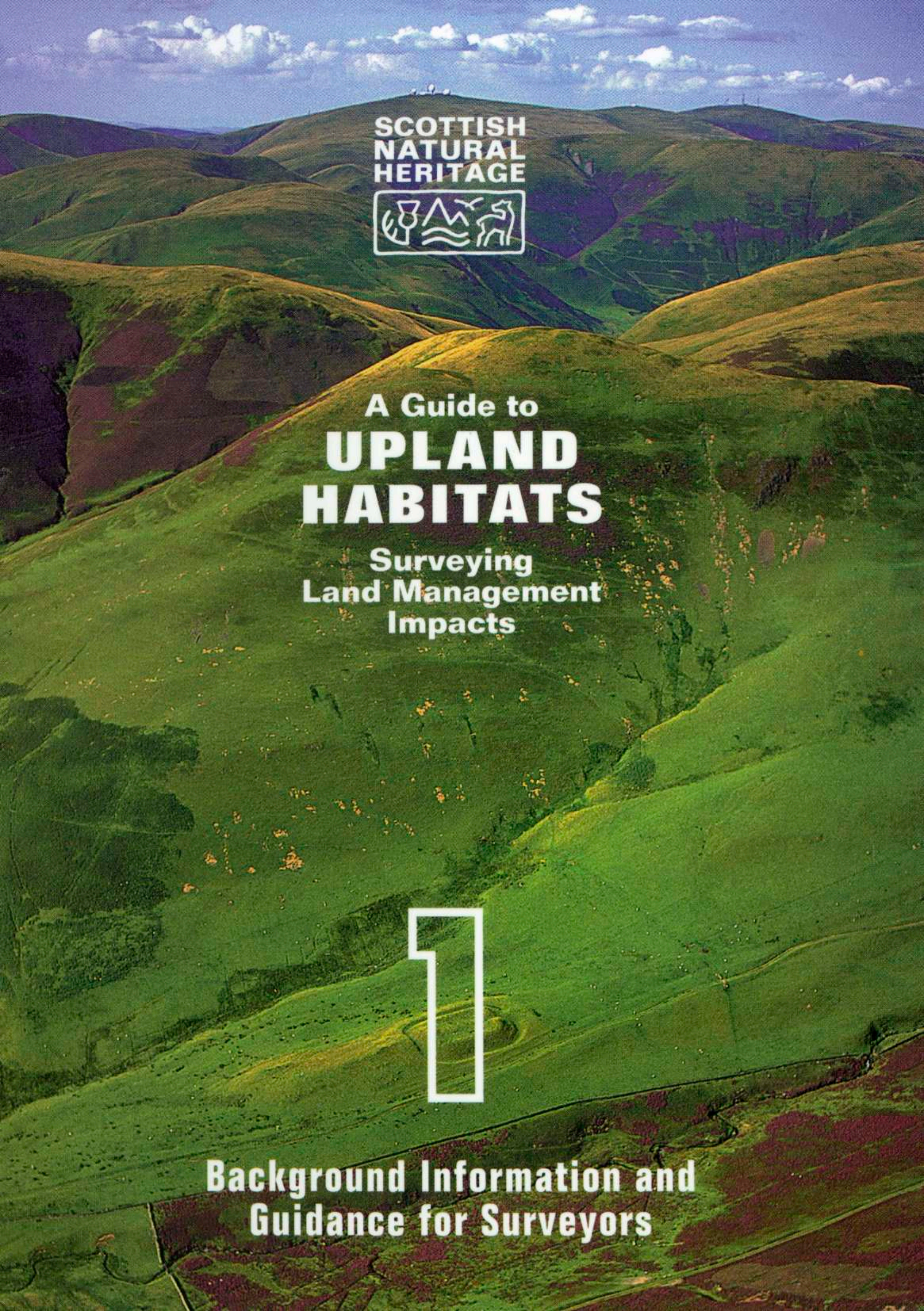

SCOTTISH NATURAL HERITAGE

A Guide to

UPLAND HABITATS

Surveying Land Management Impacts

1

Background Information and Guidance for Surveyors

A Guide

to

Upland Habitats

Surveying Land Management Impacts

Volume 1

Background Information
and
Guidance for Surveyors

by

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Part 1: Introduction

Introduction

Why is the guide needed ?

For decades there have been arguments and debates about the "state" of the uplands, and what is needed to improve them. Concern has focused especially on the impacts of high numbers of sheep and deer and on the occurrence of uncontrolled burning. At the same time a number of agricultural incentive schemes, and initiatives such as the establishment of Deer Management Groups, have recently appeared, and these provide opportunities to ameliorate or prevent impacts if agreement can be reached on objectives. Inevitably farmers, foresters, tourists and nature conservationists, and others, view the uplands from different perspectives. Whilst the tourist may delight in the purple heather clad hills in Deeside, the forester may view them as a lost opportunity for commercial woodland cover, and the nature conservationist may be concerned, instead, about the dwindling extent of young, regenerating heather, or about the lack of natural woodland regeneration. No matter where you go in the uplands, there are different views on the objectives for management and the success or otherwise of existing regimes.

Unfortunately, at the centre of these debates there has often been a failure to communicate clearly about basic facts. Often, farmers and nature conservationists use similar terms, such as "overgrazing", to make completely different points about the land and its management. This lack of clarity hinders attempts to resolve controversies surrounding the state of the uplands. A common language is badly needed to enable the nature and scale of potential impacts to be critically described and discussed. Standardised descriptive tools would also aid the planning and cost-effective implementation of changes in management designed to reduce undesirable impacts. This guide is an attempt to fill this need.

Until now, information about habitat impacts has come from either a few very local, very detailed studies or from more numerous surveys involving rapid, but very subjective visual assessments based on loosely defined criteria. The first type of assessment has been based on objective sampling and measurement. It is repeatable and produces results which are objectively justifiable to varying (usually known) degrees. But it is very time consuming and expensive and can only, realistically, be applied to quite small areas. The second approach cannot be readily repeated or convincingly justified if challenged, but can be applied quickly over very large areas. It does not necessarily give a poor result if carried out systematically by someone thoroughly familiar with a site who can draw on substantial field experience and knowledge of impacts on upland habitats.

There are a number of additional problems with both approaches, though these apply more particularly to the second approach.

- The range of variation in impacts which the observer has seen, and his or her understanding of the processes contributing to the impact, will influence the assessment. For example, someone whose experience is restricted to a part of the country in which stock numbers are relatively low will have a different conception of what heavy grazing is than someone from an area where stock numbers are mostly high.
- Assessments often do not distinguish between past impacts, present impacts, and probable future impacts. For example, some criteria based on species composition of the vegetation may identify as heavily grazed areas which were modified by heavy grazing centuries ago and which are not currently heavily grazed. At the same time they may miss areas where grazing pressure has only recently become high.
- Assessments sometimes confound the *value* of a habitat in a particular state with the *description* of its state. Differences in assessments may then be due to either changes in value and/or to changes in state. This can lead to disagreement and confusion over the assessment of impacts by different people. For example, "overgrazed" (which is a condition assessment based on value as well as state) can mean something very different to a farmer or to a nature conservationist, or indeed even to conservationists with differing views on the values of different features.
- Finally, management practicalities and considerations may influence assessments. Description of the state of the resource should be a separate process from the assessment of consequences and the formulation of management prescriptions. If this is not the case there is a risk that impact descriptions will biased. If an impact surveyor is very closely involved in management decisions, and field assessments begin to suggest that costly or unpopular management changes may be required, there may be an unconscious tendency on the part of the surveyor to modify assessments to make them more palatable or to make decisions appear easier. Equally, a desire to demonstrate management activity may bias the assessments in the opposite direction.

In this guide we attempt to resolve some of these problems by providing a suite of transparent, descriptive classes and a flexible but systematic methodology which can be applied anywhere in the Scottish uplands. It is based on a synthesis of existing relevant knowledge and experience.

Using this guide is a first step towards resolving some of the disputes within the uplands debate but it is not the whole solution. It is an aid to the process of consensus building. The next challenge is to pose clear *objectives*, from which to draw conclusions about the *condition* of different habitats and their management needs. Although use of this guide will permit impacts to be more reliably described and compared it does not set objectives. Assessments can be acted on effectively only once objectives have been stated explicitly. The step from the impact assessment to condition assessment (or evaluation) is a subtle but crucial part of rational management.

Who is the guide aimed at ?

The guide is aimed at professional field staff in the conservation agencies and non-governmental organisations, and ecological contractors undertaking field surveys. Users will require to be able to identify the commoner species of plants encountered in the Scottish uplands (including mosses and lichens). The species identification skills required are by no means as great as for using the National Vegetation Classification. Some knowledge of upland ecology will also be helpful although the guide provides much of the necessary background information. The most important requirement of a surveyor is to be observant and willing to continually test all assessments against the available field evidence.

Learning how to use the guide

The amount of information presented in the guide may at first appear to be rather daunting, although to put things in context it is considerably less than for the upland communities of the National Vegetation Classification or even a standard field guide to British birds.

In order to become familiar with the guide we suggest that surveyors initially either concentrate on one type of impact or one type of habitat. After reading the explanatory information in the first part of the guide, the field indictors should be tried out in the field. It is essential to gain some familiarity with the guide *in the field* before attempting an impact survey in earnest.

The structure and content of the guide

The guide is in two parts. Volume 1 provides descriptions of the habitats and impacts, the likely outlook for the habitats and their associated fauna and flora under particular impacts, and detailed instructions about how the guide should be used to carry out an impact survey. Volume 2 is a field guide giving the field indicators for each habitat and impact type. Although the user may decide to take only Volume 2 into the field, Volume 1 is an essential part of the guide and should be read before the user attempts to do any survey work. Nine habitats are included and these are presented in the following order in both volumes: smooth grassland, flush, tall herbs, scrub, blanket bog, wind-clipped summit heath, dwarf-shrub heath, tussock grassland and bracken.

In order to add to the usefulness of the guide Volume 1 also contains tables ("Correlation tables"), which help the user to translate between scientific names and common names of plants used in the guide, and to find the Field Guide Habitat most applicable to land, habitat and vegetation types from other commonly used classifications. A glossary of terms is also included.

The amount of information given for each habitat type or impact type varies considerably. This is deliberate and reflects the availability of information. Where accounts seem to be relatively thin we hope that readers and users will take this as a challenge to increase knowledge in these areas.

References have not been provided as both volumes are intended to be used primarily as a field handbook. Information has been drawn from a wide variety of disparate sources including most of the published scientific literature of relevance to the Scottish uplands (both journal papers and books), comments and observations from various scientific authorities and experienced field workers in the uplands (see Acknowledgements), and the experience of the authors and their colleagues in Scottish Natural Heritage. Nevertheless, it is quite possible that there have been omissions, particularly of unpublished information relating to associated species. Any errors or omissions are the responsibility of the authors.

For readers wanting to explore the ecological literature on which this guide is based, or looking for accounts of upland management and land use, the following works, and the references which they quote, will provide good starting points.

D.B.A. Thompson, D.B.A., Hester, A.J. & Usher, M.B. (Eds.) (1995). *Heaths and Moorlands: Cultural Landscapes*, HMSO.
Hobbs, R.J. & Gimingham, C.H. (1987). Vegetation, fire and herbivore interactions in heathland. *Advances in Ecological Research* **16**, 87 - 173.
Hudson, P. & Newborn, D. (1995). *A Manual of Red Grouse and Moorland Management*, The Game Conservancy Trust, Fordingbridge.
Lindsay, R. (1995). *Bogs: The Ecology, Classification and Conservation of Ombrotrophic Mires*, Scottish Natural Heritage, Battleby.
Rodwell, J.S. (Ed.) (1991, 1992). *British Plant Communities. Volume 1 Woodlands and Scrub, Volume 2 Mires and Heaths, Volume 3 Grasslands and Montane Communities*, Cambridge University Press. (These are the relevant parts of the National Vegetation Classification.)
Sutherland, W.J. & Hill, D.A. (1995). *Managing Habitats for Conservation*, Cambridge University Press (Chapter 11 Upland moors and heaths, by Thompson, D.B.A., MacDonald, A.J. & Hudson, P.J.).
Usher, M.B. & Thompson, D.B.A. (Eds.) (1988). *Ecological Change in the Uplands*, Special Publication Number 7 of the British Ecological Society, Blackwell Scientific Publications.

We would like to stress that although we believe the guide contains the most comprehensive guidance on the assessment of impacts on upland habitats currently available it should not be regarded as the last word on the subject. We hope that further research will occur on topics where knowledge is clearly lacking and we plan to develop further products and training based on the guide to make its contents as accessible and useful as possible to a wide a range of users. We would very much appreciate feedback from users about their experiences of using the guide and would welcome any suggestions about how it could be improved. Correspondence should be sent to the principal author at Uplands Team, Advisory Services, Scottish Natural Heritage, 2 Anderson Place, Edinburgh EH6 5NP. A feedback form is included at the end of this volume.

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Illustrations and photographs are by the senior author, Angus MacDonald, with the exception of Figure 27 which is by Philip Immirzi. The cover photograph is by Patricia and Angus MacDonald.

Symbols, terms and species nomenclature used in the text

Symbols and terms used

- All numbers used in the text in both volumes should be taken to be approximate.
- Decimetre = 10 cm.
- m^{-2} = per m^2.
- sheep ha^{-1} yr^{-1} = sheep per hectare per year
- < = less than
- > = greater than
- 10's, 100's = several tens or several hundreds of whatever is referred to *e.g.* 10's m^2 is an area of several tens of square metres within the range 10 m^2 - 100 m^2.

Further information on terms can be found in the glossary.

Species nomenclature

In the various parts of the guide species of plants and animals are specifically mentioned. Scientific names are used for all plant and invertebrate species, but common names are used for vertebrates (birds, mammals, reptiles and amphibians). The scientific names of vascular plants are those used in Stace, C. (1991) *New Flora of the British Isles*, Cambridge University Press, while bryophytes follow the usage in Smith, A.J.E. (1978) *The New Moss Flora of Britain & Ireland*, Cambridge University Press and Smith, A.J.E. (1990) *The Liverworts of Britain & Ireland*, Cambridge University Press. Lichens follow Purvis, O.W., Coppins, B.J., Hawksworth, D.L., James, P.W. & Moore, D.M. (1992) *The Lichen Flora of Great Britain and Ireland*, Natural History Museum Publications in association with The British Lichen Society. A table is provided to allow the user to correlate common names and scientific names of vascular plants as used in Stace (1991) and in the National Vegetation Classification. Lepidoptera nomenclature follows Emmet, A.M. & Heath, J. (1991) *The Moths and Butterflies of Great Britain and Ireland*, Volume 7 Part 2, Harley Books; dragonflies names are as in Askew, R.R. (1988)

The Dragonflies of Europe, Harley Books; for grasshoppers Marshall, J.A. & Haes, E.C.M. (1988) *Grasshoppers and Allied Insects of Great Britain and Ireland*, Harley Books, has been used; while for spiders we have followed Roberts, M.J. (1987) *The Spiders of Great Britain and Ireland*, Vol.2, Harley Books. The nomenclature for all other invertebrate groups follows that in the relevant handbooks of the Royal Entomological Society or Linnean Society.

Part 2: What the guide does

What the guide does

The type of assessment which can be made

The guide provides the means to describe the current "state" of habitats in terms of the intensity of various impact types. It is descriptive rather than evaluative. It does not provide a method for "condition" assessment, in which value criteria are applied to the description of the state of the habitat. Its descriptive classes do not distinguish between "good" (or "optimal") and "bad" (or "sub-optimal"). Such evaluative assessments depend on the objectives of management at a particular site.

Equally, the methods described in this guide are not intended to provide the degree of precision and statistical sampling rigour which would be appropriate in a scientific study designed to test hypotheses about the causes and consequences of particular impacts. Less formal methods are needed for rapid survey of large areas of ground. There is always a trade-off between (a) the area of ground which can be surveyed, and (b) the degree of detail, and the objective demonstrability of the results which can be obtained, within given constraints of time and resources. It is often more useful to have less precise data for all the ground that is of interest rather than very precise information for only a small number of sample areas. In the latter case the precision of the results for the sample areas is counteracted by uncertainties which appear when trying to extrapolate the results to a very much larger area. Of course, the two approaches are not mutually exclusive. An impact survey based on the methods in this guide can provide a useful basis for stratified sampling for more detailed studies.

How habitats are interpreted and defined

The guide covers the terrestrial habitats of unenclosed, open rangeland (moorland) on the hills and mountains of the Scottish uplands, and similar land extending down to near sea level in the far north and west.

Simply, a habitat means a type of place, and its associated conditions, in which an organism lives and can normally be found. Inasmuch as species occur together in predictable assemblages or communities then their individual habitats will also tend to overlap to form more generic habitat types. These could also be described as assemblages of species habitats or the habitat of species communities. However, habitats are not necessarily easily and neatly classifiable. Organisms vary greatly in size and space requirements, as well as in food and shelter preferences and a host of other requirements. An area which represents only one type of habitat for a large organism, which lives its life at large spatial scales, may represent a number of different habitats for small organisms which operate at much smaller scales. Indeed, some organisms are the habitat for other organisms *e.g.* the stems of woody plants provide a habitat for epiphytic lichens and bryophytes. In addition, some organisms provide, or strongly influence, the physical structure of the habitat for other organisms. These "structural species" are particularly important features to take account of in any generalised account of habitats because of their important influence on the abundance and diversity of associated "interstitial species". Also, they (or their effects) are often what give a habitat its most definable field characteristics.

To date it has been common to equate habitats with floristically defined vegetation types, such as the communities of the British National Vegetation Classification. There are problems with this approach. The presence and abundance of many upland organisms is influenced by factors such as the three-dimensional physical structure of the environment, the associated microclimate, and the potential for partitioning living space among different species. Some of the plants which define plant communities do have an important influence on these factors, as well as providing food resources. However, structural and microclimatic characteristics may be similar over a range of vegetation types, or equally they may vary within one vegetation type, *e.g.* as in dwarf-shrub heaths subject to varying browsing pressure. In many upland habitats the first changes produced by impacts are in habitat structure. This can lead to changes in the associated fauna before there are any significant changes in the floristics and thus in the vegetation community.

While planning the guide we were conscious that information on impact characteristics and responses was very limited for anything but very broadly defined habitat classes. Also, we were aware that a guide which had too many habitat and impact types would be less likely to be used. We have, therefore, used broad habitat types based on significant structural organisms and physical conditions. In this guide habitat denotes a concept somewhere between the similar concepts of biotope and ecotope (see glossary).

Nine generic habitat types are covered: smooth grassland, flush, tall herbs, scrub, blanket bog, wind-clipped summit heath, dwarf-shrub heath, tussock grassland, and bracken (there is a logic to this order described in the next section). We have excluded those habitats which are little affected by site management and those for which there is little information on impacts. Woodland and high forest are mostly very different in character from these open range habitats: they are often enclosed, and can be managed in more specific ways. They have therefore also been excluded from this guide although the scrub sections could usefully be used to assess small woodland fragments on open moorland. This range of habitats should allow assessments to be made of most of the open moorland and summit ground in the uplands.

On the whole, boundaries between these habitats are likely to be clearly definable in the field. However, some problems may be encountered and the surveyor should be aware of these. Flushes can be awkward. Their origin, often in a spring, is usually well defined but where they end can be much more difficult to decide. Also, they often show a very fragmented spatial distribution over a hillside which can make it difficult to decide where to set sensible boundaries for assessment. There is no easy solution to this problem. Other problems can arise because some habitat types can overlay others *e.g.* scrub or bracken can overlay habitats such as smooth grassland or dwarf-shrub heath. In this case it may be worthwhile to make an assessment for more than one habitat type for the area concerned, or alternatively, to make an assessment based on the habitat type which is most important to site management objectives. This situation also arises where impacts produce a succession from one habitat type to another. For example, chronically heavily grazed dwarf-shrub heath may have characteristics of both dwarf-shrub heath and smooth or tussock grassland. In this case if dwarf-shrub heath is more important for the site objectives then it should have priority over grassland in an assessment of impacts.

How impacts are interpreted and defined

In this guide impacts are disturbance factors which change the structure and composition of the habitat and its associated flora and fauna. Since the main aim of the guide is to provide a tool for site management only those impacts for which site management is usually responsible are included. The principal impacts in the uplands which fall within this definition are grazing/browsing and burning. Grazing/browsing is the most widespread and generally the most important impact type. More habitat-specific impacts can also be important *e.g.* agricultural pasture improvement of smooth grassland or drainage and drying of bog, and these are also included in the guide. In some habitats, types of impact such as insect herbivory, fungal attack, or weather damage, can be common and may produce effects which could be confused with, or may interact with, grazing, burning or drying. These are also covered in the guide. Impacts which are not readily modifiable by site management, such as air pollution effects, are not included.

In both volumes of the guide the habitat sections are presented in the same order. This order is related to grazing impact in a way which should be helpful in carrying out an assessment. The habitats fall into three groups. The first group includes smooth grassland, flush, tall herbs and scrub which all have a high probability of attracting high intensity grazing or browsing. If these are checked first and are found not to be heavily grazed/browsed it is highly unlikely that any other habitats will be heavily grazed/browsed. The second group includes blanket bog and wind-clipped summit heath which are least likely to attract heavy grazing from among the nine habitats. If these are checked and are found to be heavily grazed then it is highly likely that all other habitats will also be heavily grazed. The third group includes dwarf-shrub heaths, tussock grassland and bracken which may attract varying grazing impacts and provide less critical information about grazing impact over all habitats. Within each of these three groups the habitats are arranged in order of declining general abundance and likelihood of encounter.

Grazing/browsing, burning, and drying are classified in terms of current intensity of impact while burning includes additional categories for frequency of burning. Both intensity and frequency of fires determine the impact of burning on habitat and since they can vary independently it is important that each is assessed separately. For burning the concept of intensity needs further explanation. It could mean a variety of things including the size of the fire, the length of the fire front, the temperature at some point on the fire front, the energy released in total or per unit length of fire front, or the degree of destruction of the vegetation and soil observable after the fire. All of these are closely but not perfectly correlated and, to avoid confusion, burning intensity is here defined in terms of destruction of vegetation, plant litter and soil. This is what can be easily observed in the field and has the most direct relationship habitat characteristics.

Each impact type, for each habitat, is divided into three classes - high, moderate, or low - which cover the range of intensity or frequency of impact likely to be encountered in the Scottish uplands. Occasionally, only two classes - high or low - have been used where it was felt that knowledge was insufficient to warrant finer discrimination. Bracken is treated rather differently from the other habitats in that its main interest is as an impact on other habitats and it is assessed in terms of high, moderate or low vigour. In most cases the boundaries between the classes more or less evenly divide up the range of variation. Occasionally, more precise threshold criteria have permitted definition of class boundaries, *e.g.* browsing offtake rates which are likely to lead to a decline in cover of the dwarf-shrub *Calluna vulgaris*, but these are very few. It is important to realise that some examples of impact will be encountered which do not fall clearly into one class. In some situations the impact intensity will lie on the borderline between two classes. Where this is the case (and where an intimate mosaic of different impacts are present) it may be best to record the impact as intermediate between classes.

It is also important to appreciate that high, moderate and low impact mean different things in different habitats: they do not relate to the intensity of the disturbance factor in any absolute sense but rather to the observable effects on the structure and composition of the habitat. The distinction as it applies to grazing will serve as an illustration. "Grazing pressure" is sometimes taken to mean the absolute amount of herbage removed by the grazing animals and is closely related to local stock density. The impacts of a given grazing pressure, in this sense, may vary according to the productivity of the habitat and the amount of herbage available. Habitat impact is more closely related to proportional offtake (*i.e.* the percentage removal of a year's production) from the vegetation or from critical plant species within the habitat. A given stock density and grazing pressure may produce high, moderate or low intensities of habitat impact in different situations.

How field indicators are defined and presented, and how they should be used

The assessment of impact intensity, and frequency where appropriate, is determined from a range of field indicators for each habitat and impact type. These indicators focus primarily on *directly observable effects* of *current* impacts. The user should be aware that sometimes different impacts produce similar effects and it will not always be possible to separate the effects of, say, burning and grazing, using the field indicators.

The indicators are divided into three sets: Large-scale Indicators, Small-scale Indicators and Trend Indicators. There are Small-scale Indicators for all habitats and impact types but Trend Indicators, and occasionally Large-scale Indicators, may not be given where they are inappropriate or where present knowledge is insufficient to allow their formulation. Within each set the indicators are listed, very roughly, in order of decreasing reliability or applicability. However, this does not mean that assessments can be based solely on one or two indicators from near the top of a list: it has not been possible to order the indicators sufficiently unambiguously and clearly to justify such a short-cut approach, and neither are the differences in reliability between indicators sufficient to justify this.

The Large-scale Indicators can generally be used from a distance (up to one or two kilometres in some cases) and are based on the general appearance of a whole patch, or hillside. They use features such as colour, pattern and texture of the vegetation or ground surface. These indicators can often be applied from a vantage point so that a large area of ground (up to several hundred hectares) can be quickly surveyed at one time. Some indicators are included which require close observations of particular features but which indicate impacts over a much wider area. Large-scale Indicators can be used as the basis for a quick survey method giving a coarse, impressionistic picture of the pattern of impacts over a site. This is termed Phase 1 Impact Survey. This may be adequate for first reconnaissance of a site.

