Question 12: What were the environmental and management circumstances under which bracken invaded acid grassland, heath and bog habitats? Is the expansion likely to continue and what are the implications for agriculture and conservation of heaths and bogs?

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DUE START DATE:

- June 2002

DUE FINISH DATE:

- October 2003

OVERALL PROGRESS

- Complete

DEFINITIONS

- The bracken Broad Habitat is defined as "..areas dominated by a continuous canopy cover of bracken *Pteridium aquilinum* at the height of the growing season. It does not include areas with scattered patches of bracken or areas of bracken which are less than 0.25ha which are included in the Broad Habitat type with which they are associated. It also does not include areas of bracken under forest or woodland canopy which are included in either the 'Broadleaved, mixed and yew woodland' or 'Coniferous woodland' Broad Habitat types." (Jackson 2000).
- 'Botanical characteristics' includes several plot level and parcel level attributes. We include condition measures as analysed in the CS2000 Module 1 report (Haines-Young et al 2000) and species cover codes used for describing mapped parcels of Broad Habitat. In addition plot level botanical data recorded in 1990 and 1998 can be assigned to community units of the National Vegetation Classification and hence, to the three Priority Habitats included in the Broad Habitat. Note that plot level data will only apply to a subset of the total parcels mapped while information on change in species mapping codes will often be unavailable for parcels mapped in an unenclosed, upland setting.
- 'Extent' refers to the area of surveyed land in each square attributable to a Broad Habitat.

POLICY CONTEXT STATEMENT

1 *The Policy Context Statement was drafted in May, and takes account of comments made by attendees at the May FOCUS Workshop.*

DEFRA Public Service Agreement (PSA)[1]

2 The PSA set out the aims and objectives of individual government departments. With the formation of DEFRA in 2001 a new set of PSA statements and targets were drawn up by the ministerial team. The PSA targets are coined as specific actions some of which form relevant policy background to this question. These are:

- PSA Target 6: Bring into favourable condition by 2010 95% of all nationally important wildlife sites compared to 60% of sites currently estimated to be in such condition.
- PSA Target 14: Open up public access to mountain, moor, heath and down and registered common land by the end of 2005.
- Remaining CSR 1998 target: Contribute to a more attractive and accessible countryside by increasing the area protected and enhanced under the major agri-environment schemes.

The policy context for changes in area of the Bracken Broad Habitat[2]

3 Historical and recent changes in the extent of Bracken in GB have occurred against a shifting climate of opinion regarding the positive and negative values of the BH. During the 1980s the perceived rapid rate of expansion was seen to require aggressive action (Taylor, 1995). At one point even biological control via the irreversible introduction of alien moth species was seriously considered (Lawton 1990). At that time the negative impacts of Bracken expansion included health concerns for both humans and grazing animals, loss of high conservation value semi-natural habitats including dwarf shrub heath and acid grassland, and reduction in the economic value of moorland and grasslands. The apparent difficulty in restoring semi-natural habitat with increasing time after invasion also highlighted the need for expansion to be checked (Marrs et al 1998).

4 Through the nineties, the overwhelmingly negative view of Bracken was balanced by identification of a limited but specific range of positive wildlife values. Pakeman & Marrs (1992) reviewed the conservation value of Bracken-dominated communities in the UK. They marshalled evidence for the role of Bracken stands on more circum-neutral soils as a replacement woodland canopy beneath which a diverse vernal flora was often preserved including abundant *Viola* spp., which are food plants for several scarce butterfly species. Bracken stands can also provide valuable breeding bird habitat being locally favoured over other vegetation types by for example, whinchat and willow warbler (Pakeman & Marrs 1992). On balance however, fewer upland bird species preferred Bracken habitat than upland grasslands and dwarf shrub heath hence replacement of these habitats by Bracken would lead to a net loss of bird diversity including nationally scarce species such as hen harrier, merlin, greenshank and twite (Pakeman & Marrs 1992). Bracken encroachment into heathland, especially in lowland Britain, was also likely to reduce habitat quality for reptiles. Weighing up the positive and negative values of Bracken, Pakeman & Marrs (1992) concluded that "On balance, allowing the continued spread of Bracken will damage more communities and affect more species than control aimed at halting the spread of Bracken or removing it from the landscape."

