uestion 10: What are the possible causes for change in extent and condition of dwarf shrub heath habitats? Are there geographical variations between Environmental Zones? Is there any evidence for positive effects of conservation measures?

Simon Smart

DUE START DATE:

- March 2002

DUE FINISH DATE:

- June 2002

OVERALL PROGRESS

- The question has been addressed in a draft final report presented here.

DEFINITIONS

- The Dwarf Shrub Heath Broad Habitat has been defined in Jackson (2000) – see policy context statement below.
- 'Extent' refers to estimated area of Broad Habitat.
- 'Condition' refers to the status of Broad Habitat parcels measured in terms of their botanical characteristics. This includes the series of condition measures used in the main report and previously in the EcoFact project. They include mean Ellenberg scores for fertility, light and wetness as well as mean species richness.
- This report focuses on assessing the robustness of mapped change and avoids generating an additional set of national estimates. We therefore concentrate on evidence for change on 'surveyed land'. This means mapped parcels that were assigned to Broad Habitats in CS survey squares.

POLICY CONTEXT STATEMENT

Historical and recent changes in area and condition of Dwarf Shrub Heath[1]

Changes in extent

1 Available evidence suggests that the total area of heathland in GB has declined over the last 200 years (Gilbert & Gibbons, 1996). For English counties, the reduction in extent of lowland heaths between the mid-18th century and mid-1980's was documented by Farrell (1989, 1993) and Evans et. al. (1994), while the Monitoring Landscape Change

[1] **CS2000 mapping definition (Jackson 2000; CS2000 Field Handbook):** ">25% cover of dwarf shrubs"

project estimated that 25,800ha of lowland heath and 91,200ha of upland heath was lost between 1947 and 1969 across England and Wales (Huntings Surveys and Consultants Limited, 1986). In Scotland, Tudor et. al.(1994) used aerial photographs to show that 274,100 ha of heathland had been lost between 1943 and 1979.

2 More recent assessments of change in extent from 1984 to 1998 are covered by the Countryside Surveys of GB. These provide additional information on turnover and hence the patterns of loss and gain to other habitats that have occurred as a result of changes in extent of Dwarf Shrub Heath. Further exploration of their cause and significance forms a major component of this FOCUS topic.

3 CS2000 estimated that Dwarf Shrub Heath made up 6.4% of the land cover of GB in 1998 (Haines-Young et.al. 2000). Proportional cover was highest in Scotland (12.5%) where it was the third most abundant category behind Improved Grassland (13%) and Bog (25%). Between 1990 and 1998 the total British extent of Dwarf Shrub Heath did not show a statistically significant change. However, a significant 8.3% decline in extent was estimated for Environmental Zone 5[2] in Scotland. This decline amounts to an estimated loss of 21,000ha (SE +/-14,000) out of a total of 220,000ha in the Environmental Zone. Net losses were also estimated for Environmental Zone 6 and Environmental Zone 2 while increases were estimated for Environmental Zones 1, 3 and 4. Although none of these net changes were statistically significant this may well reflect high turnover between Broad Habitats leading to low statistical power. Because high turnover implies major habitat change, lack of statistical significance may well conceal important differences in condition between transferred stock (see below).

4 Countryside Survey estimates of land-cover stock and change between 1984 and 1990 (Barr et al 1993) were not based on the Broad Habitat classification, however meaningful comparisons can be drawn between the 1984-'90 and 1990-'98 intervals by summarising across the CS1990 heathland categories. No net change was detected between 1984 and 1990 based on an equivalent loss of 5% of the 1984 heathland stock and a gain of 5% of the 1984 stock. This compares with a 13% loss and a 9% gain between 1990 and 1998 (Haines-Young et al 2000). The largest gain from the shrub heath land-cover type between 1984 and 1990 was to conifer and a smaller but still statistically significant gain to new conifer plantation was also seen in 1990 and 1998 in Scotland. Marked turnover between Acid Grassland and Dwarf Shrub Heath also occurred in Scotland resulting in a net gain to Acid Grassland (McGowan et al 2001). In Scotland, the effects of increased grazing pressure plus afforestation may therefore be implicated in net change in extent. Further analyses of matrices of Broad Habitat change are required to assess dynamics across England and Wales. At the GB level however, most of the losses from Dwarf Shrub Heath translated into gains to Bracken and Bog Broad Habitats.

5 Net change in GB-wide heathland extent between 1990-'98 should be evaluated in terms of the published Biodiversity Action Plan target for upland heathland. This requires that dwarf shrubs increase to at least 25% cover on 50,000 ha of habitat by 2010. Since 25% cover of dwarf shrub is the CS mapping definition of the Dwarf Shrub Heath Broad Habitat we can infer that the 1990-'98 change represents an estimated loss of 58,000ha across GB. Even taking into account the range of the upper and lower 95% confidence limits (124,000 - 6,900ha) it is clear that if the BAP target were achieved by 2010 it will only have served to make up part of the apparent 8 year reduction in extent. Evaluation of the net 1990-'98 change should also take account of the apparent gain to the Bog Broad Habitat from Dwarf Shrub Heath (Haines-Young et al 2000). This may in fact constitute a positive change in line with the BAP objectives for both Broad

[2] ..marginal land at sea level and intermediate altitudes, mostly in the west and including the Scottish islands

Habitats. The apparent overall stability but regional net change in extent of Dwarf Shrub Heath between 1990-'98 conceals patterns of loss and gain that are potentially highly significant in terms of BAP objectives. Work carried out under this topic will assess the significance of these estimated changes in extent (see below).

Change in condition

6 The starting point for the FOCUS follow-up work on vegetation condition is the existing analyses of changes in vegetation condition indicators between 1990 and 1998. These results allow an initial assessment of floristic change in the Dwarf Shrub BH in terms of movement along gradients of disturbance and fertility as well as changes in species richness. At the GB level the balance of plant community types within the Broad Habitat saw grass-dominated moorland increase at the expense of the cover of heath/bog continuing a trend seen between 1978 and 1990 (Bunce et al 1999; Firbank et al. 2000). Mean Ellenberg fertility score also increased in Dwarf Shrub Heath between 1990 and 1998 but only in the England with Wales sample (Haines-Young et al 2000). However, in Scottish Dwarf Shrub Heath there was a significant reduction in mean species richness while the index conveying the proportion of Grime's stress-tolerators decreased (McGowan et al 2001; Haines-Young et al 2000).

The policy context for changes in Dwarf Shrub Heath

DEFRA Public Service Agreement (PSA)[3]

7 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.

National and international biodiversity policy

8 Obligations for conservation objectives relating to Dwarf Shrub Heath vary in their applicability to designated areas or the wider countryside as well as their emphasis on site safeguard, enhancement or maintenance. Management agreements drafted under the provisions of the Wildlife and Countryside Act (1981), CROW (2000) and legislation that implements the EEC Habitats Directive all focus activity onto designated SSSI and NNR designed to afford protection as well as positive management to the best examples of habitat types across Britain. In 1999 about 16% of upland heath was designated as SSSI (includes NNR) in England and Wales and 15% in Scotland (UHAP, 1999). Obligations for habitat and species conservation on all Dwarf Shrub Heath irrespective of designation, fall under the UK Biodiversity Action Plan that sets out a strategy for conservation of specific habitats and species. Under the UK BAP Dwarf Shrub Heath is divided into two priority habitats, upland and lowland

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

heath, each covered by their own Habitat Action Plans[4]. The total expenditure envisaged in implementing objectives under both plans is around 250K for the period up to 2010 (UHAP 1999; LHAP 1995).

