, but even when in decline, sufficient rhizome survives to permit renewed expansion when conditions allow.

2.1.3 *Distribution*

Of all the ferns, bracken is the most widely-distributed, being found virtually throughout the world. Bracken was originally an under-storey plant of deciduous woodlands, but it has proved remarkably adaptable to more open habitats, and as the landscape has become deforested over the last few millennia, bracken has become very widespread. It occurs throughout mainland Scotland, but is rare in the Northern and Western Isles. Its distribution is related to its ecological requirements, which have been summarised for Scotland by Miller *et al* (1989; 1990) as:

1 land below an altitude of 450 m and of an easterly or southerly aspect;

2 soil humus-iron podzol or brown forest soil; ie, soil is well-drained;

3 accumulated temperature is greater than 990 day °C per annum;

4 low occurrence of late frosts in the growing season.

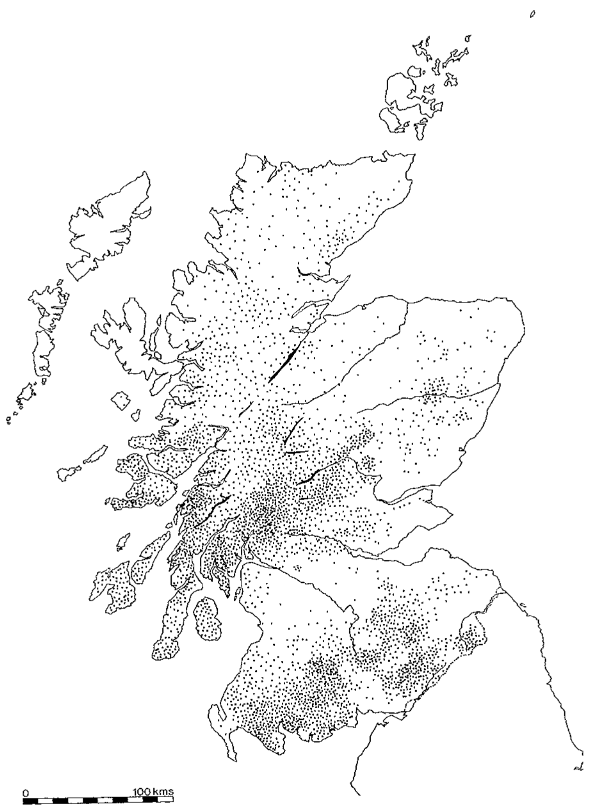

Figure 2. A map of bracken distribution in Scotland, after Tivy 1973 & Hendry 1958

After some refinement of the ecological criteria, Birnie *et al* (1996, 19) demonstrate that about 492,000 ha, or about 6.2 % of Scotland's land surface is amenable to bracken growth, of which about two-thirds is in the south-east and south-west, with only one-third in the north. These figures represent the 'potential bracken niche' in Scotland, that is the maximum potential distribution of bracken under current conditions, and not the current actual cover which is rather more difficult to estimate. Birnie *et al* (1996, 6) cite wide-ranging estimates for actual cover, between 63,250 ha and 470,000 ha depending on survey methodology. Rates of bracken spread are similarly difficult to quantify or to generalise, but Birnie *et al* (1996, 7) quote figures for Scotland of net annual changes in bracken area of between +0.4% and +2.3%, based on recent detailed aerial photography survey of selected sites by MLURI.

2.1.4 Nature conservation value of bracken

There are two main issues to consider, firstly the effect of expansion of bracken and secondly the effect of reduction in bracken extent through control measures. Only a brief discussion is possible here, but these aspects are considered in detail by Pakeman & Marrs (1992) and Birnie *et al* (1996).

In terms of bracken spread, the conservation value of bracken is poor in comparison to the value of the habitats it is replacing, for example heather moorland or rough grassland, and so the natural heritage impact of bracken spread is viewed as negative. Generally, plant communities associated with bracken are floristically poor. This is due to its vigorously competitive rhizome system, its dense above-ground growth and consequent shading out of smaller plants, and may also be linked to the release of hostile chemicals from the living bracken plant and its litter. While there are a few rare plants associated with bracken, these are shade-tolerant, relict woodland species, bracken having formed the canopy after tree removal. Bracken does not support many birds or animals.

The negative impact of bracken spread on the natural heritage implies that bracken control is desirable. However, control methods can have undesirable effects on other plants. For example spraying with asulam, the most commonly used herbicide, can seriously affect other ferns and clubmosses. Also, regardless of the method of control, there are difficulties in re-establishing semi-natural communities. At the same time, continued management is required to maintain bracken-free areas. However, when the 'environmental balance sheet' is weighed up, the continued expansion of bracken is believed to result in more damage to the natural heritage than well-targeted bracken control measures.

2.2 Ferns

Unlike bracken most other ferns are desirable elements of the vegetation and in general they do not spread aggressively or dominate the landscape. There are many such ferns in Scotland, and a useful discussion of upland ferns is given by Ratcliffe & Thompson (1988, 28). Indiscriminate control measures, especially aerial spraying, are likely to damage them, and so specialist conservation advice may be required and care should be taken to minimise impact on desirable ferns. Gullies and water courses provide a favourable habitat for many rare ferns and merit particular attention.

In nearly all cases, ferns other than bracken have positive nature conservation value and are not pernicious weeds. However, there are the occasional exceptions, notably the mountain fern, Oreopteris limbosperma which locally invades rough grassland. This could become a problem after bracken clearance and deserves monitoring. Again, specialist nature conservation advice is recommended.

Figure 3. Most ferns of similar size to bracken grow from a basal rosette, as here around an Iron Age broch, whereas bracken arises from the ground as single stems, and tends to branch more.

3 THE INTERACTION OF BRACKEN WITH OTHER ENVIRONMENTAL FACTORS

The processes of bracken growth and bracken control do not operate in an environmental vacuum, but inter-relate with other processes and characteristics of the environment. Thus, the nature of bracken growth may vary according to differences in other environmental conditions, and bracken growth may have an impact on other aspects of ecology. Similarly, bracken control measures have the potential to have variable outcomes according to differences in other environmental factors. The interactions between other environmental factors and bracken growth and control may have an indirect impact upon the condition and amenity of archaeological sites.

There is at present a dearth of literature in the UK which is directly relevant to the impact on archaeology of interactions between bracken, bracken control and other environmental variables. Some well-designed experimental research in this area could allow management advice to be imparted more confidently. By chance, the ecological literature contains a limited amount of research from which potential archaeological impact can be postulated. The most useful papers are those which explore the impacts of bracken on natural heritage, and in so doing attempt to determine whether bracken has a net positive or negative impact (Nicholson & Paterson 1976; Pakeman & Marrs 1992; Birnie *et al* 1996). In summary, while the individual effects are not all negative, most are and the overall impact of bracken encroachment on natural heritage is regarded as negative.

Some of the findings of the general bracken ecology literature appear contradictory, and it is studded with statements of the inadequacy of the amount of research in this area. Much of the UK literature exploring bracken's ecological impact is for lowland heaths in England and so may not be directly relevant to the Scottish situation. Furthermore, some environmental factors that have the most potential to affect archaeological sites are amongst those areas of bracken ecology which are least well understood, mainly because they do not have obvious nature conservation or agricultural impacts. Below-ground effects, bioturbation in particular, seem ill-explored with respect to bracken. Therefore, the following discussion has to be considered as extremely tentative.

The discussion of bracken growth and bracken control, and their interaction with other environmental factors, is concentrated on key themes for archaeological conservation; ground burrowing animals; erosion; bioturbation; and tree regeneration.

3.1 Ground-burrowing animals

Rabbits are considered the ground-burrowing animal which has the most serious impact on the condition of archaeological sites (Dunwell & Trout 1999). The preference of both bracken and rabbits for well-drained soil means they are likely to occur within similar potential niches. The most important question here is whether bracken growth inhibits or encourages rabbit burrowing, and consequently, what the likely impact of bracken control is on rabbit colonies.

Birnie *et al* (1996) suggest that bracken encroachment would have greatest impact on moderate body-sized animals with small home ranges, including rabbits (the rabbit's home range is up to about 200m from the warren), but would have less impact on mammals with large home ranges (eg red deer, foxes). The scale of impact is likely to be affected by the nature of the bracken cover, which may be considered as either continuous or discontinuous (Nicholson & Paterson 1976), because there is more forage available for herbivores through the presence of other plant species where bracken is discontinuous. Additionally, a number of animals exploit bracken to provide cover, for example for fox earths, rabbit burrows and badger setts, and badgers also use bracken as bedding (Birnie et al 1996). The larger herbivores do not normally eat bracken, but rabbits and other animals are known to do so occasionally (Birnie *et al* 1996), although whether there are ensuing toxic effects is not clear. Where bracken is discontinuous, rabbits will preferentially consume other competing plant species, which contributes to the increasing dominance of the fern (Watt 1955). There is a possibility that the massive bracken spread and increase in rabbit population observed since the mid-nineteenth century are somehow related (Page 1982).

The tentative summary must be that bracken is only a discouragement to rabbits where the bracken is so dense that it has virtually excluded all other browse, and where the stand becomes continuous for at least 200 m in every direction around an existing or potential warren site. Bracken control in such areas would allow restoration of more diverse vegetation that could

Figure 4. A discontinuous bracken infestation on a motte site, with clear evidence of rabbit erosion and burrowing.

become an attraction to rabbits (Marrs & Lowday 1992). One might also postulate that discontinuous bracken cover is positively attractive to rabbits, as it allows feeding but also gives protection to the warren. Therefore discontinuous bracken, as is often observed on archaeological sites, is no deterrent to rabbit infestation.

In conclusion, only where bracken is very extensive and dense is there a possibility of it excluding rabbits, and in any case, under such severe bracken infestation, the rhizomes will already have had an impact on the below-ground archaeology. Therefore, in such cases bracken control may not be an archaeological priority unless the main reasons are to improve amenity or to inhibit bracken spread to adjacent archaeological sites. The manager would have to consider the possibility that the controlled site would eventually become more attractive to rabbits, and also the completely unsupported hypothesis that the below-ground archaeological damage caused by rabbits could be more severe than that caused by bracken rhizomes.

Most archaeological benefit is probably available from preventing bracken from spreading further, particularly where it is discontinuous or at the advancing edge, ie before the rhizome infestation has become dense. In these circumstances rabbits are more or less a neutral factor because they are just as likely to be present before as after bracken control. Of course, methods for rabbit control might also be deployed on bracken-affected sites. Control of rabbit populations where bracken is discontinuous may slow the rate at which bracken becomes continuous. Thus, where both bracken and rabbits are present, a combination of bracken control and rabbit control would be most beneficial to the archaeology.