5 At the present time, conservation and land-management policies to some extent reflect these earlier concerns but the gravity of the Bracken problem, as perceived in the eighties, has not led to the concerted assault on its spread that might have been expected. This is partly

[1] See www.defra.gov.uk/corporate/busplan/01psa.htm

[2] Defined as "areas dominated by a continuous canopy cover of bracken Pteridium aquilinum at the height of the growing season." Does not include bracken in patches <0.25ha or bracken under woodland canopies (Jackson 2000).

because Bracken actually declined in extent between 1984 and 1990 (Pakeman et al 1996), a change that was attributed, at least in part, to the success of control measures during the period. In addition, the census survey of national parks in England and Wales also showed a decrease in dense Bracken cover in the late-seventies to mid-eighties (Countryside Commission 1991). Concerns over the effect of Bracken on human and animal health remain but while evidence for impacts on livestock is clear, proving links to human disease suffers from ongoing methodological problems (Wilson, Donaldson & Sepai, 1998; Taylor 1995).

6 Notwithstanding the recent declines in Bracken extent, current policy reflects the fact that net changes can conceal marked turnover so that Bracken encroachment still poses a serious threat to scarce priority habitats such as lowland and upland heath (Pakeman et al 1996). Since the agri-environment schemes provide one of the main mechanisms for delivering BAP objectives for heathland habitats, it is therefore not surprising that Bracken control measures feature prominently in these schemes. For example, Bracken spraying is funded in eleven of the twenty two English ESA schemes and in the heathland and coastal habitat tiers of the Countryside Stewardship Scheme[3].

7 Although the Bracken Broad Habitat has no published statement or action plan it is valued in those specific situations where the canopy is associated with abundant *Viola* spp. and where Bracken stands coincide with the recent distributions of four nationally rare butterfly species Heath Fritillary (*Melicta athalia*), Pearl-Bordered (*Boloria euphrosyne*), Small Pearl-Bordered (*Boloria selene*) and High Brown (*Argynnis adippe*) (Warren & Oates 1995). Hence, sympathetic management of Bracken mosaics is highlighted in the SAPs for all these species except Heath Fritillary, which depends on Common Cow Wheat (*Melampyrum pratense*) in association with Bracken in a very restricted range of sites on Exmoor (Warren & Oates 1995; UK Steering Group 1995). The particular importance of Bracken for the High Brown has been highlighted in its Species Action Plan. This reported that 80% of extant breeding colonies were associated with Bracken-dominated habitats (Barnett & Warren 1995).

[3] See the England Rural Development Programme links at www.defra.gov.uk.

Summary of published results from CS2000

8 The CS2000 report showed that no statistically significant change in Bracken area had occurred in any Environmental Zone or country combination. However, considerable turnover did occur with gains to the Bracken Broad Habitat from Dwarf Shrub Heath, Acid Grassland and Broadleaved woodland and, in other areas, losses from Bracken to the same three Broad Habitats (Haines-Young et al 2000).

9 Although not significant, the largest net gain in Bracken area was seen in Environmental Zone 3. However, the 95% confidence intervals (-13,000ha to +48,000ha) for the average increase of 18,000ha illustrate the considerable uncertainty that surrounds the estimate.

10 The largest increases in Bracken were estimated to have occurred in land classes that already had the highest abundance per km sqr across GB (Figs 12.1 and 12.2) with marked increases estimated for the land-classes that take in most of the Pennines, Lake District, Exmoor, Dartmoor and N.Yorkshire Moors. If true this would suggest a reversal of the manage reduction in extent seen particularly in English and Welsh national parks during the previous decade (Countryside Commission 1991).

11 Analyses of vegetation change for plots located in the Bracken Broad Habitat showed that stability largely prevailed. An increase in Ellenberg light score within bracken stands characterised by upland woodland plants implied more open conditions (CS2000 web-site data). The environmental and ecological details of this change will be explored as part of this FOCUS question.

Fig 12.1. Extent of the Bracken Broad Habitat by ITE Land-class in 1998.