The agricultural policy context

9 Since entry into the EU over 30 years ago, livestock (largely sheep) production in the British uplands has been assisted by a variety of price support mechanisms implemented as part of the Common Agriculture Policy. The most important of these measures in terms of impacts on upland heath are the Hill Livestock Compensatory Allowance Scheme (HLCA), Sheep Annual Premium (SAP), Suckler Cow Premium (SCP) and the Beef Special Premium (BSP). Given the predominance of sheep grazing in the British uplands, the HLCA scheme has been probably the most important policy driver. This has operated since 1975 in the Less-Favoured Areas that contain the majority of upland heath in Britain (UMHB, 2002).

10 Until the MacSharry reforms of the CAP in 1992 neither the HLCA or SAP schemes carried any sanction against the ecological effects of over-grazing (UMHB, 2002; Winter & Smith 2000). Since support was available on a per animal basis, the scheme acted as an incentive to increase flock size (Fuller & Gough, 1999). There is now considerable evidence that, since 1975, the impact of this policy driver has been to increase the extent of grass moor and grass heath. Certainly, evidence from analyses of change in plant species composition between 1978 and 1998 are partly consistent with these effects although difficulties still remain in teasing apart the role of additional potential drivers such as deer grazing and pollutant deposition (see below). Also the HLCA driven rate of increase in sheep numbers tailed off in the late-80s to be replaced by either a lower rate of increase or regional stability through the 90s (Fuller & Gough 1999; Kiddle 2000).

11 In response to on-going concerns about subsidised over-grazing, the headage-based HLCA scheme was replaced with the area-based Hill Farm Allowance scheme in 2001 (UMHB, 2002). It is hoped that this change should also help alleviate the particular issue of over-grazing on upland commons (UHAP, 1999).

Environmental Impact Assessment

12 In 2002 the existing government regulations that required EIA to precede planned development and forestry were extended to cover "..the use of uncultivated land or semi-natural areas for intensive agricultural purposes."[5] These extended measures complete the implementation of the European EIA Directive but also contribute to the wider aims of promoting sustainable agriculture. See policy context for T1 – Q2 for further information on the policy background.

Conservation and agri-environment schemes relevant to conservation of the Dwarf Shrub Heath Broad Habitats

- **Environmentally Sensitive Area Scheme** : Encourages lower stocking levels and appropriate heathland management. In 1999 an estimated 103,057 ha of moorland in GB was estimated as under ESA management agreement of which 71,612ha was DSH (5% of GB extent based on CS2000 estimate of total stock and UHAP (1999)). The first ESA were designated in 1987 with further designations in 1988, 1993 and 1994.

[4] See action plan texts at http://www.ukbap.org.uk/Library/library_1.htm#P3
[5] See guidelines at http://www.defra.gov.uk/environ/eia/

- **Countryside Stewardship, Countryside Premium and Tir Cymen:** Outside ESA and SSSI, conservation management of DSH can be funded under a series of competitive-entry schemes including Countryside Stewardship (England), Countryside Premium (now closed) and Rural Stewardship (Scotland) and Tir Cymen (Wales). These schemes include heathland tiers that fund management agreements designed to allow regeneration of suppressed heather. Recent changes to these schemes include the incorporation of the Moorland Scheme into the Stewardship scheme in England and, in Wales, the replacement of Tir Cymen and ESA agreements by a whole-farm scheme Tir Gofal (UHAP, 1999). The first of these schemes – Countryside Stewardship - was launched as a pilot scheme in 1991.
- **Wildlife Enhancement Schemes:** These schemes offer up to 50% funding of agreements to secure conservation management of SSSI land. They are limited in number and geographic reach. The North Pennines WES is probably the most significant in terms of impact on upland DSH. Pilot schemes were launched in 1991.
- **Moorland Management Scheme:** Run by Scottish Natural Heritage and focussed on moorland within designated SPA, SAC and SSSI.

Key actions from each Priority Habitat Action Plan[6]

Lowland heathland

- Maintain, and improve by management, all existing lowland heathland (58,000 ha).
- Encourage the re-establishment by 2005 of a further 6,000 ha of heathland with the emphasis on the counties of Hampshire, Cornwall, Dorset, Surrey, Devon, Staffordshire, Suffolk and Norfolk in England and Pembrokeshire, Glamorgan and west Gwynedd in Wales, particularly where this links separate heathland areas.
- Through the Change in Key Habitats Project (CKH) it has been estimated that there is 67,000 ha of recently modified heathland with the potential for restoration. The figure of 6,000 ha therefore represents a modest attempt to recreate approximately 10% of the existing lowland heathland resource. This target could be realistically met using existing Countryside Management Schemes. The careful targeting of 6,000 ha of lowland heathland recreation will also make a modest contribution to reversing the effects past fragmentation of the resource.
- Where significant gaps in the SSSI/ASSI coverage of lowland heathland are identified the appropriate SSSI/ASSI procedure should be implemented by 1998.
- Consider expanding Countryside Stewardship, Tir Cymen, Environmentally Sensitive Area (ESA) and Wildlife Enhancement Schemes (WES) to meet the targets for heathland management and re-creation. Determine the applicability of a new scheme similar to Countryside Stewardship for Scotland.
- Take account of the conservation requirements of lowland heathland in developing and adjusting agri-environment schemes.
- Simplify the process for submission of applications to the Secretary of State to fence lowland heathland that is common land for grazing, to maintain its wildlife interest.

[6] Actions taken from each plan at www.ukbap.org.uk/species.htm

- In areas that support lowland heathland, there should be a presumption in favour of re-establishing heathland on derelict land or land that has been used for mineral extraction.
- Encourage Forest Enterprise and the MoD to agree action plans with specific targets for heathland restoration or management for all heathland sites in their ownership with the statutory nature conservation agencies by the end of 2000.
- The long term funding of county heathland management projects, most of which have full time project officers and which play a key role in delivering heathland management needs to be addressed. Consideration should be given to establishing county heathland projects in Wales

