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Bracken control in the first year is as good as it gets!

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Summary

Bracken (*Pteridium aquilinum* (L.) Kuhn) can be problematic for various land-based sectors such as agriculture, forestry, recreation, shooting, as well as for catchment water quality. It can also have detrimental impacts on conservation sites, reducing biodiversity. The herbicide asulam has been shown to be an effective control method but herbicide use might be limited on some conservation sites. Various mechanical control methods are available, though some still require empirical evidence to assess their efficacy. A long-term field experiment was established in 2011 near Cirencester, Gloucestershire using a completely-randomised design, with 5 m × 5 m treatment plots replicated three times. The site had been routinely cut once yearly prior to the experiment to reduce bracken dominance. Three bracken management methods, deemed appropriate for small conservation sites with access issues, were considered: cutting once yearly; cutting twice yearly; and, hand pulling once yearly, each being compared to an untreated control. Frond heights and densities were used to assess plant performance and hence the efficacy of control treatments.

In comparison to the control plots that received no management intervention, all three of the mechanical control methods were found to significantly reduce frond heights and densities, each by about half. Cutting twice yearly was more effective in reducing frond height than cutting once, with hand pulling being the least effective. All three performed equally well in reducing frond density, but none demonstrated a significant longer-term (6 years) reduction in plant performance. Hand pulling required considerable time and effort delivering the least favourable outcomes, whilst cutting twice was only marginally better than cutting once. It was therefore recommended that a single annual bracken cut would give the best cost benefit for small conservation sites, enabling acceptable levels of control, but not complete eradication.

Key words: Bracken, control, cutting, pulling, herbicide, asulam

Introduction

Bracken (*Pteridium aquilinum* (L.) Kuhn) is found across most of the UK, limited only on the highest peaks (> *c.* 600 m) and within low-lying frost pockets, able to grow in a range of soil types and climatic conditions (Marrs & Watt, 2006). It has invasive characteristics, with the ability to dominate and supress other plant species (Stewart *et al.*, 2007) and as such can have detrimental effects on extensively grazed livestock systems, forestry, shooting, recreation and conservation (Pakeman *et al*., 2001, 2002; Paterson *et al*., 1997).

Those plant communities encroached upon by bracken are therefore usually considered to be floristically-poorer (Pakeman & Marrs, 1992). The spread and dominance of bracken as a weed species has likely been exacerbated by the effects of climate change in some regional areas

(Pakeman & Marrs, 1996) and significant reductions in the traditional uses of bracken, such as for animal bedding and thatch (Rymer, 1976). Recently, however, bracken has also been assessed for use as a compost (Pitman & Webber, 1998) and biofuel (Lawson *et al.*, 1986; Lawson 1987; Brackenburn, 2017).

Considerable effort has been invested into finding ways of controlling bracken. A meta-analysis of the literature (Stewart *et al.*, 2007) showed the herbicide asulam, as well as some cutting regimes, to be effective in controlling bracken. Varying the number of cuts and the timings of these in field experiments have demonstrated the efficacy of this control method (Lowday, 1987; Milligan *et al.*, 2016; Pakeman & Marrs, 1994; Pakeman *et al*., 2002). Other mechanical control methods, often referred to as bruising, breaking, crushing, crimping and rolling, are also available but are generally less well explored experimentally (Stewart *et al.*, 2007). Recent work by Millgan *et al.* (2016) showed bruising to be ineffective. Hand pulling is sometimes used and recommended by conservation organisations for controlling smaller patches of bracken (Anon., 2017; Cathersides & Parker, 2014; SWT, 2012; Vonk, 2010) but there is minimal empirical evidence to demonstrate the efficacy of this method.

This paper assesses the efficacy of small-scale, low input, mechanical bracken control methods, on a site with difficult access, over a relatively long-term period of 6 years. The effects and implications of the control methods on bracken growth characteristics over time is evaluated.

Materials and Methods

A bracken control experimental site was established in June 2011 near Cirencester, Gloucestershire (SO 948 084). The site is lightly grazed with Dexter cattle at stocking rates of between 0.05 to 0.08 LU ha^{-1}, for short periods in the autumn and late winter. In order to reduce bracken dominance, for 10 years prior to the establishment of the experiment and for each year since, the wider site has received a single annual bracken cut, done by hand using brushcutters.