However, the reliability of these Large-scale Indicators is low (speed and reliability of assessment are usually inversely related) and the surveyor usually should proceed to check his or her initial large-scale assessment with close-range observations using the Small-scale Indicators (Phase 2 Impact Survey). The Small-scale Indicators are meant for use at a patch scale and are meant to be aggregated or averaged across the whole of a patch (or other basic assessment unit). Most of the indicators should be applied at point locations, requiring some sort of averaging of point estimates across the patch. Some indicators can only sensibly be applied at a whole patch level. (Advice on how a site can be divided into patches that can be used as units of assessment is given later in Part 5 of this volume.)

Both Large-scale Indicators and Small-scale Indicators have been formulated to describe current impacts. The recent history of impacts can also sometimes be deduced from careful observation and interpretation of critical field signs. This is the purpose of the Trend Indicators. These usually involve comparisons of impact intensity suggested by different Small-scale Indicators which respond at different rates; or, comparisons of indicators of current impact intensity with features such as species composition which may not be good indicators of current impact but which are affected over the longer term. The term "trend" is used loosely: some of the indicators may only indicate changes from one year to the next rather than a consistent longer term change. However, some of the indicators can point to the long-term occurrence of, as well as change in, particular impacts and for this reason "trend" has been preferred over "change" as a descriptive term for this set of indicators.

For each indicator a number of alternative states are described and the surveyor must decide which of these most closely describes the state of the patch being assessed. For Large-scale and Small-scale Indicators these correspond to high, moderate or low impact. Indicators do not always distinguish between all classes of impact - some features can only be used to distinguish one class from the other two. Occasionally, only high and low alternatives are given where a finer discrimination does not seem justified either by present knowledge or by the range of variation likely to be encountered. Trend Indicators have states relating to increasing, decreasing or chronic (long-term, continuous) impacts.

We have attempted to make the indicator descriptions and the descriptors for each alternative state as unambiguous and clear cut as possible. In most cases the observer's decision is based on noting the presence or absence of something or the size of something relative to guideline figures. For example this is one of the indicators relating to browsing of dwarf-shrub habitat

☞ The average proportion of long-shoots of *Calluna vulgaris* and/or *Vaccinium myrtillus* showing signs of having been browsed.

(a) Where plants are more than moderately vigorous (average shoot growth > 4 cm year^{-1}).

- > 66 %. Browsing very conspicuous, difficult to find unbrowsed shoots. ... **H**
- 33 % - 66 %. Clearly browsed in general appearance though effects may be patchy. ... **M**
- < 33 %. Not obviously browsed, browsed shoots difficult to find without both intensive and extensive searching. ... **L**

What the guide does

This is one of the more precisely described indicators. Other indicators are less precisely defined, particularly where colour may be involved or where it is not possible to be precisely quantitative. For example (again from grazing impacts on dwarf-shrub habitat)

☞ Uprooting of dwarf-shrub seedlings in recently burnt patches.

- Conspicuous. ... **H**
- Not conspicuous, but possible to find with limited searching. ...**M**
- Little or none. ... **L**

Most indicators fall between these two extremes. The less precise indicators are still useful to corroborate assessments based on other indicators. There are also usually more of them and they cover a wider range of features than those for which precise criteria can be constructed. Wherever possible, illustrations are provided to help clarify what is meant when qualitative criteria are given, or else some additional descriptors relating to ease of observation or ease of finding are given. The following can be used as a general guide to what is meant when ease of finding or observation are mentioned: something easily found can be found in less than a minute at the majority of observation points within the assessment unit, while something conspicuous or easily observed can be spotted immediately from a standing position from the majority observation points within the assessment unit.

Short comments, preceded by *NB.*, appear immediately after some indicator descriptions or state descriptions. These provide qualifications, or additional information, to help interpret the more puzzling situations. An example is shown on the next page.

It is important to understand that it is unlikely that all indicators will be found, or be applicable, at any one patch or even at any one site. Some types of indicators, particularly those involving particular species, may not apply within whole geographical areas since many species have restricted geographical ranges. Advice on the latter limitation is given in another type of qualification which appears, where necessary, as a short section entitled "Geographical applicability of indicators" at the start of each impact section.

☞ Amount of flower or fruit on *Calluna vulgaris* and/or *Vaccinium myrtillus.*

NB. The abundance of flowering shoots of *Calluna vulgaris* and *Vaccinium myrtillus* can give an indication of rates of shoot removal, provided the seasonal pattern of browsing is known. If browsing only occurs in winter then new flowering shoots can be produced during the following summer, but if heavy browsing occurs during the summer most flowering shoots will be removed. The amount of flowering is also affected by weather patterns and can vary substantially from year to year irrespective of browsing impacts.

- Sparse. ...**H**
- Obvious but patchy. ...**M**
- Abundant and conspicuous. ... **L**

Can the guide be used for impact monitoring ?

Monitoring is basically just repetition of some assessment after some period of time with comparison of the results. When undertaking monitoring, as far as possible exactly the same method should be used each time the assessment is done. If the method cannot be repeated exactly then this introduces uncertainty about whether any change recorded is real or is due to differences in the assessment and recording. The less precisely methods are described and applied the more unclear and unreliable are the results of any monitoring based on them.

The guide can be used for monitoring, but with reservations. The impact assessment methods it describes are meant to be relatively quick and are not tightly defined in all respects. Some judgement is still required about where and how to make observations, and about how to interpret some of the indicators. This provides flexibility but also potentially makes assessments more difficult to repeat exactly. There is always a trade-off between flexibility and repeatability, as well as between speed and reliability, in any assessment method. The potential for repeatability can be improved if surveyors record as much as possible about how they carry out a survey.

Part 3: Habitat descriptions

Smooth grassland habitat

Structural features

The habitat is characterised by a short sward (usually less than 10 cm tall) primarily of grasses, sometimes with sedges also making a significant contribution, accompanied by a variety of forbs and bryophytes. Tussock-forming grass species may be present but they are never dominant and tussocks are usually sparse and poorly developed. The forbs often include a range of growth forms including erect, rosette-forming, creeping, mat-forming and cushion-forming types. The vegetation is grazed, often heavily, which maintains a short and relatively open sward, even although plants may grow closely packed together. Plants are often represented by dwarf growth-forms. Bare soil sometimes occurs as a result of animal activities (trampling, urine scorch), molehills, and at higher altitudes and on steep slopes the effects of soil creep, slippage, frost-heaving and rock falls. There is usually little accumulation of dead plant material in the sward. Flowers and fruits are usually of limited occurrence, due to grazing, but flowering and seed production by lower growing and less palatable plant species can sometimes be abundant even when grazing is moderately heavy.

Topographic location and physical environment

The habitat is found over a wide range of altitudes, from near sea level to 1200 m, over a wide range of slopes. However, the largest areas are found between 150 m - 500 m and on slopes of 10° - 25°.

The soils vary from moderately acid to near neutral. Occasionally, they can be moderately base-rich. Soil depth is variable and soil type ranges from skeletal soils to well-developed brown earths, brown podzolic soils and podzols. Small patches are common on alluvial deposits by upland watercourses. There is usually free drainage but sometimes there is a little drainage impedance or gleying. High precipitation, and snow-melt at higher altitudes, generally maintains soils in a more or less permanently moist state, although periods of dryness can occur in some summers. At high altitudes there is often some soil instability or immaturity due to soil creep and frost heaving and localised disturbance can be caused by slope slippage or rock falls. Both flushing and leaching of soils can be more intense at high altitudes.

Associated flora

A wide variety of associated species can be present with the greatest diversity of species occurring where the substrate is relatively lime-rich or where there is some flushing with lime-enriched waters (see **Flush** habitat). Species composition also varies with altitude and soil fertility. However, there is a core of broadly tolerant species which are typically present, more or less abundantly, in most situations. These include the grasses *Agrostis capillaris*, *Anthoxanthum odoratum*, *Festuca ovina*, *Nardus stricta*, the forbs *Galium saxatile*, *Potentilla erecta*, *Viola riviniana*, and the mosses *Hylocomium splendens* and *Rhytidiadelphus squarrosus*. Almost as widespread and common are the grasses *Agrostis canina*, *Festuca rubra*, *Deschampsia cespitosa*, the forbs *Achillea millefolium*, *Campanula rotundifolia*, *Lotus corniculatus*, *Luzula campestris*, *Plantago lanceolata*, *Succisa pratensis*, *Trifolium repens*, and the mosses *Dicranum scoparium*, *Pleurozium schreberi*, and *Rhytidiadelphus loreus*. Where soils are more lime-rich herbs such as *Carex panicea*, *Carex pulicaris*, *Bellis perennis*, *Linum catharticum*, *Prunella vulgaris*, *Ranunculus acris*, *Saxifraga aizoides*, *Thymus polytrichus*, and the mosses *Ctenidium molluscum*, *Pseudoscleropodium purum*, *Tortella tortuosa*, are likely to make a prominent contribution to the sward. Sometimes, sub-shrubs such as *Helianthemum nummularium* or *Dryas octopetala* (on lime-rich soils) may be present in the sward, while on more acid soils (particularly on dry banks) dwarf-shrub plants sometimes may be encountered as scattered, very short, heavily browsed plants. At high altitudes a variety of arctic-alpines such as *Alchemilla alpina*, *Festuca vivipara*, *Gnaphalium supinum*, *Luzula spicata*, *Minuartia sedoides*, *Persicaria viviparum*, *Polytrichum alpinum*, *Racomitrium lanuginosum*, *Salix herbacea*, *Saxifraga aizoides*, *Saxifraga oppositifolia*, *Sibbaldia procumbens*, and *Silene acaulis* become prominent. Many (but not all) of these only occur on the more lime-rich substrates. Cushion-forming species, such as *Minuartia sedoides* and especially *Silene acaulis*, can be very abundant at high altitudes and, together with viviparous species such as *Festuca vivipara* and *Persicaria vivipara*, can give these swards a very distinctive character.

Associated fauna

The above-ground fauna is relatively lacking in diversity although the habitat is an important element in the requirements of a number of characteristic upland species. The habitat is strongly favoured by larger grazing animals, particularly sheep, but information on its use by other animals is more limited. Although many plant species of high forage value are present there is limited structural variation in the habitat and a lack of cover for animals except in those rare situations where there has been little or no grazing by larger vertebrate herbivores. Also, even quite moderate amounts of disturbance by trampling and removal of plant parts by larger grazing animals can have marked negative effects on the diversity and abundance of above-ground invertebrates. Nectar resources are generally limited, although they may be more abundant in herb-rich swards over lime-rich substrates. On south-facing slopes the short swards allow the ground to absorb heat from the sun and provide relatively warm microclimatic conditions for ground dwelling invertebrates. This can be important for a limited number of species near the northern edges of their range. The soil fauna, however, is more abundant and diverse than in many other types of upland habitat. The relatively large amounts of dung deposited by grazing animals provides a distinctive habitat element of particular importance to invertebrates and the animals which prey upon them.

Skylark, Wheatear and, where damp, Lapwing are among the most characteristic birds of this habitat. Oystercatcher may also be present. Wheatear prefer unimproved swards with rocks which can be used as vantage points. Lapwing and Oystercatcher are mostly present at lower altitudes (mainly less than 500 m). Meadow Pipits are also likely to be present but in general they are sparse on the short swards characteristic of this habitat. The habitat provides important feeding (but not nesting) areas for Golden Plover, Ring Ouzel, Common Gull and crows, although they are not dependent on it. Curlew may also feed here, particularly where the soil is damp. The habitat provides one of the most important forage resources for Rabbits, and thus also for hunting Buzzards. Old rabbit burrows are also important nesting sites for Wheatears. Moles are often present (even in seemingly isolated patches at high altitudes) and, as with Lapwings and Ring Ouzels, the presence of good earthworm populations in this habitat is an important attraction. Foraging Mountain Hares positively select for this type of grassland (feeding mostly at night), particularly in spring. Both Pigmy and Common Shrews, and possibly Field Vole, are likely to be present. Lack of cover is likely to severely limit vole populations unless grazing impact has been unusually low. Common Shrews are favoured by the presence of earthworms and as they are more burrowing and subterranean feeders than Pygmy Shrews they are less affected by the lack of surface cover.

Total invertebrate abundance and diversity is generally high. The soil fauna in particular is well developed, with the presence of substantial numbers of earthworms being a notable feature especially on more base-rich brown earth soils. The soil invertebrate biomass can be three to six times that found in other moorland habitats. Surface living invertebrates are less diverse but also may be moderately abundant. Sheep dung supports a considerable number of specialised species, particularly of flies and beetles, probably contributing about 10 % to the overall invertebrate diversity. Where not heavily grazed the flowers provide food for insects which feed on nectar and pollen. In contrast to bogs and dwarf-shrub heaths the fauna tends to have affinities with lowland and Central European faunas rather than with arctic and sub-arctic faunas.

Mites, springtails and pot worms (Enchytraeidae) are the most abundant invertebrates by one or two orders of magnitude. Springtails can be up to twice as abundant as in habitats dominated by ericaceous dwarf-shrubs. However, in terms of biomass earthworms (Lumbricidae) overwhelm everything else and it is not unusual for there to be up to several hundred individuals m^{-2} on the more fertile brown earth soils. *Allolobophora chlorotica* and *Aporrectodea caliginosa* are common species, both burrowers, while *Lumbricus rubellus* is a sometimes common surface active type which is attracted to dung. Flies (Diptera) are moderately abundant and diverse. Cranefly larvae ("leatherjackets") are important, as on peat substrates, but the species composition here differs from that on peat *e.g.* typical species are *Tipula varipennis*, *T. paludosa* and *T. pagana*. Herbivores include snails, on lime-rich substrates, and slugs. Small bugs (Hemiptera), particularly frog hoppers and leaf hoppers (Homoptera), are also important herbivores, although they are generally most abundant and diverse where the grass sward is taller that is usual in this habitat. Densities of bugs (but not species diversity or biomass) also are much lower than in heather dominated habitats. Less common but often noticeable are the grasshoppers, mostly *Myrmeleotettix maculatus* (in warm dry sites) and *Chorthippus parallelus*.

Predators include ants, beetles and spiders. Ants may be abundant, particularly at lower altitudes on southerly aspects, with the most widespread including *Myrmica scabrinodis* (in shorter swards) and *M.*

ruginodis (in longer swards), *Lasius flavus* (builder of soil mound nests) and *L. niger*. Beetle assemblages are fairly distinct with rove beetles (Staphylinidae) being relatively important. Ground beetles (Carabidae) can also be abundant predatory species although species diversities are limited: the larger species tend to be scarce on short, heavily grazed grassland. Typical carabids include *Bradycellis collaris*, *Calathus melanocephalus* agg., *Loricera pilicornis*, *Nebria brevicollis*, *N. gyllenhali*, *N. salina*, *Notiophilus aquaticus*, *N. germinyi*, *Patrobus assimilis*, and *Pterostichus madidus*. Most of these are widespread or invasive species found in a variety of habitats, although *Nebria gyllenhali* and *Notiophilus germinyi* appear to be restricted to higher altitudes and latitudes. Spiders are moderately abundant though not very diverse. The most common spider group are the small, surface-dwelling members of the Linyphiidae including *Erigone atra*, *E. dentipalpis*, *Savignya frontata*, and *Tiso vagans* but widespread, relatively undemanding species such as *Centromerita concinna* (Linyphiidae) and the larger wolf spiders (Lycosidae) *Alopecosa pulverulenta*, *Pardosa pullata* and *Trochosa terricola* also occur.

Lepidoptera are comparatively scarce and of low diversity. Despite this some larger butterflies and moths can be noticeable, particularly around the lower margins of the uplands. *Cerapteryx graminis* is a characteristic moth species, the larvae feeding on *Festuca ovina* and other grasses including *Nardus stricta*. Occasionally, rapid population growth of this species can lead to localised "outbreaks" which can extensively defoliate swards. The most characteristic butterfly is *Coenonympha pamphilus*, which occurs at up to 700 m altitude and prefers very short swards. At low altitudes the butterflies *Polyommatus icarus* (where there is *Lotus corniculatus*), *Lycaena phlaeas* (where there are *Rumex* spp.), and *Aricia artaxerxes* (where there is *Helianthemum nummularium*) and *Callophrys rubi* (where there is *Helianthemum nummularium*, *Vaccinium myrtillus* and a variety of other shrubs) may all also occur, and *Maniola jurtina* may be abundant around the edges of the moorland in situations where grazing has been light.

Flushes

Structural features

Included in this type of habitat are a wide variety of upland fens, seepage-tracks, springs and rills. The common factor is soils which are wet but in which a flow of water through the soil, at least near the surface, provides some aeration. Usually, this is accompanied by a high watertable but surface wetness is not always constant. The boundaries of a flushed area are not always clearly definable; there can be gradual transitions to other habitat types in some circumstances. The vegetation is of variable height, density and structural complexity. Usually it is no taller than 50 cm at low altitudes (but can be more, especially if *Myrica gale* or other shrubs are present), while at high altitudes vegetation heights of 15 cm or less are more normal even in the absence of grazing. There is usually some mixture of small to moderately tall sedges, mosses and variable amounts and diversities of additional herbs. The character of flushes varies with altitude as well as soil conditions. There is often more bare ground in high altitude flushes. Often, flushes can be picked out from a distance by being more brightly coloured than the surrounding vegetation: during much of the year they are often greener, though flushes with much *Molinia caerulea* or *Trichophorum cespitosum* become quite orange in late summer to early autumn turning to pale fawn and russet-brown respectively in winter, while flushes dominated by bryophytes can be various hues of green, orange, red, purple, brown, or pale grey depending on species composition. Despite often appearing lusher than the surrounding vegetation they are not necessarily more productive.

Topographic location and physical environment

The habitat usually occurs as long, thin "rakes", spreading out and becoming more diffuse as they run downhill unless water flows are sufficient to form a stream. Flushes often originate from a spring-line, or they may form where there is surface drainage into water-tracks. Although individual flushes are usually small, the habitat can occupy substantial areas in total.

The habitat occurs over a wide altitudinal range, from the lowest edges of the uplands to over 1000 m. In the central Highlands high altitude forms begin to be found above about 700 m but in the far north and west of the country these can occur from about 300 m upwards, or less in very exposed locations.

Soils are variable, ranging from unconsolidated mixtures of rock fragments, silt, and humic material to well-developed gleyed mineral soils and peats of various types. The water flow in flushes replenishes mineral nutrients (*e.g.* calcium), where it has passed over, or through, mineral-rich substrates, and the dissolved oxygen may provide some replenishment of oxygen around plant roots. However, the degree of mineral enrichment can be very variable, depending on the origin and rate of flow of the water. In some circumstances there could be depleting effects. It is likely that nitrogen and phosphorus availabilities are low in most types of upland flush. When there are high levels of mineral enrichment the diversity and vigour of plants is enhanced, particularly if natural physical instability also produces a moderate degree of vegetation disturbance.

At high altitudes the water flow may derive from melting snow and the irrigating waters may have average temperatures only a few degrees above freezing point throughout the year. This reduces potential plant productivity. Temperature fluctuations tend to be reduced in water which originates from springs. This effect, in conjunction with the physical effects of the flow of water, tends to increase the time during the winter for which spring-fed flushes are free of ice and snow.

A continuous high water flow produces a stream rather than a flush. More sporadic high water flows can lead to scouring of the surface of the flush producing much bare substrate, particularly if the vegetation cover has been disrupted. Bare ground may also occur in flushes at high altitude due to low plant productivity, periodic high water flows, and disturbance caused by frost-heaving.

Associated flora

Plant diversity is usually moderate. However, many rare species are associated with flushes. The vegetation can be very variable in composition and structure depending on soil type, mineral enrichment of the irrigating water, the strength and variability of water flow, the degree of scouring, water temperature, altitude, geographical location, and the degree of grazing and trampling by animals. The greatest vascular plant diversities are found in the more lime-enriched flushes. A wide variety of species can occur but *Carex echinata*, *C. panicea*, *Eriophorum angustifolium*, *Molinia caerulea*, *Narthecium ossifragum*, *Succisa pratensis* and *Viola palustris* are typically present in a wide variety of situations while *Montia fontana* and the distinctive moss *Philonotis fontana* are often present around springs and rills. *Juncus effusus* and *J. acutiflorus* are sometimes abundant, particularly at altitudes of less than 400 m. Bog mosses (*Sphagnum* spp.) are often common in acid, peaty situations while a variety of "brown" mosses such as *Cratoneuron commutatum*, *Bryum pseudotriquetrum*, *Drepanocladus revolvens*, *Scorpidium scorpioides*, and *Campylium stellatum* (the last is light, golden-green) can be abundant where there is some degree of mineral enrichment. *Cratoneuron commutatum*, in particular, is indicative of lime-enrichment and there is sometimes deposition of lime (tufa) among its shoots. The edges of springs and rills frequently are carpeted by mosses and liverworts sometimes forming deep and extensive cushions or mats. *Saxifraga stellaris* is sometimes conspicuous in this mossy vegetation. There is often some overlap in plant species composition between flushes and neighbouring habitat types and transitions to wet forms of ***Tussock grassland***, ***Tall herbs*** and ***Blanket bog*** can occur.

Associated fauna

Flushes are important habitats for upland fauna. They are qualitatively different from most other moorland habitats, while usually occurring in intimate mosaics with them. They provide important refuge areas for moorland fauna in times of drought. They often have higher species diversities of insect groups, like beetles, and a more distinctive assemblage of species, than the surrounding moorland habitats and some of the rarest moorland spiders are associated with this habitat. Lime-rich springs and flushes are an important habitat for a number of rare flies (*e.g. Oxycera* spp.) and rare snails (*e.g. Vertigo geyeri* and *V. genesii*, both RDB1 spp. and listed on Annex II of the EC Habitats and Species Directive). At lower altitudes flushes with abundant *Succisa pratensis*, grazed by cattle, can be important for the declining butterfly *Eurodryas aurinia* (listed in Annex II of the EC Habitats and Species Directive). Flushes also support high densities of certain kinds of invertebrates such as craneflies which as both larvae and adults are important food sources for many moorland vertebrates. Moorland grouse and waders lead their chicks to flushes soon after hatching to take advantage of the abundance of invertebrate prey. Some birds, such as Black Grouse, favour flushes with tall cover. Ring Ouzels may favour flushes as foraging sites. Flushes also may be important for shrews, frogs and toads.

Tall herbs

Structural features

This habitat can include variable mixtures of plant species drawn from a wide range of taller herbs and ferns which, when ungrazed, produce dense stands of mostly deciduous vegetation up to 50 cm tall. Dwarf-shrubs or small shrubs may also be present, potentially increasing the height of the vegetation to 1.5 m and adding to its structural complexity. A variety of small herbs also may occur, particularly where open niches are provided by broken ground or substrate instability. There are strong similarities with the field layers of woodland and scrub and at altitudes below the treeline it may represent the sole surviving component of these habitats where browsing has eliminated the woody species. Where grazing pressure is low or absent this type of habitat may grade into, or form a subcomponent of, dwarf-shrub, scrub or woodland habitats.

Topographic location and physical environment

In the uplands this habitat is most often encountered on cliff ledges or other areas of very broken and rough topography to which access by grazing animals is restricted. Impoverished and suppressed examples sometimes may be found in more accessible situations.

It can be found over a wide altitudinal range from near sea level to about 900 m. Although some of the species present will vary with increasing altitudes, many of the tall herb and fern species are not strictly montane or even sub-montane and can be found over a wide range of altitudes, often occurring in the ungrazed field layers of woodlands or the banks of watercourses. Protection from winter cold by snow cover is important at higher altitudes and this means that the habitat shows a somewhat greater occurrence on north and east aspects where there is a greater tendency for snow cover to be maintained.

Soils are variable in depth and structure. They range from undifferentiated accumulations of rock fragments with variable amounts of silt, loam or humic material to more fully developed soils similar to rendzinas, brown earths or brown podzolic soils. Soil reaction can range from acid to near neutral and there is often considerable mineral enrichment directly from the substrate or by dry or wet flushing. There is usually free drainage but soils are often moist, or even wet, and to some extent this habitat grades into ***Flushes***. At higher elevations the soils are more unstable, due to freeze-thaw effects, flushing and slippage, and sometimes the physical instabilitv of the substrate, which makes the habitat more open and structurally more dynamic.

Associated flora

The most common tall herb species are *Alchemilla glabra*, *Angelica sylvestris*, *Geranium sylvaticum*, *Geum rivale*, *Heracleum sphondylium*, *Luzula sylvatica*, *Sedum rosea*, and *Trollius europaeus*. Also, *Deschampsia cespitosa* is often abundant and may be a dominant. *Rubus saxatilis* can sometimes be quite frequent in more lime-rich areas. *Crepis paludosa*, *Filipendula ulmaria*, *Succisa pratensis*, and *Valeriana officinalis* are less common dominants. Ferns such as *Oreopteris limbosperma* and, locally in the Highlands, *Athyrium distentifolium* can be abundant or dominant in specific situations.