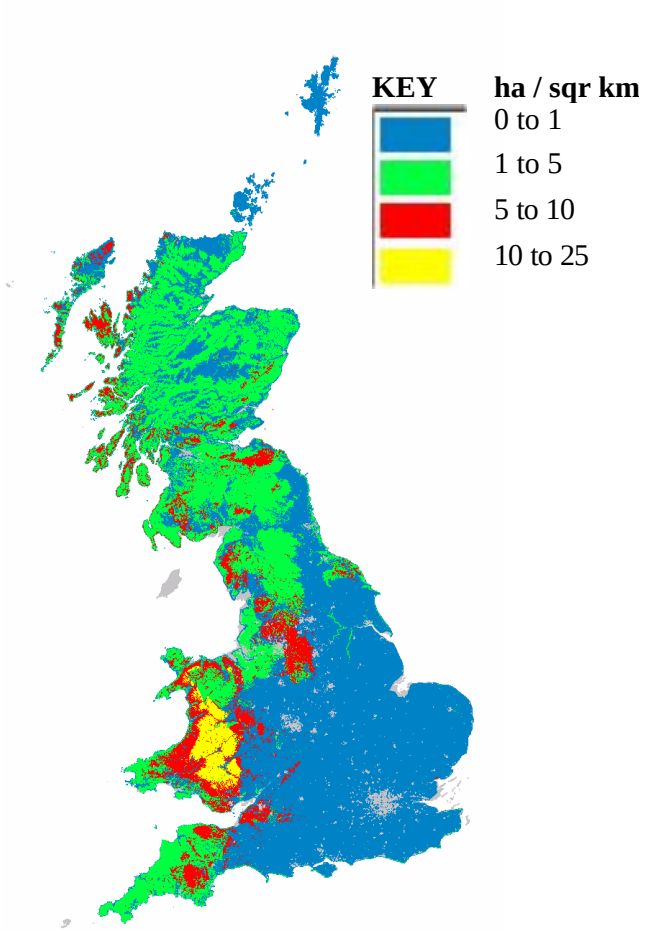
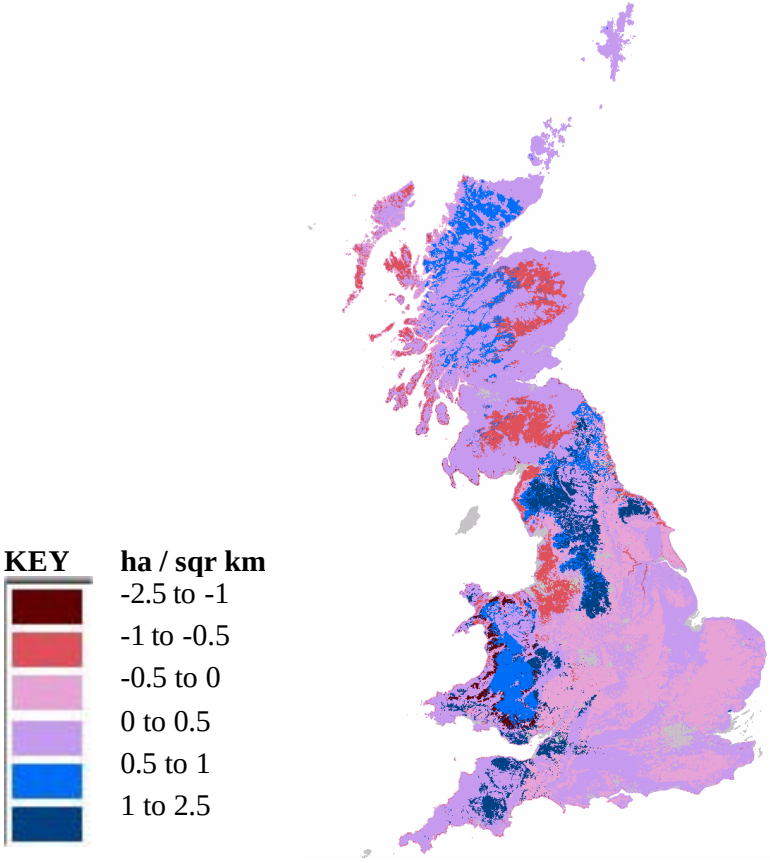


Fig 12.2. Estimated change in extent of the Bracken Broad Habitat between 1990 and 1998, by ITE Land-class.



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SCIENCE OUTPUTS

Approach to data analysis

12 The topic question focuses specifically on increases in Bracken Broad Habitat area. Because of the potential importance of Bracken expansion in reducing the area of other Broad and Priority Habitats, each and every parcel that was newly gained to Bracken was manually checked. Recorded evidence was used to make an assessment of whether the parcel allocation in 1998 was reliable, in error or where insufficient evidence was available to make a decision. To support the manual checking process and also to help assess the extent to which gained parcels actually changed in their Bracken coverage, vegetation plots from new Bracken parcels were analysed. Bracken cover change was compared across newly recruited parcels, stable parcels and parcels lost from Bracken to other Broad Habitats.

13 Identification of the environmental and management circumstances surrounding new bracken encroachment required an analysis of change at the square (total area) and plot (% cover) levels in terms of two predictors for which data was available and that could be hypothesised as constraining or promoting Bracken spread (Table 12.1). These reflect existing evidence that bracken consolidation is inhibited or slowed by grazing animals (Pakeman et al 1997) and that bracken encroachment is hypothesised to be more of a problem on lowland commons where grazing has often ceased (Farrell, 1993).