3.2 Erosion

Erosion of the ground surface clearly has a potentially damaging effect on archaeological sites, and bracken cover has both advantages and disadvantages in this respect. According to the environmental balance sheet (Pakeman & Marrs 1992), the presence of bracken deters access, thus protecting secluded areas, and may also stabilise eroding soil. However, it is regarded as a hindrance for outdoor recreation generally, and because bracken inhibits movement, infestation may obscure established routes, leading to the erosion of new routes by human or livestock movement in new and previously unaffected areas. The fact that bracken can reduce water yield in infested catchments used for public supply (Williams *et al* 1987) indicates that bracken cover reduces surface water run-off and therefore inhibits erosion. On the whole it appears that bracken largely protects areas against erosion, except for the localised concentration of erosion where bracken obstructs intended access routes.

The key archaeological question must be whether bracken control can lead to erosion. This is not a well-studied area, and the many potential variables affecting susceptibility to erosion, such as slope angle, exposure, depth of litter layer, stocking levels, human access, nature of the soil and the climate, suggest that the danger of erosion after bracken control has to be judged carefully on a site by site basis. However, a few tentative observations may be made, which largely relate to the degree of success expected for regeneration of a non-bracken vegetation cover.

In weighing up the advantages and disadvantages of different control methods, Pakeman & Marrs (1992) note that cutting results in a slow reduction in frond density and this allows re-colonisation of the site before soil erosion becomes a problem. Cutting can be targeted to areas where there is a stable underlying sward and/or at bracken fronts to prevent further encroachment. The passage of cutters disturbs the bracken litter layer, accelerating the colonisation by other species. However, to be effective, cutting needs to be carried out twice a year, over many years, and cessation leads to rapid bracken regeneration. In comparison, spraying with asulam, especially aerial spraying over large areas, can lead to a sudden landscape change from dense bracken to unsightly areas of litter. The sudden change can result in large-scale hydrological changes including increased run-off, which in turn can lead to soil erosion before colonisation by other species. More targeted application of asulam is less problematic, and can be directed at areas with a good sward and/or at advancing fronts to prevent further encroachment. As with cutting, repeat treatments are necessary.

Whichever control method is used, in terms of preventing erosion it is the regeneration of a stable vegetated (not with bracken) surface which is important, and there is some indication from experiments in lowland heaths in England on how best this can be achieved, with a combination of cutting and reseeding appearing most successful on grass-heath, but with seeding having no benefit on pure heathland (Lowday & Marrs 1992a). Disturbance to the litter layer appears important for re-establishment of vegetation, but this has to be balanced with the need not to expose or disturb the underlying archaeological sediments, and the suggestion of ploughing in of litter (Scragg 1982) is probably too damaging to be considered for archaeological sites. The more gentle option of removal of litter by raking is probably most appropriate (Lowday & Marrs 1992b).

Many archaeological sites affected by bracken occur in areas of rough-grazing, and so it is important to note the interaction between livestock and erosion. It is a widely-held view that the expansion of sheep over cattle farming in the 18th and 19th centuries in Scotland contributed to the spread of bracken because the process of cattle trampling on young bracken shoots had previously helped to keep it in check (Fraser-Darling 1955). Sheep do not have the same effect, except in localised areas where mob stocking occurs or where animals naturally congregate (Birnie *et*

Figure 3. Most ferns of similar size to bracken grow from a basal rosette, as here around an Iron Age broch, whereas bracken arises from the ground as single stems, and tends to branch more.

al 1996). The suggestion of enclosing treated areas of bracken then stocking them with cattle (Scragg 1982) has to be exercised with extreme caution on archaeological sites, because the breaking of the surface by the hooves could lead to erosion of the site.

Finally, the interaction of bracken, fires and erosion should be mentioned, given the extent to which fire is used as a heathland management technique in Scotland. Poorly managed muir-burning can involve the surface fire being too hot which leads to the wholesale removal of bracken's competitors while leaving the deep-seated rhizomes undamaged (Page 1982). The destabilisation of the surface can lead to erosion, further suppressing the re-growth of plants other than bracken. New fronds are usually the first green things to reappear and bracken takes great advantage of the nutrients released into the soil by burning. Thus, unless due care is taken, the use of fire can stimulate bracken domination, and this has to be taken into account when attempting to manage bracken on or near archaeological sites.

3.3 Bioturbation

This area of bracken ecology is particularly poorly represented in the literature. However, some tentative comments on the possible interaction of bracken, control measures and bioturbation on archaeological sites is possible. In this discussion, bioturbation on the micro-scale is meant, rather than the impact of larger biota such as rabbits and trees that are discussed elsewhere in this document.

For the purposes of this summary, bioturbation can be viewed as a natural part of soil formation processes, and is caused by the action of invertebrates and micro-organisms in the soil. As a general rule of thumb, bioturbation is more prevalent in freely-draining, fertile soils than in poorly-drained, nutrient-poor soils, because the former are more biologically active. Bracken tends to be associated with better-drained, more fertile soils (Biggin 1980; Miles 1985), and has been considered to act as a soil 'improver' (Miles 1981).

The interaction of bracken control and soil characteristics has been examined due to the nature conservation interest, because heathland and grassland areas with a high conservation value are often associated with infertile soil conditions, and where they have been lost or encroached through succession, there may be significant increases in soil fertility (Marrs *et al* 1992). Bracken control is often carried out for nature conservation purposes, and any increased soil fertility may be a problem in re-establishing desired heath and grassland species (ibid). Clearly, bracken control for nature conservation purposes cannot be separated from archaeological issues, not least because successful re-establishment of a stable vegetation cover is also important for the archaeology.

In terms of archaeological impact, two extremes of a spectrum can be deduced; either bracken encroaches on more active soils and sediments, already subject to millennia of bioturbation, where the damage is already established, or bracken encroaches on less fertile areas and enhances the degree of bioturbation, therefore stimulating the process of indirect damage to below-ground archaeology. In terms of archaeological benefit, there is more to be gained from bracken control in the latter scenario where reversion to heathland or grassland is a desirable aim. Of course, there is even more to be gained from *prevention* of bracken spread onto archaeology in areas of less active soils.

Clearly the potential scale of damage caused by enhanced soil bio-activity under bracken will depend on the nature of the archaeological sediments, and is probably particularly damaging where well-drained soft sediments and fine stratigraphy are involved, although it is also probable in such circumstances that significant bioturbation will have occurred prior to bracken infestation. The scale of damage will also depend on the length of time for which the enhanced soil fertility has operated, and so the age of the site, in comparison to the duration of better soil conditions, would be a factor.

Some research into the effects of bracken control measures on soil conditions has been undertaken in lowland heaths in England (ibid), and may or may not be applicable to the Scottish situation. Unfortunately, soil properties were not measured before the experimental work began, so although the soil fertility in the bracken infested areas was higher than for heath soils, it was not possible to say whether bracken elevated fertility or invaded particular patches due to higher soil fertility. It was clear that, over 10 years of bracken control with either cutting or asulam spraying, the techniques failed to reduce many soil chemical values to heathland levels. Marrs *et al* (1992) suggest that a more effective approach to impoverishing soils might be to remove nutrients from the system, perhaps by cutting plus removal of cuttings and litter, by sod removal, or by dilution of surface accumulations of nutrients by deep incorporation or removal of litter. The least damaging of these in archaeological terms would be removal of cuttings and litter.

3.4 Tree regeneration

Tree roots have the potential to damage archaeological sites and structures, and so the impact of bracken cover

Figure 6. Bracken infestations can frequently protect and enclose other problems, such as gorse.

and control on tree regeneration is considered. In general, bracken cover can prevent tree regeneration by reducing the establishment of seedlings and slowing the growth of saplings (Pakeman & Marrs 1992). For example, a Scottish study on natural regeneration of oak in upland semi-natural woods demonstrated that oak seedling growth is inhibited by competition from bracken, for example through shading in the growing season and smothering of seedlings by dying fronds in winter (Humphrey & Swaine 1997). Therefore bracken control improves conditions for tree regeneration, as long as grazing pressure is sufficiently low (Cadbury 1976) and, indeed, invasion by birch can cause successional problems when bracken is controlled on heaths (Marrs & Lowday 1992).

Therefore, it is recommended that where bracken control is undertaken for archaeological sites, that they are also managed to prevent any tree regeneration. Action should follow the guidelines given by The Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD) for the Environmentally Sensitive Areas, which essentially require farmers not to plant trees or encourage regeneration within 20 m of archaeological sites.

3.5 Conclusion

Bracken infestation, while damaging in itself to archaeology, may inhibit other types of environmental damage, for example by preventing tree regeneration, by stabilising eroding soils or by excluding rabbits where stands are dense and extensive. On the other hand, bracken may enhance bioturbation by acting as a soil improver, may attract rabbits where cover is discontinuous and may cause localised erosion by channeling people and animals into areas free of obstructive bracken cover. Bracken control measures have the potential to cause incidental environmental problems for archaeology, for example by encouraging tree regeneration, by increasing the risk of soil erosion or by creating a more hospitable environment for rabbits. Therefore, other management interventions may become necessary in bracken control programmes. Clearly, the likelihood of these other problems occurring will vary according to the particular site conditions and location, and a management programme should be drawn up on a case by case basis, calling on professional advice both archaeological and ecological.

Figure 7. Bracken infested standing stones on Arran.

4 THE IMPACT OF BRACKEN ON ARCHAEOLOGY

The impact of bracken on archaeology has only rarely been recognised through formal study, with most accounts of damage being anecdotal. In the three case studies presented below rigorous and systematic recording techniques have been applied to quantify the impact of bracken on the archaeological resource.

The first case study uses the records from the archaeological excavations on a roadline at Lairg, Sutherland (McCullagh & Tipping 1997) and a specialist report on bracken infestation prepared for Historic Scotland as part of the Lairg project (Owen *et al* 1992). These data give details of the sub-surface impact of infestation on archaeological sediments. Currently this project appears to have been the only significant survey and excavation project in Scotland that has recorded the sub-surface impact of bracken. The tendency of fieldworkers to avoid bracken infested areas has perpetuated a lack of understanding as to the pernicious and destructive nature of the plant.

The second case study is based on the records and reports from the excavations at Upper Tillygarmond, Aberdeenshire. These excavations were specifically undertaken to attempt to assess the visible impact of bracken rhizome systems on archaeological sediments. A sequence of test pits was distributed across the site, a deserted settlement and field system, to assess the differences between comparable infested and clear areas. As such the data from these works gives important information on the nature of the adverse impact on a typical Scottish archaeological site.