Soil acidity greatly influences plant species composition and diversity. Acid conditions tend to be indicated where *Blechnum spicant*, *Dryopteris dilatata*, *Dryopteris expansa*, *Luzula sylvatica* and *Vaccinium myrtillus* are abundant. Plant diversity is usually low on acid soils. The greatest diversity of plants are found at higher altitudes on more lime-rich soils. Widespread species indicative of relatively lime-rich soils include *Carex flacca*, *C. pulicaris*, *Cirsium heterophyllum*, *Geranium sylvaticum*, *Geum rivale*, *Linum catharticum*, *Selaginella selaginoides* and the moss *Ctenidium molluscum*. These are widespread, distinctive species occurring over a wide range of altitudes and under a wide range of grazing pressures, although the taller species may be dwarfed where there has been prolonged heavy grazing. Rare sub-arctic willows, such as *Salix arbuscula*, *S. lanata*, *S. lapponum*, *S. myrsinites* and *S. reticulata*, occur in similar situations at higher altitudes on more lime-rich substrates but are best treated as a type of ***Scrub***. They may have been more abundant in the past when browsing pressures were less.

Associated fauna

Information on the qualities of this habitat for animals is sparse. This is partly a result of its scarce and fragmentary occurrence. In heavily grazed stands small mammals, insects and other invertebrates are not likely to be diverse or abundant since the availability and diversity of food will be low and cover will be lacking. Where grazing is much reduced, or absent, food and cover will be provided for Wood Mice, voles and shrews. Insects and other invertebrates are likely to be diverse and abundant, benefiting from the diversity of plants and plant structure, food mass and shelter provided by a moderately large standing crop of plant material. What limited data there is suggests that ungrazed examples of this habitat support invertebrate species which are absent or rare in surrounding grazed moorland habitats.

Scrub

Structural features

This is a somewhat heterogeneous habitat type characterised by dominance of shrub species, but including dwarf woodland composed of stunted, slow growing trees or mixtures of these and shrubs. Tree and shrub strata are not usually distinct from each other. The vegetation height ranges from 1 m - 5 m tall, but is mostly 1 m - 3 m tall. If trees are present, and are not stunted and slow growing, then the habitat is successional and is likely to become woodland or high forest. Trees may be absent due to a history of extensive removal of timber coupled with failure of regeneration due to browsing or lack of seed sources. The habitat can also include, variously, one or more additional structural and compositional components including distinct ground (bryophytes) and field (forbs and dwarf-shrubs) strata. These field and ground layers may be dominated by dwarf-shrubs, graminoids, forbs, and/or bryophytes which have structural and compositional similarities to open moorland habitats dominated by the same kinds of plants, although the shade from the tree and shrub component provides conditions of greater shelter and humidity and, within gaps in the canopy, greater warmth than on the open moorland. These different layers may compete for expression, through competition for light and availability of seedling regeneration sites, and although they may not all be present this habitat can potentially display a more complex vertical structure than other upland habitats. Particularly characteristic is the presence of relatively large woody structures, both alive and dead, and the provision of large seeds (nuts) by tree/shrub species which are sometimes present. Habitat complexity can be enhanced further by the development of epiphytic algae, lichens and bryophytes on branches and stems and the production of fruiting bodies from fungi associated with decaying wood or the mycorrhiza of the trees and shrubs.

Topographic location and physical environment

In the uplands this habitat is most often encountered as small, fragmented stands on cliff ledges or other areas of very broken and rough topography which are relatively inaccessible to vertebrate herbivores. Stands are sometimes found in more accessible situations where browsing pressure has been low. The habitat can be found on slopes varying from almost level to almost vertical and it occurs over a range of altitude from near sea level to about 900 m. The greatest variety of types is found below 500 m, and the greatest frequency and extent of occurrence is probably at altitudes of less than 300 m. Certain types only occur at higher elevations: juniper scrub occurs mostly above 300 m and sub-arctic willow scrub is mostly found above 600 m. At altitudes higher than about 600 m protection from severe winter weather by snow cover is probably important, and the higher occurrences tend to be on northerly aspects where snow cover is more reliable. Although some of the associated species occur only towards one or other of the altitudinal extremes, many of the species can be found over a wide range of altitudes.

Soils are very variable in depth, degree of development, acidity, fertility and moisture status. Types range from unstructured rankers to podzols, peaty podzols, brown podzolic soils, and brown earths. Soils are usually relatively free draining but often permanently moist or even wet. Only occasionally is there some gleying or peat development. Mostly they are acid but can be almost neutral. This variation in soil conditions considerably affects the composition of the flora.

Associated flora

The main tree and shrub species are *Betula pubescens*, *Juniperus communis*, *Salix cinerea*, *Salix aurita*, and *Sorbus aucuparia*. Rarer but distinctive scrub forming species are *Salix lapponum* (at high altitudes), *Populus tremula*, *Corylus avellana* (at lower altitudes, especially near the west coast) and, around the low altitude margins of the uplands, *Ulex europaeus* and *Cytisus scoparius*. High altitude sub-arctic willow scrub, which usually occurs only where there is some lime-enrichment of the substrate as well as no grazing, may be composed of *Salix arbuscula*, *S. lanata*, *S. lapponum*, *S. myrsinites* and *S. reticulata* singly or in various mixtures. *Pinus sylvestris* and *Betula pubescens* may sometimes be present at the very rare occurrences of natural treeline as stunted and twisted "krummholz", while *Betula pendula*, *Crataegus monogyna*, *Fraxinus excelsior*, *Ilex aquifolium*, *Prunus padus*, *Quercus petraea*, *Salix caprea*, and *Ulmus glabra* may all occur on occasion (usually at lower altitudes).

The dwarf-shrubs, herbs and bryophytes in the field and ground layer can be very variable. The tree and shrub layer can act as an overlay over a variety of other open moorland habitat types with which there can be a strong similarity in flora. Typical species include subsets from the following: the dwarf-shrubs *Calluna vulgaris*, *Vaccinium myrtillus* and *V.*

vitis-idaea; the graminoids *Agrostis capillaris*, *Anthoxanthum odoratum*, *Deschampsia flexuosa*, *Holcus mollis*; the ferns *Blechnum spicant*, *Dryopteris dilatata*, *Pteridium aquilinum*; the forbs *Galium saxatile*, *Oxalis acetosella*, *Potentilla erecta*, *Viola riviniana*; and the bryophytes *Dicranum majus*, *D. scoparium*, *Hylocomium splendens*, *Lophocolea bidentata*, *Mnium hornum*, *Plagiothecium undulatum*, *Pleurozium schreberi*, *Pseudoscleropodium purum*, *Rhytidiadelphus loreus*, *R. squarrosus*, *R. triquetrus*, and *Thuidium tamariscinum*. The precise mix of species present depends on the degree of shade cast by the trees and shrubs and the acidity and wetness of the soil (as well as grazing and burning effects). As the tree and shrub canopy becomes more complete species more characteristic of true woodland or high forest habitat become more prominent, *e.g.* herbs such as *Anemone nemorosa*, *Circaea lutetiana*, *Geum urbanum*, *Hedera helix*, *Hyacinthoides non-scripta*, *Lonicera periclymenum*, *Oxalis acetosella*, *Primula vulgaris*, *Rubus fruticosus*, *Trientalis europaea* can variously become more prominent. Lichens are usually poorly represented in the ground layer but as epiphytes on the stems and branches can be diverse and sometimes abundant.

Associated fauna

No attempt is made here to define or summarise all major aspects of the typical fauna of scrub. This is partly because this would entail an extended digression into the faunal communities of true woodland or high forest habitat, which is outside the scope of this guide, and partly because stands of upland scrub can be very heterogeneous in composition, structure, degree of fragmentation, and isolation and this is likely to be reflected in the associated faunas. Also, information specific to upland scrub is limited.

Nevertheless, a few generalisations can be attempted. Scrub potentially provides a wide array of resources for fauna including both live and dead wood in relatively large sizes, sap runs, rot holes, nectar and pollen from flowers (mostly of herbs in the field layer), seeds (some of large size), leaves and shoots, mostly within a relatively sheltered microclimate. The amounts of some of these resources are likely to be inversely related to each other. Wood is present in dwarf-shrub habitats but in smaller total amounts and in items of much smaller dimensions. The balance of faunal functional types and the total faunal species diversity is likely to depend on the mix of habitat components present and the complexity of the physical structure of the habitat. Diversity is likely to decline if the trees and shrubs become totally dominant. Particular herbivore groups can also influence the availability of resources for other groups. An example is the negative effects of heavy grazing of the field layer by larger herbivores on the abundance and diversity of moth and sawfly larvae which feed preferentially shoot tips, through removal or reduction in quality of food and incidental predation.

Typical small mammals include Field Vole, Bank Vole, Common Shrew, Wood Mouse, Rabbit and Mountain Hare. Carnivores preying on these may include Weasel, Stoat, Pine Marten, Fox, Wild Cat and Badger. Most small mammals, particularly voles, require some herbaceous ground cover. The amount of this, which is inversely related to the density of the shrub and tree layer, is an important determinant of small mammals diversity and abundance. However, Wood Mice may forage in areas with little ground cover and rabbits may establish colonies in woodland with little ground cover if there are nearby areas of herbaceous growth on which they can forage. Large herbivores may include Roe Deer, Red Deer, Sika Deer, sheep, and more rarely cattle and feral goats.

Bird species present are mostly a subset of those which occur in lowland scrub and woodland with one or two exceptions. Which species are present is influenced by which tree and shrub species are present (particularly whether coniferous or broad-leaved), the height and density of trees (trees are mostly short), the presence of old wood with holes for nesting, and the density of shrub and field layers. The commonest birds are usually Willow Warbler and Chaffinch, along with Tree Pipit, Wren, Robin, Stonechat, and Whinchat. Other species which may use scrub to a greater or lesser extent for breeding or feeding include Sparrowhawk, Buzzard, Black Grouse, Wood Pigeon, Tawny Owl, Long-eared Owl, Dunnock, Redstart, Blackbird, Song Thrush, Redwing, Mistle Thrush, Whitethroat, Wood Warbler, Spotted Flycatcher, Pied Flycatcher, Goldcrest, Long-tailed Tit, Coal Tit, Blue Tit, Great Tit, Treecreeper, Carrion/Hooded Crow, Bullfinch, Siskin, and Redpoll. Some open moorland birds, such as Meadow Pipits, may persist where trees and bushes are scattered. Scrub fragments on steep, rocky slopes are favoured nesting sites for Ring Ouzel. Black Grouse favour areas of habitat mosaics which include scrub and woodland.

For the invertebrates, some of the species will be the same, or similar, to those found in other habitats which are analogous to the field layer in this habitat (see ***Dwarf-shrub heath***, ***Tall herbs*** and ***Tussock grassland*** habitats). The diversities of leaf feeding invertebrate herbivores on widespread trees and shrubs tend to be similar to the diversities on similarly widespread dwarf shrubs and herbs. Indeed, there can be some overlap in species. Very restricted species, such as sub-arctic willows, are unlikely to support a very diverse or abundant invertebrate fauna, although rare specialist species are known to occur. However, compared with dwarf-shrubs and herbs, trees and shrubs have the potential to support additional functional types such as bark and wood boring species and dead wood specialists. Functional types such as leaf miners and gall-makers are likely to be much more abundant and diverse than in other upland habitats. Fungi also tend to be more abundant and diverse than in other upland habitats and this also provides opportunities for a wider array of invertebrates fauna. Wood Ants (*Formica* spp., such as *F. lemani*) are a sometimes distinctive feature of areas of scrub and woodland while the sawflies (Symphyta) are an insect group which is likely to be much more abundant and diverse than in the other upland habitats. Alpine willows are known to be hosts for rare arctic sawflies. The shelter provided by scrub is likely to be important for many species including some otherwise open ground species of Lepidoptera and Odonata.

Blanket Bog

Structural features

This habitat type is characterised by soil conditions which are acid, infertile, and waterlogged close to the ground surface. Other than in pools, there is usually a shallow, relatively aerated surface layer. The depth of this layer is determined by closeness of the watertable to the surface. The shallowness of the aerated surface layer severely restricts the rooting depth and vigour of many plants which might otherwise grow on this sort of nutrient-poor substrate. The most characteristic species are bog mosses (*Sphagnum* spp.) and a small number of graminoids which have air conducting tissues in their roots and are capable of growing in waterlogged conditions, such as *Eriophorum* spp. and *Molinia caerulea* (the latter especially in the west). Where *Eriophorum vaginatum* is present it contributes a sometimes pronounced tussocky component to the vegetation (*Molinia caerulea* usually does not show strong tussock-formation except in water-tracks and flushes). The decomposition characteristics of most of the main structural plant species perpetuate the soil conditions and lead to the formation of peat. The poverty of plant mineral nutrients is illustrated by the often frequent occurrence of insectivorous plants, particularly *Drosera* species. The bryophyte layer is an important component forming more or less extensive, undulating or hummocky surfaces. It is usually at least 3 cm deep but when luxuriant it can attain an average depth of 15 cm. Bryophyte hummocks may be up to 50 cm high. The sedge, grass and herb component is generally 20 cm - 30 cm tall but may sometimes be as short as 10 cm or exceed 50 cm. Graminoid tussocks may exceed 30 cm tall but well developed tussocks are not always present, particularly where the ground is wettest and soil water is stagnant. A woody dwarf-shrub component is less characteristic and, though often present, it is usually either patchily distributed and/or weakly developed with plants often less than 20 cm tall. Tussocks and hummocks provide structural variation and increase the amount of surface material which is not completely waterlogged.

Blanket bogs are characterised by a range of distinctive structural features including pool, "wet hollow", "lawn", "ridge", "hummock" and "peat mound" elements. Their collective arrangement is termed "patterning". The wetter the climate the more pronounced patterning becomes. Pools are a conspicuous feature of some of the most fully developed and most distinctive examples of blanket bog, though they are not always present. Although strictly pools could be considered a separate aquatic habitat their existence is heavily dependent on the integrity and normal functioning of the surrounding bog and complexes of bog surface and pools are best regarded as a single composite habitat. Pools vary considerably in size, shape, depth and orientation. Large pools are very long-lived features though shallow pools may sometimes temporarily dry out. Wet hollows, which are more clearly part of the bog habitat proper, are small features (0.5 m^2 - 1 m^2) in which a dense carpet of aquatic or semi-aquatic *Sphagnum* mosses grow in shallow water. "Lawns" dominated by *Sphagnum* mosses within 10 cm of the watertable may be extensive in flat wet depressions, or they may occur as a narrow band around pool edges or form part of a small scale mosaic of patches (each up to 1 m^2) between wet hollows, ridges and hummocks. Ridges are usually the most extensive surface feature and are formed from relatively firm peat between 10 cm - 20 cm above the water table and support a vegetation in which sedges and dwarf-shrubs may be prominent. Ridge can occur as small scale surface features (up to 2 m^2 in size) between other structural features but in comparatively dry situations it may be the only surface feature present giving the bog a relatively uniform appearance. Hummocks are formed largely by bog mosses but growing on their tops there may be dwarf-shrubs, sedges, grasses and mosses more characteristic of heathland. Peat mounds are a highly localised and unusual structural feature found in the extreme north and west of Scotland. They stand 1 m - 2 m above the surrounding mire expanse and are characterised by being composed completely of peat with a covering of heath vegetation dominated by dwarf-shrubs, with an underlying dense layer of mainly heathland mosses.

Topographic location and physical environment

Blanket bog occurs throughout the Scottish uplands but its distinctive characteristics are most fully expressed, and it occurs most extensively, in the wetter west and north. It occurs over flat, gently sloping or undulating terrain. It occurs most extensively between 100 m and 600 m altitude but its range extends from sea level to (exceptionally) near 900 m. It generally occurs on slopes of less than 10°, but can sometimes be found on slopes of up to 25°. Blanket bog can form extensive flat moors broken only by rivers, lochs and roads (*e.g.* in the vast flows of Caithness, Sutherland and north Lewis) or a more patchy cover where the landscape is more rugged and broken (*e.g.* in much of west Scotland). Where hills are more rounded, with convex slopes, blanket bog can form extensively on hill-top plateaux, ridges, and saddles (*e.g.* in the Grampians). The nature of the topography largely determines whether transitions to other habitat types are abrupt or gradual. The degree to which continuously wet and humid conditions are maintained at the soil surface is a critical factor and differences in total annual rainfall, average humidity (and its variability), and accumulated annual temperatures considerably influences the presence of particular species, vegetation components and types of surface patterning.

Underlying the vegetation is peat: partially decomposed plant remains. This is generally more than 2 m deep, though sometimes it is considerably deeper and occasionally as shallow as 0.5 m. The peat is generally acid to very acid and poor in plant mineral nutrients. The top 10 cm - 50 cm is usually more fibrous and spongy with some degree of aeration. Water moves through this upper layer relatively quickly. Below this, compaction increases and stagnant, waterlogged conditions are more or less continuous. Water movement and decomposition occur very slowly in this deeper zone which makes up the main mass of the peat.

Associated flora

In bog pools and wet hollows *Eriophorum angustifolium* is one of the most commonly encountered plants. *Menyanthes trifoliata*, *Sphagnum auriculatum* and *S. cuspidatum* are also frequent in these situations and sometimes *Drosera rotundifolia*, *Erica tetralix*, *Rhynchospora alba*, *Sphagnum recurvum* and *Vaccinium oxycoccos* may be locally abundant around the margins.

On the vegetated bog surface *Sphagnum capillifolium* is often the most widespread and abundant bog moss. *Sphagnum papillosum* is only slightly less widespread and frequent and is an important peat-former. Other widespread and usually frequent species include the "sedges" *Eriophorum angustifolium*, *Eriophorum vaginatum* (in slightly drier situations) and the dwarf-shrubs *Erica tetralix* and *Calluna vulgaris* (the latter only where there is some unwaterlogged rooting medium). The grass *Molinia caerulea* and "sedge" *Trichophorum cespitosum* are only slightly less widespread and frequent species. The bog mosses *Sphagnum magellanicum*, *S. recurvum*, *S. subnitens*, *S. palustre*, and *S. tenellum* are also common. A range of other species can be locally frequent, and sometimes abundant, in particular types of situation or within particular geographical areas. These may include: bryophytes such as *Aulacomnium palustre*, *Odontoschisma sphagni*, *Racomitrium lanuginosum*; lichens such as *Cladonia arbuscula*, *C. portentosa* and *C. uncialis*; herbs such as *Drosera rotundifolia*, *Narthecium ossifragum* (in water-tracks and bog flushes), *Polygala serpyllifolia*, *Potentilla erecta* and *Rubus chamaemorus*; and dwarf-shrubs such as *Betula nana*, *Empetrum nigrum*, *Erica cinerea*, *Myrica gale*, *Vaccinium myrtillus* and *Vaccinium uliginosum*. Where there is drying of the peat or the peat is shallow (less than 50 cm deep), or where there is some water movement and increase in the supply of plant mineral nutrients, then a range of other dwarf-shrub, herb, grass, sedge and moss species may be found. These are generally more characteristic of acid grasslands, dwarf-shrub heaths or flushes than of blanket bog.

Associated fauna

The vertebrate fauna is moderately diverse, and includes some characteristic species, although few species are both widespread and abundant. Invertebrates are abundant and diverse in the pool systems but less so on the terrestrial bog surface. A wide range of species will use the habitat on occasions. Food resources are limited since many of the plant species have relatively unpalatable foliage, especially the *Sphagnum* mosses and other bryophytes which constitute a substantial proportion of the plant biomass. Pollen, nectar and berry resources are also relatively limited in comparison with dwarf-shrub habitats. However, the early spring flushing of some of the common grasses and "sedges", *e.g.* the early-emerging flower heads of cottongrasses, can make these areas attractive to herbivores at certain times of year. The oxygen depleted and acid conditions a short distance below the surface also restricts the abundances and diversity of soil organisms, although some of these species do occur at high densities and can provide a seasonally important food resource for other species. The pool component provides an important source of prey and the greatest faunal diversities are associated with bogs in which pool systems are present.

A wide variety of bird species use blanket bog areas, with the greatest diversity being found in the north of Scotland. Among the most widespread and characteristic birds are the Golden Plover, Dunlin, Greenshank, and to a lesser extent Curlew and Red Grouse (the last particularly on drier bogs in which *Calluna vulgaris* is common). These species both nest and feed on the bog but may also use surrounding flushes, dwarf-shrub heaths, and grasslands and they all occur in other habitats, sometimes at greater densities. Open water, either as pools or associated lochs and watercourses, are important feeding areas for Greenshank. In a few locations Greenland White-fronted Geese winter on blanket bogs, feeding on the leaf bases of cottongrasses and other "sedges". Passerines tend to occur at comparatively low densities compared with drier moorland habitats but Meadow Pipits and Skylarks can be numerous. Other species which use blanket bog mainly as a relatively safe nesting refuge include Red-throated Diver, Greylag Goose, Mallard, Teal, Widgeon, Common Scoter, Common Gull, Black-headed Gull, Arctic Skua and Great Skua. Other species which may nest in bog habitat but are not strongly dependent on it include Whimbrel, Snipe and Redshank. A number of species such as Peregrine, Golden Eagle, Hen Harrier, Merlin, Short-eared Owl, Hooded Crow and Raven may hunt or scavenge over bogs (with Hen Harrier and Short-eared Owl sometimes also roosting and nesting where there is well developed ground cover).

The full range of wild moorland mammals, plus cattle and sheep, may use bogs at some time. However, bogs are not the preferred habitat of any of these, although they may be attracted to it at certain times of year by the flushing of particular plants or seasonal peaks in the availability of prey species. Water Voles may also be present in small numbers and Common Lizards and Adders are not uncommon. Amphibians are a distinctive component of the vertebrate fauna.

The invertebrate fauna is moderately diverse, particularly flies (Diptera). The fauna typically has affinities with the faunas of arctic or sub-arctic regions, although one of the commonest flies, *Empis verralli*, is only doubtfully found outside Britain. There is some overlap of species, particularly predatory species, with flushes, dwarf-shrub heaths and acid grasslands. Species which are aquatic, semi-aquatic, or sensitive to desiccation are particularly characteristic. Craneflies and spiders are particularly diverse in this habitat when compared with other moorland habitats.

The aquatic fauna of the pools is diverse and includes a number of rare and scarce waterbeetles as well as a wide range of micro-organisms, small crustaceans, aquatic mites, chironomid midge larvae and a selection of other aquatic insects groups. The aquatic phase extends into the wet bog mosses around pool margins and in wet hollows. Dragonflies and damselflies, which have aquatic predatory larvae, are among the most obvious of the invertebrates: particularly characteristic are *Sympetrum danae*, *Leucorrhinia dubia* (scarce), and *Coenagrion hastulatum* (very rare in eastern Highlands, RDB 2); the scarce *Aeshna caerulea* and *Somatochlora arctica* are bog species most likely to be found near to trees and scrub; *Aeshna juncea* and *Libellula quadrimaculata* are common but not distinctively bog specialists. The widespread though rarely seen chrysomelid beetle *Plateumaris discolor*, whose larvae feed on the roots of *Eriophorum*, is thought to be an important prey item in the diets of wading birds of the blanket bogs.

The average number of terrestrial species found on the terrestrial bog surface tends to be similar to that on drier dwarf-shrub heath though the composition and abundances of groups varies and the total invertebrate biomass may be somewhat higher. Most of the soil fauna occurs in the top few centimetres of the soil above the water-logged peat. The most abundant terrestrial invertebrates are the nematode worms, pot worms (Enchytraeidae, *e.g. Cognettia sphagnetorum*), springtails (Collembola), mites (Acari), craneflies (Tipulidae), and bugs (Hemiptera); most of the terrestrial invertebrate biomass consists of populations of the first five of these. In numbers of individuals each of these groups exceeds most other invertebrate groups by one to two orders of magnitude. Nematodes and mites are less abundant than in other moorland habitats although they still occur in huge numbers, while pot worms can be as abundant as in grassland on brown earth soils. Flies (Diptera) in general are abundant and diverse and species belonging to the Empidae, Dolichopodidae and Phoridae are well represented in addition to Tipulidae. Craneflies are an important prey species and the most common species are *Molophilus ater* (whose larvae feed on decomposing plant remains and other decomposer organisms) and *Tipula subnodicornis* (whose the larvae feed mainly on *Eriophorum* and mosses). At higher altitudes there is usually a pronounced spring peak of emergence of these flies. Lepidoptera species and densities are much lower than on dry heaths although a small number of fairly distinctive and sometimes conspicuous species like *Coenonympha tullia* and *Euthrix potatoria* do occur.

Predatory invertebrates include arachnids, ground beetles (Carabidae) and rove beetles (Staphylinidae). Spiders densities tend to be quite high in comparison with other uplands habitats. Characteristic species include the wolf spiders (Lycosidae) *Pirata piratacus*, *Pirata uliginosus*, *Antistea elegans* (Hahniidae), and the small Linyphiidae *Ceratinella brevipes*, *Lepthyphantes angulatus*, and *Walckenaeria clavicornis*. Linyphiid spiders form a high proportion of the spider fauna, much higher than in other habitats with the exception of high altitude heaths (altitude is probably the more important factor). Also, species such as the wolf spiders *Alopecosa pulverulenta*, *Pardosa pullata*, *Pardosa nigriceps*, and *Trochosa terricola*, and the linyphiids *Centromerita concinna*, *L. ericaeus*, *L. zimmermanni*, *Silometopus elegans*, which occur in a range of moorland habitats, are often common. Orb-web spiders tend to be scarce except in peat haggs where the spiders can find anchorage points for their webs. Harvestmen can also be quite abundant predators: the commonest species is *Mitopus morio* but *Rilaena triangularis* and *Lophopilio palpinalis* may be quite frequent. Typical carabid beetle species include *Agonum ericeti*, *A. fuliginosum*, *Carabus nitens*, *C. violaceus*, and *Pterostichus diligens*, and *P. nigrita* s.l. while a number of widely occurring species such as *Carabus problematicus*, *Dyschirius globosus*, *Leistus rufescens* and *Loricera pilicornis* can be abundant.