Table 12.1. Potential correlates of change in Bracken cover between 1990 and 1998. Analyses were carried out at the level of the 1km square where change in total Broad Habitat area was the response variable, and at the level of individual vegetation plots where change in % cover was the response variable.

Predictor	Expected relationship
Plot located on common land[4]	Increase on lowland commons more than upland commons
Sheep density	Less increase or stability with higher sheep density

14 The significance of bracken encroachment and persistence on linear features has rarely been addressed. Issues include the effect of bracken increase on the diversity of existing plant communities (eg. Smart et al, in press) and the extent to which linear features operate as corridors or safe havens for bracken in spite of control measures implemented on larger areas of unenclosed land. Tests of change in bracken cover at the plot level were carried out to quantify the relative importance of change in abundance on linear (roadverges, field boundaries, streamsides and hedges) as opposed to areal features (fields and unenclosed land plus remnant fragments of semi-natural habitat). Changes in cover were also analysed by a division of GB into 3 upland and 3 lowland zones and by country (England, Scotland and Wales).

15 NVC matching of vegetation plots in Bracken parcels was carried out to assess the representation of the two major Bracken communities W25 *Pteridium aquilinum – Rubus fruticosus* underscrub and U20 *Pteridium aquilinum – Galium saxatile* stands. The distinction is significant since W25 is the major locus for fritillary populations while U20, in which Violets are rare, is rarely used (Warren & Oates 1995).

[4] Identified from GIS coverage of GB provided by FRCA, Leeds.

16 In order to draw together the implications of this work an initial discussion was held with the two national experts on Bracken ecology; Dr Mike LeDuc and Professor Rob Marrs.

What were the environmental and management circumstances under which bracken invaded acid grassland, heath and bog habitats?

Part 1 - Manual review of the evidence for newly recruited Bracken parcels

Methods

17 In order to fully assess the robustness of increases in extent of bracken, each Field Assessment Booklet (FAB) was examined for each square in which change had been attributed. In each FAB the following evidence was examined:

- Broad Habitat change map
- BH map annotated by field surveyors
- The original 1990 field maps
- Changes in field recording codes including clear use of the change codes 702 (amendments to an incorrect BH map) and 701 (real change in BH extent)
- Presence of plot data and plot photographs coinciding with changed parcels
- Digitisers and surveyors notes

18 In addition to the review of field mapping information, condition measures from plots within parcels recruited to bracken or lost from bracken were compared with condition change in stable parcels of the donor Broad Habitat to determine whether, for example, Bog that ostensibly changed to bracken in 1998 was characterised by unusually low wetness scores in 1990 (Table 12.2) given that bracken cannot tolerate permanently waterlogged conditions. In addition, it was hypothesised that bracken was likley to increase where substrate fertility had increased between 1990 and '98 or where it started out at higher than average values for the vegetation type in 1990. Although bracken responses to N and P are not straightforward (Gordon et al 1999), there is some evidence that the invasibility of bracken is enhanced by elevated N, and even more by N and P, as a result of stimulated rhizome extension (Whitehead et al 1997).

19 Changes in the cover of bracken were also graphed for plots in new bracken parcels to test the expectation that bracken should have increased in abundance.

Table 12.2. Expected difference in Ellenberg scores between plots in parcels of unenclosed broad habitats that lost extent to bracken between 1990 and 1998 and parcels that remained stable.

Donor Broad Habitat	Ellenberg wetness	Ellenberg fertility
Bog to Bracken	**Lower**	**Higher**
Acid grassland to Bracken	N/a	**Higher**
Dwarf Shrub Heath to Bracken	N/a	**Higher**

Results

20 The majority of increases in mapped Bracken were supported following a review of the available mapping evidence (Fig 12.3). Uncertain parcel changes were more typical of upland zones where mapping straight onto pre-prepared Broad Habitat maps often meant an absence of additional coding to indicate either corrections to an incorrect map or 'real' change.

21 The largest increase in surveyed area of bracken was seen in zone 3 comprising the uplands of England & Wales. 49% of the gain was at the expense of Acid Grassland and 26% at the expense of Bog. On ecological grounds, the aversion of bracken to waterlogged conditions casts doubt on the gain to Bog. Little could be confidently inferred from analysis of pots in a subset of parcels lost to bracken from bog because sample size was so small (Fig 12.4). However, there was no indication that the Bog parcels lost to bracken were appreciably drier than stable bog in 1990 (Fig 12.4) while both groups showed a decline in wetness score between surveys.