Upland heathland

- Maintain the current extent and overall distribution of the upland heathland which is currently in favourable condition.
- Achieve favourable condition on all upland heathland SSSIs/ASSIs by 2010, and achieve demonstrable improvements in the condition of at least 50% of semi-natural upland heath outside SSSI/ASSIs by 2010 (compared with their condition in 2000).
- Seek to increase dwarf shrubs to at least 25% cover where they have been reduced or eliminated due to inappropriate management. A target for such restoration of between 50,000 and 100,000 ha by 2010 is proposed.
- Initiate management to re-create 5,000 ha of upland heath by 2005 where heathland has been lost due to agricultural improvement or afforestation, with a particular emphasis on reducing fragmentation of existing heathland.
- Review and modify livestock support mechanisms in the Less Favourable Areas (LFAs) through further lobbying for reform of Common Agricultural Policy (CAP), to promote sustainable agricultural management of upland heathland. Promote a more integrated approach to environmental, agricultural and socio-economic policy through CAP reform. Continue to reduce overgrazing by implementing the environmental cross-compliance conditions.
- By 2002 review and consider common land legislation with a view to improving the sympathetic management of upland commons.
- By 2004, review, and modify where necessary, muirburn legislation to ensure appropriate management of upland heathland.
- When reviewing management prescriptions in agri-environment schemes and woodland initiatives, consider whether additional measures are needed to maintain and/or improve the condition of upland heathland.
- Protect upland heathland from inappropriate development, such as wind-farms and quarrying, including by identification in relevant development plans.
- Consider the adequacy of existing planning guidance on the impacts of certain developments on upland heathlands, for example wind farms, and revise if required.
- Acknowledge the importance of upland heathland in country, regional or other forestry strategies.
- Develop by 2005 regional strategies to reduce red deer numbers in Scotland to levels where upland heathland is maintained in favourable condition.

Acknowledgements:

13 Dr Angus MacDonald (SNH) and Professor John Milne (MLURI) provided useful advice for this policy context statement.

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SCIENCE OUTPUTS

Part1: Analyses of change in extent and condition of Dwarf Shrub Heath

Approach

14 Changes in extent and condition of Dwarf Shrub Heath (DSH) could have taken place following the operation of a series of land-use drivers before 1990 and during the eight year interval. These include:

1. Increased grazing by sheep in upland Britain following increases in stocking density through the mid-seventies to the late-nineties (Fuller & Gough, 1999).
2. Increased grazing by deer in upland Britain following local increases in numbers since the sixties (Deer Commission, 2001).
3. Afforestation and clear-felling.
4. Under-grazing and reduced biomass removal in lowland Britain resulting in succession to scrub and woodland.
5. Atmospheric N deposition in both upland and lowland Britain. This peaked around 1990 (NEGTAP 2001) having increased for most of the 20th century.
6. Changes from and to DSH could have been driven by the effects of conservation measures funded under agri-environment agreements. These measures include reduced grazing in the uplands, rewetting of degraded bog following blocking of grip drains, bracken spraying and increased grazing on lowland heaths. Attempts to detect the effects of conservation measures are covered under Topic7.

15 In the unenclosed uplands, the changes in Broad Habitat allocation of surveyed parcels are also known to be affected by real difficulties in mapping change in the extent of Broad Habitats. For example, it was acknowledged in Haines-Young et al (2000) that the changes between DSH and Bog "*..probably reflect different interpretations by field surveyors in complex habitats.*" Therefore, in parallel with an assessment of the role of the drivers listed above, the robustness of the mapped change needs to be taken into account. There are however, limits on the extent to which this can be done. This is because mapping in unenclosed upland habitats was done onto a colour coded Broad Habitat map so that mapping decisions were not formulated as code strings available for later analysis. Hence, the only options are manual checking of the field maps (a prohibitively lengthy process in most cases) or extraction of the 1990 mapping data as a guide to the probability that the 1990 Broad Habitat allocation was correct. The shifts from DSH to Conifer plus all those involving lowland heath were checked manually given the small number of CS sample squares involved.

16 In addition to mapped data, condition measures derived from the vegetation plots can be used to compare actual changes in plots within parcels that changed Broad Habitat versus the kind of change that would be expected given Broad Habitat change. To aid interpretation, condition measure data from the changing parcels were also compared with condition measure data for plots in stable parcels. There are however, limits on the extent to which vegetation plot data can be assumed to track mapped changes in the total surveyed area. Firstly, plots sample only a subset of the total number of parcels and secondly, mapped parcels can be heterogeneous so that changes in the botanical character of a plot may not represent the overall change in character of the parcel.

17 The Broad Habitat changes that are covered by this assessment of change in extent and condition are listed in Table 10.1 along with the expected directions of change in plot-derived condition measures.

Table 10.1 Expected changes in vegetation condition measures in plots within parcels that change Broad Habitat allocation between 1990 and 1998.

Broad Habitat grassland change; 90 to 98	*Number of repeat plots*	*Aggregate class change*	*Light score*	*Fertility Score*	*Wetness score*	*pH score*
DSH to Acid grassland	15	VIII to VII	up	Up	n/a	n/a
Acid grassland to DSH	12	VII to VIII	down	down	n/a	n/a
DSH to Conifer	Too few plots					
DSH to Bog	23	Use CVS classes	n/a	down	up	n/a
DSH to Bracken	10	VIII to VI	n/a	up	n/a	up
Bog to DSH	20	Use CVS classes	n/a	up	down	n/a
Bracken to DSH	4	VI to VIII	n/a	down	n/a	down

Results – change in mapping codes

DSH to Conifer

18 Nine CS survey squares saw a change in allocation from DSH in 1990 to Conifer in 1998. These nine squares and their respective parcels were checked manually. Out of a total of 42ha of surveyed land that changed Broad Habitat, 9ha was doubtful because of mapping or digitising error while the remainder appeared to reflect real change. The largest loss of DSH occurred in one of the two squares in Environmental Zone 6 where a quarter of the square had been planted with Sitka Spruce since 1990. In all other squares that saw apparently real change, parcel areas were all well below one hectare in size. In one of these squares in Environmental Zone 4, DSH was lost to self-sown *Pinus sylvestris* on part of a disused railway embankment.

Changes involving lowland heath

19 Because of the particular land-use and conservation issues surrounding lowland heathland, any changes involving DSH in CS squares in Environmental Zones 1, 2 and 4 were manually checked (Table 10.2). All of the lowland squares that saw a loss of DSH to conifer were in Environmental Zone 4. Of these three squares one involved a loss of DSH to recently planted *Pinus sylvestris* shelter-belt. According to surveyors notes in 1998 this was designed as a windbreak and for pheasant rearing. The second square in Environmental Zone 4 also saw a loss to plantation while the third square was detailed in the previous section. Of the three other squares in Environmental Zone 4 that lost DSH, two appear doubtful in that the field maps did not appear to support any change while in one square, DSH was again lost to succession on part of a disused railway embankment but this time to tall-herb vegetation and hence, to the neutral grassland Broad Habitat. Of the remaining lowland squares to have seen loss of DSH, one in Environmental Zone 2 seems to have seen a real loss of 6ha to Bracken, while the only square in Environmental Zone 1 lost a small fragment of DSH to tall-herb vegetation dominated by *Deschampsia cespitosa* in 1998 and grazed by horses, cattle and sheep.