Wind-clipped summit heath

Structural features

A very short and sometimes patchy wind-clipped mat of vegetation, usually less than 10 cm thick, distinguishes this habitat. The vegetation cover can be almost complete at lower altitudes and in less exposed situations, but at higher and more exposed locations there is usually much bare ground caused by frost heaving and wind erosion. This is particularly the case where the vegetation changes to *Juncus trifidus* heath where the character of the vegetation changes to scattered patches of low, tussocky growth. Evergreen and deciduous vascular plants, including flower and berry producing prostrate dwarf-shrubs, may be abundant but frequently either mosses or lichens are dominant. Shoots and stems of plants are often oriented in approximately the same direction, parallel to the prevailing wind direction. Where there is some flushing by seepage from lime-rich rocks gradations to montane, dwarf-herb rich types of ***Smooth grassland*** may occur. Vegetation productivity is very low.

Structurally very similar vegetation can occur at lower altitudes in extremely exposed situations, especially near the coast. The less extreme temperature regimes here result in differences in species composition, with a reduced contribution from Arctic-Alpine species, and a close floristic relationship with sub-montane ***Dwarf-shrub heath***.

Topographic location and physical environment

This habitat normally occurs at high altitude. The lower limit is typically about 600 m in the most "continental" parts of the east, central Highlands but descends down to less than 250 m in the north-west Highlands. The climate is severe. It is normally cold and wet, with frequent strong winds, for much of the year. The habitat occurs on exposed convex slopes, ridges and plateau tops where, although subject to snow-lie in winter, the snow does not accumulate to form significant drifts. Sometimes, these areas are blown almost clear of snow and are then exposed to severe frost, the desiccating effects of wind and damage by ice-crystal blasting.

Soils are very dynamic due to vigorous frost heaving and the redistribution of surface material by the wind. They are usually shallow, acid and poorly developed, often being not much more than humic material mixed with rock fragments, boulders or gravel. Sometimes, deeper soils with podzol profiles can be found in hollows. Soils may remain almost continously moist because of prolonged periods of high humidity but equally, in some situations, particularly in the drier eastern Highlands, parched conditions may periodically occur in summer due to the combination of shallow, free-draining soils and strong drying winds.

Associated flora

Mosses, particularly *Racomitrium lanuginosum*, and/or lichens such as *Cladonia arbuscula, C. rangiferina*, and *C. uncialis* (and to a lesser extent *Cetraria islandica, Coelocaulon aculeatum, Alectoria nigricans*, and *Sphaerophorus globosus*) are very abundant. *Racomitrium* heaths are most abundant in the western half of the country, and at high altitudes, while lichen heaths are better developed in the east and at somewhat lower altitudes. *Juncus trifidus* heaths occur at high elevations, mostly in the Cairngorms. At high altitudes *Carex bigelowii* is a common associate of *Racomitrium lanuginosum* and the bryophytes *Dicranum fuscescens* and *Polytrichum alpinum* also can by moderately abundant. Dwarf-shrubs such as *Calluna vulgaris, Vaccinium myrtillus, Empetrum nigrum* (subspecies *hermaphroditum* at higher altitudes) may be frequent. In some situations *Arctostaphylos alpinus, Juniperus communis* subspecies *nana*, or *Loiseleuria procumbens* may be moderately frequent, particularly at higher altitudes. Fine-leafed grasses such as *Deschampsia flexuosa, Festuca ovina* and *F. vivipara* are often present in small amounts. In scattered localities, particularly in the western Highlands, mat-forming or cushion-forming flowering plants such as *Silene acaulis, Minuartia sedoides, Sibbaldia procumbens, Armeria maritima*, and *Alchemilla alpina* may be present in small amounts.

Associated fauna

The fauna is not very diverse but it does include some very characteristic and specialised species. Among the most obvious are two birds, the Dotterel and the Ptarmigan, with additionally Snow Bunting on the highest tops in the Highlands. Golden Plover may also be present, particularly where the habitat is associated with montane bogs and extensive flushes. A sparse presence of Meadow Pipits and Wheatears is also fairly typical, with Ravens often frequently seen in western areas, while Red Grouse and Skylarks are marginal associates. Birds of prey such as Golden Eagle, Peregrine and Kestrel may sometimes hunt over this type of area.

Mountain Hares occur, while shrews, voles, Wood Mice, Foxes, Stoats and Weasels may all occur sporadically.

Invertebrates are also relatively limited in diversity. Many of these live under stones or deep within the shelter of the vegetation mat. A small number of characteristic day-flying moths occur, such as *Psodos coracina*, *Anarta melanopa* and the very local *Zygaena exulans subochracea* (RDB3), all of whose larvae feed on crowberry and ericaceous dwarf-shrubs. A range of specialised Arctic-Alpine, Alpine, Boreal and Northern species from a range of groups including sawflies, empid flies, crane-flies, muscid flies, anthomyiid flies, weevils, predatory carabid and staphylinid beetles, harvestmen, linyphyiid spiders and wolf spiders occur. The crane-fly *Tipula montana* is often the most obvious species during its brief period of adult emergence and it is an important diet component for a number of birds. Some of the more specialised insects have a reduced ability to fly, and are therefore unlikely to disperse and recolonise, should their habitat be damaged.

Dwarf-shrub heath

Structural features

This habitat type is characterised by the high frequency, and sometimes overwhelming abundance, of dwarf-shrubs. These provide a low, woody, structural element which is usually partially, or completely, evergreen. The vegetation is generally between 10 cm and 30 cm tall but both very short patches and patches up to 50 cm are not uncommon. Less commonly the vegetation may reach a height of 100 cm. Spatial variation in structure is often considerable, both between patches and within patches. This is determined to a large extent by the pattern, frequency and intensity of a variety of types of disturbance (see below), but also by which species of dwarf-shrub and associated species are present. Also characteristic is the potential occurrence of high densities of flowers (and pollen, berries and seeds) over extensive areas for two to three months of summer, although this is sometimes reduced by factors such as heavy browsing. A well developed stratum of forbs, mosses, lichens and plant litter is often present under or between the dwarf-shrubs and this may form a dense mat up to 10 cm thick. If the dwarf-shrubs are very dense this mat may be relatively thin and composed mostly of plant litter. Epiphytic algae, lichens and bryophytes are sometimes present on the stems of the dwarf-shrubs in less disturbed patches. Generally, bryophytes and lichens are more diverse, frequent and abundant than herbs.

Topographic location and physical environment

These heaths occur throughout most of the climatic range of the Scottish uplands. They occur over a wide range of altitudes and slopes. They occur most extensively between 200 m and 700 m but their range extends both down to sea level and up to over 900 m. At high altitudes, and in very exposed locations at lower altitudes, they grade into wind-clipped, prostrate heaths (see ***Wind-clipped summit heath***). Differences in humidity and annual temperature range considerably influence the development of different vegetation components and alter their species composition. The depth and duration of snow influences both the occurrence of this habitat and its species composition, with the diversity and structural development of the dwarf-shrubs being reduced both in exposed areas with little snow cover and in areas of regularly heavy snow cover.

Soil types range from shallow, fragmentary rankers to better developed acid podzols. Less commonly the soils may be acid to near neutral brown earths. There is often a well-developed peaty, humic layer on top, sometimes 10 cm or more thick, but true peat soils are rarely involved and are always less than 0.5 m thick. However, the vegetation on deeper peats which have become dry, through drainage or erosion, becomes dominated by dwarf-shrubs and is superficially similar to this habitat (see ***Blanket bog***). Soils are mostly free draining and never waterlogged, though they may remain moist because of high rainfall. Sometimes there is partial drainage impedance as a result of the development of an iron pan in the soil.

Associated flora

Common dwarf-shrubs species include *Calluna vulgaris*, *Empetrum nigrum* (subspecies *nigrum*), *Erica cinerea*, *Vaccinium myrtillus*, and *Vaccinium vitis-idaea*. Of these *Calluna vulgaris* has the widest geographical and ecological range and is usually the most abundant species. Other widespread species include forbs such as *Galium saxatile* and *Potentilla erecta*; the grasses *Deschampsia flexuosa* and *Festuca ovina*; the fern *Blechnum spicant*, particularly in western areas; the bryophytes *Dicranum scoparium*, *Hylocomium splendens*, *Hypnum cupressiforme*, *Pleurozium schreberi*, and *Racomitrium lanuginosum*; and the lichens *Cladonia arbuscula*, *C. portentosa* and *C. uncialis*. More locally the dwarf-shrubs *Arctostaphylos uva-ursi*, *Empetrum nigrum* (subspecies *hermaphroditum*), and *Genista anglica* can be common in particular situations. In areas of oceanic climate bryophytes can become very abundant and diverse, including a range of characteristic and sometimes colourful mat-forming liverworts (including *Anastrepta orcadensis*, *Bazzania tricrenata*, *Diplophyllum albicans*, *Herbertus aduncus hutchinsiae*, *Mastigophora woodsii*, *Mylia taylori*, *Pleurozia purpurea*, *Ptilidium ciliare*, *Scapania gracilis*, *S. ornithopodioides*). Lichens are found in the greatest abundance and diversity in the more continental parts of the eastern Grampians, and sometimes in coastal situations. There is often some overlap in species composition with acid grasslands, acid woodlands and bogs. A range of different associated herbs may be frequent in particular situations including: *Agrostis capillaris*, *Alchemilla alpina*, *Anthoxanthum odoratum*, *Carex pilulifera*, *C. pulicaris*, *Cornus suecica*, *Danthonia decumbens*, *Lathyrus linifolius*, *Luzula campestris*, *Melampyrum pratense*, *Molinia caerulea*, *Nardus stricta*, *Primula vulgaris*, *Prunella vulgaris*, *Pyrola* *media, Rubus chamaemorus, Solidago virgaurea, Trichophorum cespitosum, Thymus polytrichus* and *Viola riviniana.*

Associated fauna

The fauna, particularly the invertebrates, is moderately diverse and includes a small number of characteristic species. The food resources provided by dwarf-shrubs include berries and substantial amounts of pollen and nectar at certain times of year, as well as green shoots and foliage of widely varying palatability to herbivores. However, much of the faunal diversity is probably due to structural variation in the habitat produced by the wide range of plant types and growth forms present, enhanced by the spatially patchy and temporally variable disturbance regimes produced by burning and grazing. Different heights and densities of vegetation and different periods free from disturbance favour different species. The interface between dwarf-shrub habitat and other moorland habitats seems to be important for many species.

The most obvious members of the fauna include birds such as Red Grouse, Black Grouse, Merlin, Hen Harrier, Curlew, Golden Plover, Meadow Pipit, Short-eared Owl, Twite, Stonechat, Whinchat and Ring Ouzel. *Calluna vulgaris* and *Vaccinium myrtillus* provide a major item in the diet of Red Grouse and Black Grouse. Mountain Hare also is a characteristic species for which *Calluna vulgaris* is a major dietary component but, like Red Deer, open moorland is not an absolute requirement. If there is access to open woodland or scrub this will be utilised preferentially. Small mammals are usually present and sometimes moderately abundant. Field Vole and Pygmy Shrew are the most characteristic species but Wood Mouse and Common Shrew may also be present. This is an important hunting habitat for Golden Eagles and for upland mammalian predators (ranging from Weasels to Foxes) since live prey types of appropriate sizes are usually present and sometimes abundant. Common Lizard, Adder, and Slow Worm also may be present, particularly where there is a combination of patches of taller vegetation for cover and short vegetation for basking. Amphibians may be present in damper areas.

The most abundant soil invertebrates are nematode worms, pot worms (Enchytraeidae), springtails (Collembola) and mites (Acari). Earthworms are scarce: they are about an order of magnitude less abundant than in grassland. Above ground, mites, springtails, thrips (Thysanoptera) and to a lesser extent bugs (Hemiptera) are the most numerous invertebrates, although Lepidoptera contribute the greatest above-ground biomass. The tiny sap-sucking psyllid *Strophingia ericae* (Hemiptera), which lives in the leaf axils of *Calluna vulgaris*, can occur at densities of 1000's m^{-2} but they appear to have little effect on the plants. The populations of some Lepidoptera species and of the Heather beetle (*Lochmaea suturalis*) can occasionally reach "outbreak" proportions and cause considerable localised defoliation. The diversity of herbivorous and predatory invertebrates is moderately high and includes representatives from a wide range of taxonomic groups. For example, 15 % - 20 % of the total British carabid beetle and spiders faunas can be associated with this type of habitat.

Predatory species tend to be most strongly influenced by soil wetness and vegetation structure and few are restricted to this habitat. Important predatory groups include arachnids and ground beetles (Carabidae). Hammock-web spiders (Linyphiidae), which mostly feed on small prey such as mites and springtails, tend to be the most abundant and diverse of the spiders. Common characteristic spiders include the wolf spiders *Alopecosa pulverulenta* and *Pardosa nigriceps*, the theridiid *Robertus lividus*, the gnaphosid *Gnaphosa leporina*, and the linyphiids *Centromerita concinna*, *Lepthyphantes ericaeus*, *L. mengei*, *L. zimmermanni*, *Pelecopsis mengei*, and *Walckenaera acuminata*. Harvestmen, particularly *Mitopus morio*, are also common arachnid predators. Typical carabid beetles are *Bradycellus ruficollis*, *Calathus micropterus*, *Carabus nitens*, *Carabus violaceous*, *Trechus obtusus* and *Trichocellus cognatus*. Species such as *Calathus melanocephalus* agg., *Carabus problematicus*, *Nebria salina*, and *Patrobus assimilis* are relatively common and occur widely in many different moorland habitats but are often more abundant in drier dwarf-shrub habitat. The widespread, diurnally active tiger beetle *Cicindela campestris* can be conspicuous on recently burnt areas and tracks. Some of these spider and carabid beetle species are more characteristic of short, open vegetation (*e.g.* in the early years after a fire) while other species are more strongly associated with taller, denser, less disturbed vegetation. Many of the larger carabid species, which are often flightless and have slower rates of population growth, are much more abundant in rougher, less frequently disturbed types of vegetation such as dwarf-shrub heath. Dwarf-shrubs can provide relatively tall and rigid anchorage points required by many web-spinning spiders.

There are usually about 10 - 30 species of Lepidoptera at any one locality although the total number of species associated with this type of habitat over the whole of Great Britain is probably at least four times greater. Widespread characteristic species include the moths *Anarta myrtilli*, *Ematurga atomaria*, *Entephria caesiata*, *Eulithis populata*, *Eupithecia* *nanata*, *Hydriomena furcata*, *Lasiocampa quercus callunae*, *Lycophotia porphyria*, *Macrothylacia rubi*, *Perizoma didymata*, and *Pavonia pavonia* (the last is the only representative of the silk-moth family in the British fauna). Although some of these are large diurnally active species, most have cryptic colour patterns. This is a major habitat for most of these species although only a small number of them are strictly confined to it.

A wide variety of species use the enormous nectar and pollen resource which extensive and vigorous dwarf-shrubs provide. These include conspicuous bumblebees species such as *Bombus jonellus*, *B. lucorum*, and especially the more specialised and local *Bombus monticola*, as well as domestic honey-bees.

Tussock grassland

Structural features

The habitat is characteristically dominated by tussock forming grasses with a small proportion of associated non-tussock forming grasses, forbs and bryophytes. Stands may be almost completely dominated by one species. Tussocks are normally 10 cm - 30 cm in diameter but can be smaller or larger. There may also be scattered, and usually poorly developed, dwarf-shrub plants. The vegetation is usually grazed, though often only lightly. The dominant tussocks are usually lightly grazed, or ungrazed, but the associated plants may be more heavily grazed. The average height of the vegetation is normally 10 cm - 20 cm, with the inter-tussock vegetation varying from several centimetres to more than 10 cm tall (depending on grazing intensity) with the tussock part of the vegetation up to 30 cm tall. Less commonly, tussocks can be up to 50 cm tall over tussock cores 20 cm - 30 cm tall, with flowering shoots approaching 75 cm. At small spatial scales (less than a metre) the vegetation can be structurally diverse but at larger scales the habitat usually is relatively homogeneous. Structural variation is mainly provided by the tussocks. Large, old tussocks (one to several decades old) may become senescent, dying back from their centres. There is usually a well developed accumulation of dead plant litter up to a decimetre or so deep (although this may be reduced by burning), especially around the tussocks. Grass flowers, mostly of the dominant species, and their succeeding seed crop, may be abundant but nectar producing flowers and seeds of other species tend to be sparse.

Topographic location and physical environment

The habitat is found over a wide range of altitudes, from near sea level to 1200 m, predominantly on gentler slopes (less than 20°) but occasionally on steep slopes of more than 45°. Altitude indirectly influences which grass species are dominant, and the composition of the associated fauna and flora.

The soils are generally acid, infertile, and humus-rich at the surface. The last feature may be sufficiently well developed to form a distinctly peaty layer up to several decimetres thick. At low altitudes the habitat also may occur on less acid soils. Drainage may vary from free to impeded (with some gleying) and although the soils tend to be moist throughout the year they are usually not waterlogged, at least near the surface. If the watertable occurs close to the surface then stagnant soil conditions are alleviated by the flow of water through the soil. At high altitudes snow-melt may contribute to maintaining permanently moist conditions. Soil types can include podzols, brown podzols, gleyed podzols and gleys. Particularly at high altitudes, the soils may be poorly developed and fragmentary.

Associated flora

The associated flora is relatively poor. The dominant species are usually either *Nardus stricta* or *Molinia caerulea*, although *Deschampsia cespitosa* also may be dominant in a more limited range of situations. *Deschampsia cespitosa* and *Molinia caerulea* tend to form the largest tussocks. The larger rushes, mostly *Juncus effusus* and *J. acutiflorus*, may also sometimes be prominent in wetter situations, particularly where there are gradations to flushes, and *Juncus squarrosus* can become abundant where heavy grazing has been persistent. Although more usually a subsidiary species, *Deschampsia flexuosa* may occasionally form tussocky grassland in ungrazed situations on more freely draining soils. Among subsidiary species there is often some overlap with species of the more acid forms of ***Smooth grassland***, and with ***Flush***, ***Blanket bog*** and ***Dwarf-shrub heath*** habitats. Widespread subsidiary species include the grasses *Agrostis capillaris*, *Anthoxanthum odoratum*, *Deschampsia flexuosa* and *Festuca ovina* with, at higher altitudes, *Festuca vivipara* and the sedge *Carex bigelowii*. *Festuca ovina* sometimes forms small tussocks. *Agrostis stolonifera* and *Holcus lanatus* can be widespread in more flushed situations at lower altitudes. The most widespread forbs are *Galium saxatile* and *Potentilla erecta*. The greatest range of species occurs in flushed areas. The dwarf-shrubs *Vaccinium myrtillus*, and *Calluna vulgaris* to a lesser extent, can be present in small amounts. In some locations *Carex binervis* or *Luzula sylvatica* can be abundant and conspicuous elements but they are not characteristically common species. The bryophyte element includes *Hylocomium splendens*, *Pleurozium schreberi*, *Ptilidium ciliare*, *Racomitrium lanuginosum*, *Rhitidiadelphus loreus* and *Rhytidiadelphus squarrosus*, although not all of these are likely to be present at any one site.

Associated fauna

The fauna is relatively impoverished overall, but the habitat is of value to particular faunal groups. Some of the characteristics of the habitat are part way between those of smooth grassland and dwarf-shrub heath and this is reflected in the associated fauna. Plant species of high palatability to both vertebrate and invertebrate herbivores are not very abundant and this limits the abundance and diversity of these animals. However, the shelter and cover provided by the relatively tall sward, and its varied vertical structure, are important positive features for a number of species groups. The tussocks are potentially important wintering sites for invertebrates, although information on this specific to upland tussock grasslands is lacking. Disturbance by grazing animals and by frequent burning (such as burning every other year) may also strongly influence the abundance and diversity of the fauna. Many of the associated above-ground invertebrates are much reduced by even moderate levels of disturbance. Frequent burning is not uncommon in some localities and is likely to diminish the value of the habitat for much of the fauna.

Meadow Pipit is probably the commonest and most characteristic bird species, probably occurring in greater abundance in this habitat than in any other upland habitat. Skylark and Whinchat are also quite characteristic and moderately common while Twite are strongly associated with this type of habitat. Curlew and Snipe are often quite abundant as breeding birds on wetter areas where the dominant grass is *Molinia caerulea* and at low altitudes around the margins of the uplands there may be nesting Redshank. Short-eared Owl nests in this type of habitat and both it and Kestrel will hunt over this type of ground for small mammals. Wheatear may be present, where there are rocks or other structures which can be used as vantage points, but are generally less common than on ***Smooth grassland***. Voles and Shrews can be moderately abundant and, sometimes, very abundant. Their predators, ranging in size from Weasels to Foxes, are therefore also likely to hunt over ground of this habitat type. Pygmy Shrews are likely to be more abundant than Common Shrews since they are favoured by the plentiful ground cover and, unlike the Common Shrew, the scarcity of earthworm prey does not greatly affect them. Common Lizard, adder and Slow Worm may also be present.

Since the soils are usually acid, and often peaty, and the vegetation is relatively slow to decompose the soil fauna has similarities to that in dwarf-shrub habitat. The most abundant faunal groups are nematode worms, pot worms (Enchytraeidae), springtails (Collembola) and mites (Acari). Earthworms are usually scarce but some do occur: *Lumbricus eiseni* is particularly characteristic of peaty soils. Above-ground invertebrate diversity is limited, although some groups are quite diverse. Spiders can be both diverse and abundant, particularly the small spiders belonging to the

Linyphiidae. Typical species include *Pachygnatha degeeri* (Tetragnathidae), the wolf spiders (Lycosidae) *Alopecosa pulverulenta*, *Pardosa pullata*, and *Trochosa terricola*, and the Linyphiids *Centromerita bicolor*, *Erigone dentipalpis*, *Erigonella hiemalis*, *Monocephalus fuscipes*, *Oedothorax retusus*, and *Silometopus elegans*. Some of these also occur in other moorland habitats. Beetles and bugs (Hemiptera), the latter mostly leaf hoppers, may also be quite diverse and abundant. Where there is little disturbance the larger *Carabus* and *Pterostichus* species of ground beetle can be well represented. Lepidoptera are generally of low diversity and abundance but there are some specific associations: the caterpillars of *Erebia aethiops* feed on tussocky *Molinia* in sheltered situations at lower altitudes, and at high altitudes *Erebia epiphron mnemon* feeds on *Nardus stricta*. *Macrothylacia rubi*, *Cerapteryx graminis*, *Euthrix potatoria* are generalist species which may all sometimes be abundant. More specialist species that may sometimes be conspicuous include *Argynnis aglaja* (where there are *Viola* spp.) and *Coleophora caespititiella* (*Juncus* seeds), and *Eurodryas aurinia* (where there is abundant *Succisa pratensis* in lightly grazed damp situations at low altitudes). The last is of particular importance being a strongly declining species listed in Annex II of the EC Habitats and Species Directive. The adaptable grasshopper species *Chorthippus parallelus* and *Omocestus viridulus* may also be present.

Bracken

Structural features

Bracken (*Pteridium aquilinum*) is a large, vigorous fern with a worldwide distribution. It forms the main and sometimes sole plant species in a structurally very distinctive type of habitat. The distinctive features are a relatively tall and uniform canopy of large, deciduous fronds over a deep litter layer. The fronds are usually about 1 m tall but can sometimes reach 2 m tall. The frond litter may take ten to twenty years to completely decay and so can build up to considerable depths in vigorous stands of bracken. The dense shade cast by the live bracken fronds and the smothering effect of the heavy fall of slowly decaying frond litter (a vigorous bracken stand will produce about 8 - 14 tonnes ha^{-1} yr^{-1} of dry frond material) means that few other plants can survive under dense bracken. However, bracken also can form a partial or complete overlay on other types of upland habitat, as a result of invasion, and where it remains sparse to moderately dense plants from these other habitats can survive and may even prosper. This particularly applies to those species which grow and flower during early spring and summer since the bracken canopy usually does not fully develop until mid-June to the mid-July. In some respects, bracken growing in this way mimics woodland in its effects on associated species.

Topographic location and physical environment

Bracken can grow vigorously in full daylight in open situations unlike many other ferns which prefer shaded, sheltered, and humid conditions. It grows in woodland but it cannot survive in very heavy shade. The altitudinal range of moorland bracken is from sea level to about 450 m, and more rarely up to about 600 m. It is sensitive to frost and wind damage, and low spring temperatures reduce its vigour. These factors probably determine its altitudinal limits. Frosts may also determine a lower altitudinal limit in locations where strong temperature inversions occur.