The third case study is based on recording from the monitoring programme for the Environmentally Sensitive Areas (ESA) scheme in Scotland. The ESA data gives details on the patterning of infestation including the variation in the infestation of differing monument types in comparison to the overall distribution of the bracken fern and an examination of any coincidental environmental factors that may encourage or enhance bracken fern infestation.

4.1 Case Study: Lairg Roadline

The archaeological investigations at Lairg, Sutherland, took place between 1988 and 1997 in advance of the upgrading of the A836 trunk road and focused on a corridor of land, *circa* 3.5 km long by 0.3 km wide, to the south of the village. The road upgrading works were instigated by the then Highland Region Road Authority. The Lairg study area, albeit artificial in its confines, can be seen as typical of such northern Scottish valleys.

4.1.1 Recording methodology

The Lairg project has utilised what is now a standard 'package': archaeology; artefact analysis; palaeobotany; palynology; and palaeo-pedology. Information on the extent and impact of bracken is available from three main sources: a vegetation survey; a topographical survey; and the stratigraphic and soil science descriptions from trial trenching.

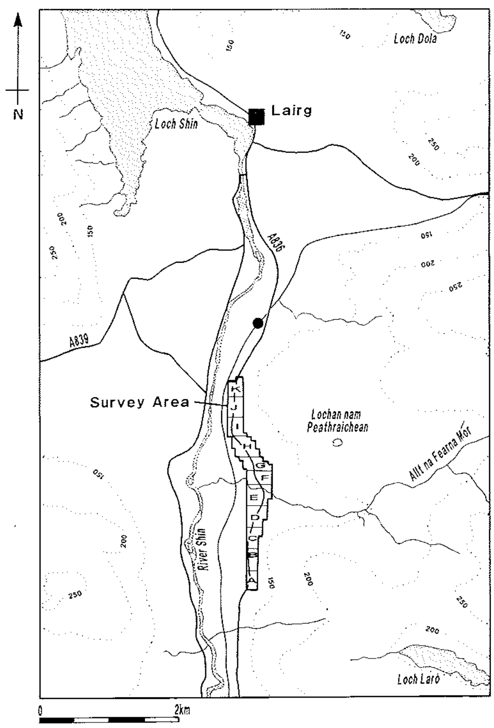

Figure 8. Lairg project area.

4.1.2 The distribution of bracken at Lairg

The distribution of bracken infested sites was marked, displaying a concentration at the northern (Survey Blocks H, J and K) and at the southern (Survey Blocks A and B) limits of the study area. This perhaps reflects the fact that large, intervening tracts of the survey area are characterised as heather-clad, peaty, organic topsoil, inimicable to bracken colonisation.

In addition, the severity of the infestation, indicated by whether bracken was the first, second or third most dominant vegetation type, appears to be greater in the northern survey blocks (especially Survey Block K). This survey block covered an area of crofting land, which had been improved in the 1950s and 1960s, and was the only pasture suitable for lambing although its use had declined in the recent past with only two crofts still being worked full-time.

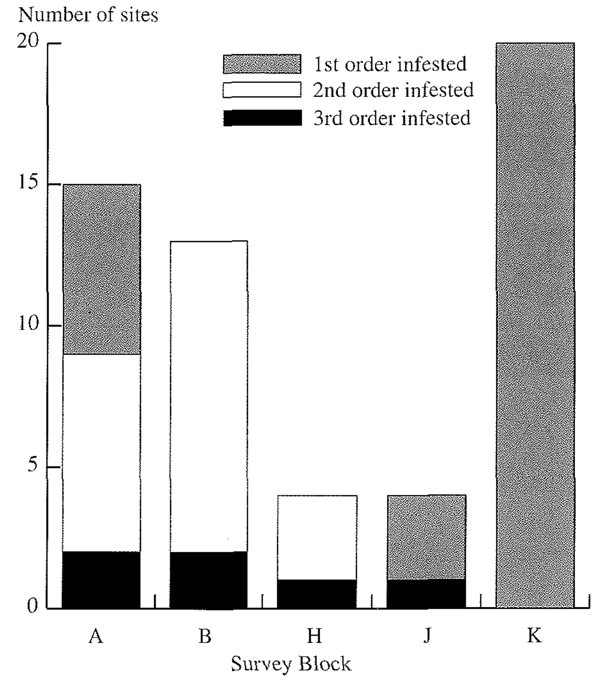

Figure 9. Distribution of bracken infested sites at Lairg.

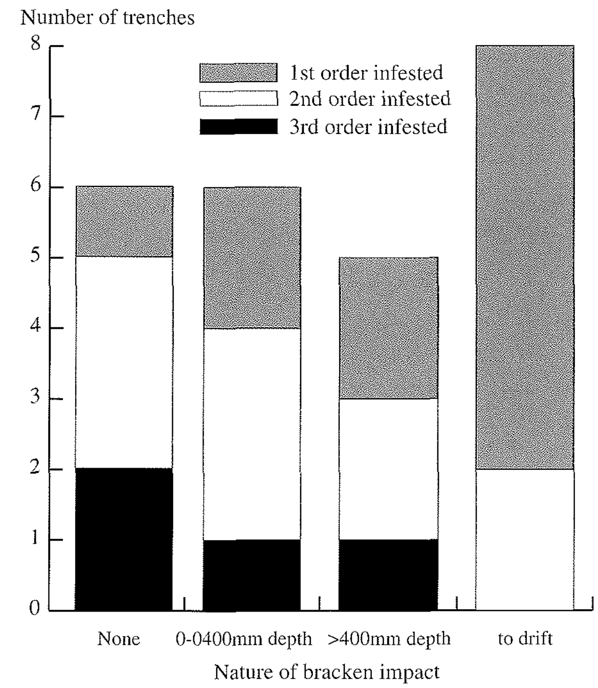

Figure 10. Distribution of bracken impacts between trial trenches at Lairg.

4.1.3 The impact of bracken at Lairg

In 1989, 25 trial trenches were excavated at 23 of the 56 sites identified as bracken infested. The excavation record specifies both general land use and vegetation cover for each site, as well as the size, abundance and type of rhizomes present in every context and feature seen in section. Thus it is possible to make detailed observations, in the case of each of these sites, as to the degree and effect of bracken rhizome intrusion.

Six trial trenches had no recorded bracken rhizomes. Clearly when a site is only partly infested the location of the trial trench in relation to the infestation will significantly affect whether bracken rhizomes are identified. Of those trenches that do have bracken rhizomes present there appear to be three main orders of infestation:

1. a dense, compact mat of bracken rhizomes at a relatively shallow depth, normally between 200 and 400 mm below the surface. The formation of this mat does not appear to have been caused by archaeological sediments, and non-drift sediments are still available for colonisation at a deeper depth. The formation of this mat may reflect a high groundwater level or may be a characteristic of bracken ecology;

2. bracken rhizomes have not formed a mat but have still failed to exploit the full depth of sediments available. The trial trenches with these characteristics are often described in the records as riddled with rhizomes. The rhizomes tend to stop at depths of between 600 and 900 mm. This form of infestation may illustrate a natural depth limit to which bracken rhizomes will penetrate, and hence the typical form of infestation in deep soils where rhizome depth is not limited by environmental factors such as groundwater or drift geology;

3. the rhizomes have fully exploited all sediments overlying the drift geology. The archaeological sediments in these trenches were often characterised as having been severely disturbed by the bracken rhizomes. Indeed in one case the excavator recorded that the whole monument had suffered severe damage from rhizome intrusion.

The presence of bracken infestation does not necessarily exclude the potential for an excavator to recognise complex stratigraphy. In the case of a post-medieval long-house, finely stratified ash and charcoal layers remained well-defined beneath a wall even though bracken infestation had penetrated the area. However, the survival of such stratigraphy reflects the fact that bracken rhizomes, unlike other smaller forms of turbation such as grass rootlets or microfauna, can have relatively low density. This does not change the fact that the condition of sediments and the validity of

Figure 11. Aerial view of Upper Tillygarmond.

palaeo-environmental studies have been compromised, and in this particular case the layers were also protected by a well-built overlying wall.

A series of general observations can be made:

1 Bracken shows a preference for the soft, stratified, freely draining, sandy loam topsoils found on many of the upstanding monuments and bracken rhizomes do not generally exploit the less fertile, underlying stony mineral subsoils. Where rhizome intrusion is recorded in the subsoils, it is invariably superficial and of low density;

2 The depth of rhizome penetration varies. Generally, it is seldom seen to exceed a depth of 600 mm, and the rhizome mass tends to become thinner below about 200 mm;

3 Bracken is consistently found to flourish on stony features (such as cairns and dykes) and on embanked soils (such as hut banks), presumably because these features provide a well-drained environment which corresponds to the plant's own preference;

4 Topographic surveys will tend to recognise upstanding features which in turn offer premium environments for the plant, all other factors being favourable. The Lairg survey did not include the diversity of site types which would allow for the effect of the plant on levelled sites with buried negative features to be determined.

In conclusion the Lairg project illustrates examples of vigorous intrusion by bracken rhizomes into otherwise well-preserved archaeological stratigraphy, and includes some examples of extreme rhizome disturbance. This demonstrates that bracken had a significant damaging impact on the archaeological resource.

4.2 Case Study: Upper Tillygarmond

AOC Archaeology, in Feburary 1999, undertook a case study to attempt to characterise, through visual attributes, the impact of bracken rhizomes on a range of archaeological sediments (Cook 1999). The chosen site was a deserted settlement and associated field system at Upper Tillygarmond, approximately 7 km south-west of Banchory, Aberdeenshire. This site was first located during examination of the aerial photographs taken by Moira Greig of Aberdeenshire Council and subsequently surveyed by Derek Alexander of the Centre for Field Archaeology in March 1998.

The site had survived in an area of unimproved pasture, which lay uphill and adjacent to improved, enclosed farmland. The site does not spread across the whole of the hill, where there are very shallow soils and extensive exposures of bedrock. Indeed many of the elements of the field system appear to have been truncated by the rectilinear walls enclosing the improved ground, presumably nineteenth century in origin. Consequently the deserted settlement has survived in a narrow strip where the soils were too marginal to warrant enclosure and improvement in the nineteenth century, but had proved suitable for exploitation in earlier times. This implies that the deserted settlement pre-dates the improvement period but is probably of post-medieval date.

The deserted settlement is comprised of two farmsteads, each of which is a collection of several rectangular structures around an enclosed yard. A number of denuded, curvilinear field banks have been recorded around the farmsteads, and stretching away to the north-east. Among the field banks to the north-east are a collection of turf covered stony mounds, probably clearance cairns. To the west, and upslope, of these features, an oval or sub-rectangular structure was identified. The dissimilar form and location of this structure, in comparison to the farmsteads, led to the suggestion that this could be earlier.