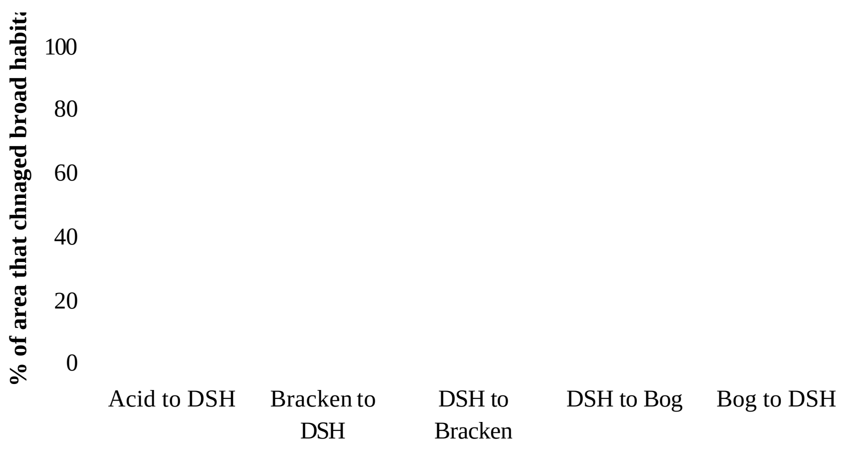
Table 10.2 Changes between 1990-’98 in surveyed area (ha) involving DSH in lowland Environmental Zones only.

Loss from DSH	*EZ1 E&W*	*EZ2 E&W*	*EZ4 Scotland*
To Conifer	0.0	0.0	**0.3**
To Improved & Neutral	**0.2**	0.0	**0.3**
To Acid grassland	0.0	**0.1**	0.0
To Bracken	0.0	**6.0**	**0.2**
Stable	0.0	**50.6**	**4.1**

Other changes from and to DSH

20 The majority of changes from and to DSH involved surveyed land allocated to Broad Habitat mosaics in 1990 (Figure 10.1). However, making an assessment of the reliability and causes of these changes is limited because of the lack of coded mapping data from 1998. The absence of parcel coding for 1998 partly reflects the change in mapping methodology that was made to address the very real problems in mapping change in the unenclosed uplands. The CS2000 pilot mapping exercise showed, for example, that attempts to map upland habitat mosaics in detail at two times and then to measure change were prone to a large amount of mapping error. In light of this, surveyors in 1998 were encouraged to record change only on a pre-prepared Broad Habitat map that amalgamated the numerous parcels recorded in the 1990 survey into a simpler and smaller number of polygons that could be realistically checked while minimising mapping errors. However, only limited information could then be recorded onto the Broad Habitat map. The consequence of this was that often no information was recorded to indicate whether change was real or was intended as a correction to the 1990 map. The issue is particularly important for the treatment of mosaics. Given the absence of information on change and the known problems that existed with upland Broad Habitat mapping, the safest conclusion is that much of the turnover between DSH, bog, bracken and acid grassland is probably attributable to the processing of spatial mapping errors.

Figure 10.1 Proportion of surveyed area in CS squares that saw a change in extent of DSH and that comprised parcels coded as mosaics in 1990.



21 Information on the primary code composition of the mosaics that changed Broad Habitat from or to DSH also illustrate the diverse make-up of these areas of surveyed land (Figure 10.2). The change to 1998 may have involved only a part of the total extent of each mosaic in each square but the absence of 1998 coded data means that further assessment of 1998 allocations is only possible using vegetation plot data, since their locations can be matched with the specific area that saw Broad Habitat change. However, this assessment can only be partial because only a subset of parcels were sampled by vegetation plots.

Figure 10.2 Primary codes associated with 1990 parcels all or part of which changed to or from DSH between 1990 and 1998.

Results – comparison of condition measures

Change between DSH and Acid grassland

22 Plots located in DSH that changed to acid grassland had a mean fertility score closer to values typical of stable DSH. The small increase in score between 1990 and 1998 is consistent with a change to acid grassland but the magnitude of the change was small and only marginally larger than the increase also seen in stable acid grasslands (Figure 10.3).

Figure 10.3 Change in Ellenberg fertility score in repeat plots located in DSH or Acid grassland in 1990 and 1998

Ellenberg fertility score

3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2

90 98 90 98

Acid grass DSH

3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2

90 98 90 98

DSH to Acid grass Acid grass to DSH

Mean+SE
Mean-SE
Mean

DSH to Bracken
Bracken to DSH
Acid to DSH

23 The larger increase in fertility score for plots within parcels that changed from acid grassland to DSH is inconsistent since a decrease or stability would be expected (Figure 10.3). Comparing change in light score was not informative because the mean scores for plots in stable DSH and acid grassland were very similar (Figure 10.4).

Figure 10.4. Change in Ellenberg light score in repeat plots located in DSH or Acid grassland in 1990 and 1998

0% 20% 40% 60% 80% 100%

% of parcels with primary code

Ellenberg light score

7.05
6.90
6.75
6.60
6.45

90 98 90 98

Acid grass DSH

7.05
6.90
6.75
6.60
6.45

90 98

DSH to Acid grass Acid grass to DSH

Mean+SE
Mean-SE
Mean

24 Changes in aggregate class membership were based on few plots, so the results should be treated with some caution. Overall, there was little change in aggregate class so that

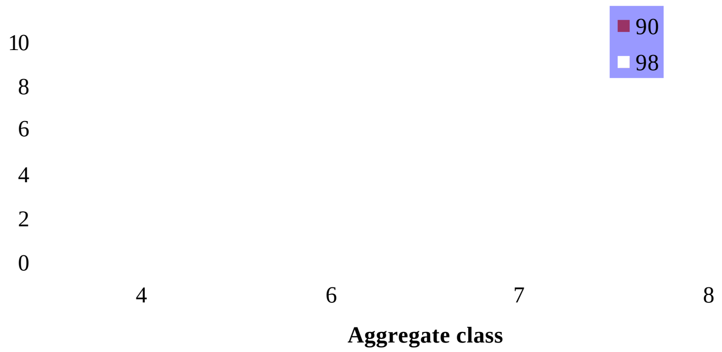
for these subsets of changing parcels any floristic changes could not have been large (Figure 10.5).

Change between DSH and Bracken

25 Mean fertility scores convincingly separated the stock of unchanging bracken and DSH (Figure 10.6). However, the small number of plots from parcels that changed Broad Habitat did change appreciably in their mean score while the mean values for ’90 and ’98 suggest placed the sample in between the means for stable acid grassland and bracken. This perhaps reflects the variability typical of the vegetation mosaics in which most of the changes to and from DSH occurred. The same inconclusive message comes from the comparison of pH scores (Figure 10.7), although changes in light score do appear to have moved in the expected direction (Figure 10.8).