Provided there is a good water supply and the soils are not prone to either droughting or waterlogging, bracken can grow on a range of soil types of reasonable rooting depth (more than 30 cm) from infertile peaty soils to moderately fertile acid brown earths. Bracken will grow in shallower soils in the west where moisture supply is more continuous, provided the soil water is not stagnant. Feeding roots grow into the decaying litter layer and ensure the recycling of mineral nutrients. Nutrient recycling is probably better developed in bracken stands than in many other types of moorland vegetation. Colonising rhizomes may improve conditions for bracken growth by helping to break up hard pans in the soil and by improving soil aeration. In soils where rooting is restricted by waterlogging, hardpans, stoniness, or where the soils are very nutrient poor, the rhizomes as well as feeding roots may partially or completely rise up into the decaying frond litter. The litter layer may also acts as a soil mulch which reduces water loss in drought conditions, although moisture from short, light falls of rain may be intercepted and evaporated before it can filter into the soil

Associated flora

Bracken can be found growing with a wide range of other upland plant species, or none at all. Vernal plants like *Hyacinthoides non-scripta* may survive successfully in all but the densest bracken. *Vaccinium myrtillus* will persist for longer under a bracken canopy than will *Calluna vulgaris*, since it is more shade tolerant and starts growing earlier in the season. In moderately dense bracken the most common associated plants variously include *Agrostis capillaris*, *Anthoxanthum odoratum*, *Potentilla erecta*, *Deschampsia flexuosa*, *Festuca ovina*, *Galium aparine*, *Galium saxatile*, *Holcus mollis*, *Hyacinthoides non-scripta*, *Rubus fruticosus* agg., *Urtica dioica*, and *Vaccinium myrtillus* according to soil conditions.

Associated fauna

Few animals are associated with large expanses of dense, vigorous bracken. The fronds and litter can offer shelter but the movement of larger animals may be restricted and potential food sources within the stand are likely to be limited for both herbivores and carnivores. Less vigorous and more fragmented bracken is of greater habitat value. Lower altitude bracken stands are sometimes used as breeding sites by Willow Warbler, Tree Pipit, Whinchat, and Yellowhammer while very occasionally Nightjar, Twite, Ring Ouzel, Black Grouse, Red Grouse, Short-eared Owl, Hen Harrier and Merlin use bracken for nesting cover. Whinchat is one of the few bird species to show a strong, positive association with bracken. Flocks of small birds such as Willow Warblers may forage among bracken in the late summer and this may attract birds of prey like the Merlin. Birds characteristic of open moorland, such as Red Grouse, Golden Plover, Curlew and Short-eared Owl, tend to avoid bracken unless it is sparse. Fox, Rabbit, Red deer and Roe deer may use bracken as cover. Where there is a mosaic of small patches of bracken with other moorland vegetation, Wood Mice, voles, Pygmy and Common Shrews, reptiles and amphibians may use the bracken for cover while foraging mainly outside it.

Insects are usually sparse on bracken fronds, often less than five individuals per frond, but the total diversity of insects associated with bracken is about average for a plant of similar widespread distribution and abundance. In Britain, about 40 species of herbivorous invertebrates have been recorded using bracken and for 27 of these it forms an important part of the diet, but only about six species are found in most areas. There are 11 species which are restricted to bracken. In general, leaf chewers are much less common than sap-suckers and gall-formers. Beetles seem to be unusually sparse on bracken. Ants, and some other insects, may be attracted to the nectaries which are present on bracken fronds. However, the nests of many ant species are likely to be adversely affected if shaded by the fronds. Additional species will be associated with other plants, for which bracken may provide a suitable habitat. For example, *Viola* spp. growing in the pseudo-woodland conditions under bracken can provide good habitat for the eggs and caterpillars of a number of declining species of fritillary butterfly. The litter and soil under bracken may also harbour additional species. Information on the latter is very sparse although it is known that dense litter can harbour sheep ticks.

Part 4: Impacts

Grazing, browsing and trampling

General

Types of herbivore

Upland habitats can be grazed and browsed by a wide range of herbivores including cattle, sheep, Red Deer, Mountain Hares, Rabbits, feral goats, ponies, voles, birds such as Red Grouse and Black Grouse, and a range of invertebrates including snails, slugs, and a wide variety of insects including, principally, grasshoppers, bugs, beetles, sawflies and the caterpillars of butterflies and moths. Small mammals and invertebrates generally are most abundant where the vegetation is not very short or heavily grazed by larger herbivores. Invertebrate herbivory is often not very obvious but effects of vole grazing can be quite conspicuous. Sheep have the greatest, and most widespread, effect although other herbivores can be more important in particular situations. In terms of geographical breadth of potential impacts, Red Deer and voles are the next most important herbivores.

Each type of herbivore has specific effects. For example, heavy grazing by different herbivores will reduce swards to different minimum heights: Rabbits will graze swards shorter than will sheep, Red Deer and hares which will in turn graze swards shorter than cattle, ponies (usually) and goats. Herbivores also differ in the degree of selectivity they show in grazing and browsing. Generally larger herbivores at less selective than smaller ones at a small, between-plant scale. For example, Red Grouse select shoot tips (mainly of heather), and sheep and Red Deer are more discriminating in the plants they select than are cattle. On the other hand, larger herbivores such as cattle and Red Deer have larger home ranges, and form larger and more socially cohesive groups, which can result in quite strong selectivity at the landscape scale.

Foraging patterns of herbivores

Grazing and browsing patterns always have a distinctly patchy character across a whole range of spatial scales from discrimination between adjacent plants of the same species to differential selection of different parts of a landscape. As grazing and browsing pressure increases, discrimination becomes less pronounced, grazed or browsed patches become larger and join up, and to a lesser extent more of each shoot or leaf is removed with each bite.

There are often pronounced and predictable patterns of use at a landscape scale. The heaviest grazing occurs over lime-rich soils or where there is some flushing of soils by mineral-enriched waters. Areas in which the vegetation has a higher content of nitrogen, which are not necessarily lime-rich areas, are also selected. Many herbivores show remarkable abilities to detect differences in nutrient contents, even between plants of the same species and sometimes even between different parts of the same plant. Recently burnt areas are often strongly selected, in part, for this reason. The shoots of plants newly resprouting after fire can have concentrations of nitrogen and phosphorus which are 50% to 100% greater than in older stands, although the effect rapidly disappears over the first five years after burning.

Exposure to wind is the other major environmental factor which influences foraging patterns. Larger vertebrate herbivores tend to graze less in areas which are very exposed, particularly at higher altitudes. Deer, and goats in particular, show strong shelter seeking behaviour. In the summer, large herbivores may actively seek out cooler, more exposed situations at higher altitudes to escape various biting flies which may pester them at lower altitudes.

Shelter-seeking behaviour can concentrate large numbers of animals within a small area and produce very heavy trampling and dunging which may considerably alter both the area involved and adjoining areas. Heavy and extensive snowfall can also restrict animals to limited parts of their range and produce localised heavy impacts. Attraction rather than avoidance can also concentrate grazing animals *e.g.* sites of supplementary winter feeding supplied by farmers and deer managers can result in local heavy trampling and grazing.

Some areas escape grazing and browsing. Deep water and cliffs provide obvious obstructions to the activities of grazing and browsing animals. To provide a completely effective barrier the lowest section of sheer cliff face needs to be about 1.5 m for sheep, or about 2 m for deer. Very broken ground can also provide partial, or almost complete, protection. For example, rough block scree is largely avoided by large herbivores, particularly cattle and to a lesser extent Red Deer and sheep (but not goats), while unstable fine scree or very wet, boggy ground provide a lesser degree of discouragement. Even if the barrier is not complete it may still have some effect if it is almost complete and is strategically placed relative to herbivore foraging patterns. For example, a cliff on the lower edge of a patch of scrub will tend to divert sheep dispersing from lower altitudes after using supplementary feeding points, after gathering, or as part of their normal diurnal, uphill, foraging patterns. Very occasionally, human disturbance can influence the foraging habits of wild herbivores sufficiently to permit the regeneration of trees and shrubs (*e.g.* in parts of the Northern Corries of the Cairngorms).

Digestibility and palatability of plants

Mosses, dwarf-shrubs, coniferous trees and shrubs, and coarse, tussocky graminoids tend to be less palatable and digestible than other types of upland plant. Digestibility and palatability are influenced by a number of factors including nutrient contents, moisture contents, ease of prehension or severance of shoots, and the content of indigestible structural materials or unpalatable secondary compounds (such as tannins and related compounds). However, potential digestibility and palatability are not identical. *Nardus stricta*, for example, is potentially quite digestible yet it is one of the most unpalatable of upland grasses probably due to its high silica content. There can also be interactions between grazing and palatability which can lead to either increased or decreased intake. Some woody scrub species, *e.g.* birch, may produce less palatable shoots after being browsed. On the other hand, heavy grazing of grass and herb swards increases the proportion of young leaves and decreases the proportion of old leaves and dead leaf material. This increases the average digestibility of the sward since dead plant material generally is less than half as digestible as live, green material. The amount of dead material in most habitats rises over winter, leading to a decline in average digestibility of available forage. This applies particularly to those habitats most favoured by herbivores during the growing season, and makes habitats more similar in their attractiveness at this time of year. For example, evergreen ***Dwarf-shrub heaths*** become as, or more, attractive to herbivores than ***Tussock grassland*** or even ***Smooth grassland*** in winter.

Whether a particular species is heavily grazed or browsed does not depend solely on its individual palatability but rather on its palatability relative to what other forage or browse is available. The apparency of plants to herbivores is also important. Where a plant of a more palatable species is growing within dense cover of less palatable species it often gains a degree of protection. Another effect is "impact by association" when small amounts of less palatable (though not unpalatable) species growing among more palatable species may experience enhanced grazing or browsing. At small spatial scales this can be due to herbivores being unable to select finely enough, but it can also be the result of foraging behaviour at larger spatial scales. For example, dwarf-shrub heath immediately adjacent to preferred smooth grassland can be subject to heavier browsing than dwarf-shrub heath more distant from the smooth grassland.

Unpalatable species are sometimes taken in small amounts (even by sheep) depending partly on what else is available, on the stage of plant growth, and on how intimately mixed the unpalatable plants are with more palatable species. For example, *Nardus* leaves may be grazed when they first appear in early spring or when other more preferred forage is in short supply. If herbivores can be selective because there is sufficient palatable herbage, and the plants or patches of different composition are of a sufficient size, then unpalatable species (*e.g. Nardus stricta*) are likely to spread. If there is a high proportion of less palatable species in the vegetation there is likely to be an accumulation of dead plant litter in the sward which further reduces the attractiveness of the vegetation to grazing animals.

Effects of grazing and browsing on plants

Usually only the shoot tips of woody plants are consumed by herbivores. This is likely to lead to a greater or lesser degree of stunting, and a densely branched growth-form, in the plants affected. When browsing is very heavy the removal of shoot material may extend into woody parts of the shoot, older than the most recent year's growth. Browsing into old shoot material can sometimes result in partial or complete dieback of the branch affected, though not necessarily of the whole plant. Conifers, and other evergreen species, are likely to be more severely affected than deciduous species.

Sensitivity to grazing or browsing is often inversely related to palatability. Some highly palatable species can be heavily grazed with little adverse effect. They may, in fact, benefit from the suppression of competing species. On the other hand, woody plants mostly can only withstand removal of a limited proportion of their yearly growth without being weakened and succumbing to competition, disease or the effects of severe weather. The morphologies and physiologies of woody plants, particularly shrubs and trees, are more geared towards upward growth rather than lateral spread. This tends to reduce their capacity to adapt to, and persist under, heavy pressure from herbivores. That said, many woody species can persist for some time in dwarf or prostrate forms when heavily browsed. The more palatable grasses, sedges and rushes are more resistant to being grazed because their growing points are situated at the base of the leaves, near to ground level, where they are relatively protected. Also, they are often more able to quickly produce compensatory growth. Rosette-forming herbs also maintain their chief growing points close to ground level. These herbs which compensate quickly for defoliation often come to replace dwarf-shrubs, shrubs and trees under prolonged heavy grazing and browsing. This brings about considerable changes in habitat characteristics.

There are also pronounced seasonal aspects to grazing and browsing. Dwarf-shrubs and coniferous shrubs are browsed mostly in the winter half of the year when the green leaves of graminoids, which are strongly preferred by vertebrate herbivores like sheep and cattle, are much less available. Deciduous shrubs (though possibly not *Myrica gale*) are more likely to be browsed in summer. The season of use also affects the impacts of grazing and browsing. Impacts on woody plant vigour tend to be most severe when browsing occurs in late summer or autumn. However, grazing of grasses and herbs at this time of year tends to have least impact since it permits many species to flower and set seed and the plants are dying back for the winter anyway.

The removal of a plant's annual production reduces not only its vegetative vigour. Its seed or spore production also is reduced by the enforced reduction in plant size as well as by the direct removal of reproductive parts. However, plants kept small and slow growing may live longer than they would when growing at their maximum rate and to their maximum size. They are unlikely to survive indefinitely in this state but occasional fluctuations in grazing pressure, or in the patchiness of grazing, may permit intermittent flowering, reproduction and long-term persistence. In the absence of grazing, plants are able to grow to their full stature and their flowering is unrestrained. However, in ungrazed situations small herb species may not be able to persist in the tall, dense vegetation which can develops. This results from direct competition for light and a decline in the availability of suitably open seedling establishment sites. A deep layer of dead plant litter often develops where there is little or no grazing and this is usually insufficiently consolidated, and too prone to drying out, to provide a good seedbed. This scarcity of regeneration niches can affect plants of all sizes and types. Grazing by large herbivores can alleviate this by opening up the vegetation and disturbing the ground, particularly if such effects are intermittent so that any newly established plants are not grazed or browsed as soon as they appear. At lower altitudes, absence of browsing may permit colonisation by trees and shrubs, but many upland stands are far from potential seed sources and natural succession may be long delayed in many locations.

The effects of herbivory on nutrients

Grazing and dunging can potentially affect nutrient cycling in a number of ways, although present understanding of this in hill pastures is incomplete and it is unclear if grazing effects are consistent. Dunging tends to increase rates of decomposition and nutrient cycling since most of the mineral nutrients in the herbage ingested are returned in dung and urine (as much as 60% of ingested material is deposited as dung). These nutrients are mostly in non-organic forms which are immediately available for plant uptake although also susceptible to loss from the system by leaching. This in turn can increase the nutrient contents and palatabilities of the herbage and decay rates of plant litter, though possibly not total nutrient content of the upper soil horizons. Regardless of any increase in soil nutrients, grazed and browsed plants tend to have higher average nutrient concentrations since herbivory stimulates the production of new growth which is associated with increased nutrient mobilisation in the plant.

Trampling and erosion

A very significant effect on nutrient cycling occurs when soil erosion occurs. Heavy grazing can be implicating in this, at least in exacerbating erosion initiated by other factors, by reducing the density of the protective vegetation cover and by direct exposure of bare soil in heavily trampled and grazed areas. The hooves of most large herbivores are quite small relative to their body size (and sharp edged): the hoof pressure exerted by a cow is about two and a half times that exerted by a sheep, which in turn is about two to three times the pressure exerted by a human foot. These characteristics increase the likelihood that soil will be exposed by their activities. Also, on steep slopes or banks sheep tend to open up crescent shaped “sheep scars” by rubbing. Soil erosion impacts due to herbivore activity are most likely to occur peat soils, or very friable mineral soils with low clay content.

Smooth grassland

This habitat is heavily selected by herbivores and moderate to heavy grazing is virtually ubiquitous, although at higher altitudes the direct effects of grazing are not always easy to see other than in the form of dung. Grazing animals can include cattle, sheep, Red Deer, Mountain Hares, Rabbits (less commonly voles, feral goats and ponies) and a range of invertebrates including snails, slugs, grasshoppers and bugs (frog hoppers and leaf hoppers). Sheep have the most widespread, and generally the greatest, effect. Heavy grazing by different herbivores will reduce swards to different minimum heights: sheep, Red Deer and hares graze swards down to 3 cm and sometimes to as little as 1 cm; Rabbits more regularly reduce swards to 1 cm but over limited areas; cattle, ponies and goats do not generally take swards down to less than 6 cm, although they are capable of reducing sward height to 3 cm in exceptional circumstances and ponies may create patches of even shorter sward. Cattle select between plants less than sheep do and tend to "mow" the surface of the sward, taking the rougher and less palatable species which sheep tend to avoid. Obvious grazing effects by voles (mostly by Field Vole *Microtus agrestis*) only occur rarely in either lightly grazed situations, where the sward has become tall enough to provide some cover, or in high altitude stands where winter snow provides cover. Snails are most numerous where the soil is lime-rich and become scarce on acid substrates. Snails and slugs can sometimes contribute significantly to the total grazing pressure, particularly in higher altitude or oceanic situations where they are favoured by the high humidity. Slugs graze plants at a much smaller scale than the larger herbivores, selecting parts of individual flowers, leaves and shoots. Their slime trails, although soon washed away by rain, provide a conspicuous indicator of their activity.

Annual production of grasslands varies considerably from year to year. The number of herbivores grazing a particular area can also vary from year to year. If, over a year, herbage production is greater than herbivore consumption then sward height will increase and dead plant litter will tend to accumulate as a "thatch" in the base of the sward. Year to year variations in plant productivity can lead to temporary accumulations of "thatch" while climate change can lead to longer term changes. Any accumulation of dead material reduces the quality of the sward for grazing animals.

Sward height also changes over a single seasonal cycle. In early summer herbage generally grows faster than grazing animals can consume it. This results in *average* sward heights being tallest in early to mid summer. However, there can still be considerable variation in sward height with the most preferred patches and plants being kept relatively short. As the season progresses the proportion of the sward which is short increases and average sward height declines, although the least palatable parts of the sward continue to get taller until lack of available herbage forces their consumption or until growth stops in autumn.

Generally, a high proportion of the biomass of swards comprise plants which are relatively palatable and digestible to herbivores. Although there are some differences between animals, the more palatable species are generally *Achillea millefolium*, *Agrostis capillaris*, *Alchemilla* spp. (other than *A. alpina*), *Anthoxanthum odoratum* (but less favoured by Rabbits), *Bellis perennis*, *Briza media*, *Campanula rotundifolia*, *Cynosurus cristatus*, *Deschampsia flexuosa*, *Festuca rubra*, *Holcus lanatus*, *Pilosella officinarum*, *Leontodon autumnalis*, *Lolium perenne*, legumes, orchids, *Plantago lanceolata*, and *Poa* spp. *Carex* spp. are of variable palatability. Less palatable species include: *Agrostis canina*, *Cerastium fontanum*, *Cirsium* spp. (though *C. heterophyllum* is more palatable), *Galium saxatile*, *Nardus stricta* (high in silicates, very unpalatable), *Potentilla erecta*, *Prunella vulgaris*, *Ranunculus acris*, and *Thymus polytrichus*. Mosses are generally unpalatable to most vertebrate herbivores. Cattle are more likely than sheep to graze mature *Nardus*, but less likely to heavily graze herbs. Voles graze *Agrostis capillaris* more than *Agrostis vinealis* and *Holcus mollis*. Unpalatable species are sometimes taken in small amounts even by sheep. For example, *Nardus* leaves may be grazed when they first appear in early spring, when other more preferred forage is in short supply, or when the leaves are sparsely and intimately mixed with the leaves of more palatable species in the sward. Unpalatable species (*e.g. Nardus stricta* or mosses such as *Rhytidiadelphus squarrosus* or *Polytrichum* spp.) are likely to spread except where grazing is either exceptionally heavy or exceptionally light. Mosses such as *Hylocomium splendens* and *Pleurozium schreberi* tend to benefit after severe vole grazing.

Sometimes selective grazing effectively "weeds" grasses from among other plants in the sward, particularly rosette and cushion-forming forbs. However, there are limits to how selective even sheep can be in their biting. Where selectivity cannot be exercised sufficiently finely, or a lack of forage encourages animals to be less selective, it is not uncommon to see pulled up, but uneaten, tufts of a variety of less palatable plants (or plant parts), such as *Huperzia selago*, *Minuartia sedoides*, *Nardus stricta* (small tufts), *Festuca ovina* (basal tufts), *Luzula* spp., *Saxifraga hypnoides* and *Silene acaulis*, lying on the surface of sward. This can be particularly striking in some high altitude stands in which cushion forming species are abundant and grasses relatively sparse; the effects are unlikely to be significantly deleterious for most of these species and may contribute to the small scale between-patch diversity which can be encountered in these stands.

Most grasses, and some forbs like *Leontodon autumnalis* and *Plantago lanceolata*, are highly palatable to herbivores and are heavily grazed. However, their growth forms (their main growing points remain at or near ground level) and physiologies are well adapted to both reducing the likelihood of lethal injury from grazing and to subsequent quick recovery. Indeed, in a community context, they probably benefit from grazing by the suppression of less resilient competing species. The dominant grasses in this type of grassland tend to increase tiller densities when grazed, in contrast to the dominant species in ***Tussock grassland***. Other species are more sensitive. For example, *Euphrasia* spp., *Linum catharticum*, *Gentianella* spp., and *Rhinanthus minor* are sensitive to heavy grazing (this may be partly because they are either annuals or biennials). Some orchid species may be prevented from flowering even under low herbivore densities and low general grazing impact. Some species are more sensitive to grazing at particular times of year *e.g. Conopodium majus*, *Lathyrus linifolius*, and orchids are susceptible to heavy spring grazing. Many herbs escape being grazed because of their small size or creeping habit and although the plants in the sward may be tightly packed, their shortness reduces competition for light and promotes high small-scale diversities of small and creeping herbs.

Other, less expected species may persist vegetatively in the sward. Herb-rich swards are often found in association with crags and broken ground on which tall herbs and dwarf-shrubs find protection from grazing. Some of the tall herbs and dwarf-shrubs can sometimes be found as very dwarfed specimens in the usually heavily grazed sward of this habitat type, and are easily overlooked. Their dwarf state is maintained by being repeatedly grazed to 5 cm height or less, which also prevents flowering. These dwarfed plants may be long-lived but long-term persistence probably depends on the periodic establishment of new plants from seed dispersed from adjacent cliff ledges (see also ***Tall herbs***). Lower growing sub-shrubs such as *Helianthemum nummularium* and *Dryas octopetala* survive rather better although flowering and seed production are often much reduced by grazing. This is particularly the case with *Dryas* which is usually larger, more luxuriant and more floriferous when growing on ungrazed ledges.

Generally, for plants to set seed under the grazing pressures normally encountered in this habitat they must flower within about 3 cm of the ground surface, although sheep show some avoidance of grass flowering stems taller than this at moderate grazing intensities. Summer grazing only allows a limited amount of flowering and seed production, although complete suppression of flowering by all species only results from exceptionally heavy and prolonged grazing. The abundance of shorter-lived herb species will depend on the balance between the amount of seed set and the density of small bare areas and openings in the sward where seedlings can establish. The former increases as summer grazing pressure declines while the latter increases with increasing grazing pressure. This could be important for the continued presence and long-term persistence of annual and short-lived perennial species (*e.g. Euphrasia* spp, *Gentianella* spp., *Linum catharticum*), particularly those which do not form a persistent soil seedbank. Species which do form persistent seedbanks include *Agrostis* spp., *Anthoxanthum odoratum*, *Campanula rotundifolia*, some *Carex* spp. such as *C. pilulifera*, *Cerastium fontanum*, *Cirsium* spp., *Danthonia decumbens*, *Deschampsia cespitosa*, *Galium* spp., *Gentiana nivalis*, *Holcus lanatus*, *Juncus* spp., *Leontodon autumnalis*, *Luzula* spp., *Linum catharticum*, *Lotus* spp., *Plantago lanceolata*, *Poa* spp., *Potentilla erecta*, *Prunella vulgaris*, *Ranunculus* spp., *Thymus polytrichus*, and *Trifolium repens*. However, if soil disturbance is heavy, particularly at lower altitudes (less than about 400 m) certain tall, dominating and unpalatable species such as *Juncus effusus*, *Senecio jacobaea*, or *Cirsium arvense* may establish large persistent patches of low botanical diversity and negligible forage value (but of value to some invertebrates).

A number of mechanisms can produce bare ground in the sward, one of which is grazing and trampling. Tiller densities decline in taller swards and if these are subsequently heavily grazed bare areas can be revealed. Trampling, urine scorch, decaying cow dung, molehills, soil erosion, rock falls, solifluction and frost heave can all create open patches in the sward and provide situations where seedlings can establish. Also, on steep slopes or banks sheep tend to open up crescent shaped "sheep scars" by rubbing. Strong selection for this habitat by grazing animals can lead to heavy trampling pressures which can be important in initiating or exacerbating erosion, particularly on soils with a low clay content.

Cow pats may take over a year to completely disappear, particularly if they become dried out at any stage, and can smother underlying vegetation. However, dung can also introduce seeds from elsewhere. The species involved most frequently are *Anthoxanthum odoratum*, *Cerastium fontanum*, *Holcus lanatus*, *Lolium perenne*, *Poa annua*, *Poa pratensis*, *Rumex acetosella*, *Stellaria media*, *Veronica serpyllifolia* but other species may also arrive including *Agrostis capillaris*, *Juncus* spp., and *Sagina* *procumbens*. Appreciable effects on vegetation composition are only likely with heavy dunging by cattle.

Aside from the potential to cause soil erosion, grazing and dunging can potentially affect nutrient cycling in a number of ways, although present understanding of this in hill pastures is incomplete and it is unclear if there are any consistent grazing effects. Trampling could lead to soil compaction but this may be counteracted by the high level of activity of the soil fauna, particularly earthworms, which are partly encouraged by the relatively large amounts of dung deposited here. Grazing animals can spend considerable proportions of their time in this habitat even when they have reduced the vegetation to a very short sward. As a result, nutrients could potentially be imported to this habitat because the total herbage intake of the herbivores may be higher on other habitats.