As the site lies in ground that is currently marginal, it suffers from a number of problems. These include bracken, rabbit and gorse infestations. In addition there is evidence across the general area of erosion damage from stock movement and, to a lesser extent, from vehicular movement.

4.2.1 Methodology

The main aims of the field investigation were to explore the nature of the impact of bracken rhizome systems on archaeological sediments. This was carried out through the excavation of a series of fourteen test pits spread across a deserted settlement and field system. These test pits were excavated in order to compare archaeological sediments where bracken infestation was active with those where it was not currently visible. The test pits were also intended to show the extent to which above ground visual indicators can provide an estimation of rhizome infestation and its likely archaeological consequences. The bracken in each of the test pits was recorded in detail, principally through section drawings and photography.

4.2.2 Site selection criteria

The site had been identified as having partial bracken coverage, an essential requirement if the impact of bracken on certain sediments was to be compared with comparable sediments that were not infested. The type of site selected, a post-medieval deserted settlement, was also thought advantageous as it was both of moderate cultural significance while having a good probability of distinct stratigraphy (walls, surfaced floors, collapse deposits etc).

The excavations did expose some excellent stratigraphy with bracken infestations in the form of upstanding walls and rubble collapse layers. However, there was a notable lack of surfaced floors or complex soft sediment stratigraphy. Consequently the site did not provide the ideal circumstances, although there was sufficient diversity in stratigraphy to address the issues of bracken infestation.

4.2.3 Bracken stem density

The surface densities of bracken stems from the test pits in infested areas varied widely. The majority had surface densities between 15 and 45 per m^2 (6 test pits) while two locations had densities in the 80s per m^2.

4.2.4 The penetration of rhizome

The depth of bracken rhizome penetration, relative to the available depth of sediment, varied markedly. While no infestation penetrated less than 0.15 m, many failed to penetrate the full depth of the available sediment. Whether or not the full depth of available sediment was exploited did not seem to be directly linked to either the surface density of stems or the actual depth of sediment.

The bracken rhizome penetrated a variety of deposits from structural walls to drainage ditches. Interestingly, the bracken rhizomes did not significantly penetrate the wall cores of either of the two farmsteads where they were investigated. This may suggest that the rhizome had difficulty penetrating this sediment, perhaps because of its compacted nature or perhaps the wall core had a higher relative moisture content than the surrounding sediments. The rhizome systems were consistently recorded as having penetrated deepest in areas of loose rubble collapse rather than soft sediment.

4.2.5 The density of rhizome activity

The infested test pits, regardless of the surface stem density or the form of the penetration, exhibited a consistently high volume of bracken rhizome. The distribution, in section and in plan, of bracken rhizome in the infested test pits was evenly spread through the infested zone of substrate. This contrasts with the previous excavation evidence from the Lairg excavations that rhizome infestations had a tendency to form distinct mats.

The main exceptions to this pattern of even distribution were the farmstead wall cores, discussed above, and the trackway drain. One test pit through a roadside drain or ditch proved to have a visible concentration of rhizomes in the core of the fill of the drain.

The absence of surface evidence for bracken infestation proved almost universally to match an absence of rhizomes in the underlying sediments. The exception was a test pit in the yard of one of the farmsteads where there was evidence of previous bracken infestation. The surrounding farmstead was extensively infested by bracken, and the presence of degraded rhizome is thought to reflect the dynamics of advance and retreat in the extent of the surrounding rhizome system.

4.2.6 Adverse impact

One of the main aims of the excavations was to explore the consequences of bracken rhizome systems by examining comparable features with and without bracken infestations. The purpose was to characterise the nature of any adverse impact that the bracken rhizome system may have on archaeological sediments.

In visual terms the strongest and most immediate impact was the percentage of the matrix that appeared to be rhizome. The density of bracken rhizome can clearly be seen, predominantly effecting the clast rich and clast supported contexts. The field indications were that the rhizomes, through their exploitation of the inter-clast spaces, appeared to be causing an increase in the size of these spaces. Should this be the case then it is to be expected that, over a suitable period of time, the infestation could destabilise clast rich contexts. This may result in the degradation of features, fracturing of wall faces and slumping of rubble banks or ramparts.

Given that these works were undertaken during February, there was minimal evidence of the impact of the rising fronds. Where the commencement of fronds was observed, they also appeared to be contributing to the enlargement of inter-clast spaces. As fronds are

Figure 12. Test pit 8 at Upper Tillygarmond, unexcavated.

Figure 13. Test pit 8 at Upper Tillygarmond, part excavated.

Figure 14. Test pit 8 at Upper Tillygarmond, fully excavated.

seasonal, it is perhaps to be anticipated that they will also cause marked heave in the sediments of clast rich earthworks.

The absence of any complex matrix-supported stratigraphy within the features examined does not allow the effect of bracken rhizome on such deposits to be securely judged. However, the sheer volume of rhizome associated with bracken cover gives an indication of the intensity with which any rhizome system would infest such sediments. This intensity would strongly suggest that infestation would be highly destructive to the visible characteristics of such contexts and would accelerate the homogenisation of contexts within the biologically active zone of the soil.

4.3 Case Study: Environmentally Sensitive Areas

Environmentally Sensitive Areas (ESAs) are designated under Section 18 of the Agriculture Act 1986 and, in Scotland, administered by Scottish Executive Rural Affairs Department (formerly SOAEFD). There are currently ten ESAs, which cover 1,491,285 hectares, or 19% of Scotland's land mass, and incorporate approximately 4560 farmers and crofters.

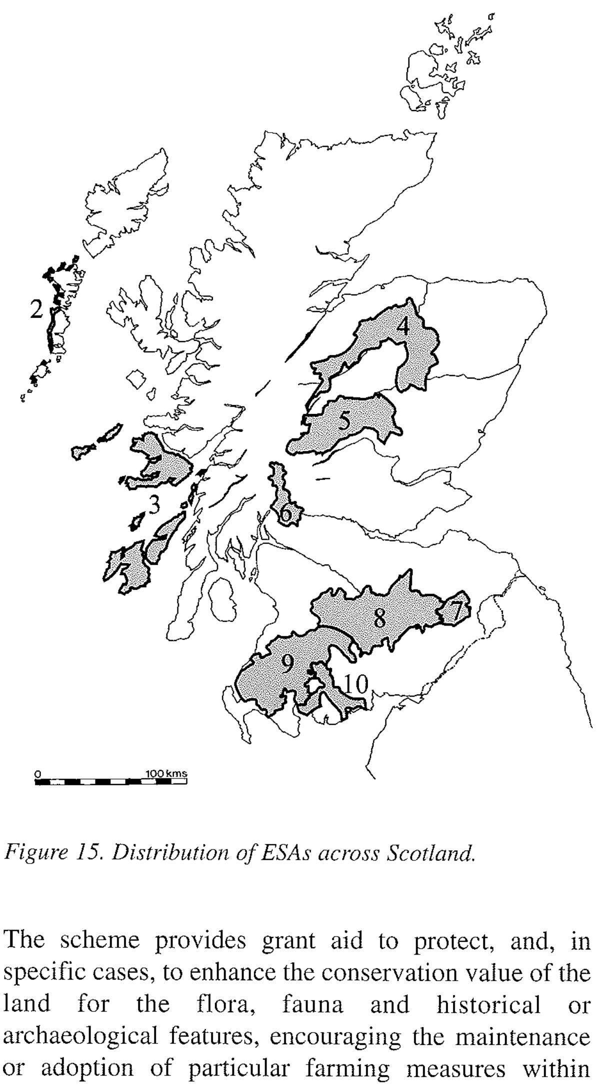

Figure 15. Distribution of ESAs across Scotland.

The scheme provides grant aid to protect, and, in specific cases, to enhance the conservation value of the land for the flora, fauna and historical or archaeological features, encouraging the maintenance or adoption of particular farming measures within prescribed areas. This is achieved through the preparation of whole-farm conservation plans, which integrate all activities on an individual farm. The conservation objectives are achieved by the implementation of a series of mandatory protection measures (Tier 1) and optional management measures (Tier 2). These measures have been selected because they are believed to have a predictable positive impact on the condition of the flora, fauna and historical or archaeological features.

4.3.1 Monitoring programme

The monitoring and evaluation of policy initiatives is a general requirement laid down on all government departments. SERAD have commissioned a consortium led by the Macaulay Land Use Research Institute (MLURI), Institute of Terrestrial Ecology (ITE) and Biomathematics and Statistics Scotland (BioSS), in collaboration with AOC Archaeology and ADAS, to monitor and evaluate the effects of ESA prescriptions from the ecological, landscape and archaeological points of view.

In order to monitor the degree to which the stated aim of the scheme (to protect sites and allow for their management) has been achieved the impact of the scheme is being analysed using two distinct monitoring schemes, Prescription Monitoring (the monitoring of ESA protection and management prescriptions on known features) and Background Monitoring (the monitoring of scheme and non-scheme impacts on the resource as a whole).

4.3.2 Background monitoring techniques

Background Monitoring of the archaeological resource has involved the survey, by AOC Archaeology, of a sample of eighty 1 km^2 areas, distributed equally between the ten ESAs. The 1 km2 areas have been chosen so as to be proportional to the extent of the six land strata, defined by ITE, within each ESA. This sample represents roughly 0.5 – 1 % of the total land area of the ten ESAs, and should contain a similar proportion of the total of all sites of archaeological interest (known and unknown).

The survey involved a general walkover survey of the square to identify undocumented sites and to verify the existence of sites identified from an initial desk study. Each site was then assessed for the various parameters relevant to the ESA protection and management prescriptions. The information gathered through the monitoring of sites (both known and unknown) from this structured sample of 1 km^2 blocks of land provides a snapshot of the condition of the archaeological resource within each ESA.

4.3.3 Bracken distribution in the archaeological resource

One of the key parameters recorded on archaeological sites is the presence and extent of bracken infestation. Bracken was recorded when it was visible on or within 20 m of the site, as defined by the survey teams. When bracken was identified the intensity of infestation was determined as a rough percentage of ground covered. This allowed the site to be categorised for infestation in three general bands: 0-10%; 10-50%; 50-100%. Once the primary monitoring data had been modified to be proportional to the land strata distribution within each ESA it was possible to extrapolate the level of infestation in the archaeological resource as a whole, and the severity of the infestation.

Clearly the levels of bracken infestation in the archaeological resource differ dramatically across Scotland with the preponderance of infestation being on the Inner Hebrides and the west coast mainland. In the Argyll Islands ESA 96.3 % of the archaeological resource has some level of bracken infestation either on site or within 20 m. Such a high percentage may, to some extent, be an exaggeration caused by the dangers of extrapolating from a sample. Regardless of this exaggeration the relative levels of bracken infestation, and its intensity, across the ESAs are likely to be generally valid and give a snapshot view of the condition of the archaeological resource.