Figure 10.5 Change in aggregate class membership of plots within parcels that changed, a) from Acid grassland to DSH and b) from DSH to Acid grassland , between 1990 and 1998.

a)



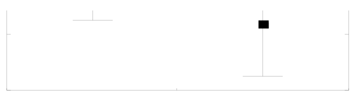


Figure 10.6 Change in Ellenberg fertility score in repeat plots located in Bracken or DSH in 1990 and 1998

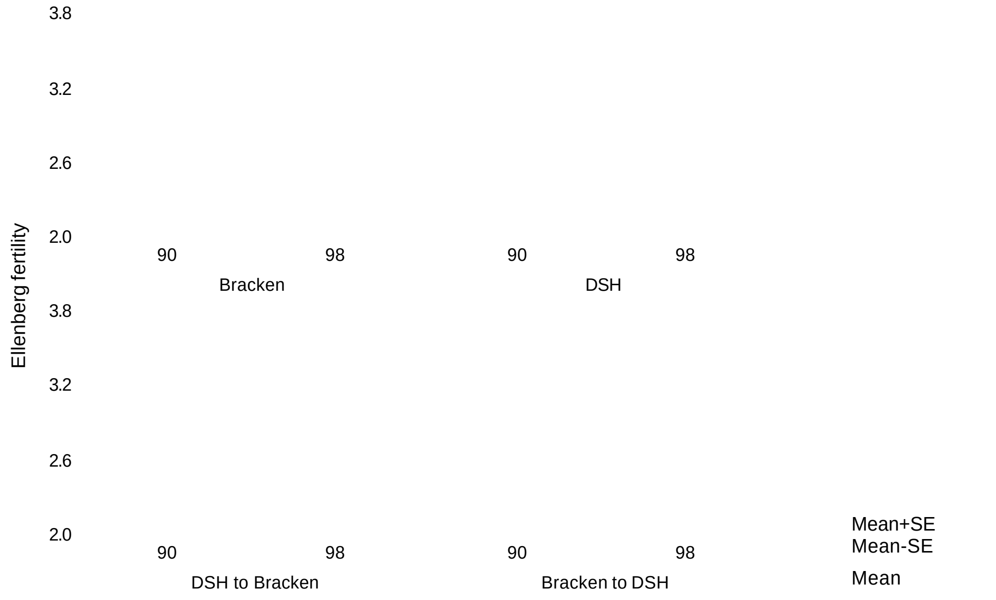


Figure 10.7. Change in Ellenberg pH score in repeat plots located in DSH or Bracken in 1990 and 1998

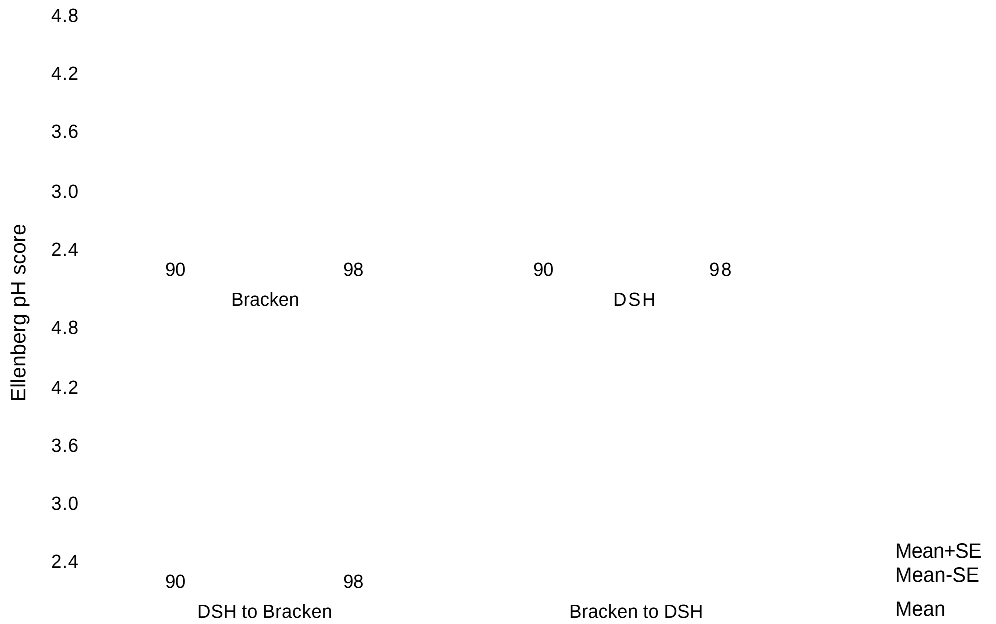
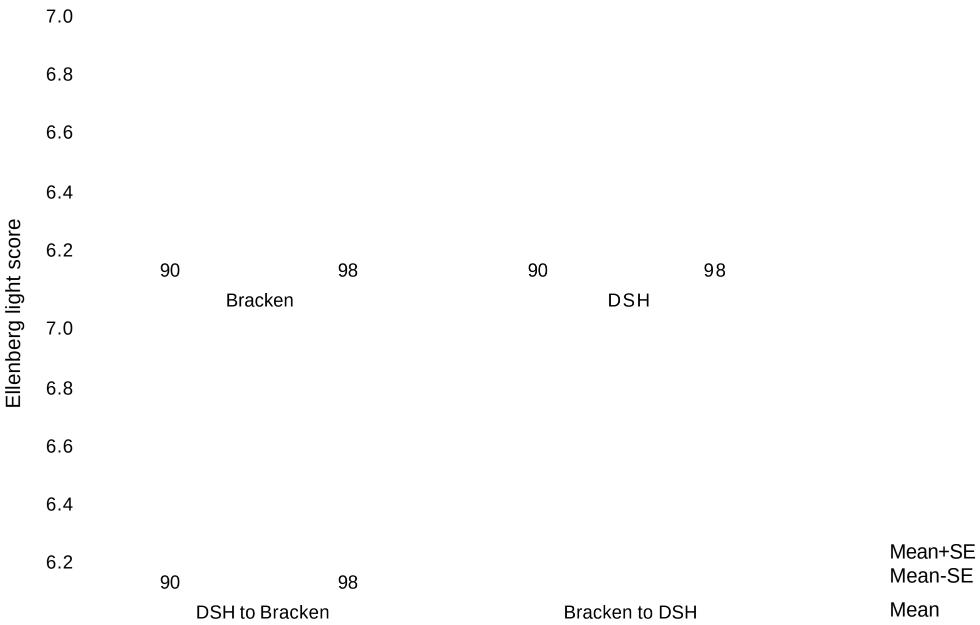


Figure 10.8 Change in Ellenberg light score in repeat plots located in DSH or Bracken in 1990 and 1998



Change between DSH and Bog

26 DSH and bog are well separated by differences in mean fertility score while plots in a subset of parcels that changed between the two had means that are closer to bog rather than DSH (Figure 10.9). An even better separation between DSH and bog is seen in terms of mean wetness score (Figure 10.10). Mean scores for parcels that changed fell between the two and again this may reflect the inherent variability of the vegetation within mosaic parcels. The decline in mean wetness score for plots in parcels that moved from bog to DSH is consistent but a decline in score was also seen in the plots from stable bog parcels (Figure 10.10).