22 When Ellenberg fertility scores were compared between stable parcels and those lost to bracken there was little difference between the groups apart from Dwarf Shrub Heath (Fig 12.5). The higher 1990 fertility scores associated with plots in DSH parcels that changed to bracken indicated species compositions typical of higher nutrient status than plots in stable DSH. This is consistent with a greater likelihood of invasion in more fertile heaths but the higher fertility score could also indicate that the parcels were already supporting sparse to dense bracken in 1990. Field mapping evidence did however suggest that the majority of increases at the expense of DSH were intended as real change.

Figure 12.3. Results of a manual checking of every parcel newly mapped as the Bracken Broad Habitat in 1998. Based on available evidence, each allocation was judged to be real (yes), in error (no) or uncertain based on a lack of evidence upon which to make a decision (n/y).

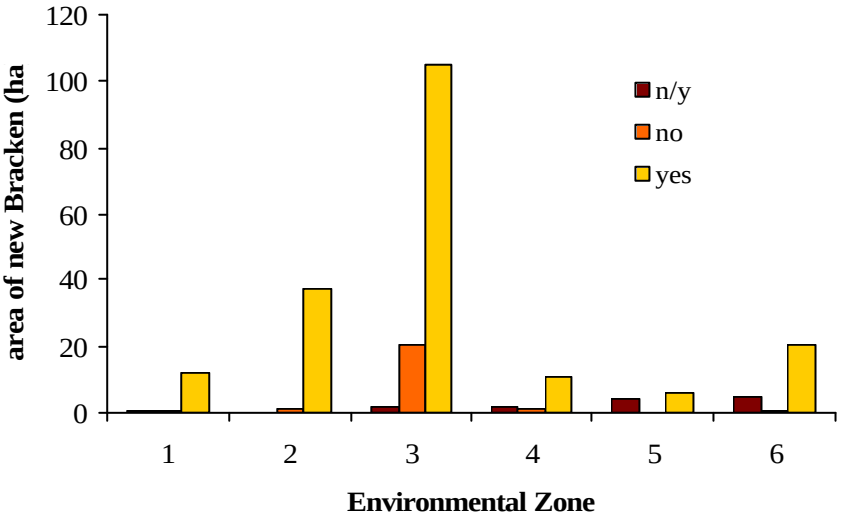


Figure 12.4. Comparison of change in mean Ellenberg wetness scores for plots in parcels that were mapped as Bog in 1990 and 1998(n=164) versus parcels that changed from Bog to Bracken (n=5). Targeted Y plots only.

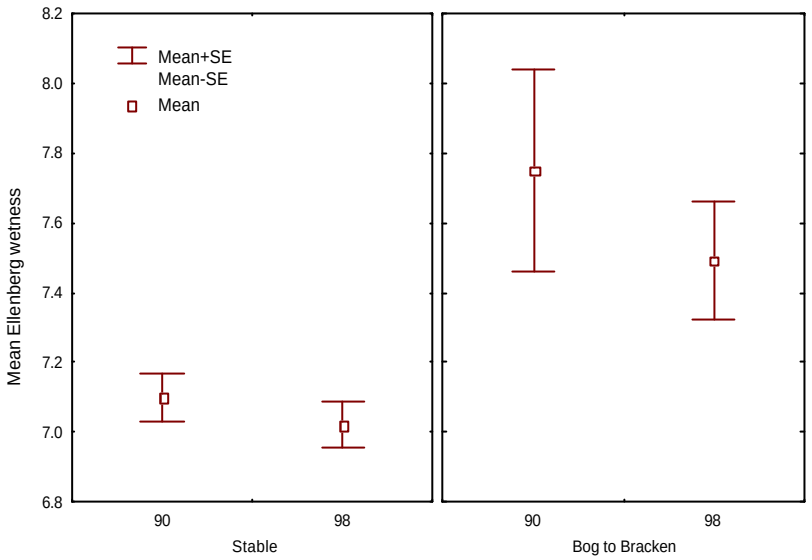
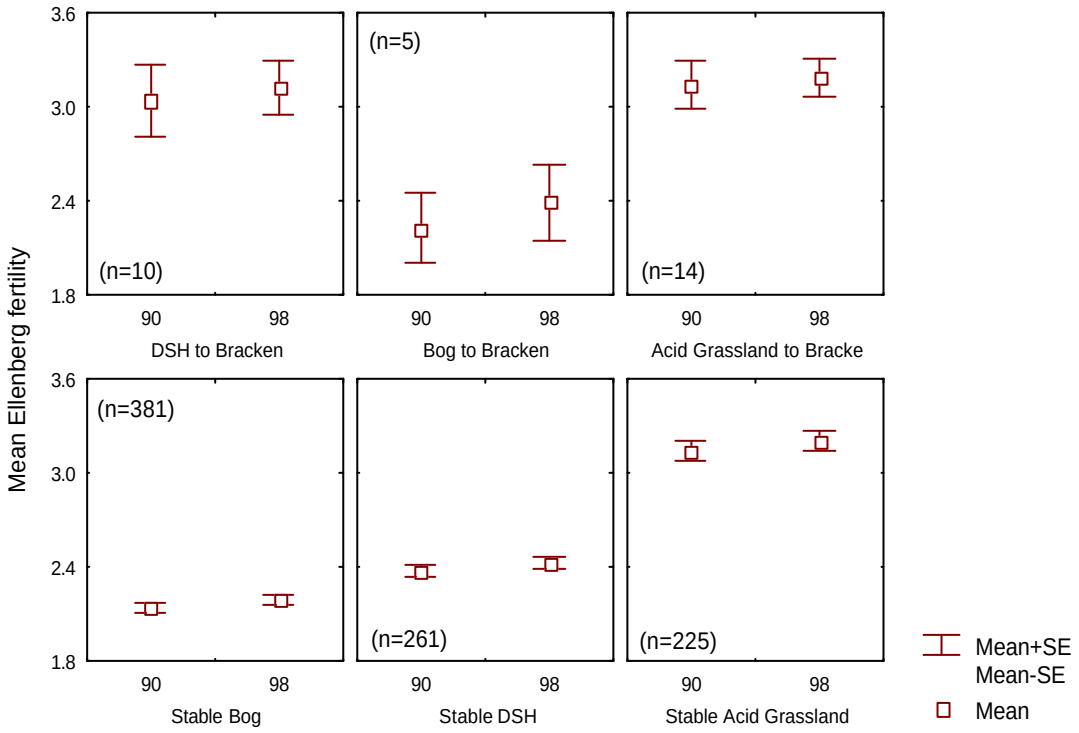