The general distribution of bracken in Scotland shows a strong concentration of bracken infestation in the west and south-west of Scotland. Comparison between the distribution of bracken infestation in the archaeological resource of each ESA and the general distribution of bracken infestation in Scotland is problematic. The available mapping of bracken infestation in Scotland is based primarily on a study conducted in the late 1950s. This study established the total infestation at 182,000 ha, of which 25% occurred in the old county of Argyll (Hendry 1958). Subsequent studies have suggested a range between 162,000 ha and 470,000 ha. The main reasons for the variability in the quoted levels of infestation has been the lack of reliability in the available estimation methods and the difficulty of mapping bracken precisely.

While the general distribution of bracken infestation in both the archaeological and ecological data can be seen to be comparable there is a discrepancy between the actual level of infestation recognised by the two sets of data. Clearly the ESA archaeological monitoring programme is recognising a much higher density of bracken infestation on archaeological sites than is present in the landscape as a whole, even with the acceptance of the problems in mapping bracken infestation in these more general surveys. The factors causing this increase in density are uncertain although it is possible that the nature of archaeological sites are such that they both preferentially attract bracken infestation and at the same time inhibit mechanised access for bracken control.

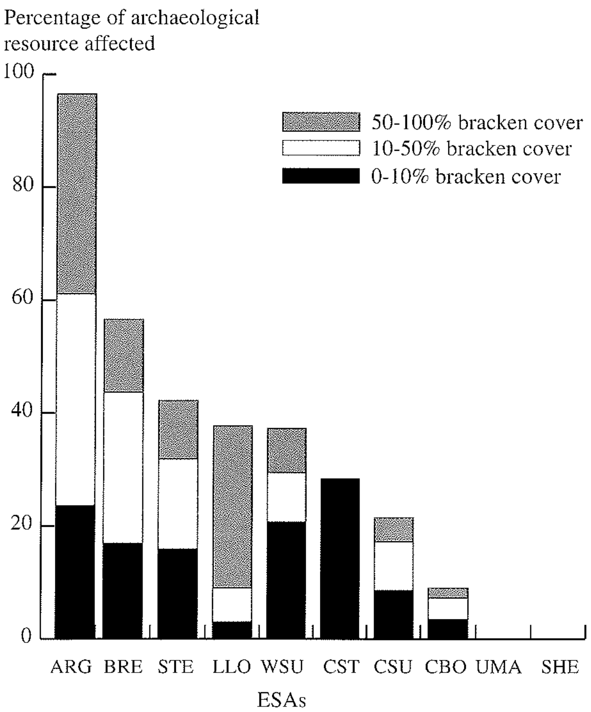

Figure 16. Levels of bracken infestation in the archaeological resource in the ESAs.

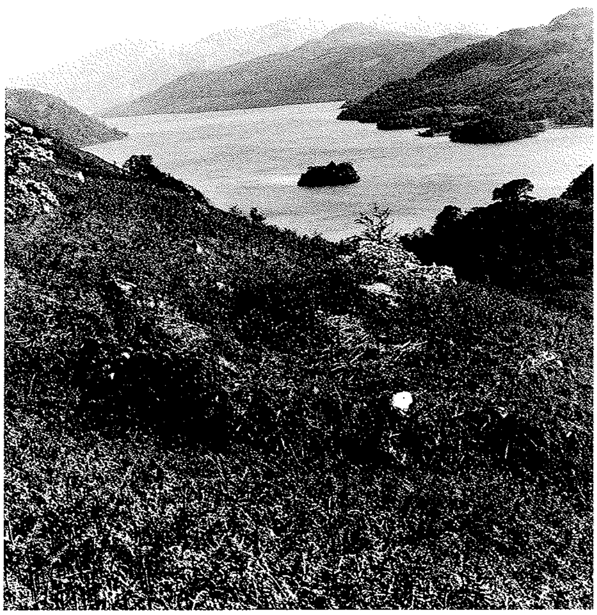

Figure 17. Bracken infested rectangular rubble and earthen enclosure in the Loch Lomond ESA.

4.3.4 Bracken infestation intensity and preferences

There appears to be a marked variability in the intensity of bracken cover within each ESA. Loch Lomond ESA and Western Southern Uplands ESA, for instance, have comparable overall levels of bracken infestation within their archaeological resource but they have fundamentally different patterns of infestation intensity. The infested sites in the Loch Lomond ESA are characterised as being severely affected with relatively few sites having minor infestation problems, while this situation is reversed in the data from the Western Southern Uplands ESA. The explanation for this is uncertain although the physical nature of the sites may play a significant part in these characteristics.

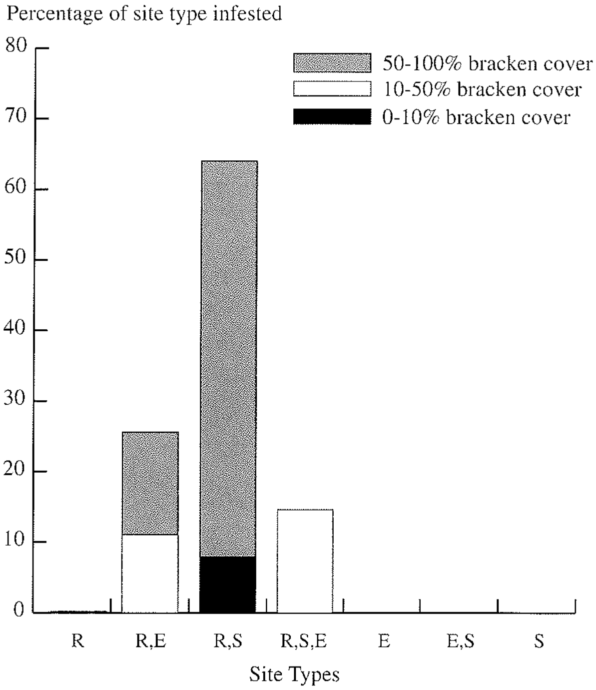

Figure 18. Levels of infestation by site type in the Loch Lomond ESA.

For the purposes of monitoring the archaeological sites were classified according to their constituent elements rather than interpretative categories. Four main constituent elements were used: rubble (R) - an upstanding feature which was supported by clasts (usually stones or boulders); earthwork (E) - an upstanding feature which was matrix supported; standing structure (S) - a feature or element of a feature which remained as it was built or erected; cropmark (C) - a negative, sub-surface feature which was known to exist. Consequently it is possible to determine the infestation pattern on each combination of constituent elements.

There appears to be no universal pattern to the intensity of infestation based on the constituent elements of the site. In Loch Lomond ESA there are sites which are solely comprised of earthworks or rubble but have not been infested. Infestation is most pronounced on those sites which consist of a combination of elements including rubble. In comparison the range of sites available for infestation in the Western Southern Uplands ESA is much broader and all site types which are present have been infested to some extent. The majority are infested at a low intensity, including those site types which were severely infested in Loch Lomond ESA.

Figure 19. Bracken infested structure in the Western Southern Uplands ESA

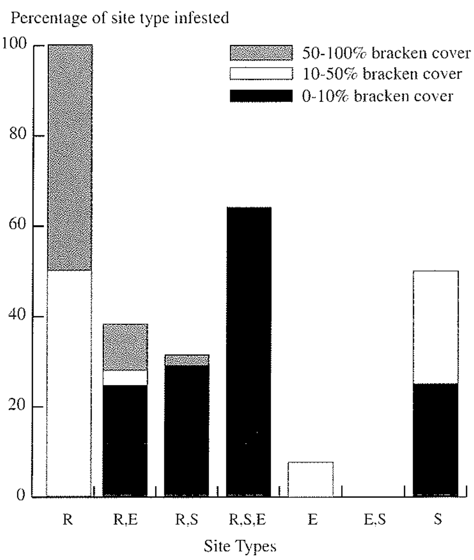

Figure 20. Levels of infestation by site type in the Western Southern Uplands ESA.

4.3.5 *Coincidental environmental factors*

The ESA archaeological monitoring programme has also recorded site condition data for a wide range of other environmental and management factors. These include variables such as erosion, tree cover, scrub cover, rabbit damage, and the presence of heather. Preliminary studies of these variables in comparison to the presence of bracken have not identified any positive links with bracken infestation except that bracken infestation is limited where other variables are dominant.

4.4 Discussion of adverse impact

The case studies above have begun an examination of the interaction between bracken and archaeological sediments. Examples of such studies are rare, perhaps reflecting the preference to undertaking studies on factors that have a higher visibility in their impact.

Discussed below are the main types of adverse impact that can be recognised. Clearly some of these impacts have been inferred and have not yet been confidently proven. Further work, including more consistent and systematic recording of bracken impact on sites being excavated for any reason, should in time address the paucity of evidence.

There is clear evidence that many types of archaeological site are located in areas that are preferentially exploited by bracken. Specifically, many surviving upstanding archaeological sites are located in areas which were once exploited agriculturally and hence have suitable soils for bracken growth. In addition, the prior exploitation may have improved soil conditions compared to surrounding areas leading to localised habitats more favourable to bracken growth.

The survival of upstanding features on archaeological sites tends to be a consequence of the sites lying in ground that, since the early nineteenth century, has been viewed as marginal. This has meant that the sites have been largely excluded from continuing management practices such as bracken suppression.

4.4.1 *Rubble and embanked features*

Given bracken's preference for freely draining soils, it is clear that rubble or embanked features can be the most severely infested. In these circumstances there is increasing evidence that bracken rhizome systems will enmesh the rubble or wall features with rhizomes. In visual terms the strongest and most immediate impact will normally be the percentage of the matrix that appears to be rhizome.

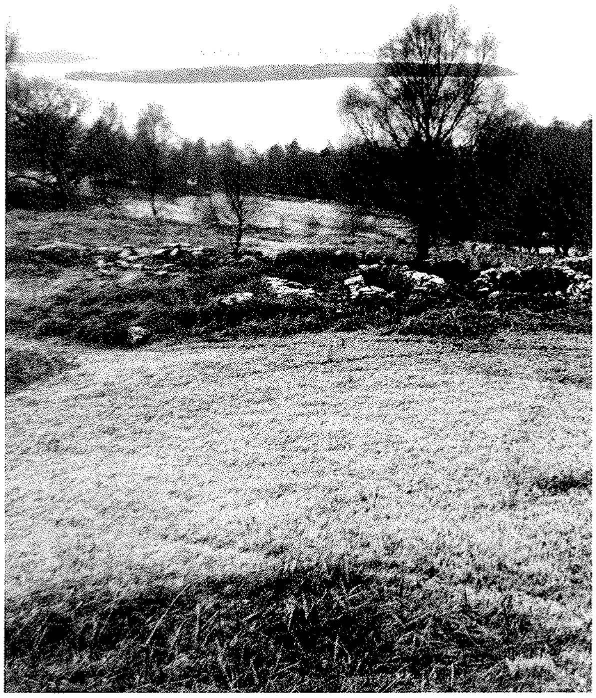

Figure 21. Bracken infestation concentrating on a deserted settlement, while avoiding or being excluded from neighbouring open ground.