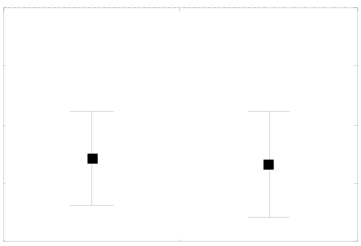


Figure 10.9 Change in Ellenberg fertility score in repeat plots located in Bog or DSH in 1990 and 1998

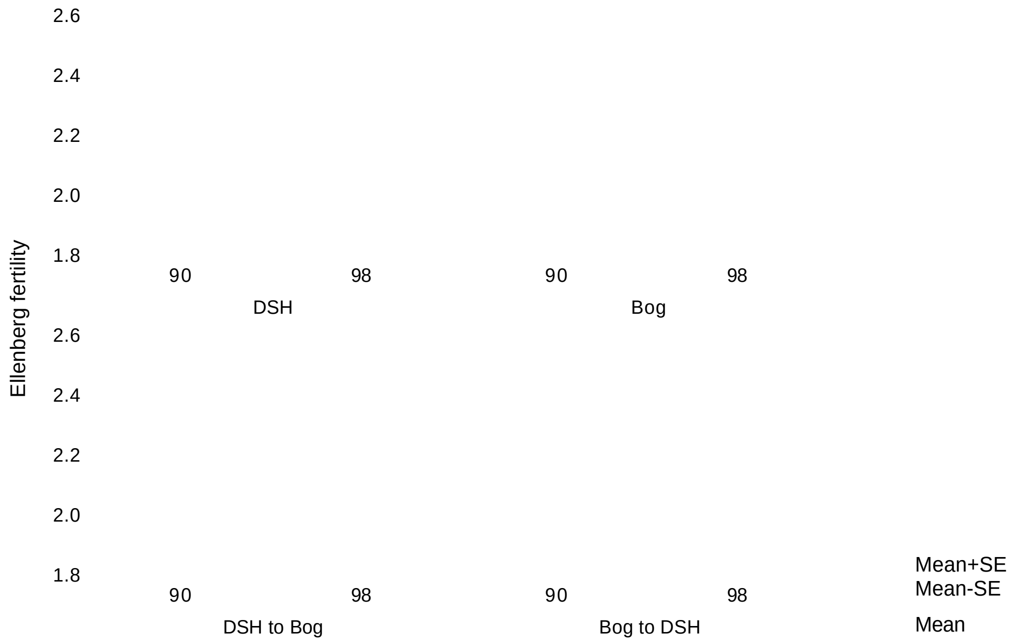
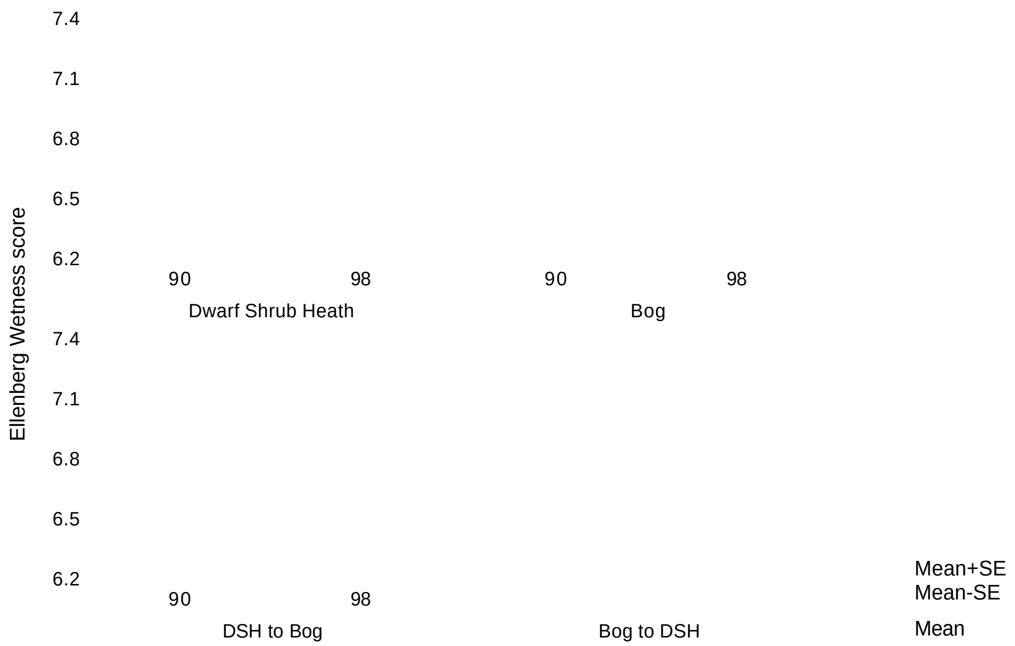
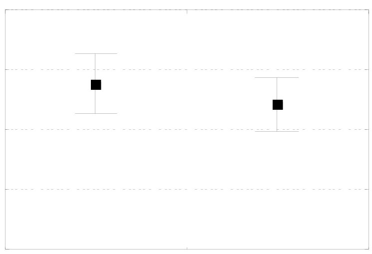


Figure 10.10 Change in Ellenberg wetness score in repeat plots located in Bracken or Acid grassland in 1990 and 1998



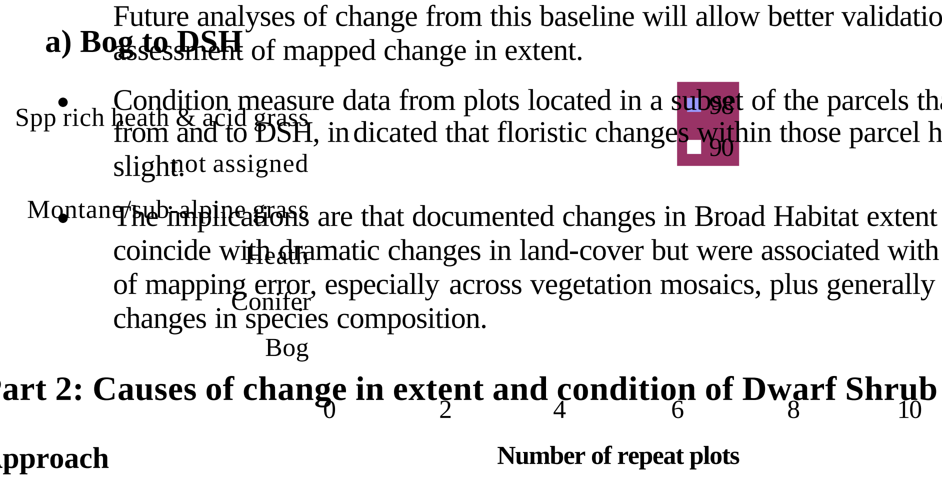
27 The main indication from the pattern of change in condition measures is that floristic change in the small sample of vegetation plots has been slight. This conclusion is reinforced by the overall stability seen in these plots when changes between CVS classes were examined (Figure 10.11). Since DSH and bog are both included in ACVIII (Heath/bog), shifts in plant species composition were examined in relation to a grouping of CVS classes into the habitat types used to determine empirical Critical Loads for nitrogen. This classification conveniently discriminates between heath and bog. Correspondence between CVS classes and the CL habitat classification has been carried out by Prof M. Ashmore as part of a project investigating the relationship between vegetation change and sources of nutrient enrichment in CS plot data.

Figure 10.11 Change in habitat type membership of plots within parcels that changed, a) from Bog to DSH and b) from DSH to Bog , between 1990 and 1998. The habitat types were formed from groupings of individual CVS classes based on the Empirical Critical Loads for Nitrogen habitat classification (Werner & Spranger, 1996). This classification provides a convenient way of discriminating between heath and bog.