The experiment was a completely randomized design with four treatments: (1) cut once yearly (early-June); (2) cut twice yearly (early-June and mid-August); (3) pulled once yearly (early-June); and (4) an untreated control. The treatments were replicated three times, with each of the twelve plots being 5 m × 5 m. The parameters used to assess bracken growth performance were frond heights (cm) measured from ground level for 20 systematically sampled plants within each plot and frond density (fronds m^{-2}) determined by counting all plants within the plots.

Repeated measures ANOVA was used to assess for any significant differences between treatment mean frond heights and densities, with Fisher's Protected LSD (5% level) showing where differences occurred (Genstat, 2017). Assumptions of normality and equal variance were confirmed using the default Genstat (2017) residual plots. Mean frond heights and densities, showing 95% confidence limits, were graphically presented (Fig 1 and 2).

Results

As would be expected there were no significant differences between June frond heights for all plots before treatments (P=0.226). These initial measurements were a culmination of a single annual bracken cut across all plots that had been carried out for the previous 10 years.

After the initial benchmark June frond height measurements were made, the Control plots showed significantly taller fronds compared to all other treatments after the first year (2012) and this continued through to 2017 (Fig. 1). June frond heights of the Controls for years 2012 to 2017 were within a range of 81.4 to 117.7 cm (Fig. 1) these being about a third taller than each of the three mechanical treatment frond heights (Fig. 2).