Field indications are that the rhizomes, through their exploitation of the inter-clast spaces, appear to cause an increase in the size of these spaces. Should this consistently be the case then it is to be expected that, over a suitable period of time, the infestation could destabilise clast rich contexts. This may result in the degradation of features, fracturing of wall faces and slumping of rubble banks or ramparts.

The process of fronds rising through sediments may also contribute to the enlargement of inter-clast spaces. As fronds are seasonal, it is perhaps to be anticipated that they will also cause marked heave in the surface form of clast rich earthworks.

Consequently the most severe effects of bracken infestation are expected to be concentrated on rubble and embanked features. Over a prolonged period it is expected that the effect will be a degradation in the form of upstanding features and the destruction of wall faces and rubble features.

4.4.2 *Palaeo-environmental potential*

It has been shown that bracken rhizome systems may not necessarily prevent the visible identification of complex stratigraphy within matrix supported sediments. However, the commonly high intensity of infestations will undoubtedly compromise the taphomony of any palaeo-environmental samples, especially for smaller inclusions, and this may also introduce problems in terms of isolating reliable material for radiocarbon dating. In addition the role of bracken in heightening biological activity will probably lead to an acceleration in the degeneration of palaeo-environmental inclusions in archaeological sediments.

Consequently bracken infestations should be considered as having a probable severe adverse impact to the palaeo-environmental integrity and content of sediments.

4.4.3 Waterlogged sediments

The scientific data, and archaeological data, have all supported that bracken rhizomes will not exploit consistently, or frequently, waterlogged contexts. Consequently archaeological sediments that meet these criteria are unlikely to be at risk from adverse impact from bracken.

4.4.4 Inadvertent damage

Mature bracken stands that are continuous will mask archaeological sites with topographic features (banks, walls etc). This clearly heightens the risk of inadvertent damage to the site and hence should be considered an adverse impact.

Figure 22. Sites in densely infested landscapes, even where the bracken is discontinuous, can easily be damaged by accident. There is a field system and deserted settlement within the foreground of the picture.

5 THE MANAGEMENT OF BRACKEN INFESTED ARCHAEOLOGICAL SITES

The presence of any bracken on an archaeological site is damaging. However the impact of the damage should be evaluated against the extent of the site, its cultural significance and the scale of other detrimental impacts. These considerations are likely to require professional archaeological advice.

5.1 Assessing the condition of the site

The management of any archaeological site requires a condition assessment to determine both the physical extent and nature of the site and also the proportions affected by any potentially damaging factors. As shown by the case studies, bracken is a threat and therefore should be recorded. Any condition assessment should determine both the physical extent of the bracken and its density to provide a baseline survey against which the effectiveness of bracken control can be measured. Where bracken is present but control measures are not implemented the initial condition assessment will enable the manager to identify subsequent change in bracken cover.

Figure 23. Condition assessment of a site in progress.

Condition assessments should be carried out when the bracken is mature, between July and August, to allow an accurate record of cover. Any assessment should not only look at the condition of the site but also its surroundings to identify any bracken which could potentially encroach onto the site. Given that bracken can spread quickly, a precautionary zone of 50m around the site should be examined. Furthermore the condition of the site should be re-assessed at least every five years, and more frequently where bracken is a serious problem or where control procedures are being implemented.

5.2 When to manage bracken

Bracken on archaeological sites has been studied in too few instances to be able reliably to relate its surface manifestation with its sub-surface impact. While some general guidelines can be given these should be subject to further review as information becomes available. For example the intensity of the impact may be predetermined by the nature of the sedimentology and hydrology of the substrate.

The fundamental principle in bracken management should be the prevention of encroachment rather than the eradication of current infestations. Sites which currently have or have had dense bracken cover are already damaged and therefore should have a lower management priority than sites which are only partly infested or are in danger of encroachment. The only exception to this is where eradication is for the promotion of amenity value or on health and safety grounds rather than for the protection of the archaeological sediments.

The consequences of bracken control should be carefully considered before implementation. In particular, as outlined previously, the impact of the control measures on the natural heritage value of the site should influence the management decision. Also the consequences of removing bracken cover should be assessed, especially where the site to be managed incorporates steep slopes which once cleared could suffer erosion.

Figure 24. Large continuous stands of bracken can engulf sites, like this standing stone in Argyll.

5.2.1 Proxy measure hypothesis

It is important, in terms of assessing likely below-ground damage, to know whether the above ground manifestation of bracken cover is a good guide to the degree of rhizome infestation. Lowday & Marrs (1992a) established three measures of bracken performance: frond density; frond height; and frond biomass, and discovered a high degree of inter-correlation between them in lowland heaths in England. Using these measures of performance, Marrs *et al* (1993) showed that the majority of the variation in summer frond performance could be explained by rhizome biomass. It therefore seems reasonable to use the above ground manifestation of bracken in summer as a guide to the biomass of the rhizome. While precise measures of above-ground manifestation may be required for experimental research on bracken impact, it is likely that more subjective observation of frond density and height would be sufficient for most management purposes.

5.3 How to manage bracken infestation

Effective management of a bracken infestation requires the implementation of a long term management plan which uses a range of differing techniques. The management plan should be formalised as a written document supported by mapping which covers, at a minimum, a five year period of costed works which are to be implemented. The need for such a long-term programme reflects the fact that the techniques principally control and suppress bracken rather than bringing about its eradication. Consequently, intermittent or poorly planned management regimes will waste resources without resolving the problem.

	Reference	Rubble dominated sites or sites with upstanding structures	Sites principally comprising steep earthworks or site on steep slopes	Sites principally comprising gentle earthworks	Sites with no upstanding remains (inc. cropmarks and findspots)
Physical control techniques					
Cutting	6.1	Possible	Possible	Yes	Yes
Crushing	6.1	Possible	Possible	Yes	Yes
Pulling	6.2	Yes	Yes	Yes	Yes
Cultivation	6.3	No	No	No	Possible
Stock	6.4	Possible	Possible	Yes	Yes
Burning	6.5	Possible	Yes	Yes	Yes
Establish tree cover	6.6	No	No	No	Possible
Herbicide control techniques					
Hand spraying	6.8.1	Yes	Yes	Yes	Yes
Vehicle mounted spraying	6.8.2	No	No	Possible	Yes
Aerial spraying	6.8.2	Yes	Yes	Yes	Yes

Figure 25. Control techniques summary table.

	Reference	Possible negative impacts from control technique
Physical control techniques		
Cutting	6.1	Vehicular damage; impact on desirable flora and fauna
Crushing	6.1	Vehicular damage; impact on desirable flora and fauna; compaction damage
Pulling	6.2	Slight ground disturbance
Cultivation	6.3	Severe ground disturbance
Stock	6.4	Initiation of erosion; health implications for stock; physical damage to upstanding features
Burning	6.5	Overburn affecting archaeological sediments; damage to upstanding features
Establish tree cover	6.6	Moderate to severe ground disturbance depending on intensity
Herbicide control techniques		
Hand spraying	6.8.1	Impact on desirable flora and fauna
Vehicle mounted spraying	6.8.2	Impact on desirable flora and fauna; vehicular damage
Aerial spraying	6.8.2	Impact on desirable flora and fauna

Figure 26. Constraints summary table.

The management plan should include an impact assessment of the proposed control techniques on both the archaeological site and the natural environment. Cognisance of the condition assessment is essential and care should be taken to monitor the efficacy of the management plan through recording the spatial extent and density of the bracken both during and after the initiation of control techniques. Any works on a Scheduled Ancient Monument should be approved in advance by Scottish Ministers, through Historic Scotland.

The control technique summary table is a guide to which techniques are appropriate depending on the nature of the archaeology. See Section 6 for a full discussion of each technique.

The selection of the most appropriate techniques to use can only be made in reference to the specific nature of each individual archaeological site and the level of bracken infestation. The principal constraints and issues raised by the application of each technique are presented in the archaeological constraints summary table and discussed in more detail in Section 6.

5.4 Costs and grants

5.4.1 Costs

The cost of bracken control on archaeological sites is dependant on the structure of the individual management plan and the nature of the archaeological site.

Where sites are well-preserved and/or remote, mechanised control techniques are likely to be inappropriate and so costs of control will tend to be higher. Conversely, level sites may allow very rapid, and hence cheap, mechanised control. Many physical control methods can be structured into the more general management of land, for example alteration of stocking levels.

The cost of herbicide control techniques again is subject to the size of the area being treated and the application method. A guideline price in 1997 for aerial application of asulam across landscape areas was £120 per hectare. However the often limited extent of archaeological sites and the consequent use of non-aerial application methods could substantially increase this price.

5.4.2 Grants: Historic Scotland

Grants towards the better management of archaeological sites are available under the Ancient Monuments and Archaeological Areas Act 1979. Payments are also available towards long-term site management, but funds are limited and likely only to be available where need is urgent, other sources are not available and a well-founded management plan has been created.

5.4.3 Grants: Agricultural Grant Aid Schemes

Agricultural grant aid schemes can often be used to gain funding for bracken control programmes which can include the treatment of archaeological sites as an element of an agricultural landscape.

Both the Environmentally Sensitive Area scheme (ESA) and the Countryside Premium Scheme (CPS) offer grants for bracken control, but only as part of an integrated scheme of conservation options over the whole management unit. Between them these schemes cover the whole of Scotland and are administered by the Scottish Executive Rural Affairs Department (SERAD). These schemes will be merged into a single new scheme in 2000.

Crofting Counties Agricultural Grant Scheme (CAGS) provide specific funding up to 60% of approved costs for bracken control, administered by SERAD. The Crofting Township Development Scheme tops up differences in bracken grant rates.

Agricultural Business Improvement Scheme (ABIS) grants are available for heather regeneration, with bracken control as an integral element.

Grants are also available under Objective 1 funding to participants in the Highlands and Islands Agricultural Programme who can receive a 60% grant for bracken control.

The Forestry Commission may also give a discretionary grant of 50% of the cost of bracken control where it is needed to encourage woodland regeneration on land adjacent to, or within woodlands. This is unlikely to be compatible with archaeological bracken control since regeneration must not be encouraged on or within 20 m of an archaeological site.