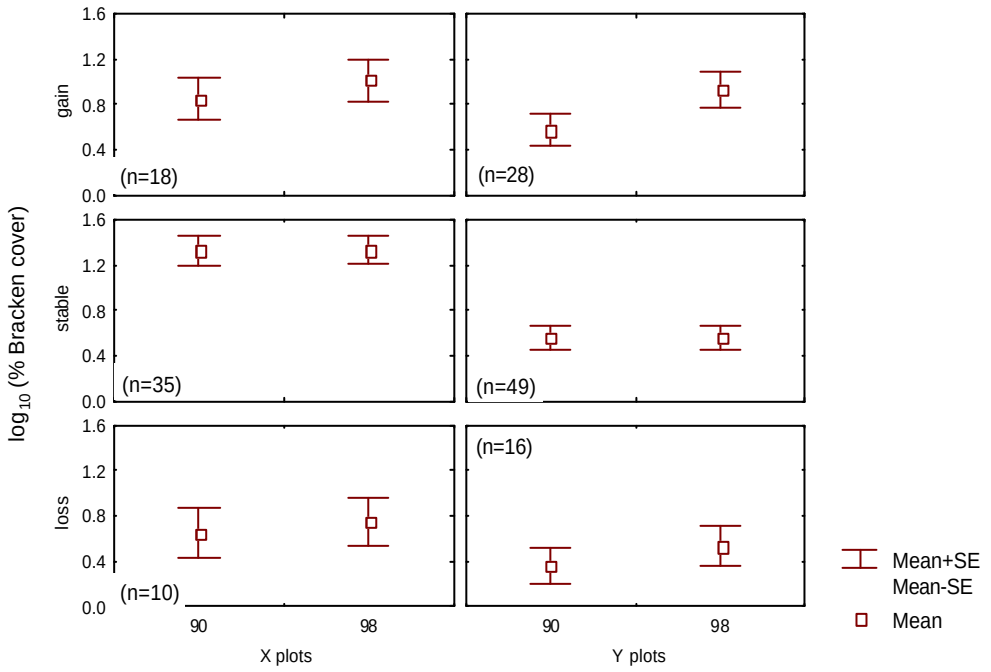
Figure 12.5. Comparison of mean Ellenberg fertility score between plots in stable unenclosed broad habitat parcels and plots in parcels lost to the bracken broad habitat by 1998.