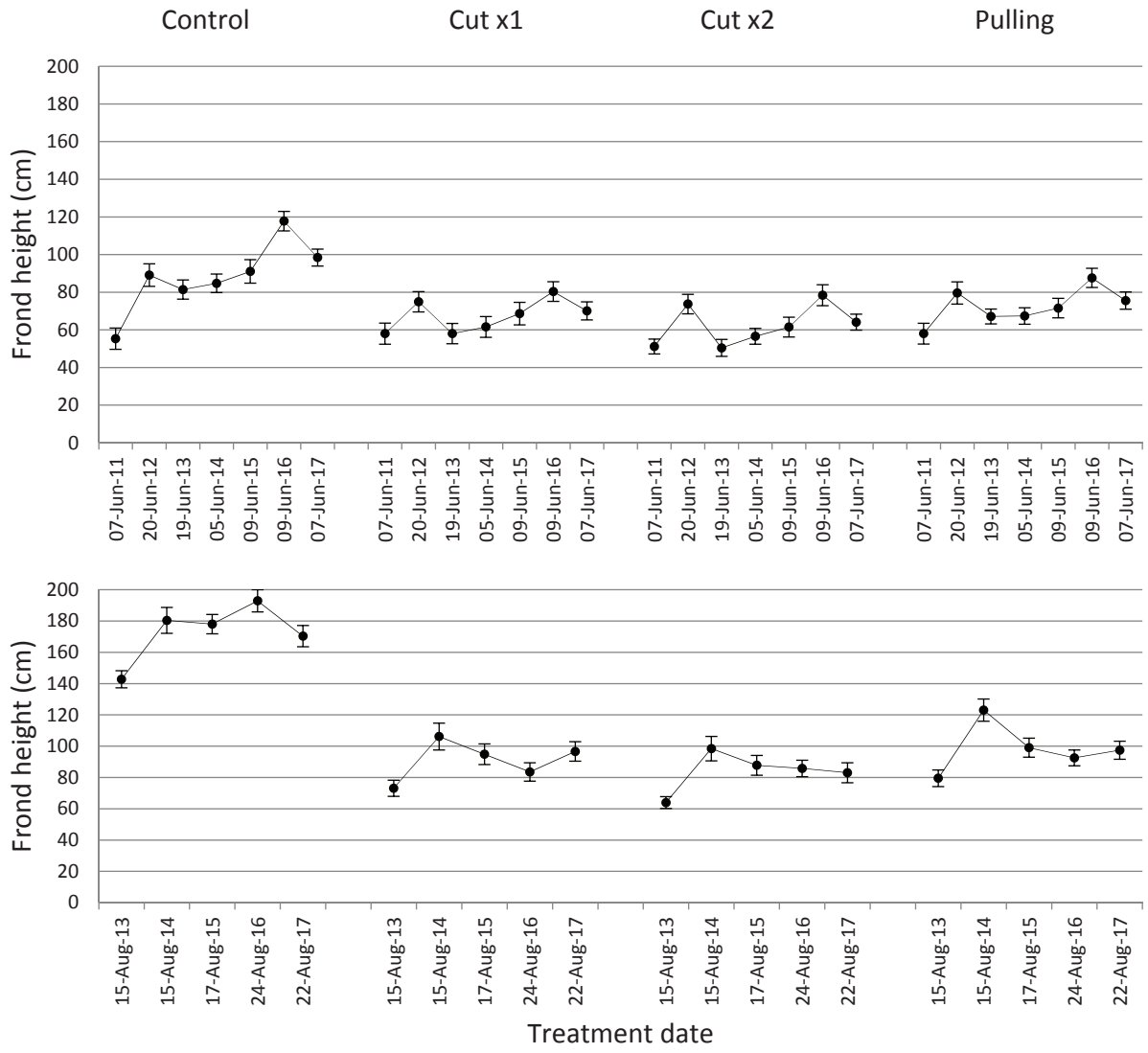

Fig. 1. Comparison of mean June and August plant heights for each bracken treatment over time, showing ± 95% CI. Fisher's Protected LSD (5% level) values were 7.161 and 9.109 for June and August data, respectively.

This was also shown to be the case when all frond height data was pooled across all years, with the overall mean Control June frond height (93.4 cm) being about 20 cm taller than the other treatments (Table 1). The June Pulling treatment had the second tallest frond height, followed by the Cut ×1 and Cut ×2 (74.6, 67.4 and 63.2 cm, respectively). All were significantly different from one another (Table 1).

Table 1. *Comparison of bracken mean frond heights (cm) and densities (fronds m^{-2}) measured in June and August, between 2013–17. Fisher's Protected LSD (5% level) was used to show where significant differences occurred, as indicated by different letters within columns*

Treatment method	June frond heights	August frond heights	June frond density	August frond density
Cut ×1	67.4 b	90.9 b	16.1 a	9.8 a
Cut ×2	63.2 a	83.8 a	14.6 a	8.1 a
Pulling	74.6 c	98.3 c	20.9 a	11.8 a
Control	93.4 d	172.9 d	22.7 a	23.0 b