6 CONTROL TECHNIQUES

The text below lays out the differing control techniques which could be used within an individual management plan. This text is largely based on Scottish Natural Heritage's Information and Advisory Note, No. 24 *Bracken Control.* However the advice presented here has been tempered by archaeological concerns and input from other sources and should therefore not be assumed to be concordant with Scottish Natural Heritage's view.

6.1 Physical control; cutting and crushing

The cutting and crushing of growing fronds causes the gradual starvation of the bracken rhizomes. These are low cost techniques which are not weather dependant and should be the first option for small areas of bracken or light infestations. Furthermore these techniques can easily avoid damage to non-target species.

Fronds should be cut or crushed twice a year. Cutting is best carried out on maturing fronds around the middle of June and again six weeks later for at least three successive years. Hand cutting is generally preferable to the use of machinery.

Crushing is best carried out during early frond growth while the stems are still brittle. Crushing with a roller is less effective than cutting, but is useful both as a follow-up treatment on sprayed areas and on difficult terrain.

The judgement of which mechanism to use must be determined in reference to the physical nature of the archaeological site. Both mechanical techniques can have a deleterious effect on upstanding archaeological sites, especially when they are within irregular terrain, whereas hand-cutting is probably the least damaging of all control techniques. Do not use the mechanical techniques where there is any significant risk of damage to the archaeology.

Elements of the natural environment, such as ground-nesting birds can also be affected by this control method. Where necessary this can be avoided by delaying treatment until after the nesting and fledging period.

Figure 27. Large deserted settlement sites can cover several fields. The impact of boundaries can create stark differences within one site.

Figure 28. The longhouses in the field with stock suppression still suffer from some infestation problems.

6.2 Physical control; pulling

Hand pulling of sparse bracken fronds can be an effective means of follow-up treatment or even a means of limiting the encroachment of a bracken infestation onto an archaeological site. Pulling should be undertaken at the same times as those suggested for cutting. Ground disturbance on archaeological sites must be minimised.

6.3 Physical control; cultivation

Cultivation is effective on areas accessible to machinery, although on sloping ground it could lead to erosion. This control method works by both exposing the bracken rhizomes to winter frost and physically damaging them. Ploughing from late June to early August is most effective. Two passes with deep tines intersecting at right angles have successfully controlled bracken without ploughing.

However, cultivation, including the use of tines, can have a severe and damaging impact on archaeological sites and should therefore only be used on or in proximity to archaeological sites when it can be shown that there is no significant archaeology within the depth of the plough or tine.

6.4 Physical control; stock

Stock will naturally suppress vegetation, including bracken. Correct stocking levels in autumn and winter can break up the litter layer allowing frost to damage the bracken rhizomes. Winter feeding is essential for this method to prevent stock from being poisoned by eating dead bracken or rhizomes. Direct trampling during the early periods of frond growth can also help to control a bracken infestation. Care should be taken however to remove the stock before they start eating the young bracken. In general, cattle and pigs have been shown to be more effective than sheep in suppressing bracken.

Maintaining effective and even stocking levels in large open areas, within which an archaeological site may be only a small element, is difficult. Consequently enclosing the archaeological site may prove the most effective way of ensuring the application of a required stocking level. Care should be taken in enclosing any archaeological site to ensure all of its elements are enclosed together and that a minimum safety cordon of 10 m is left around the limit of the archaeological site.

Any alteration in the existing stocking levels, particularly by the introduction of larger mammals and supplementary feeding, can result in an increase in erosion which may have a detrimental effect on archaeological and historical sites. The identification of a stocking level which suppresses bracken while avoiding erosion can provide a cost effective and practicable long term aftercare treatment to supplement other control methods.

It is important to stress that there is no such thing as a perfect stocking level. The most appropriate stocking level for any land will vary not only between farms but between different areas on the same farm and from one season to the next. The type, age and structure of vegetation, soil and drainage are all important factors.

Pigs, while particularly effective bracken destroyers, are generally unsuitable for archaeological sites as they will root out the carbohydrate rich rhizomes and eat them. This process will substantially destroy any other vegetation cover in the immediate vicinity and will lead to erosion. Consequently rooting pigs should never be used on archaeological sites unless it can be shown that there are no archaeological sediments within the depth which will be affected by the erosion.

6.5 Physical control; burning

Burning of the bracken litter layer will have no direct effect on the bracken rhizome. However the use of fire, by the release of nutrients from the burnt litter, will help to break the dormancy of rhizome buds. Consequently, if used as a pre-treatment to herbicide control it can increase the percentage of the rhizome system impacted upon by the herbicide and reduce regrowth. In addition if the burning is done in autumn this technique deprives the bracken colony of the litter layer and may therefore help frosts penetrate to the depth of the rhizome. However, burning may create problems for regrowth of other, less damaging plant cover.

Burning is unlikely to have a direct impact on archaeological sites unless the burning is allowed to either remove all vegetation cover, initiating erosion, or penetrate the ground to the depth of the archaeological sediments or where there are upstanding stone structures within the areas of bracken infestation. Any burning should be conducted in accordance with the recommendations laid down in *A Muirburn Code* published by Scottish Natural Heritage.

6.6 Physical control; establishing tree cover

The establishment of tree cover has been identified as a long-term control technique, because the tree cover will eventually reduce the bracken density by shading the ground. However the initial establishment of the trees may be difficult because of the bracken infestation.

This control technique is not advisable on any archaeological site as the establishment of tree cover simply substitutes an alternative management threat to the archaeology. However, where mature trees are already established and providing shade, it may be less damaging to leave at least some trees rather than clearing them if a site is therefore left exposed to bracken and scrub growth.

6.7 Herbicide control; choice of chemical

There are two main herbicides which can be used in the control of bracken infestations; Asulam and Glyphosate, both of which are translocated herbicides.

6.7.1 Asulam

Asulam is the only form of chemical control which has a label recommendation, (trademark Asulox manufactured by Rhône-Poulenc) and is the more specific and cheaper of the two available chemical treatments. Asulam is reasonably specific, principally killing bracken and ferns but some effects have been noted against non-target species including lesser spearwort, bird's-foot trefoil, greater bird's-foot trefoil, bog pondweed, marsh thistle, species of saxifrage, a range of grasses and some rush species. Consequently, care should be taken in the application of Asulam close to rare ferns, either by avoiding application methods which have inherent drift problems or by covering ferns with polythene both during spraying and the immediate hours afterwards.

Asulam has no effect in the year of application but will cause a 98% reduction in the number of fronds in the year following application. The remaining 2% will re-emerge and within five years will re-infest the land. Asulam will not move more than 1 m along a rhizome from the frond which was treated.

The recommended dosage rate of Asulox, an aqueous solution containing 40% Asulam, is 11 litres per hectare. To improve the rate and degree of Asulox uptake, Rhône-Poulenc recommend the use of an adjuvant. The recommendation varies depending on the application method, but in general Agral is recommended where water is the dilutant and Adder or Actipron for waterless or low volume applications.

6.7.2 Glyphosate

Glyphosate is a broad-spectrum herbicide (a common trademark is Roundup) affecting most forms of vegetation, and consequently this herbicide should not be used where it may affect non-target species. However, the nature of bracken growth makes the application of Glyphosate by weed wiper a useful and practical technique, even where there is other vegetation below the bracken. Care must be taken to avoid drift. Consequently Glyphosate is not approved for aerial application.

Glyphosate has the dual advantage of offering a broader window for application and causing browning symptoms in the bracken, which allows for the easier assessment of the even-ness of application. The latter allows targeting of aftercare and increases the efficacy of long-term control.

6.8 Herbicide control; application method

The environmental implications of herbicide application should be carefully assessed and mitigated against. A pre-treatment survey should always be undertaken to assess the consequences of herbicide treatment on the environment. Such a pre-treatment survey should include as a minimum; the impact on ferns and other flora, the danger of stock consuming treated bracken, impact of application on surrounding watercourses and groundwater, the exclusion of stock and people during treatment.

Timing of application is important for effective results. Asulam should be applied when the bracken fronds are fully expanded and bright green, but before any die-back of the tips. Usually this will be mid-July to mid August but this depends on altitude and season. Glyphosate has a slightly broader window of application.

The method of application should be determined on the basis of; the herbicide being used, the size of the infestation to be treated, the presence of sensitive flora and the nature of both the topography and the archaeology.

6.8.1 Hand spraying

Knapsack sprayers with hand lances or booms are useful for small areas and follow-up treatment. They are a labour intensive method of applying herbicide because of the weight of liquid carried, which should be limited to around 10 litres a load, and the effort in keeping the boom above the fronds. Only motorised knapsacks should be used as manual versions are excessively fatiguing. As a guideline, knapsack spraying should not take place within 10m of a watercourse or site of ecological importance. It is advisable to use a marker dye within the liquid so that treated fronds can be distinguished.

Ultra-low volume drift spraying is an excellent method of treating large open areas of continuous bracken, even in rough terrain. The use of this equipment safely is a skilled operation and requires great attention to detail. Drift spraying requires a steady wind, and the bracken has to be walked in swathes of 3 m width at a slow pace, the speed being determined by the feed nozzle used. There is a danger of drift causing under-application on the target area as well as effects on adjacent, non-target areas. As a guideline, ultra-low volume drift equipment should not be used within 100m of a watercourse or site of ecological importance.

Weed wipers can also be used, although these are only approved for use with Glyphosate. Gangs of weed wipers can be highly effective on uneven ground and where upstanding archaeology remains exist. Spot treatment with a rope-wick is another appropriate method of applying herbicide to discrete patches of bracken, or as a follow-up treatment.

6.8.2 Vehicle-mounted spraying

All types of herbicide can be applied by vehicle-mounted booms. The boom must be constantly high enough for even coverage of the fronds. Spray booms need to remain level during work. A long boom will exaggerate the rise and fall of the land, so this is an inappropriate method on uneven ground. Dense stands of bracken should be surveyed for obstacles and hazards before works commence.

The use of vehicles on archaeological sites should be carefully assessed against the fragility of the archaeological remains. Professional advice should be sought, as appropriate. It may prove necessary to identify vehicle routeways across a site in advance of spraying to ensure that upstanding remains are not damaged. Also vehicles should not be used on elements of the site which have become saturated by ground water, and hence may be prone to wheelspin and rutting. Tracked vehicles are more likely to be able to cope with a wide range of ground conditions.