Impacts are not necessarily simply related to herbivore densities. For example, how grazing pressure is distributed seasonally can have a considerable influence on the nature and intensity of impacts. However, to help in determining if an impact assessment will be worthwhile the following crude density guidelines can be used: some heavy impacts are likely to occur at herbivore densities greater than 5 ewes ha^{-1} yr^{-1} , or the equivalent for other herbivores, while impacts are likely to be mostly light at densities of less than 2 ewes ha^{-1} yr^{-1}. These guide figures are for submontane ground below about 750 m; above this these thresholds should be halved.

Flush

Physical disruption by trampling ("poaching") is the most obvious indicator of impact. In severely poached situations there may be an extensive, uneven surface of bare mud, peat, gravel, or rock fragments pitted with the holes created by the animals' hooves. To some extent the amount of poaching will depend on the size of the flush and the reach of the grazing animals. In very small flushes animals may graze intensely without standing in them. However, sheep will often follow flushed rakes uphill and therefore may trample even very narrow flushes. Cattle are much larger and heavier animals and produce a more severe poaching effect. During the Red Deer rut wallowing by stags can cause severe but very localised effects in peaty flushes.

Severe poaching is usually very localised, rarely occurring in patches larger than a few hundred square metres. Heavy poaching may initiate scouring and fragmentation of the vegetation, sometimes leaving small patches perched above the general watertable. This is likely to be most severe where large animals like Red Deer and cattle concentrate. Flushes near to supplementary feeding sites are liable to be heavily poached. Once scouring has been initiated and erosion has occurred it may not be possible to determine from field indicators if poaching was involved. At moderate levels of usage by grazing animals some poaching may occur, particularly when heavier animals like cattle are present, but this is not likely to be so severe and extensive as to lead to significant erosion of vegetation and soil. However, rushes may become abundant. Rushes produce large amounts of seed which persists in a dormant but viable state in the soil for many decades and this seed bank can be activated once disturbed. An abundance of rushes may indicate past soil disturbance by poaching (or attempts at drainage) rather than current impacts. Light to moderate poaching may enhance small scale habitat diversity for both plants and animals by increasing small-scale variation in physical structure and environmental conditions. Some species, such as *Pinguicula vulgaris* seem to benefit from the disturbance to the vegetation caused by light to moderate trampling.

Flushes are often relatively more attractive to grazing animals than the surrounding habitats. Often there are broad-leaved grasses, sedges and herbs in the flushes which grazing animals find palatable, and which may have higher mineral nutrient concentrations, than the plants found in surrounding habitats. Growth in spring usually starts earlier in flushes than in other habitats, particularly acid heaths. Consequently when surrounded by acid heaths flushes are frequently heavily grazed even though total numbers of grazing animals may be quite low.

Most plants of flushes, other than mosses, are moderately to highly palatable to grazing animals. The vigour and flowering of plants, particularly the taller, more vulnerable herbs, is likely to be reduced through the removal of yearly production, reduced plant size and the removal of potential flowering shoots. Some orchid species (*e.g. Dactylorhiza pupurella* and *D. incarnata*) may be prevented from flowering even under low herbivore densities and low general grazing impact. However, some species such as *Equisetum* spp., *Erica tetralix*, *Juncus conglomeratus*, and *J. effusus*, are less readily eaten and are grazed significantly only when most of the other species have been depleted, though cattle and goats will graze the rushes even at moderate stocking rates. Many flush plants are not very deeply or securely rooted and so may be uprooted during grazing, with the less palatable material being spat out or dropped. This becomes more marked as grazing intensity increases.

Long-term heavy grazing tends to produce some convergence in species composition between flushes and surrounding heath and grassland communities.

The response of the vegetation to relaxation of grazing may be slow and not very pronounced since many types of flush are not very fertile, even if fed by lime-rich water. However some significant changes may occur, particularly at lower altitudes (less than 400 m) on deeper, slightly acid, moderately mineral-enriched soils. In these circumstances stands of tall herbs dominated by single species such as *Filipendula ulmaria* may be formed, with smaller plant species becoming suppressed. On occasion species such as *Schoenus nigricans* or *Trichophorum cespitosum* may come to dominate particular flushes. On more acid soils *Molinia* may become dominant if light grazing follows a period of heavy grazing. Shrubs such as *Myrica gale* also may become tall (up to 2 m) and dominant in the absence of browsing animals.

Tall herbs

The heaviest grazing occurs over lime-rich soils or where there is some flushing of soils by mineral-enriched waters. Information on the responses of this habitat to grazing is restricted largely to heavily grazed situations, where it is virtually eliminated, or to ungrazed situations. However, impoverished types do occur in moderately grazed situations. These are most often encountered where the soil is relatively acid: the dominant species in these circumstances tend to be among the less palatable of the tall herbs.

Most tall herbs are palatable, or very palatable, to grazing animals. Ferns, in general, are relatively unpalatable although some species may be heavily selected *e.g. Athyrium distentifolium*, *Blechnum spicant*, *Cystopteris montana*, *Dryopteris dilatata*, *Osmunda regalis* and *Polystichum lonchitis*. Many tall herbs and ferns are not well adapted to survive repeated cropping. Although they may survive in a dwarfed state they are unlikely to survive indefinitely unless occasional fluctuations in grazing pressure, or in the patchiness of grazing, permit intermittent flowering and reproduction. Tufted and relatively coarse grasses can become dominant during prolonged heavy grazing, although *Deschampsia cespitosa* plants may be heavily grazed at high altitudes and may be reduced to small, compact tussocks. Very grassy stands tend to indicate persistent heavy grazing and some species-rich *Agrostis-Festuca* and *Deschampsia cespitosa* grasslands may have been derived from this type of habitat. *Luzula sylvatica* and *Oreopteris limbosperma* are widespread species on more acid soils which persist under moderate grazing and which therefore are useful indicators of potential tall herb vegetation.

Because this habitat usually occurs in small patches, access by grazing animals usually results in removal of a large proportion of the vegetation production and severe impoverishment or decimation of the habitat. The longer grazing continues the more impoverished the habitat is likely to become. At moderate proportional grazing offtakes there will be a greater likelihood that the grazing animals will select plants differentially with the less palatable species being less heavily grazed. In this situation the effects of grazing animals will be to partially impoverish the habitat. The habitat could occur more widely, more extensively, and in a more fully developed form if grazing pressures generally were much reduced. Limited observations (*e.g.* at Creag Meagaidh) suggest that average herbivore densities need to be reduced to below about 20 ewes km^{-2}, or the equivalent density for other herbivores, if this is to begin to occur.

In the absence of grazing, plants are able to grow to their full stature and their flowering is unrestrained. However, although the presence of tall plant species sensitive to grazing adds to the plant diversity some small species may not be able to compete if the vegetation becomes tall and dense. At lower altitudes, absence of browsing may permit colonisation by trees and shrubs, but many upland stands are far from potential seed sources and the competitiveness of the vegetation when tall and dense may considerably slow rates of succession to scrub or woodland even when seed sources are present.

Scrub

The most important impact on scrub is browsing of the tree and shrub component by large herbivores. Most examples of upland scrub are in situations where large herbivores are absent or occur infrequently. Browsing and grazing has the potential to alter habitat structure and composition, if not in the short-term then certainly in the long-term. In the short-term, effects on the structure of the field and shrub layers is most apparent but in the long-term simplification of both structure and composition of all habitat components can occur. Generally, effects are seen first in the shrub layer and field layer, particularly reductions in height, vigour and abundance of seedlings and small saplings of shrubs and tree, tall forbs and dwarf-shrubs, but in the long-term the most important effect is loss of the tree and shrub component through lack of regeneration. As well as removal of leaves and shoots herbivores can also damage plants by bark-stripping; smooth barked individuals and species are most likely to be attacked.

Animals are attracted to scrub not only because of the availability of palatable browse and grazing but also because of the shelter afforded from inclement weather. This can concentrate large numbers of animals within a small area and produce heavy trampling and dunging which may considerably alter not only this habitat but also adjoining ones. Whilst trampling can create germination niches for tree seedlings, such heavy use will cause a net loss of saplings due to both browsing and trampling damage.

Sheep, Red Deer, and Roe Deer are most commonly responsible for grazing and browsing impacts, but cattle, Sika deer, and feral goats can be locally significant. Goats and deer potentially can have the greatest local impact because they have a greater propensity for browsing than do sheep or cattle. Voles can have a significant effect by consuming seeds and seedlings while Mountain Hares, and more locally, Rabbits can also substantially reduce regeneration by browsing the leading shoots of saplings or by bark stripping and girdling stems. Voles usually require a well developed herbaceous field layer for cover and/or food and where this is present their impacts can be significant. Such conditions are likely to be inversely related to use by larger herbivores. Field evidence for the effects of voles, Rabbits and hares are often less obvious than the effects of large animals like sheep, cattle and deer but can be quite distinctive: shoots are usually severed with a sharp, oblique cut (unlike ruminants they have both upper and lower incisors), and browsed plants are tightly clipped wherever they are within reach. Occasionally, certain invertebrate herbivores *e.g.* the moth *Operophtera brumata*, can undergo population explosions which result in extensive defoliation of trees and shrubs, but although such effects are dramatic their effects on habitat composition and structure are usually transitory.

Palatability of trees and shrubs varies greatly. Although there are some differences among herbivores, in general the more palatable trees and shrubs include *Cytisus scoparius*, *Fraxinus excelsior*, *Ilex aquifolium*, *Populus tremula*, *Salix* spp., *Sorbus aucuparia* and *Ulex europaeus*. *S. aucuparia*, and the leguminous shrubs *C. scoparius* and *U. europaeus*, are particularly palatable. The less palatable species are *Alnus glutinosa*, *Betula* spp., *Juniperus communis*, *Myrica gale* and *Pinus sylvestris*. Herbivores can show quite subtle degrees of selectivity: in Scandinavia it has been found that voles feeding on willows prefer male plants, which may have implications for attempts to ensure the regeneration of the rarer willow species. Plants of the field layer also vary in their palatability: *Geranium sylvaticum*, *Hedera helix*, *Lonicera periclymenum*, *Luzula sylvatica*, and *Rubus fruticosus* are more palatable while *Oxalis acetosella* and *Hyacinthoides non-scripta* are less palatable. Many of the field and ground layer species which occur are not unique to this habitat and further information on relative species palatabilities can be found under other habitats (see ***Dwarf-shrub heath***, ***Tall herbs***, ***Smooth grassland*** and ***Tussock grassland***).

The differing palatabilities of species can interact to produce quite subtle effects. For example, juniper is unpalatable not only relative to other trees and shrubs but also to most field layer species, yet it can be observed to be heavily browsed in certain situations. This can occur where it is the main shrub species and the field layer in winter is covered by snow for a prolonged period, or where the forage in the field layer is very sparse (*e.g.* after having been reduced by heavy grazing) or of low palatability. Another example is tree seedlings growing within a field layer of relatively low palatability *Calluna vulgaris* which often are little browsed till their leading shoots appear above the dwarf-shrub canopy and become apparent to herbivores.

Susceptibility (or a high probability) of being browsed or grazed is not necessarily the same as vulnerability (or sensitivity) to being browsed or grazed. For example, *Sorbus aucuparia* usually attracts heavy browsing yet is quite resilient in its response. On the other hand, *Pinus sylvestris* saplings are more likely to die as a consequence of browsing than saplings of *Betula* spp., *Salix* spp. or *Sorbus aucuparia*. Many woody species can persist for some time in a dwarf state under heavy browsing. For example, stunted birch saplings only one or two decimetres high but several decades old can often be found in upland scrub or woodland fragments which are heavily browsed. If woody plants can make some height growth despite browsing pressure they may eventually escape from the effects of browsing (though not bark stripping) as more and more of their shoot system and foliage rises above the reach of the herbivores. The critical height is about 1 m for sheep browsing and about 2 m for Red Deer and cattle browsing. However, as growth rates may be no more than a few millimetres to a few centimetres per year, under conditions of chronic heavy browsing, escape may require prolonged periods of time and many individuals may never make it.

Summer browsing, and browsing which removes more than the current year's shoot growth, is most likely to be damaging. Browsing into old shoot material in the least resilient species may result in partial or complete dieback of the branch or even of the whole plant. In the most resilient species, on the other hand, it may stimulate resprouting from the base of the stem (as in coppicing), although if repeated very frequently the plant may well be weakened. Less drastic browsing which removes large amounts of the current year's total shoot growth may lead to severe stunting. Information on critical offtake rates for different species is almost non-existent but an educated guess is that if more than 66% of the annual shoot production of woody species is continually removed deleterious consequences are likely to follow. (In terms of field indicators this degree of offtake probably translates into signs of browsing of some description on almost 100% of shoots.)

The effects of grazing and browsing on the continued persistence and abundance of particular species within the community can depend on competitive interactions with other plant species. For example, *Deschampsia flexuosa* appears not to be heavily suppressed by heavy grazing in scrub habitats on acid soils, possibly because its relatively high shade tolerance allows it to retain its competitive edge against other species that might otherwise capitalise on its reduced bulk and ground cover, whereas in open moorland habitats its abundance is often much reduced by grazing. On the other hand, *Luzula sylvatica* appears to show the opposite behaviour, surviving and even spreading under moderate grazing when growing on the open hill in tussock grassland and boggy areas but being much reduced by grazing in woodland and scrub. Under moderate to heavy grazing and browsing pressure mosses of the ground layer may become a prominent habitat component due to their generally low palatability to large vertebrate herbivores and to reduced competition for light from plants in the field and shrub layers, but even mosses may be reduced by heavy trampling disturbance.

Over the long-term, large herbivores can also have positive effects. Particularly if their effects are intermittent they can help to ensure the regeneration of trees and shrubs. Under conditions of little or no use by large herbivores few germination niches will be created for tree and shrub seedlings, with seedlings having to compete with dense ground layer and field layer vegetation for space, light and nutrients. A deep layer of dead plant litter also will not provide a sufficiently consolidated seedbed to permit good seedling establishment. Regeneration is likely to be confined to areas where the litter layer has been disturbed or been removed by the activities of animals or weather. An episode of moderate to heavy grazing can enhance the rate of creation of suitable seedbed conditions. Sometimes, scrub regeneration can be prolific after exclusion of grazing by fencing or stock reduction. This is caused by rapid growth of established but suppressed seedlings as grazing pressure is released. Whilst the sudden absence of grazing benefits shrub and tree seedlings and saplings which are already established, the rapid development of a dense field layer will return the system to one in which seedling establishment rates are low. To permit the long-term growth of seedlings and saplings leading to regeneration of scrub herbivore densities probably need to be less than about 5 Red Deer km^{-2} or 10 sheep km^{-2}.

Blanket bog

Blanket bogs usually do not attract such heavy herbivore usage as grasslands or dwarf-shrub heaths. However, most areas of blanket bog habitat are, or have been, subjected to some degree of grazing by sheep and/or Red Deer at densities equivalent to 0.5 ewes ha^{-1} or less. Although livestock densities are usually comparatively low, blanket bog habitat is more fragile than either grassland or dwarf-shrub habitats, and impacts can sometimes be substantial. Effects are usually as much a consequence of trampling as removal of plant material. Sheep are attracted to the relatively dry, ridge areas and drier bog margins which are usually richer in dwarf-shrubs and more palatable graminoids. Intervening wet basins or pool systems tend to be avoided although sheep may be attracted (sometimes fatally) to pools in which there are lush growths of *Menyanthes trifoliata*.

Trampling tends to flatten the surface spongy layer which is typical of peat forming bog communities. This alters the hydrological properties of the surface layer, reducing its water retention and enhancing flushing in water-tracks. It also diminishes aeration in what is the main rooting zone for many plants. Where trampling and grazing impacts are heavy and chronic the spongy surface layer is likely to be largely destroyed and bare peat will be exposed. This often occurs first around specific features such as peat cutting banks, fence lines, rock outcrops, and pools but becomes more widespread as impact intensity increases.

The tissues of *Sphagnum*, and most other bryophytes, have low protein contents and high concentrations of lignin-like compounds. This makes then unpalatable, at least to larger vertebrate herbivores. Although *Sphagnum* mosses are not consumed to any extent, they constitute the habitat component which is generally the most sensitive to trampling and, because of their functional importance to the bog habitat, impacts on *Sphagnum* mosses are one of the most important indicators of intensity of general herbivore impact. Throughout the bog, trampling may dramatically reduce, or even eliminate, *Sphagnum* mosses. Physical damage, from scraping and hoof-prints, may be noticeable even at comparatively low livestock densities and before there are any very obvious impacts on other habitat components. Loss of *Sphagnum* vigour or cover is one of the first indications of progression to a depauperate, drier form of bog or wet heath, although it should be noted that this can also occur after drainage or burning.

Effects on other habitat features begin to appear at higher levels of herbivore use. Noticeable browsing of dwarf-shrubs may become apparent (see ***Dwarf-shrub heath*** for indicators). Care needs to be exercised when assessing impacts on dwarf-shrubs, particularly *Calluna vulgaris*, since they can appear weak and stunted even in bogs experiencing low impacts: *Calluna vulgaris* shows little tolerance of waterlogging of its roots and grows poorly where the water table is very near the surface. Grazing and trampling tends to accentuate the development of tussocks in tussock-forming "sedges" and grasses, particularly *Eriophorum vaginatum* and *Molinia caerulea*, since animals tend to walk between tussocks and preferentially graze inter-tussock vegetation (which contains less dead leaf material). Livestock browse/graze *Calluna vulgaris* and *Eriophorum vaginatum* mostly in the period from winter to early spring but tend to change to *Molinia caerulea*, *Trichophorum cespitosum* and other grasses, "sedges" and herbs during the spring and summer. The new flowering shoots of *Eriophorum vaginatum* are attractive to herbivores, particularly as they often appear early in the growing season (first appearing among the tussock leaves in late March to early April) before much new growth has appeared on other preferred forage species. The flowering shoots of *Rubus chamaemorus* are similarly often heavily grazed even when there are few obvious signs of grazing on other species. If there is profuse flowering and fruiting of either of these species on a bog then overall grazing impact is likely to be low. At the opposite extreme species, such as *Empetrum nigrum*, *Erica tetralix* and, to a lesser extent *Eriophorum angustifolium*, are relatively unpalatable and will only be browsed under very heavy livestock densities. Any obvious browsing of these species is a good indicator of overall heavy herbivore impact.

Some bog species have a greater resilience to the effects of trampling and grazing than others. Where impacts continue for years to decades some species become more common, including *Carex panicea*, *Eriophorum angustifolium*, *Trichophorum cespitosum* and *Sphagnum tenellum*. *Trichophorum cespitosum* shows some tolerance of trampling and soil compaction and it is often concentrated along animal paths where these are lightly to moderately used (under heavy usage even it suffers). Trampling also creates gaps in the vegetation where non-bog species can colonise, particularly *Juncus squarrosus* and *Nardus stricta*.

Wind-clipped summit heath

These heaths are not strongly favoured by grazing animals but during spells of good weather in summer they may be used periodically by high numbers of sheep and Red Deer. Mountain Hares are often present, and may be seen at high densities during the day, although much of their feeding is likely to be done at night on other habitats at lower altitudes. They may occasionally occur at sufficiently high densities to produce local changes in the vegetation through grazing and scraping.

Grazing animals using these montane heaths also use other associated types of habitat. For example, flushes are often grazed preferentially where they support a more palatable vegetation of grasses and sedges. The intensity of usage of high altitude flushes can provide a useful pointer to the likely impacts on adjacent montane heaths. If they are lightly grazed then it is likely that there will be little impact on the montane heaths.

Trampling and dunging by grazing animals can produce impacts as great as, or even greater than, the grazing of plant parts. Small openings in the vegetation can be produced very readily by the hoofs of grazing animals in this fragile type of vegetation, particularly if animals move quickly across an area. These openings can provide points at which it is easier for the wind to further disrupt the vegetation mat, possibly leading to erosion of the soil. Trampling effects are often most noticeable around terraces and boulders where the provision of some shelter, or places to rub, may encourage habitual use. With continued heavy usage the composition of the vegetation can change with an increase in plants such as *Galium saxatile*, *Potentilla erecta*, fine-leafed grasses and the hardiest of the broad-leaved grasses. Invasion by these species is encouraged by the local fertilising effect of herbivore dung and urine. This effect is most pronounced in hollows in which dung and its residues tend to accumulate. These new species are often more palatable to grazing animals and will attract even heavier grazing pressure, reinforcing the pattern of vegetation change. However, changes in species composition are likely to be slow because of climatic constraints on plant productivity.

High rates of trampling can also destroy up to 30% of nests of ground nesting birds such as the Dotterel. The critical density of dung given in the field indicators relates to significant levels of damage to nesting Dotterel by trampling of sheep and deer. This threshold is likely to be lower than the threshold for noticeable effects on the vegetation. Significant effects on the habitat and its associated fauna are likely to begin to appear when average herbivore densities, over the summer months, are greater than about 20 ewes km^{-2} or about 10 Red Deer km^{-2}. If herbivore densities are known to be greater than this then a impact assessment on the habitat would be desirable.

Dwarf-shrub heath

Dwarf-shrubs can only withstand a limited proportion of their yearly growth being removed without being weakened and succumbing to competition, disease or the effects of severe weather. Grasses, sedges and rushes are more resistant and often come to replace dwarf-shrubs under prolonged heavy grazing and browsing. This brings about considerable changes in habitat characteristics. Evergreen dwarf-shrubs are browsed mainly in the winter half of the year when the green leaves of graminoids, which are strongly preferred by vertebrate herbivores like sheep and cattle, are much less available.

Vigorous, dominant *Calluna vulgaris* can withstand removal of up to 40% of its total yearly shoot production without effect on its productivity, although individual *Calluna* plants growing in isolation can tolerate removal of 60% or more. (The percentages of shoot numbers browsed, given in the Field Indicators for heavily grazed, correspond approximately to the 40% rate of offtake of total shoot production). This does not mean, however, that at lower rates of shoot removal *Calluna* may not lose cover to other species with which it may be competing. Weak or old *Calluna*, especially, may only be able to withstand offtakes half as great. The vigour of *Calluna* and other dwarf-shrubs varies considerably for a variety of reasons. *Calluna* is likely to lack vigour in one of the following states or situations: when old and woody (stems more than 10 mm diameter); on peat soils in wet heaths and bogs; at higher altitudes (above about 600 m); at exposed locations (even at sea level) where it is reduced to a wind-clipped carpet less than 20 cm deep and sometimes less than 10 cm deep; or where it is shaded by trees and shrubs.

Calluna vulgaris, as well as being the most widespread of the dwarf-shrubs, is also one of the most vulnerable to heavy browsing pressure. Other species are either more resistant, or are less palatable, or escape being browsed due to the way they grow. *Vaccinium myrtillus* is palatable but rhizomes provide protected buds and reserves which facilitate replacement of browsed shoots and make it slightly more resistant to browsing than *Calluna*. *Erica cinerea* seems to be moderately palatable but the extent to which it is browsed can be very variable. *Myrica gale* shoots are moderately palatable, though the aromatic leaves may be less so, and it also has rhizomes. *Salix repens* is relatively palatable but its creeping stems to some extent can escape being browsed. The leathery leaves of *Vaccinium vitis-idaea* are relatively unpalatable and it also has rhizomes. *Erica tetralix* and *Juniperus communis* do not have rhizomes but are unpalatable. Juniper bushes only tend to be browsed when snow covers other more palatable species. *Arctostaphylos uva-ursi* and *Empetrum nigrum* are relatively unpalatable and they also escape browsing by their low, creeping form of growth.

Patterns of damage and the resulting growth responses of the plant can be distinctive. When browsing is very heavy the removal of shoots may extend into woody material, older than the most recent year's growth. This can be damaging, sometimes leading to dieback of whole branches. More usually, browsing removes only the tips of the dominant, normally upwardly-growing main shoots (or "long-shoots"), promoting increased production and growth of side shoots. When heavy browsing has continued for a long time outward and upward shoot growth becomes much restricted. This produces the densely packed, contorted and tightly intertwined masses of shoots which characterise the "drumstick", "topiary" and "carpet" forms of growth mentioned in the Field Indicators. The total mass of foliage is reduced when *Calluna* is heavily browsed and it may appear to have a greyish cast due to the greyish stems showing through the foliage. On extensive rough grazings very heavily browsed *Calluna* is usually of local occurrence *e.g.* in zones adjacent to ***Smooth grassland***.

The amount of flower and fruit present can give some indication of browsing pressure, and also when it occurs, if used carefully. If heavy browsing only occurs during winter, ending before *Calluna* and *Vaccinium myrtillus* start to grow, many of the potential flowering shoots will have been removed. But, provided the bases of the long-shoots have remained undamaged replacement long-shoots will develop and flower during the summer. If the new shoots of the dwarf-shrubs are substantially browsed in the summer (which usually only happens when there is a shortage of preferred forage) this will greatly reduce flowering and fruiting even if the shoots are only partially consumed. If very heavy browsing during the winter removes nearly all the current shoots back to the previous year's growth then this may also reduce flowering in the following summer.

As a guide to deciding on the merits of carrying out an impact assessment the following herbivore densities can be used as a rough guideline. Where herbivore densities are greater than about 2 ewes ha^{-1} yr^{-1}, or the equivalent for other herbivores, extensive areas are likely to be heavily browsed while at less than 0.5 ewes ha^{-1} yr^{-1} most of the area is likely to be lightly browsed.