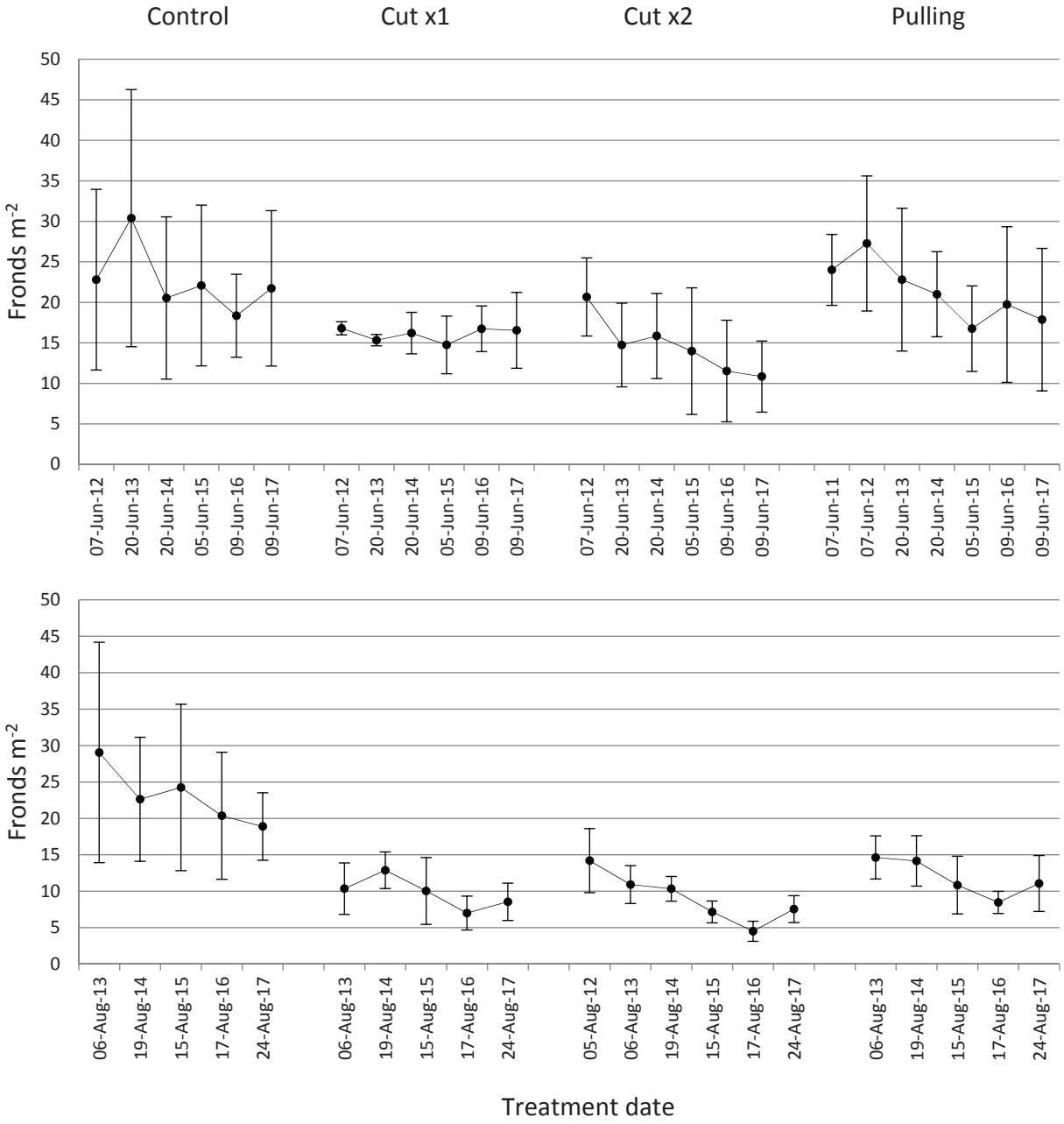

Fig. 2. Comparison of mean June and August frond densities (frond m^{-2}) for each bracken treatment over time, showing ± 95% CI. Fisher's Protected LSD (5% level) values were 12.852 and 9.812 for June and August data, respectively.

Frond heights within plots were again measured in mid-August for all years except for 2011 and 2012 (Fig. 1 and Table 1). These measurements represented the re-growth that had occurred since early June, after they had either been cut or pulled, approximately 5 weeks earlier. There were few significant differences in re-growth frond heights between these treatments, both within years and across years, but when each of the treatments were pooled to compare overall means, similar differences to those of the June frond height measurements occurred (Table 1). The mean Control frond height (172.9 cm, range 142.8–192.9 cm) was nearly double that of the other treatments with the Pulling being second tallest (98.3 cm) followed by the Cut ×1 and Cut ×2 (90.9 and 83.9 cm, respectively).

There were no significant differences in June frond densities between the Control and the three bracken management treatments. However, the Control frond densities were significantly greater than for all treatment re-growth plant densities in August (Table 1). The range of Control frond

density values at this time was between 18.9 to 29.1 fronds m^{-2}, approximately twice those of the re-growth August plant densities for each of the three treatments which had a range of 4.5 to 14.6 fronds m^{-2}. The wide variability of frond densities, as reflected in the 95% confidence intervals in Fig. 2, probably reflected the patchy growth characteristics of bracken.