23 Although only a subset of those parcels gained to bracken were associated with vegetation sampling plots, increases in bracken cover would still be expected in this random sample of new areas. Comparisons of change in bracken cover between stable bracken versus parcel gained and lost revealed subtle differences between the two types of areal plot (Fig 6). In X plots, parcels gained to other broad habitats from bracken began with relatively low bracken cover in 1990 compared to stable parcels and new bracken parcels. Hence actual reductions in bracken cover are likely to have been modest and from low starting points. In addition, examination of X plots in parcels newly recruited to bracken suggested that cover was already relatively high in 1990 although not as high as in stable bracken parcels (Fig 6). The implication is that losses from other broad habitats to bracken were more likely to affect areas already well invaded by 1990. In Y plots, bracken cover appeared to have increased in parcels both lost from and gained to bracken. Cover was also notably lower in stable Y plots than X plots. This may reflect the small size of Y plots (4m2) relative to X plots(200m2) and hence the lower probability of Y plots coinciding with bracken, particularly when sparsely distributed. It also probable that the targeting of Y plots on atypical vegetation makes it more likely that the broad habitat dominant would have been absent.

24 Overall, analyses of bracken cover change suggested that switches in broad habitat were unlikely to have involved large magnitude change in bracken dominance. This conclusion is also supported by the few relevant photographs of 1990 and 1998 plot pairs. In all cases these indicated that bracken was present in the parcel on both occasions although abundance varied greatly. Photographic evidence was however limited and was treated very cautiously because of differences in angle of shot and of seasonal effects on frond cover.

Figure 12.6. Changes in bracken cover between 1990 and 1998 in fixed vegation plots within parcels that were gained to bracken, lost from bracken and therefore gained to other broad habitats, or in parcels mapped as bracken in both years. Only areal plots are shown.



What were the environmental and management circumstances under which bracken invaded acid grassland, heath and bog habitats?

Part 2 -Correlation analyses of change in area (1km squares) and cover (vegetation plots)

Methods

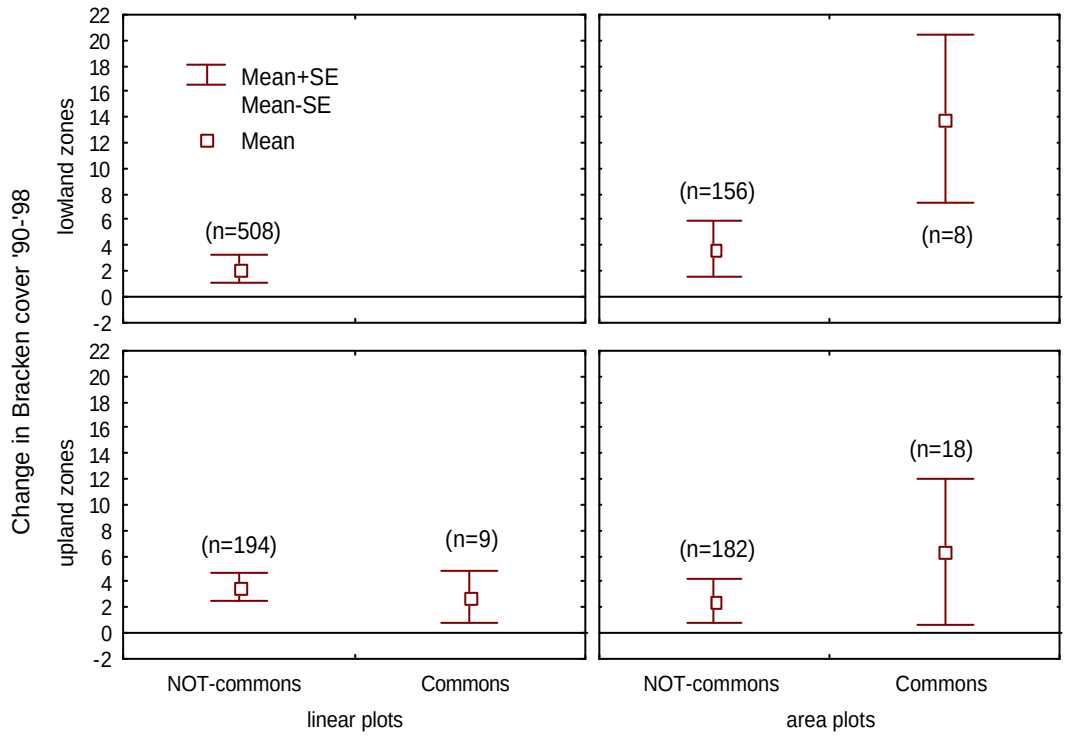
25 Mixed-model analyses of variance were used to test whether differences in modelled sheep density per 1km square in 1988 (Dragosits et al 1998) and location on upland and lowland common land, could explain significant change in either bracken extent across survey squares or cover change in vegetation plots. Plots were grouped as either areal (X and Y) or linear (RV, SW, H, B).