Tussock grassland

Many of the general principles described under ***Smooth grassland*** also apply here.

Grazing animals can include cattle, sheep, Red Deer, Mountain Hares, voles (particularly the Field Vole *Microtus agrestis*), less commonly feral goats and ponies, and a range of invertebrates including slugs, grasshoppers and bugs (frog hoppers and leaf hoppers). Rabbits can sometimes have localised effects. Sheep have the most widespread effect but the larger, less selective herbivores like cattle are likely to have the greatest impact when they are present. The effects of grazing by voles (Field Vole *Microtus agrestis*) can sometimes be very conspicuous, especially in situations where there has been some snow cover over winter when extensive networks of chewed-out runs are often revealed in the spring. Feather mosses such as *Hylocomium splendens* and *Pleurozium schreberi* tend to become more abundant after severe vole grazing.

The dominant, tussock-forming species tend to be relatively unpalatable (particularly *Nardus stricta*) and so the greatest impact is on the subsidiary, inter-tussock species. Cattle, however, show less discrimination and can substantially diminish the tussock component in the vegetation, creating a habitat more akin to ***Smooth grassland***. Over the habitat as a whole grazing is usually light although some of the subsidiary plant species may be quite heavily grazed. Grazing and trampling of the inter-tussock vegetation probably enhances the discreteness of tussocks. The tough structure of tussocks provides some resistance to the effects of livestock trampling. Although this habitat is less strongly selected by grazing animals than ***Smooth grassland*** it covers much larger areas and a significant proportion of livestock forage may be obtained from it, even if much of the material consumed is of relatively low average digestibility. Grazing is likely to be heaviest in late winter and spring, although higher altitude types may be grazed in the summer (being snow covered in the winter). Plant production considerably exceeds herbivore consumption in most circumstances and considerable amounts of dead plant litter accumulate in the sward both as standing dead leaves and as a deep layer in the base of the sward.

Species present vary in their palatability and digestibility to grazing animals. Although there are some differences between animals some generalisations can be made. More palatable species include: *Agrostis capillaris*, *Anthoxanthum odoratum*, *Campanula rotundifolia*, *Deschampsia flexuosa*, and *Molinia caerulea* (from spring to early autumn). Less palatable species include: *Agrostis canina*, *Cerastium fontanum*, *Cirsium* spp. (though *C. heterophyllum* is more palatable), *Galium saxatile*, *Juncus* spp. (especially *J. effusus*, although *J. acutiflorus* is more palatable), *Molinia* (autumn and winter), *Nardus stricta* (very unpalatable), and *Potentilla erecta*. The unpalatability of *Nardus* is probably related to its high silica content, and toothed cuticle, since its potential digestibility is quite high. Mosses are generally unpalatable to vertebrate herbivores. *Juncus* spp. are most readily taken by goats and to a lesser extent by cattle (especially in winter) although sheep will graze *J. effusus* flowers around the edge of clumps and cattle will readily graze *J. acutiflorus*. Cattle, goats and Rabbits are more likely to graze *Nardus* tussocks than sheep or deer. Cattle will tend to graze the larger *Nardus* tussocks more than smaller tussocks. Unpalatable species are sometimes taken in small amounts, even by sheep, depending on what else is available and sometimes on the stage of growth of the plant *e.g.* *Nardus* leaves may be grazed when they first appear in early spring or when other more preferred forage is in short supply over winter or when sheep densities are very high.

The dominant tussock-forming grass species are relatively slow growing (*e.g.* the growth rate of *Nardus stricta* is about half that of *Agrostis capillaris*) and tend to show a decline of tiller density and vigour if they are grazed or defoliated over a number of years, unlike the dominants of **Smooth grassland**. *Molinia caerulea* is potentially larger and faster growing than *Nardus stricta* and may displace it in some circumstances, especially on wetter soils where there is no grazing. Compared to non-tussock grasses, tussock grasses have relatively large internal stores of carbohydrate and mineral nutrients, and more protected perennating buds. These reserve features allow them to recover quickly from infrequent disturbance. However, frequent disturbance can lead to a decline in these reserves and a decline in plant vigour.

Grazing, browsing and trampling

Grazing influences seed production and seedling establishment. The dominant grass species normally flower and set seed abundantly (though seed set may be poor at higher altitudes), and the seeds may persist for some time in the soil seedbank. Establishment of new plants from seed can sometimes occur abundantly when there are suitable seedbed conditions. This is most likely to occur after heavy grazing, or possibly after burning to encourage new growth for livestock forage. For *Nardus*, seedling establishment usually only occurs close to existing tussocks, although seed may be dispersed over longer distances in sheep fleeces or in cattle dung. The small seeds of *Molinia* perhaps may be dispersed greater distances by wind though there is little information on this. Both the abundance and flowering of associated herbs tends to be limited either by competition with the dominant tussock-formers for light or because of heavy grazing of the inter-tussock vegetation. The accumulation of a deep litter and raw humus layer also reduces the chances of seedling establishment even for those species which do manage to produce seeds. Some associated species form seedbanks which may aid their long-term persistence including *Agrostis* spp., *Anthoxanthum odoratum*, *Campanula rotundifolia*, some *Carex* spp. such as *C. pilulifera*, *Cerastium fontanum*, *Cirsium* spp., *Danthonia decumbens*, *Galium* spp., *Holcus lanatus*, *Juncus* spp., *Luzula* spp., and *Potentilla erecta*. If soil disturbance is heavy, particularly at lower altitudes (less than about 400 m) *Juncus effusus* may establish large persistent patches. Where grazing has been heavy for a long time, but without significant soil disturbance, *Juncus squarrosus* often becomes established and may become abundant.

Grazing probably does not have very marked effects on nutrient cycling in this habitat at typical grazing intensities. There may be some export of nutrients if the grazing animals have access to ***Smooth grassland*** where they are likely to spend more time (distance, home range and social behaviour permitting). Overall, nutrient dynamics are likely to be dominated by the production of large amounts of plant litter of relatively low nutrient content and with slow rates of decay.

Local livestock densities which correspond to grazing impact classes are difficult to give since much will depend on the selectivity of the herbivores concerned (*e.g.* cattle versus sheep), the palatability of the dominant tussock-forming species (*e.g.* *Nardus* versus *Molinia*), the palatability and amount of inter-tussock vegetation, and the availability and palatability of other forage resources. As a crude guide grazing impacts are likely to be extensively heavy if herbivore densities exceed 2 ewes ha^{-1} yr^{-1}, or the equivalent for other types of herbivore (less for cattle), while impacts are likely to be mostly light at densities of less than 0.5 ewes ha^{-1} yr^{-1}. In situations where either tussock grassland or smooth grassland could develop, sheep grazing tends to encourage the development of tussock grassland while cattle grazing has the opposite effect.

Bracken

Bracken itself is little grazed by wild or domestic livestock, although goats may take some. Bracken dominated vegetation is of little grazing value although the relatively green grass revealed when weak bracken dies back in autumn is of some agricultural value as a useful "late bite". It once did have some agricultural significance as a cheap and plentiful source of animal bedding and, in limited areas, regular cutting would have considerably checked its vigour.

Green bracken is toxic to grazing animals. If the green fronds are consumed frequently over a few weeks severe poisoning occurs. Cattle seem to be more sensitive than sheep and may be killed. Even if consumption by livestock is not sufficient to produce short-term toxic symptoms, cancers may develop in the long-term. Livestock may be particularly at risk during dry springs and summers when the attractiveness of young bracken fronds to grazing animals is enhanced by a shortage of green grass. Also, the dense litter of bracken can harbour sheep ticks which may transmit various diseases (*e.g.* louping ill) to grouse and sheep.

Trampling is an important factor reducing bracken vigour. Cattle produce a greater trampling effect than sheep, being larger and heavier animals, and can push through taller, denser bracken stands. Sheep may also produce limited trampling effects around the edges of bracken areas and may partially graze the fronds, possibly selecting for the fronds which have already been weakened by other factors. Limited information suggests that sheep densities in the immediate vicinity of the bracken need to be more than about 3 ewes ha^{-1} to produce significant trampling or grazing damage. The impact of grazing animals may be self-reinforcing. Reduced vigour resulting from trampling and grazing makes access easier and encourages grasses and other plants growing beneath the bracken which are attractive to the grazing animals. This, in turn, may further increase trampling and other damage to the bracken.

Herbivory by insects

General

Most insect herbivory produces very few easily discernible effects in most upland habitats. Occasionally, however, significant defoliation or dieback of plants can be produced when certain species undergo periodic population explosions. The species responsible are most often certain widespread and adaptable moth species with broad diet preferences. Conspicuous effects are most frequently observed in ***Dwarf-shrub heath*** and ***Scrub***.

Smooth grassland/Tussock grassland

Significant defoliation of large areas of pasture can occasionally be caused by population explosions of caterpillars of the moth *Cerapteryx graminis* (Antler Moth). This species will feed on a variety of grasses including even *Nardus stricta*.

Scrub

Occasionally, moths such *Agriopis aurantiaria* (Scarce Umber), *A. marginaria* (Dotted Border), *Operophtera brumata* (Winter Moth), *O. fagata* (Northern Winter Moth) and *Orgyia antiqua* (Vapourer) can undergo population explosions which result in extensive defoliation of trees and shrubs, but although such episodes are dramatic their effects on habitat composition and structure are usually transitory. Such outbreaks may be more common at higher altitudes near the potential treeline. It is usually an early summer phenomenon.

Dwarf-shrub heath

Insect herbivory is widespread and common on dwarf-shrubs but is usually not at all obvious. The caterpillars of a small number of species of moths, and the grubs of *Lochmaea suturalis* (the Heather Beetle), sporadically occur in sufficient numbers within localised areas to produce noticeable "outbreaks" of defoliation visible as patches of "browning". Usually, only *Calluna vulgaris* or *Vaccinium myrtillus* are affected; *Erica* spp. seem to be mostly avoided. The commonest moth species involved are *Operophtera brumata* (the Winter Moth), *Abraxas grossulariata* (the Magpie Moth), and to a lesser extent *Orgyia antiqua* (the Vapourer). Outbreaks of Magpie moth on *Calluna* occur particularly in north-west Scotland. The small size of these animals means that they do not remove large chunks of shoots, as do larger grazing or browsing animals like sheep or deer. Rather, they nibble at individual leaves and the softest parts of the shoot tips. They usually damage much more of the plant than they actually consume. This leads to considerable water loss and browning of the plant: in the case of moth attacks this usually becomes obvious by late spring/early summer but in the case of *Lochmaea suturalis* it is not usually obvious till late summer. Within any one outbreak the caterpillars or grubs tend to develop synchronously so affected patches tend to have fairly sharp edges corresponding to where feeding stopped prior to pupation. Outbreaks are unpredictable but they may be triggered by a run of warm winters. Severe outbreaks usually only last from one to four years, and at lower altitudes the larvae are often found to be heavily and lethally infected by parasitoids. The winged adults of *Abraxas grossulariata* and *Lochmaea suturalis* can disperse widely but they are not very strong fliers. The adult females of *Operophtera brumata* and *Orgyia antiqua* are flightless, being almost or completely wingless, but the newly hatched caterpillars are very small and can readily disperse on the wind by producing a silk thread which acts like a parachute or sail. Outbreaks can sometimes be observed to occur successively downwind of what would have been the prevailing wind direction during the dispersal period.

Bracken

Occasionally, significant damage by certain very polyphagous herbivorous insects such as the moths *Spilosoma lutea* (Buff Ermine) and *Ceramica pisi* (Broom Moth), and the chafer beetle *Phyllopertha horticola*, has been recorded. Outbreaks of these species are not very common and are usually of short duration, producing little lasting impact on the bracken.

Burning

General

Important general features of burning

Burning occurs most frequently and extensively on ***Blanket bog***, ***Dwarf-shrub heath***, and ***Tussock grassland*** but it also may affect ***Tall herbs***, ***Scrub*** and ***Wind-clipped summit heath***. However, not all parts of these habitats are affected. Sometimes areas remain unburnt for long periods where there are barriers to the spread of fire.

Expanses of water, very wet boggy ground and flushes, or sparsely vegetated rocky ground (either horizontal or vertical) can all block fire spread if sufficiently wide. To provide a moderate degree of security such barriers need to be at least 2 m, and preferably greater than 3m, high or wide. However, to ensure a high degree of protection over the long-term (many decades to centuries) such barriers probably need to be at least 10 m wide or 5 m high. Wet boggy ground and flushes may not present a barrier to fire during drought conditions.

The degree of protection offered by physical barriers depends to some extent on the frequency of burning of adjacent habitats and on the intensity of fires which occur there. Different frequencies of fire in nearby areas may affect the risk of fire spreading to unburnt remnant areas but exactly how risk will be affected is not very clear. With frequent nearby fires there may be an increased probability of burning material being lifted over the barrier by convection from the fire front, although this is balanced by frequent fires also often being relatively cool and patchy. On the other hand, where fires are infrequent there is often a greater fuel build-up between fires and fire fronts are more intense, more continuous and produce greater convection, which increase the probability that the fire will cross a barrier of any particular size.

In areas not protected by barriers to fire spread, the effects of burning depend on both the intensity of impact of individual fires and the length of time between fires. These two aspects should be distinguished when assessing burning. The intensity and frequency characteristics of fires are affected by both the amount of fuel which accumulates between fires and its potential for ignition. The amount of fuel is determined by the productivity of the plants; the dimensions and density of stems, foliage and plant litter; the dispersion of this potential fuel in space, and its moisture content. The moisture content in turn is influenced by weather conditions, often following a seasonal pattern, and the species composition.

Habitat effects are also influenced by the size of areas burnt and by interactions with grazing animals. For example, a small burnt patch in the midst of a large area of long unburnt moorland is likely to attract the concentrated attentions livestock with consequent impacts on post-fire vegetation recovery. On the other hand, very large fires may reduce structural variation in the habitat, which may be perpetuated for very long periods.

Intensity of immediate impact

Intensity of immediate impact can vary greatly. The degree of impact is determined by the pattern of available fuel: this in turn is determined by the amount and spatial distribution of potential fuel material, modified by the pattern of moisture content.

During exceptional summer droughts everything becomes comparatively dry and when burnt releases large amounts of energy. This can create positive feedback in the combustion process since the heat generated may be sufficient to drive the water from any remaining moister material and raise it to its ignition temperature. (Woody material needs to be raised to temperatures above about 300°C before self-sustaining, exothermic combustion can occur). Such conditions produce the highest intensity impacts which may destroy the regenerative capacity of the vegetation and even the soil itself.

Where humus-rich or peaty soils ignite, soil nutrient and water holding characteristics can be greatly altered. Any remaining burnt or charred soil is likely to lack humus, have poor water holding characteristics, poor structure for plant root development, be easily destabilised by winter freezing and thawing, and be prone to erosion. There may also be high levels of mineral nutrients immediately after an intense fire (from the ash and as a consequence of increased mineralisation rates) which may not be conducive to the growth of some plant species. However, soluble nutrients are likely to be rapidly leached by the normally high rainfall in upland areas. After very intense fires, revegetation is a slow process dependent on the gradual stabilisation of the remaining soil and slow immigration and establishement plant life.

In a properly controlled management fire during the winter muirburn season, burning is undertaken when the above-ground fuel load is mostly dry and flammable, but the plant litter and partially humified material below is still moist. The weather is usually quite cold. Under these conditions a large proportion of the energy released by combustion is used to raise fuel temperatures. This generally results in fires of low to moderate impact. Fires burning against the wind often remove more of the above ground material. This is because they burn for longer at any particular spot they pass over, and there is therefore greater radiative transfer of heat to the vegetation and ground, although flame temperatures are not necessarily higher.

In a moderate intensity fire most of the above-ground woody and dead material will be removed but the litter and moss layer will be only partially and patchily consumed. There will be little or no rise in temperature deeper than 1 cm below the soil surface during the fire, and even at the soil surface there will be only a modest and brief rise in temperature. Creeping and underground stems, rootstocks, stem bases and seeds in the soil, and much of the litter and soil invertebrate fauna, will remain insulated and protected from heat and flame.

Low intensity fires result when the above-ground vegetation is still moist or where there is little accumulation of potential fuel. Such fires tend to burn irregularly and much material is left unburnt. However, such fires are not necessarily small. They are often head fires, which burn with the wind rather than against it, and their light impact is sometimes because they travel quickly over the ground. Large, uncontrolled fires which occur during the winter are often of low intensity although they may affect large areas of ground.

On the whole, winter fires have less drastic effects on habitats than summer fires. Summer fires are likely to have more drastic effects on the associated fauna since in winter much of the bird fauna will be absent and much of the invertebrate fauna will be dormant and well protected in the damp litter and soil. Exceptions to this general rule may be deciduous ***Scrub*** and ***Tall herbs***. In both cases the vegetation usually has too high a moisture content in summer to burn readily (except in severe droughts). However, more information will be needed on the effects of burning in these habitats before effects can be stated definitively.

Plant responses and vegetation recovery

Fire impact is also affected by the abilities of species to either avoid fire damage or recover from it. Resilience to burning varies between species and according to the age/size of plants. Many herbs and woody species have the capacity to resprout from dormant buds on the lower stem which, being close to the ground surface and insulated by damp field and ground layer material, often survive the passage of all but very hot fires. In woody plants the ability to resprout after fire (or browsing) is often most vigorous in young stems but tends to decline with age. (Where layering has occurred, stems are physiologically and morphologically "young" even if the plant as a whole is chronologically old. However, dormant buds on prostrate stems are more vulnerable to damage by heavy burning than are more deeply insulated stem bases). Older stems, on the other hand, tend to have thicker bark which increases the probability that the critical, living cambial layer immediately under the bark will not be exposed to lethal temperatures (temperatures of approximately 60°C for more than a minute, or shorter times for higher temperatures).

Persistence is also conferred by an ability to rapidly recolonise burnt areas even if pre-existing plants have been destroyed. Some species of herbs, dwarf-shrubs, shrubs and trees have seeds which either are widely dispersed by wind or birds and/or lie dormant for prolonged periods in a soil seed bank. Flowering and seed production of plants is often enhanced after burning (in the absence of grazing), particularly in the second summer after late winter burning. This can help to promote rapid recovery even if vegetative recovery is slow. Seeds of many species often germinate well on recently burnt ground, provided the substrate remaining is consolidated and stable, since there is likely to be much reduced competition from established plants, reduced predation of seed and seedlings by small mammals, and the more extreme daily and seasonal temperature fluctuations on recently burnt ground can help to break seed dormancy.

Frequency

The frequency of fires is a relative concept which varies from habitat to habitat. The crucial factor is the time required for the slowest maturing component of the habitat to achieve its characteristic stature, abundance, structure, and species composition. Where recovery is very slow, burning could be considered frequent even if many years elapse between successive fires.

Frequent fires limit the accumulation of standing plant material and dead litter. This affects subsequent fuel loads and fire temperatures, though available fuel loads and fire intensities are also affected by weather conditions and the moisture content of the vegetation and soil at the time of burning. Although frequent fires prevent the accumulation of large amounts of potential fuel material they also limit development of a moisture holding and insulating layer of dead plant litter and mosses. This reduces the protection afforded to the more fire sensitive plants, like surface-creeping dwarf-shrubs and clubmosses, and increases the likelihood that the surface or upper layers of the soil will be "cooked". Not only will this kill some of the seeds and rootstocks from which plants might regenerate but it may also affect soil properties. With frequent burning the upper layers of humus-rich or peaty soils are likely to become somewhat "rubbery" and their capacity to absorb and store water in a form available to plants will be reduced. Frequently-burnt areas often have soils with a thin peaty or humic surface layer which fluctuates between being waterlogged and droughted, producing poor seedbeds and difficult growing conditions for most plants.

At the landscape scale it is common to find that a greater area is burnt within a given period where fires are frequent than where fires are infrequent, although it is not inevitable that this has to be the case. This means that fire-sensitive, slowly reproducing (or slowly dispersing) species are more likely to be eliminated in a landscape with frequent fires since there is a higher probability that refuge areas will be burnt or much reduced within any given time.

Tall herb

Luzula sylvatica can accumulate substantial amounts of dead leaf litter, if not heavily grazed, which potentially could provide fuel to carry a fire. The habitat may occasionally be burned, particularly on acid soils where *Luzula sylvatica* may be dominant, and dwarf-shrubs may be present, and there may be adjacent dwarf-shrub heaths from which fires could spread. It is unclear what effects this may have but *Luzula sylvatica*, *Oreopteris limbosperma* and possibly other species may be sensitive to repeated burning. Occasional light fires may increase plant species diversity by reducing the dominance and of the most vigorous species and by reducing the potentially smothering accumulation of plant litter. During the growing season tall herb stands are unlikely to burn due to their high moisture contents.

Scrub

Fire affects not only the persistence, composition and structural characteristics of scrub but also its pattern of distribution. Throughout the uplands scrub is often represented only by very small remnants. These are usually restricted to ledge situations and rocky outcrops, not only because of browsing pressure but also because of repeated burning of less protected areas. Poorly located, uncontrolled fires which sweep up steep open ground and partially vegetated cliff faces are not uncommon, reducing even the remaining fragments of scrub.

Scrub of *Cytisus scoparius* and *Ulex europaeus*, on the margins of the uplands, often does not show this fire-influenced distribution, or at least not in the same way. Browsing appears to be a more important determinant of the occurrence of these species, although as with other forms of scrub burning can increase vulnerability to browsing by making new growth more accessible and palatable to browsers. *Cytisus scoparius* and *Ulex europaeus* recover well from fire by resprouting from basal branches or stem bases (*Ulex*) and by prolific seedling regeneration. Being fast growing species, these species can quickly dominate burnt areas where browsing is light, infrequent or absent.

The intensity and frequency characteristics of fires in scrub are affected by the amount of fuel which accumulates between fires and its potential for ignition. Scrub can produce potentially large amounts of fuel but this is not always very flammable. Living green foliage of broad-leaved, deciduous trees and shrubs usually has too high a water content to burn readily. This is not so applicable to conifers (*e.g.* juniper) in which secondary compounds greatly increase flammability, and non-coniferous evergreens such as *Ulex europaeus* which can have a relatively high flammability even in summer. Fires in scrub are carried and sustained by fuel in both the field and shrub/tree layers. In scrub fires the canopy will usually ignite or be killed, which is not always the case in woodlands and high forest. This is because in scrub the distance from the canopy to the ground is very short, well within flame height from the field layer, and there is usually a continuous distribution of fuel from ground to canopy. Also, even if the tree and shrub canopy is sufficiently dense to suppress the field and ground layer it is then likely to be sufficiently dense to sustain a fire on its own.

Summer fires during drought conditions could be very damaging since virtually all components of the habitat become potential fuel. Fires could also be damaging in winter under more normal muirburn conditions since the water contents of trees and shrubs are lower than in summer. Critical tissues are then more likely to reach lethal temperatures, or even ignite, as the fire passes. However, this is not always the case. In winter the moisture content can remain high in the field layer, and especially in the ground layer, and this can greatly reduce the intensity of fire and its damaging effects.

Many woody species, but not conifers such as pine and juniper, have the capacity to resprout from dormant buds on the lower stem which quite often survive management fires. "Fire coppicing" can be the result of moderate frequency burning. Many scrub-forming species have seeds which are widely dispersed by wind or birds and which germinate and establish best on recently burnt ground.

Species of the ground and field layer also vary in their responses to fire. Many of them are the same as those in other habitats and their responses are unlikely to vary much from their behaviour elsewhere. Further details can be found under ***Dwarf-shrub heath***, ***Tussock grassland***, ***Tall herbs*** and ***Blanket bog*** habitats.

In scrub, the tree and shrub component is the component which is likely to be slowest to achieve its characteristic stature, abundance, structure and species composition. Although its tree and shrub species may establish a presence within less than five years of burning, fully developed scrub providing distinctive and characteristic habitat features is likely to take many decades to develop. How long this will take will depend on the species concerned and the conditions in which they are growing. Generally, an average interval between fires of less than 15 years should be considered frequent burning; return times of 15 - 30 years can be considered moderately frequent; and intervals greater than 30 years can be considered infrequent. However, for rapidly growing scrub-formers such as *Cytisus scoparius* and *Ulex europaeus* these return times could be halved, while for very slow growing scrub near the altitudinal or exposure limits of scrub growth it would be safer to double them.

Blanket bog

Blanket bog is burned to a variable extent. In the east controlled burning of small patches to improve sheep and grouse production may be evident. The emphasis here is to encourage the growth of *Calluna vulgaris*. In the west the practice of burning is characterised by the occurrence of large, mostly uncontrolled fires set with the aim of producing a fresh spring bite of *Molinia caerulea* (and to a lesser extent *Eriophorum vaginatum* and *Trichophorum cespitosum*) for sheep and Red Deer.