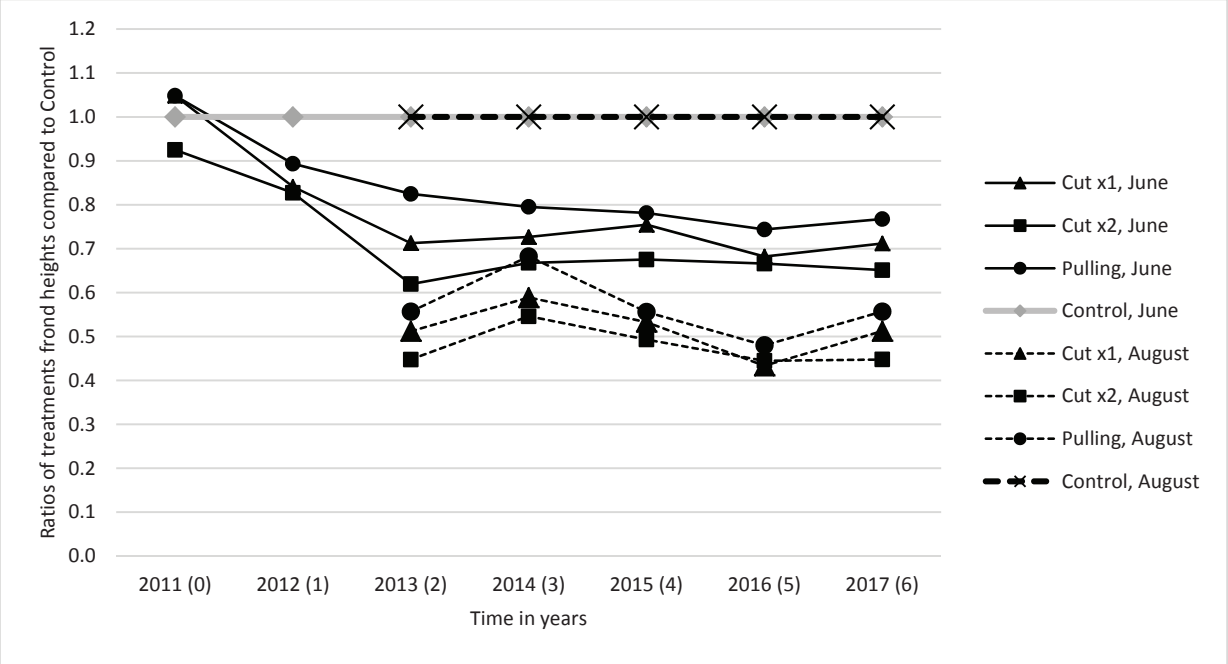

Fig. 3. Ratios of treatment frond heights compared to Control frond heights for each of the years 2011–17, where number in parentheses indicates the time in years from when the experiment was established in 2011. No August measurements were made for years 2011–12.

Discussion

Frond height was used as an indicator of plant vigour and hence, plant response to different mechanical management treatments. Whilst differences across mean treatment frond heights did not always occur within individual years, there were consistent significant differences for both June and August mean frond heights data when pooled across all years (Table1). Overall the mean frond heights for the Control were up to double those of each treatment, with the Pulling treatment having the tallest, followed by the Cut ×1, with Cut ×2 having the shortest overall mean frond height. This significant reduction in bracken appeared therefore to justify use of these control methods, but resource implications were also a consideration.

Pulling has received minimal attention as a method of bracken control with little available experimental work (Stewart *et al.*, 2007). The assumption might be that removing more of the frond stem, including that part directly connected to the rhizome, would result in greater depletion of plant resource. Anecdotal evidence amongst conservation organisations suggests this to be an effective method (e.g. Gloucester City Council Countryside Unit, 9 October 2012). However, the within season plant re-growth and the new growth in the following years of the pulled treatment were significantly taller than for both cut treatments (Table 1). Whilst it has been recognised that cutting bracken reduces frond vigour, the pool of frond buds remain and can lead to increased frond densities after cutting (Lowday, 1987). It might be speculated that the more vigorous re-growth in the Pulling treatment may have been due to a stimulating effect on buds and whilst the Pulling treatment plant density was not significantly different from other treatments, they did appear to be consistently more on observation for all the experimental period (Fig. 2). Pulling bracken is also time consuming and laborious and without any significant or longer-term benefits to bracken control compared to the cutting regimes, this method is not recommended here.

The high variability in frond density (Fig. 2) associated with patchy growth, is typical of bracken stands and is likely to be a combination of habitat variability, including soil depth and condition, competition with other plants and climate (Marrs & Watt, 2006) and localised bracken growth variability associated with a ventilating effect due to decaying petiole bases (Anderson, 1961). This variability probably accounted for the lack of significant differences in frond densities within management treatments over time and between treatments. It was, however, observed that each of the treatments showed a decreasing trend in frond density over time (Fig. 2).

Where management was removed, bracken growth in the Control plots achieved maximum sustained growth after 3 years with a plant height range of 170.4 to 192.9 cm (Fig. 1). This near doubling of frond height (Fig. 3), demonstrated the rapid recovery of a bracken stand which had, up until the start of the experiment, received a single annual cut for a period of 10 years. Hence, without repeated and sustained management, bracken stands were shown to quickly recover forming dense canopies.

Conclusion

It was clear that the mechanical management methods used in this work would never completely eradicate bracken. This was deemed acceptable as bracken does have benefits for some priority species such as the pearl-bordered fritillary butterfly (Barnett & Warren 1995). However, all treatments were shown to reduce bracken stand density by about half of what it would have been if no treatment had been applied, thus justifying such management intervention.

The most effective treatment in controlling bracken was that of cutting twice in a season, followed by cutting once, with pulling once being least effective. However, when other externalities, such as time and labour were considered, together with the marginal gains between cutting twice *vs* once, the recommendation would be that the single annual cut treatment be the one that is recommended. The levels of bracken control achieved soon after the onset of management appeared to be a good indicator of maximum longer-term control levels, enabling decisions at an early stage to be made about whether the level of control was acceptable or not.

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References

Anderson D J. 1961. The structure of some upland plant communities in Carnarvonshire. 1. The pattern shown by *Pteridium aquilinum. Journal of Ecology* **49**:369–376.