Results

26 Neither of the two potential predictors proved capable of explaining any of the temporal variation in area of Broad Habitat or in Bracken cover in plots.

27 Exploratory analyses did however, hint at a weak effect of common land crossed with the upland/lowland split although analyses of variance indicated lack of statistical significance at $p<0.05$, in part due to very low samples sizes from within lowland commons (Fig 12.7).

Figure 12.7. Change in mean Bracken cover within area (X,Y) plots versus linear (RV,B,H,SW) plots. Plots were classified by location; either in or outside upland or lowland commons. No linear plots were recorded on common land in the lowlands. Also sample sizes differ greatly with far more plots located outside common land. N?? Lowlands and uplands were defined by environmental zone.



28 Analyses of variance without predictors (intercepts only) were used to simply test if Bracken cover change had occurred between surveys. By plot type and country, significant increases occurred in England in Y plots (small fragments of semi-natural habitat) and in Scotland on streamside plots. Overall, field boundaries also showed a significant increase in cover (Table 12.2).

29 Increased dominance of bracken in small semi-natural habitat fragments is consistent with the reduction in species richness and inferred increase in shade seen particularly in species-rich grassland fragments between 1990 and 1998 (Haines-Young et al 2000).

30 It is notable that increased bracken cover was much more a feature of the linear network and small habitat fragments than larger areas of habitat in fields and unenclosed land in the uplands (Table 12.3).

Table 12.3. Results of mixed-model, analysis of variance of change in Bracken cover in fixed vegetation sampling plots in GB; 1990-'98. Joint absences were excluded.

Plot type	*Mean change (% cover)*	*SE*	*df*	*T value*	*P*	*Direction*
X	0.4	1.5	86.9	0.25	Ns	-
Y	7.8	2.4	151	3.26	0.0014	Up
SW	4.4	1.0	153	4.33	<0.0001	Up
RV	1.6	1.5	91.9	1.05	Ns	-
B	4.3	1.8	92.6	2.34	0.0215	Up
H	-2.4	2.2	67	-1.09	ns	-

Implications of bracken expansion for agriculture and conservation of heaths and bogs

Part 1 – Representation of the two bracken-dominated NVC communities

Methods

31 Plots that were located in the bracken Broad Habitat in either 1990 or 1998 were selected. Only area plots (X and Y) were selected, linear plots will be dealt with separately. Only data from the central 4m2 nest of each X plot was used so as to match dimensions between X and Y plots.

32 Botanical data were allocated to the units of the NVC (Rodwell 1992) using the MAVIS software. Although widely and justifiably recognised as a poor substitute for expert judgement (eg. Palmer 1991), we implemented an objective and hence repeatable rule for selecting a single best-fitting community unit. Each plot was assigned to the community unit that appeared most often in the list of top ten coefficients. If tied, then the top coefficient was chosen.

Results

33 The two major bracken communities were uncommon in CS plots within plots mapped as bracken Broad Habitat (Fig 12.8). In fact W25 was only represented in the 1990 data. Also considerable floristic change seems to have taken place. The two fertile mesotrophic grassland communities MG1 and MG7 gained plots as did the group of swamp communities while acid grasslands, *Nardus* grassland (U5), *Molinia* (M25) and woodland communities all saw reductions.

34 The results should be treated cautiously because of known problems with the use of matching software to generate the best fit to the NVC. However it seems that parcels

allocated to the bracken Broad Habitat contain much more floristic variation within them than would be expected from homogenous stands of bracken.

Figure 12.8. NVC community groups represented in CS repeat plots located in parcels that were bracken Broad Habitat in either 1990 or 1998.

Implications of bracken expansion for agriculture and conservation of heaths and bogs

Part 2 –Summary of results and future prospects

35 While the majority of increases in bracken extent were judged to be real, increases in bracken abundance are likely to have been played out in parcels with bracken already present by 1990. This is consistent with the rarity of new colonisation from spores and the fact that the vast majority of increases in bracken occur as a result of rhizome penetration from nearby stands (Rob Marrs pers onta.). Although an attractive idea, testing for a relationship between bracken proximity and broad habitat change would be very unreliable because of the lack of complete data on bracken abundance below the size of a minimum mappable unit as well as on linear features, within CS sample squares.

36 In terms of the conservation status of Priority Habitats, the most significant change was the apparent increase in bracken at the expense of DSH in zone 2 (already highlighted in the Topic 4 report on DSH) and at the expense of Bog in zone 3. The loss from Bog must