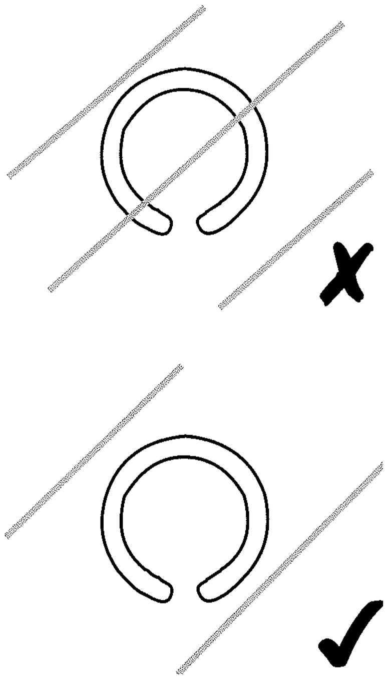

Figure 29. Vehicular application of suppression techniques should ensure that routes are identified that avoid damage to archaeological features.

Vehicular weed wiping can also be carried out. Weed wiping techniques tend to cost approximately half that of aerial spraying.

6.8.3 Aerial spraying

Only Asulam is approved for aerial application. The specific recommendation on dispensing Asulam is at the rate of 11 litres per hectare. Aerial spraying is best suited to the application of herbicide to large uniform areas of uninterrupted bracken covering even topography and should be carried out by helicopters to allow terrain hugging techniques to be used. Aerial spraying should not be used to treat an area greater than that which can have aftercare in subsequent years to ensure the prevention of re-growth.

Aerial spraying greatly increases the risk of spray drift which can cause damage to other vegetation and affect watercourses. Consequently appropriate buffer zones, normally 250m for ecological sites with sensitive species and 160m for watercourses, should be left. In addition low wind speeds are essential, certainly less than 10 knots. Ground markers should always be used to define the area to be sprayed both to minimise accidental spray drift and to assist the matching of passes, which will maximise the even-ness of application.

Aerial spraying is unlikely to be feasible for archaeological sites except where they are either extensive or being treated as an element of a larger bracken control programme.

6.9 Herbicide control; notifications

Landowners using herbicide for the control of bracken should notify the following bodies prior to the application:

- Water Authorities for public water supplies;
- Environmental Health Departments of local authorities for private water supplies;
- The Scottish Executive Rural Affairs Department when grant aid is being sought;
- Scottish Natural Heritage where land is adjacent to or within a SSSI or in an ESA;
- Scottish Environment Protection Agency.

There are also legal requirements to notify Scottish Natural Heritage if aerial spraying is carried out on or within 1500m of a SSSI and to notify the Scottish Environment Protection Agency if aerial spraying is carried out within 250m of any water.

6.9.1 Herbicide; storage and use

The use of herbicides is regulated by a range of legislation. During all operations involving pesticide use the regulations governing supply, storage and use of herbicides should be fully complied with. These include:

- The Food and Environment Protection Act (FEPA) 1985;
- The Control of Pesticides Regulations 1986;
- The Control of Substances Hazardous to Health (COSHH) 1988.

Since 1989 a *Certificate of Competence in the Use of Pesticides* is required for all users of agrochemicals, unless the operator was born before 1 January 1965 and uses the chemical only on their own land and does not supervise others in the use of pesticides.

6.10 Biological control

Biological control has yet to become an authorised treatment method for removing bracken infestations. Two possible avenues of biological control are being actively pursued by research work. The first technique, identified by Professor John Lawton, Director of the Centre for Population Biology at Imperial College, involves the use of the larvae of a South African moth, *Conservula cinisigna*, which feeds exclusively on bracken and, as an imported species, has no natural predators.

The second technique, identified by Dr Mike Burge, Department of Bioscience and Biotechnology at the University of Strathclyde, involves the use of fungal spores to induce 'curl tip' in bracken, a condition which kills the growing tips of the plant. The most probable application method would be through the use of a cocktail of fungal spores and chemicals applied by a spray.

Both biological control methods have the potential to manage bracken infestation in a cheaper and in some respects a more environmentally friendly manner. However, their disadvantage is that, once released into the environment, their effect is not selective and they may eliminate bracken in habitats where it is desirable, for example as understorey in semi-natural woodland, or where it is necessary for the survival of certain host-specific invertebrates. Neither method is currently commercially viable, though should they become so, they could be applicable control methods.

6.11 Aftercare

Without effective aftercare, bracken will stage a rapid come-back. Regenerating fronds or areas missed during initial action programme must continue to be suppressed by supplementary methods. Where herbicide is the main suppressant, suitable supplementary methods could include physical control through adjustment of stocking levels and the cutting or crushing of surviving or regenerating fronds.

Where the original bracken infestation was very dense and there was no understorey vegetation it may be appropriate to manipulate the revegetation of the surface. This can be done by a number of methods including raking or burning to break-up the bracken litter and so as to aid regeneration of grass cover, re-seeding with a fast growing and environmentally appropriate grass mixture, or surface cultivation, although the last will normally be inappropriate on archaeological sites.

6.12 Health and Safety

The presence of bracken in the environment represents a risk to personal health and safety as do all of the various control measures discussed above.

Any management plan for control of bracken infestations must include suitable risk assessments and ensure that appropriately trained personnel are used for individual tasks. No works should be carried out by persons unaware of the risks to themselves and others should they incorrectly carry out their tasks.

Bracken itself represents a personal Health & Safety risk to any person in its vicinity. Specifically, bracken tissues contain twenty-eight known groups of toxic, teratogenic and carcinogenic chemicals, so caution should be exercised when handling freshly cut or crushed bracken fronds. Bracken also provides a favourable habitat for sheep ticks *(Ixodes ricinus)* which can cause diseases such as Louping ill, tick-borne fever, pyaemia and Lyme Disease. In addition, bracken spores, which are most prevalent during the late summer, have been tentatively identified as potentially carcinogenic, so prolonged exposure should be avoided.

7 SUMMARY OF MANAGEMENT PROCESS

The management of an individual archaeological site should always be part of a considered approach to the archaeological resource of the whole land holding. The suppression of bracken may be one element in the range of management actions required to safeguard the archaeology resource on the land holding. The process summarised below is orientated to the consideration of bracken, but could equally be applied to all environmental factors that are impacting on archaeology.

Identify archaeological sites on the land

Gather as much information about the sites on the land. The best sources of information are the National Monuments Record of Scotland, the local Sites and Monuments Record and the 1st edition Ordnance Survey. With this information prepare a guide to the archaeology that includes:

- a base map of the land holding (1:10000) clearly marking the limit of control
- mark on the base map the limits of all Scheduled Ancient Monuments
- mark on the base map the known limits of all other sites of archaeological interest
- mark all limiting factors in the control of bracken (watercourses; SSSIs; ferns etc)
- prepare a concise, numbered gazetteer of the archaeological sites.

Undertake condition assessments

Using the base map as a guide to the archaeological resource, undertake condition assessments on the archaeological sites. The condition assessments should, as a minimum, include a sketch plan that shows:

- the principal archaeological elements of the site (banks, walls; ditches etc)
- the extent of adverse environmental factors (bracken, scrub, trees, built structures, supplementary feeding, ploughing etc).

The sketch plan should be supplemented by a written record that includes information on:

- the density and height of the bracken stand (s) and its extent
- the extent and severity of other environmental factors.

Where possible the condition assessment should be supplemented by colour print photographs that are representative of the site's condition.

Identify aspirations

Once the extent and condition of the archaeological resource is known, the land manager must identify their aims. In general it is suggested these should reflect the need to:

- safeguard significant archaeological sites
- maintain the character of archaeological sites
- enhance the visibility of archaeological sites

The identification of aspirations will allow the targeting of remedial work against the most damaging, adverse impacts.

Preparation of management plan

A management plan should be prepared for each site where bracken management is identified as necessary. Specialist advice should be sought where necessary. This plan should cover:

- the character of the infestation (encroaching, discontinuous stands etc) and hence identify feasible control techniques
- the character of the archaeology (rubble, earthen, on sloping ground etc) and hence identify the main constraints imposed
- the selected set of control techniques (including aftercare tactics)
- the notifications necessary before commencement of works
- the strategy and funding for applying the techniques over a minimum 5 year period
- the possible adverse consequences (eg erosion, tree or scrub regeneration) and how they would be mitigated
- the monitoring protocols to track effectiveness.

The management plan should then be implemented and the identified protocols followed.

APPENDIX A
FURTHER INFORMATION AND ADVICE

A.1 Advice for scheduled archaeological sites

For advice on the protection and management of scheduled archaeological sites contact the Inspectorate of Ancient Monuments in Historic Scotland:

Historic Scotland
Longmore House
Salisbury Place
Edinburgh EH9 1SH 0131 668 8777

A.2 Advice for unscheduled archaeological sites

For advice on the protection and management of unscheduled archaeological sites contact your council archaeologist. Council archaeologists are in post in all local authority areas bar City of Dundee, Midlothian, Perth & Kinross and West Lothian.

Information about archaeological and historical sites throughout Scotland are held in the National Monuments Record for Scotland:

Royal Commission on the Ancient and Historical Monuments of Scotland
16 Bernard Terrace
Edinburgh EH8 9NX 0131 662 1456
Council archaeology services also hold local Sites and Monuments Records.

A.3 Information on the impact of bracken

Bracken Advisory Committee
Prof. Roy Brown
Director of Research
Bishop Burton College of Agriculture
Beverley
East Yorkshire HU17 8QG 01964 553000

Rhône-Poulenc Agriculture
Fyfield Road
Ongar
Essex CM5 0HW 01277 301125

Forestry Commission
231 Corstorphine Road
Edinburgh EH12 7AT 0131 334 0303

Heather Trust
Arngibbon House
Arnprior
Kippen
Stirling FK8 3ES 01360 85420

Scottish Environment Protection Agency
Erskine Court
The Castle Business Park
Stirling FK9 4TR 01786 457700

Scottish Natural Heritage
Research and Advisory Services Directorate
2 Anderson Place
Edinburgh EH6 5NP 0131 447 4784

Scottish Executive Rural Affairs Department
Pentland House
47 Robbs Loan
Edinburgh EH14 1TW 0131 556 8400

A.4 Suggested reading

Historic Scotland *Managing Scotland's Archaeological Heritage*. Historic Scotland information leaflet. Available free from Historic Scotland.

Historic Scotland *Archaeological information and advice in Scotland*. Historic Scotland information leaflet. Available free from Historic Scotland.

Rhône-Poulenc 1997 *Bracken Management Handbook, Integrated Bracken Management, a guide to best practice*. Available free from Rhône-Poulenc.

Scottish Natural Heritage 1996 *Bracken Control*, Information and Advisory Note No. 24. Available free from Scottish Natural Heritage.

North York Moors National Park 1993 *Bracken Control, Follow-up Treatments and Aftercare*, Advice Note. Available free from the North York Moors National Park Authority.

Forest Research 1998 *Review of Bracken Control Methods in the New Forest*, Technical Note 22/98.

APPENDIX B
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