Anon. 2017. *Supporting guidance for bracken management. Rural Payments and Services, Scottish Government*. 9 January 2017. Available at: https://www.ruralpayments.org/publicsite/futures/topics/all-schemes/agri-environment-climate-scheme/management-options-and-capital-items/primary-treatment-of-bracken---manual/guidance-for-bracken-management#110264 (Last accessed 9 January 2018)

Barnett L K, Warren M S. 1995. *Species Action Plan: Pearl Bordered Fritillary* Boloria Euphrosyne. Wareham, Dorset, UK: Butterfly Conservation.

Brackenburn. 2017. *Brackenburn*. https://www.brackenburn.co.uk/ accessed:261117.

Cathersides A, Parker E. 2014. *Landscape Advice Note: Problem Weeds*. Swindon, UK: English Heritage.

Genstat. 2017. *Genstat 18th edition for Windows*. https://www.vsni.co.uk/
Lawson G J. 1987. Hill weed compensatory allowances: very alternative crops for the uplands. In *Agriculture and conservation in the hills and uplands. Grange-over-Sands, NERC/ITE,* pp. 99–106. Eds M Bell and R G H Bunce. *NERC/ITE Symposium* **23**.
Lawson G J, Callaghan T V, Scott R. 1986. Bracken as an energy resource. In *Bracken: ecology, land use and control technology*, pp. 239–248. Eds R T Smith and J A Taylor. Carnforth, UK: Parthenon Press.
Lowday J E. 1987. The effects of cutting and asulam on numbers of frond buds and biomass of fronds and rhizomes of bracken *Pteridium aquilinum*. *Annals of Applied Biology* **110**:175–184.
Marrs R H. 2016. The effectiveness of old and new strategies for the long-term control of *Pteridium aquilinum*, an 8-year test. *Weed Research* **56**:247–257.
Marrs R H, Watt A S. 2006. Biological flora of the British Isles: *Pteridium aquilinum* L. Kuhn. *Journal of Ecology* **94**:1272–1321.
Milligan G, Cox E S, Alday J G, Santana V M, McAllister H A, Pakeman R J, Le Duc M G, Pakeman R J, Le Duc M G, Marrs R H. 2001. *Integrating bracken control and vegetation restoration, Moorland Research Review 1995–2000*. Helmsley, UK: North York Moors National Park Authority.
Pakeman R J, Marrs R H. 1992. The conservation value of bracken *Pteridium aquilinum* L. Khun- dominated communities in the UK, and assessment of the ecological impact of bracken expansion or its removal. *Biological Conservation* **62**:2101–2114.
Pakeman R J, Marrs R H. 1996. Modelling the effects of climate change on the growth of bracken *Pteridium aquilinum* in Britain. *Journal of Applied Ecology* **33**:561–575.
Pakeman R J, Thwaites R H, Le Duc M G, Marrs R H. 2002. The effects of cutting and herbicide treatment on *Pteridium aquilinum* encroachment. *Applied Vegetation Science* **5**:203–212.
Pakeman R J, Le Duc M G, Marrs R H. 2002. A review of current bracken control and associated vegetation strategies in Great Britain. *Web Ecology* **3**:6–11
Pakeman R J, Marrs R H. 1994. The effects of control on the biomass, carbohydrate content and bud reserves of bracken *Pteridium aquilinum* L. Kuhn, and an evaluation of a bracken growth model. *Annals of Applied Biology* **124**:479–493.
Paterson S, Pakeman R J, Marrs R H. 1997. Evaluation of a bracken *Pteridium aquilinum* L. Kuhn growth model and the effects of control strategies across a range of climatic zones in Great Britain. *Annals of Applied Biology* **130**:305–318.
Rymer L. 1976. The history and ethnobotany of bracken. *Botanical Journal of the Linnean Society* **73**:151–176.
Stewart G B, Pullin A S, Tyler C. 2007. The Effectiveness of Asulam for Bracken *Pteridium aquilinum* Control in the United Kingdom: A Meta-Analysis. *Environmental Management* **40**:747–760. https://doi.org/10.1007/s00267-006-0128-7
SWT. 2012. *Staffordshire Wildlife Trust Reserve Management Plan, 2012 to 2022: Highgate Common*. Stafford, UK: The Wolseley Centre - Staffordshire Wildlife Trust.
Vonk R. 2010. News from Stour Wood and Environs. *RSPB Colchester Local Group Newsletter* **58**.