Conclusions

- The majority of surveyed lowland heath did not change Broad Habitat at between 1990 and 1998. Small losses were attributable to succession, bracken encroachment and improvement.
- Other changes to and from DSH are impossible to fully evaluate because of the lack of 1998 mapping data consistent with the shift to a more realistic and simpler mapping method. The recommendation to change mapping methods was made as a result of a field trial prior to CS2000. This exercise exposed the difficulty of accurately mapping vegetation boundaries in upland habitats and the spurious spatial patterns that resulted from attempts to map change. The simplified method was shown to reduce mapping error but there is reason to believe that during the 1998/99 field season, surveyors did not discriminate adequately between changes intended as corrections to 1990 mapping errors and real change in habitat extent.
- In recognition of the severe problems in recording change in the uplands, additional 4m^2 vegetation plots were located at random in unenclosed upland habitats in 1998 (up to 10 per square stratified by area of each broad habitat). Future analyses of change from this baseline will allow better validation and assessment of mapped change in extent.
- Condition measure data from plots located in a subset of the parcels that changed from and to DSH, indicated that floristic changes within those parcel had been slight.
- The implications are that documented changes in Broad Habitat extent did not coincide with dramatic changes in land-cover but were associated with a high level of mapping error, especially across vegetation mosaics, plus generally more subtle changes in species composition.



Part 2: Causes of change in extent and condition of Dwarf Shrub Heath

Approach

28 CS provides evidence of change across national ecosystems in terms of the extent of different Broad Habitats and by quantifying change in the condition of the plant communities that make up these Broad Habitats. The use of indices such as Ellenberg scores provides indirect evidence of the processes involved including eutrophication and disturbance. Given [redacted] nsequence of environmental and land [redacted] ses about the relative contribution of [redacted] that track land-use change at com[redacted]

29 We used three nationa[redacted] nd condition of DSH was related to [redacted] d, sheep stocking density and w[redacted]

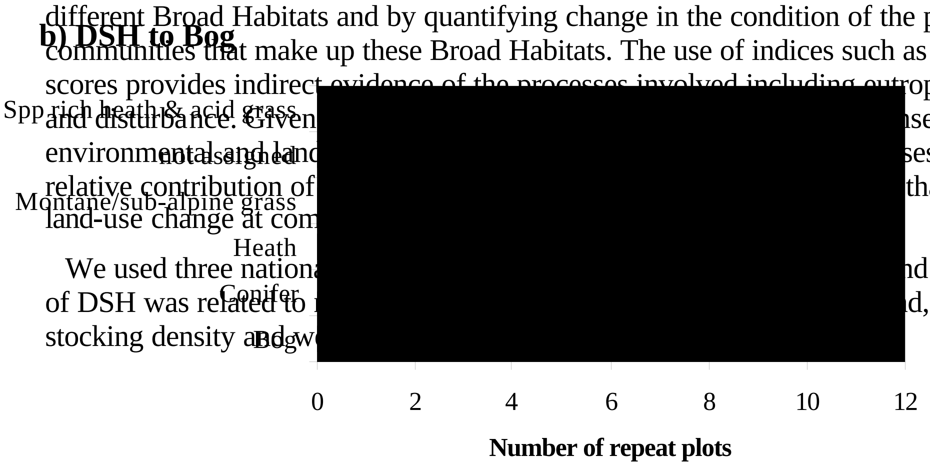


Table 10.3 Datasets used to quantify hypothesised drivers of change in extent and condition of DSH between 1990 and 1998.

Driver	*Dataset*
Deer grazing (Scotland only)	Numbers of deer in and change in numbers for open range areas (taken from Deer Commission 2000)
NHx deposition (wet + dry)	Modelled NHx deposition estimates at 5x5km square resolution for GB for 1996 (CEH Edinburgh)
Sheep grazing	Modelled estimates of sheep density per 1km square for 1988 (MAFF census) generated as part of the development of the Dragosits et al (1998) ammonia emissions model.

30 The ability of each driver to explain significant change was tested for all DSH in GB as well as by Environmental Zone in accordance with the requirements of the topic question. Analyses were also attempted based on whether squares that contained DSH were inside or outside Less Favoured Areas (LFA) and also by division in to Disadvantaged and Severely Disadvantaged areas. In practice, virtually all squares in upland Britain were in LFA. Also all Welsh squares were in SDA while 29 out of 32 English upland squares were in SDA. Therefore this division of upland squares was abandoned. Analyses involving deer commission data were carried out separately reflecting the fact that open ranges only comprise part of the total area of Scotland.

31 Four types of ecological response were analysed:

1. Change in area of DSH from and to any other Broad Habitat type,
2. Change in area of DSH from and to acid, neutral or improved grassland,
3. Change in cover-weighted Ellenberg fertility score in vegetation plots located in parcels mapped as DSH Broad Habitat in 1990 or 1998,
4. Change in Ellenberg fertility score in vegetation plots assigned to the Upland *Calluna* heaths and Lowland dry and wet heaths Critical Load (empirical N) habitat types on the basis of their CVS class membership (see above and Werner & Spranger 1996).

32 Fitting of the explanatory variables to change in fertility scores used a mixed modelling approach to take into account the fact that CS plots were nested within squares. In addition, Environmental Zone, mean altitude in each square and minimum January temperature were included to allow for the possibility of climatic and altitudinal constraints on the vegetation response. The proportional extent of other Broad Habitats in each CS square in 1990 were also introduced as explanatory variables to allow for the dependence of change on the amount of different types of land-cover present at the start.

Results

33 The only variability to be significantly explained by the predictors was change in cover-weighted Ellenberg fertility scores in plots defined as heathland on the basis of their species composition in 1990. Even so only 9% of the variation in Ellenberg score was explained (Tables 10.4 & 10.5).

Table 10.4 Results of fitting predictors to change in extent and condition of DSH between 1990 and 1998.

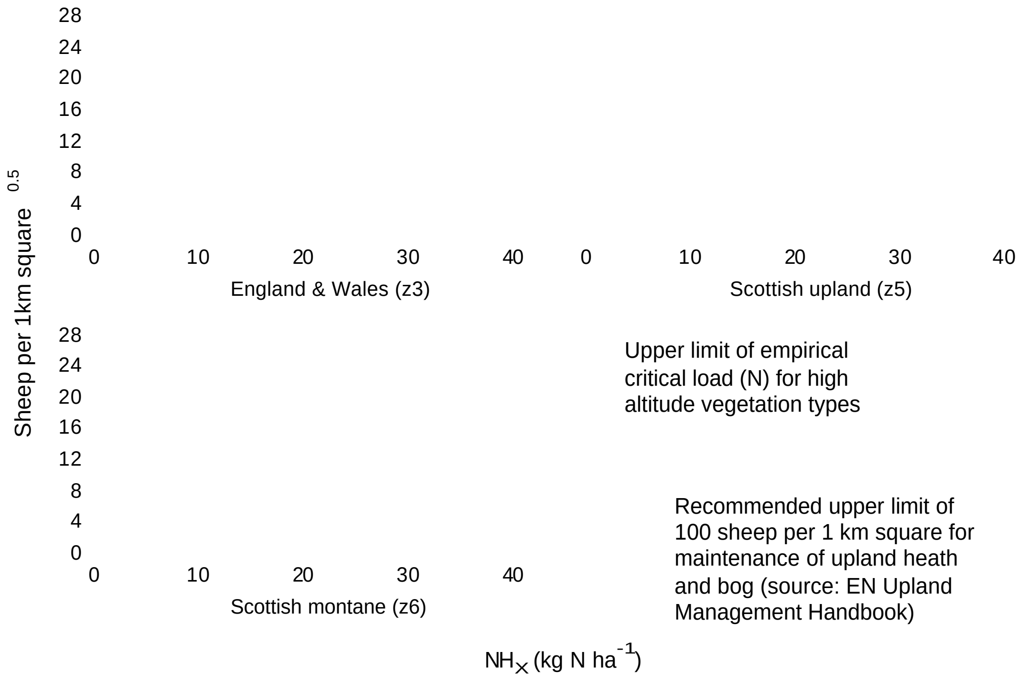
Response	***Significant effects***
Turnover of DSH area with all other Broad Habitats	None
Turnover of DSH with acid, neutral and improved grassland	None
Change in Ellenberg fertility scores in plots located in DSH Broad Habitat parcels	None
Change in Ellenberg fertility scores in plots in heathland defined by CVS class in 1990	1) Modelled sheep density per 1km square 2) Proportion of acid grassland present in 1990

Table 10.5 Mixed model ANOVA results for change in cover-weighted Ellenberg fertility scores between 1990 and 1998 for plots classed as heathland (n=522 plots).

Effect	***Regression coefficients***	***Estimated DF***	***F value***	***P***
Modelled sheep density	0.0173	148	12.02	0.0007
% acid grassland in 1990	0.0027	93.4	5.35	0.0230

34 Regression coefficients for the two significant variables were both positive indicating that larger values of sheep density and proportion of acid grassland in 1990 are associated with increasingly positive change in Ellenberg fertility score and therefore a shift toward species compositions that reflect greater substrate fertility. When tested in the absence of all other effects the proportions of woodland and bog in 1990 as well as modelled NHx deposition were also individually significant but when tested together to determine the best but fewest predictors they were excluded. No effect of Environmental Zone was detectable although analyses under a parallel GANE-funded project, has found that more of the variation in Ellenberg fertility change in England & Wales, across all upland vegetation types when analysed together, is explained by sheep density than NHx but the reverse applies in Scottish Environmental Zones. This seems to reflect the greater range of variation in sheep density in English and Welsh CS squares than in Scotland (Figure 10.13).

Figure 10.13 Range of variation in modelled sheep density (1988) and NHx deposition (1996) in CS sample squares in upland Environmental Zones of GB. Note that the y-axis is the square root of estimated sheep count as this was the variable used in regression analyses.



Conclusions

- Analyses attempted to explain change in extent and condition of DSH across Britain in terms of ammonia deposition, sheep grazing, deer grazing (Scotland only) and the proportion of different Broad Habitats present in each CS square in 1990.
- The only ecological response to be partly explained by any of the predictors was change in Ellenberg fertility score. Sheep density and amount of acid grassland present in 1990 were the best predictors such that higher estimated sheep numbers in 1988 and a larger area of acid grassland would be associated with a larger shift toward plant species composition typical of higher fertility. Detected relationships were however, weak and most variation remained unexplained.
- Tests of the effects of deer numbers suffered from the coarse resolution of the open range counts while generally high levels of unexplained variation in the response data are likely to be due to the coarse resolution of the other predictors, the absence of finer-scale data on land management plus sampling error in the CS data on extent and condition change.
- The analytical results presented here should not be thought of as a failure even though unexplained variation remained high. Our goal was to detect and attribute signals in the data on change in condition and extent rather than to produce predictive equations with high explanatory power. It remains true however, that turnover and change in **area** of Broad Habitat was not explained by any of the selected predictors.

- Failure to explain shifts in area are consistent with the fact that a significant proportion of quantified turnover between DSH and other Broad Habitats is probably attributable to mapping error and the failure to discriminate corrections to the 1990 map from real change in upland unenclosed land.

SUMMARY

The significance of change in extent and condition

- Changes to and from DSH, bog and bracken are impossible to fully evaluate because of the lack of 1998 mapping data consistent with the shift to a more realistic and simpler mapping method in the unenclosed uplands in CS2000.
- The majority of surveyed lowland heath did not change Broad Habitat between 1990 and 1998. Small losses were however, attributable to succession, bracken encroachment and improvement.
- Condition measure data from plots located in a subset of the parcels that changed from and to DSH, suggest that floristic ch[redacted]rcels had been slight.
- The implications are that documented changes in Broad Habitat extent did not coincide with dramatic changes in land-cover and were associated with a high level of mapping error, especially across vegetation mosaics. However, because of the simplification of the mapping methods adopted in 1998 in upland environments, vegetation mosaics were particularly lacking in parcel level detail. This is consistent with the recognition that changes in extent of patches making up mosaics of vegetation could not be accurately mapped. However, the consequence is that parcel level detail was not recorded hence checking change is often impossible on a parcel by parcel basis. The conclusion to be drawn is that, even with a simpler mapping method, estimates of overall change in proportion of upland broad habitats are also prone to a high degree of estimation and therefore mapping error.

Causes of change in extent and condition

- Analyses attempted to explain change in extent and condition of DSH across Britain in terms of ammonia deposition, sheep grazing, deer grazing (Scotland only) and the proportion of different Broad Habitats present in each CS square in 1990.
- The only ecological response to be partly explained by any of the predictors was change in Ellenberg fertility score. Sheep density and amount of acid grassland present in 1990 were the best predictors such that higher sheep numbers in 1988 and a larger area of acid grassland present in 1990 were associated with a larger shift toward plant species compositions typical of higher fertility.
- Tests of the effects of deer numbers suffered from the coarse resolution of the open range counts while generally high levels of unexplained variation in the response data are likely to be due to the coarse resolution of the other predictors, the absence of finer-scale data on land management plus sampling error in the CS data on extent and condition change.

FURTHER WORK AND RECOMMENDED CHANGES TO CS METHODS

35 While recognising the arguments against asking CS square land-owners for management information (potentially eroding their good will and possibly influencing their future management in the square), from the point of view of improving our ability to explain changes, it would be useful to circulate a questionnaire in the next CS. Securing the publicised support of the CLA, NFU, CPRE etc. might be a useful way to allay suspicions among land-owners while also emphasising its importance.

36 In general, future analyses of change in upland Broad Habitats will be strengthened by analysis of repeat data from the U plot baseline laid down in CS2000. These $4m^2$ fixed plots were randomly located in unenclosed Broad Habitats (up to 10 per 1km square) to provide additional information on vegetation condition. Analysis of vegetation change in these plots between '98/'99 and future surveys will augment the coarsely resolved mapping of upland land-cover and help to counterbalance the recognised imprecision of mapping change in extent in the unenclosed uplands.

37 Future surveys should also allow and encourage surveyors to clearly discriminate between 'real' change and amendments to field maps intended to correct the earlier survey record. This issue applies largely to upland mapping where, in 1998, surveyors were encouraged to record change directly onto a pre-prepared Broad Habitat map.

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