High impact fires are most likely if burning occurs during drought periods when the surface of the bog has dried out and especially if the surface peat has become dry. This is most likely to be the case with summer fires, outside the statutory muirburn season. Normally, rapid revegetation in blanket bogs is dependent on there being surviving stem bases, roots, dormant seed and surviving *Sphagnum* mats and hummocks. All these occur at the surface and some or all may be partially or completely destroyed in a high impact fire. Revegetation will then depend on the slow influx of spores and seed from outside the area. The peat itself also may be damaged or consumed. When dry peat ignites, surface and underground combustion can continue for long periods, sometimes for months if heavy rain is infrequent. In this situation the peat is consumed mostly by "glowing combustion" though this can periodically burst into the more dramatic and familiar "flaming combustion". This leads to partial or complete destruction of the peat and much altered hydrological characteristics. Any remaining burnt or charred peat is likely to be irreversibly dried and contain bituminous deposits produced by distillation during the fire. It will present a poor substrate for plant colonisation. High levels of mineral nutrients immediately after heavy fire (both directly from the ash and as a consequence of increased mineralisation rates) may not be conducive to the growth of some bog species, although soluble nutrients are likely to be rapidly leached by the normally high rainfall. Significant revegetation therefore may take a very long time, and the vegetation which does develop may be different from what was originally present.

Extensive, persistent mats of algae and crust-forming lichens, or mosses such as *Polytrichum commune*, *Campylopus* spp. or *Racomitrium lanuginosum*, are often among the first types if vegetation to colonise areas of bare peat produced by heavy burning. They may persist for one or more decades. Among the first *Sphagnum* mosses to colonise wet, bared peat are *S. tenellum* and *S. compactum*, which are more resistant to drought than other *Sphagnum* species. Recolonisation by these species may form the basis for restoration of other *Sphagnum* mosses and bog habitat characteristics.

In a moderate impact fire much of the above-ground woody material will be removed but much of the litter and most of the moss layer will be only partially and patchily consumed. In a moderate impact fire there will be little or no rise in temperature deeper than 1 cm below the soil surface during the fire, and even at the moss surface there will be only a modest and brief rise in temperature. *Sphagnum* mats and hummocks will often survive if merely their surfaces are killed (when they become bleached of colour), or even if the surface one or two centimetres are consumed, provided other deleterious factors like drainage, drought or trampling do not also occur. Live *Sphagnum* tissues capable of regeneration, under moist conditions, persist in a dormant state as much as 20 cm below the surface of mats and hummocks. Large, dense *Sphagnum* hummocks which tenaciously retain large amounts of moisture are likely to be least affected by fire. Where hummocks are partially destroyed they may be invaded by graminoids, dwarf-shrubs, *Racomitrium lanuginosum*, *Polytrichum commune* or a number of "feather" moss species. The proportion of *Sphagnum* mats and hummocks likely to be damaged during a fire increases with increasing dryness of ground, and decreases with increasing wetness. In a moderate impact winter fire much of the associated flora and invertebrate fauna will remain insulated and protected from heat and flame.

Low impact fires result when most of the above-ground vegetation is still moist or where there is little accumulation of potential fuel. Average fire temperatures are low and are strongly influenced by variations in the moisture content of the vegetation. Such fires tend to burn irregularly. The high moisture contents of *Sphagnum* mats and hummocks ensures that they are largely unaffected or only very superficially singed. Any effects on *Sphagnum* mosses are most likely to be seen immediately around burnt dwarf-shrub bushes where combustion would have been most intense. After light fires the regeneration of dwarf-shrubs, particularly *Calluna vulgaris* and *Erica* spp., is largely dependent on resprouting since poor seedbed conditions are produced. Light fires may produce a more open canopy of dwarf-shrubs, reducing the shading of the *Sphagnum* mosses and other bog species and encouraging their growth. However, any benefit to *Sphagnum* species and other bog species is likely to be offset by an increased frequency of low humidity and desiccation and increased growth of *Eriophorum vaginatum*, *Molinia caerulea*, or *Trichophorum cespitosum*, unless the bog surface remains continuously wet.

Frequent fires can greatly change habitat characteristics. Provided fires are light and the substrate remains wet, frequent fires may reduce shading by dwarf-shrubs which may favour an increase in cover of *Sphagnum* mosses relative to dwarf-shrub cover. This may not occur very often since areas which remain wet are unlikely to be burnt frequently. The most likely beneficiary of frequent fires are the graminoids and in most situations the *Sphagnum* component is likely to decline. The precise dynamics of recovery of bog species after fire are not yet fully understood. Some mosses (*e.g. Polytrichum* spp. and *Campylopus* spp.) and lichens (*e.g.* various *Cladonia* spp.) capable of colonising bare peat and tolerating both the flush of mineral nutrients and the more variable moisture conditions immediately after fire, may become abundant after frequent fires. *Racomitrium lanuginosum* may also become abundant under these circumstances, though it may also be a natural component where a severe oceanic climate similarly contributes to producing bare, but humid, surfaces which it can colonise. Graminoids like *Eriophorum* spp., *Molinia caerulea* or *Trichophorum cespitosum* generally recover more quickly than dwarf-shrubs, although frequent burning may reduce tussocks to small hard mounds (less than 10 cm diameter). Dwarf-shrubs lose ground to these competitors unless there is sufficient time between fires (generally more than 20 years) to enable the dwarf-shrubs to grow tall enough to overtop them. Plants with rhizomes (*e.g. Rubus chamaemorus* or *Vaccinium uliginosum*) have underground parts with well-protected buds and reserves which are largely unaffected by fire, unless the fire is very severe and consumes the upper layers of the peat. These species are likely to be favoured by frequent fires. Frequent fires which are moderate to high intensity may also affect the physical nature of the upper surface of the bog. Bogs with this history tend to be firm underfoot, although the surface may still be very wet at some times of year (especially winter), and they have a "bumpy" surface texture (from the small hard tussock of graminoids) rather than an undulating surface of soft, spreading *Sphagnum* mats and hummocks.

On blanket bogs burning at intervals of 20 years or less should be considered frequent.

Wind-clipped summit heath

Sometimes montane heaths, particularly dwarf-shrub mats, are burned. This may be done deliberately or, more frequently, may be the result of fires which run uphill out of control after having been started in the sub-montane zone. This is a very obvious impact that needs no description. It is potentially very damaging because of the slow revegetation rates and the high risks of erosion on bared ground at high altitudes. Burning this habitat is of absolutely no value for game or agriculture.

Dwarf-shrub heath

Normally, rapid revegetation in dwarf-shrub heaths is dependent on stem bases, roots and dormant seed which survive the passage of fire. Most of these are found at the soil surface or in the upper 3 cm - 8 cm of the soil and may be consumed in a high impact fire. The soil itself also may be damaged or consumed. Even when not consumed the water holding characteristics of the soil may be deleteriously affected by intense fires which may delay regeneration of the vegetation. After severe sires significant revegetation may take a very long time, and the vegetation which does develop may be different from what was originally present.

Where the soil surface is bared but not burnt this can provide good seed-bed conditions for many plant species, including tree and shrub species with wind dispersed seeds such as *Betula* spp. and *Pinus sylvestris*, as well as dwarf-shrubs. Vigorously flowering stands of *Calluna* can produce around 100,000 seeds m^{-2} yr^{-1} and a dormant seed bank of 10,000 viable seeds m^{-2} to near a million seeds m^{-2} can accumulate in the soil. In moorland edge situations in some parts of the country seeds of the bushes *Cytisus scoparious* and *Ulex europaeus* may lie dormant in the soil for many decades, geminating abundantly after a fire.

Low intensity fires tend to burn irregularly and leave much material unburnt. After such fires the unburnt dead plant litter, and to a lesser extent the mosses, provide very poor seed-bed conditions: moisture availability around young seedlings fluctuates widely and seedlings often becoming droughted before their roots have penetrated the soil. In these conditions, the regeneration of dwarf-shrubs, and other plants, is largely dependent on resprouting. This will be poor if the stem bases of the dwarf-shrubs are old and thick (greater than about 5 mm thick in the case of *Calluna vulgaris*). This effect may produce a more open canopy of dwarf-shrubs, reducing the shading of the associated mosses and lichens and encouraging their growth. *Molinia caerulea*, *Nardus stricta* or *Trichophorum cespitosum*, if present, also may benefit.

Frequent fires can greatly change habitat characteristics. Grasses like *Nardus stricta* or *Molinia caerulea* generally recover more quickly from the combustion of their above-ground parts than dwarf-shrubs, sometimes regaining their former stature and bulk within one or two growing seasons. Dwarf-shrubs take longer to regain height and bulk, although species such as *Calluna vulgaris*, *Juniperus communis*, and *Vaccinium myrtillus* eventually will grow taller than the grasses. This means that dwarf-shrubs lose ground unless they have sufficient time between fires to overtop these competing species. Plants with rhizomes (*e.g. Vaccinium myrtillus* and *Vaccinium vitis-idaea*) have underground parts with well-protected buds and reserves which are largely unaffected by fire, unless the fire is very severe and consumes the upper layers of the soil. This makes these species less sensitive to fire frequency as well as fire intensity.

Frequent removal of the sheltering canopy of dwarf-shrubs makes conditions less favourable for those plants whose growth and survival depends on the maintenance of constant high humidity. This applies particularly to the more delicate bryophytes, especially many liverwort species. It also may affect some ferns such as *Blechnum spicant*, particularly on drier, eastern moorlands. However, some mosses (*e.g. Polytrichum* spp. and *Campylopus* spp.) and crust-forming lichens, better adapted to the drier conditions immediately after fire, are likely to be encouraged by frequent fires. Although frequent fires prevent the accumulation of large amounts of potential fuel material they also limit development of a moisture holding and insulating layer of dead plant litter and mosses. This reduces the protection afforded to the more fire sensitive plants, like surface-creeping dwarf-shrubs and clubmosses, and increases the likelihood that the surface or upper layers of the soil will be damaged.

Where burning is infrequent, or does not occur, there are also distinctive effects. The sheltered but not completely shaded conditions under and among the dwarf-shrub bushes provide conditions similar to those under woodland and this favours the growth of bryophytes and certain lichens, particularly if the area also is relatively undisturbed by larger grazing animals. Flowering plants, with the exception of the dwarf-shrubs, and possibly invading tree and shrubs, are usually not very varied or abundant since patches of bare ground suitable for seedling germination and growth are very limited due to the dense growth of bryophytes or lichens, or the shade cast by the dwarf-shrub canopy. Only the more shade-tolerant species, such as *Deschampsia flexuosa*, *Listera cordata* or *Pyrola* spp., or species with long-lived seeds which can persist until rare openings appear (*e.g. Carex pilulifera*), are likely to be at all frequent and even they are usually relatively inconspicuous. The grass *Deschampsia flexuosa* can form vigorous clumps or tussocks in any gaps in the vegetation and it can very quickly grow, flower, disperse seeds and spread in one to two growing seasons after a fire.

In a previously burnt patch of dwarf-shrubs all the plants may grow and age at roughly the same rate. This means that in the absence of further burning the dwarf-shrubs may go through cycles of abundance. Eventually, however, an uneven mixture of dwarf-shrub plants of different sizes and ages will develop in the absence of burning. This end point is likely to be reached more quickly if the starting point is not a dense, uniform stand of tall *Calluna vulgaris* or *Vaccinium myrtillus*. The development of an uneven-aged stand is promoted by the ability of many of the dwarf-shrubs, including *Calluna vulgaris*, to rejuvenate by forming roots on trailing stems or branches ("layering"). This occurs widely but is most frequent and strongly developed in moist, humid situations where the trailing stems are growing through a dense mat of plant litter and mosses but where there are still light gaps in the vegetation which permit the survival of shoots and foliage carried by the trailing branches. This process can result in the development of widely spreading but vigorous bushes. These can quite quickly grow into any small gaps caused by the death if individual stems. In dense, tall patches this tends not to occur because trailing stems become suppressed by heavy shading.

On drier, mineral soils in warmer parts of the east the frequency of fires should be considered frequent if the fires occur at intervals of less than 10 years, and moderately frequent if the fire return period is 10 - 20 years; while in wet, cold, exposed locations in the west, or at higher altitudes, these periods should be doubled.

Tussock grassland

In some areas tussock grasslands are burned frequently. For example, *Molinia* grasslands in the west may be burned nearly every year. However, burning usually is less frequent than this although still frequent by the standards of muirburn in dwarf-shrub habitat. Burning is carried out to reduce the amount of standing dead litter in the vegetation, making green material more accessible to grazing livestock, and to encourage an earlier flush of green material in the spring. Earlier spring growth is probably triggered mostly by the increased temperature fluctuations experienced by plants growing in the dark surfaced ground following burning.

The amount of standing biomass of tussock grasslands is similar to that in dwarf-shrub heaths if the tussock core material is included. The amount of dead leaf litter potentially available as fuel is similar to the amount of fuel in pioneer to early building phase heather stands. The amount of potential fuel available depends on time elapsed since the last fire, the removal of plant production by grazing, and the moisture content of the litter. Fires can, therefore, potentially be as intense as in heather, with similar maximum temperatures having been recorded. However, the amount of fuel, the way it is distributed in space and the distribution of moisture in it, mean that fires are generally not as intense as in dwarf-shrub stands and average temperatures are much lower. Often much litter remains damp and unburnt.

Although tussocks usually provide concentrations of fuel, the basal buds and internodes of the tussock-forming graminoids are usually well protected from damage. Characteristics that confer resistance to damage include the high density of basal shoots, protective leaf sheath coverings, a high moisture content, and insulation by associated moist litter. This is clearly seen in *Molinia caerulea*: the buds and swollen basal internodes ("bulbs") are 5 cm - 7.5 cm below the abscission layer at the base of the leaf blades, which usually marks the limit of burning into tussocks, and are therefore little affected by burning. However, every time there is a fire some of the protective litter is removed. If burning is frequently repeated tussock size may be reduced as a result of death of more exposed, peripheral tillers. Frequent burning may also lead to reduced plant production.

Vegetative recovery of tussock-forming species is usually rapid with substantial regrowth during the summer following winter burning. Fires during the growing season, when the vegetation is dry enough to burn, have much more damaging effects from which even tussock species may be slow to recover. Associated species may not recover as quickly, often having been more severely damaged in the fire, and frequent fires may reduce the diversity of associated species. Frequent fires are likely to favour the spread of the dominant tussock-forming species although individual plants may at the same time show reduced tussock size. Moderately frequent burning is likely to help to maintain the presence of a range of herb species while infrequent burning will tend to promote tussock senescence and permit dwarf-shrubs to become dominant (if they are present).

Regeneration from seedling growth can also occur although good seedbed conditions may not be present either because of a lack of exposure of soil after the fire or because of lack of consolidation of otherwise suitable substrate. If bare humus or soil is exposed it may take two to three years to consolidate sufficiently to provide a good seedbed, by which time any seedlings are likely to face severe competition for light from parent plants. A rapid increase in *Deschampsia flexuosa* in the first two to three years after burning, as a consequence of prolific flowering and seed production, can be a conspicuous feature of burnt areas which are little grazed.

The following can be used as a guide to assessing frequency of burning in relation to the average time between fires: frequent, 3 years or less between fires; moderately frequent, 4 - 10 years; and infrequent, more than 10 years between fires.

Peat cutting

Blanket bog

This impact is obviously only applicable to blanket bog. The most obvious and drastic impacts on bogs occur when the vegetation is disrupted and peat mass is lost or deliberately removed. Peat cutting is an instance of this kind of impact. Not only may this disturb or destroy the associated flora and fauna, but the hydrology of the bog may be severely altered. This may lead to drying of the bog, which in turn will lead to a loss of the most distinctive habitat features. Such changes may be long lasting.

Peat cutting is a practice with an ancient pedigree. It has produced significant local losses of bog habitat over many centuries. There are a number of different methods of peat cutting differing in their scale of operation and the degree of disturbance they cause to the habitat.

One of the most highly mechanised and destructive is "milling". There are a number of milling operations in the drier eastern parts of Scotland. Milling requires the removal of the surface vegetation and the digging of deep drains. Between the drains working fields are cambered to encourage surface water run-off and this may cause a drying effect for many years, even if extraction ceases. A rotavator works over the stripped areas, scarifying the bare peat surface to a depth of a few centimetres. The "milled" peat is left on the surface to dry for 24 hours or so before being repeatedly turned then finally harvested when it reaches 40% - 55% moisture content. The milled peat is sucked from the surface by machinery resembling a gigantic vacuum cleaner.

Another technique involves the extrusion of "sausages" of peat from within the peat mass using machinery based on a modification of the mole plough. The machinery runs over the site in parallel passes, creating slits 1.5 m deep about 1 m apart, through which long sausages of peat are extruded in lines on the peat surface. These are cut to size and left to dry before stacking and final removal several weeks later. This type of peat extraction has been carried out as a commercial and domestic activity since the mid-1980's but in Scotland it has mostly been for small scale, domestic fuel purposes. Depending on the number of passes made by the machinery the surface vegetation may be more or less destroyed and the surface peat compacted. In commercial operations, the peat sods are not easily lifted if they get entangled with vegetation, so some operators strip the mire of its vegetation prior to extraction. Deep drains at the margins are sometimes cut to dry the peat surface sufficiently to allow access by vehicles. In wet conditions slits in the peat created by extrusion machinery close up at the surface but in periods of low rainfall they re-open as the surrounding peat shrinks. This reopening leads to further drying and repeated episodes of oxidation of the peat.

Block cutting (sometimes called "baulk and hollow") is widespread in eastern, southern and lowland areas, and also in the west where peat is cut for the whisky industry. The peat surface is dried for machine use by cutting two long end drains at the site periphery. Vegetation is then scraped off from parallel strips 2.5 m wide, leaving 6.5 m gaps untouched along which machines operate. Peat is machine cut along the entire length of the scraped area and resulting blocks stacked on adjacent vegetated baulks. The cutting process is repeated in successive years until hollows throughout the site have been cut to a depth of 0.75 m - 1.0 m. Short term stacking of the peat blocks on the baulks results in local damage to the remaining vegetation through shading and leaching of highly acidic water from the cut blocks.

Peat cutting by hand is the traditional method of cutting for domestic peat supplies and has a long history in many blanket bog regions of Scotland, notably the Outer Hebrides, Shetland, Orkney, Caithness and Sutherland. However, in many areas it is now being superseded by more mechanised forms of extraction, *e.g.* Hymac with modified bucket or extrusion machines, even for domestic supplies. Traditional hand cutting extraction reached a peak of activity in the late eighteenth to early nineteenth centuries. Domestic cutting for fuel is often concentrated in areas of bog adjoining rivers, tracks or roads where access is relatively easy. The surface turf is first removed. The plant roots, undecomposed plant material and fibrous peat in the next 25 cm is then cut, to provide peats which burn quickly when dried. A second cut, deeper into the humified peat then follows, working progressively backwards into the mire surface. Third and following cuts can be made up to a depth of 1.5 m, often leaving steps in the hollow area. Traditionally, the turfs of surface vegetation are carefully relaid on the newly exposed cut peat in the hollows as cutting progresses, encouraging rapid regrowth and restricting exposure of bare peat which could otherwise initiate erosion. This commendable practice is now not always followed. The peat sods are lifted and stacked on the baulk to dry over summer. Drains are sometimes hand cut into hollows to prevent water collecting during cutting in very wet conditions. After cutting is abandoned these drains usually become blocked with aquatic *Sphagnum* mosses and sometimes rushes.

All peat cutting leaves a certain amount of bare peat. A bare peat surface provides a very hostile environment for plant species to colonise, and may remain unvegetated for several years. Drainage is also a feature of most types of peat cutting and if drains remain operative the dried surface will support only heath and grass species rather than bog vegetation. However, the lowered surface of cut hollows, coupled with slumping of the sides of drains leading to their blockage, can lead to the restoration of wet bog habitat conditions over part of the worked area. However, the higher baulks are likely to remain relatively dry and heath-like for a considerable time, if not indefinitely. Wherever drains are cut, and particularly when they are directed into streams or natural drainage features like flushes and sink holes, there is a risk of initiating erosion.

Erosion

General

Soil erosion can occur in a number of upland habitats, principally ***Smooth grassland***, ***Blanket bog*** and ***Dwarf-shrub heath***. Peat soils are particularly susceptible to erosion once their protective vegetative cover has been removed and consequently erosion is most widespread, and often most severe, in ***Blanket bog*** habitat. Erosion in other habitats is also mostly due to the physical susceptibility of the underlying substrates, *e.g.* very friable soils with a low shear strength (often because of a low clay content) on steep slopes, coupled with exceptional weather events (*e.g.* very heavy rainstorms) which produce unusually high hydrological loading of the soil. These effects can be exacerbated by heavy grazing and trampling and frequent or high intensity burning, which may weaken or strip away the protective cover of vegetation and further destabilise the soil.

Blanket bog

Erosion is a widespread feature of blanket bogs, and takes several forms. The relative importance of processes which might potentially initiate erosion are not fully understood. Anecdotal evidence points to erosion being caused by poorly located drains, severe burning, heavy grazing or peat cutting. On the other hand, some authorities suggest that erosion may also be natural process, brought about by a mechanical or hydraulic overloading of the peat deposit in vulnerable locations *e.g.* on a convex slope at the edges of a plateau. Alternatively, some erosion may be a natural consequence of changing climate over the last millennium with bog drying during the "Medieval warm period" (11th to 13th centuries AD) priming bog surfaces for subsequent erosion during the severe conditions of the succeeding "Little Ice Age" (14th to 19th centuries AD). Once the erosion has begun both moorland management and natural forces such as wind, rain and frost can exacerbate the loss of peat. In extreme cases up to 20 mm of peat may be lost from gully surfaces during a single rainstorm.

Five main types of erosion have been described: "microerosion" (or "microbroken surface"), "erosion complex", "downhill erosion gullies", "sheet erosion", and "bog bursts".

Where microerosion occurs the peat surface is broken by a network of shallow channels up to 10 cm deep, separated by slightly raised, drier islands. The channels are predominantly bare peat but can be vegetated by *Sphagnum tenellum*, *S. cuspidatum*, *Eriophorum angustifolium* and sometimes *Trichophorum cespitosum* when not heavily grazed and trampled by livestock.

An "erosion complex" occurs when there are interlinked deep gullies, up to 2.5 m deep in extreme cases, which dissect the peat expanse into isolated upstanding peat ridges or "haggs". Peat is steadily washed away through the gully system. Erosion complexes often occur at stream-heads and on plateaux within the blanket mire expanse. Peat haggs support dry bog vegetation which may progress to dry heath: plant species typically present may include *Calluna vulgaris*, *Erica cinerea*, *Eriophorum* spp., "feather" mosses, *Racomitrium lanuginosum*, *Trichophorum cespitosum*, and some *Sphagnum capillifolium*. Often some *Carex panicea* is present. Gullies may have a base of bare peat, or exposed mineral soil and rock. Various stages of recolonisation can be seen, typically by species capable of growing on bare peat (*e.g.* the moss *Polytrichum commune*) or non-mire vascular plants which root into the mineral ground underlying thin peat (*e.g. Juncus squarrosus* and *Nardus stricta*). Occasionally, gullies may become blocked by peat slumping from surrounding ridges. Water then collects and allows recolonisation by *Eriophorum angustifolium* and *Sphagnum cuspidatum*. This may in some cases form the basis for regeneration of part of the erosion complex, with long term upward accumulation of peat from the gully floor. Well-developed erosion complexes such as those present on Shetland and Rannoch Moor have been dated at between 300 - 400 years old. We cannot yet predict the long-term development of such areas.

On sloping ground erosion often takes the form of a series of deep, parallel gullies running downhill, separated by dry ridges up to 20 m - 30 m apart. In such a system surface water is lost from the upper peat expanse, often a hill-top plateau. The sides and bottoms of such downhill erosion gullies may be vegetated by non-mire grass and heath species, but are in most cases there are steep banks of bare peat. The dry ridges, which are considerably wider than those in an erosion complex, tend to be dominated by *Calluna vulgaris*, sometimes with *Empetrum nigrum*, with only patchy *Sphagnum* mosses. Other typical bog species such as *Erica tetralix*, *Eriophorum angustifolium* and *Trichophorum cespitosum* may also be present.

Sheet erosion may occur where patches of bare peat, larger than 10 m^2, are exposed. A variety of impacts may cause peat exposure such as slippage of the peat mass on slopes, peat cutting, or heavy trampling by domestic livestock or deer. The surface of the peat becomes highly susceptible to wind and water erosion through drying and the effects of winter freeze-thaw cycles. Peat may be almost entirely lost on sloping ground, with grass and heath species recolonising thin peat and exposed mineral subsoil. However, on flatter hill-tops remaining thin peat may be successfully revegetated by *Sphagnum* mosses and associated bog species, provided that surface waterlogging is maintained.

A bog burst is a rare, but often highly visible feature. The whole peat mass shears away from the mineral soil, usually where there is a steep incline but sometimes on very gentle slopes. As far as is known "bog bursts" occur after very heavy rainfall events. The probable prime cause is hydraulic overloading of the peat. Instability may be exacerbated if peat has been removed or disturbed at the foot of slopes by peat cutting or stream erosion. There is some circumstantial evidence that drainage operations can be a contributory factor, though the causal link remains unconfirmed.

Drainage

General

Drainage most frequently affects ***Blanket bog*** habitat, although ***Flushes*** may also be affected. ***Flushes*** may be affected either by having water drained from them or by having drainage water from elsewhere led into them, potentially leading to scouring.

Blanket bog

Removal of peat by erosion or peat cutting are clearly dramatic disturbances that are likely to lead to drying of the bog. Surface drying may also be deliberately engineered by the cutting of deep, closely spaced drains, as a preparation for afforestation, or by cutting shallow surface drains ("moor grips") to improve sheep grazing. The former has drastic effects but the effects of the latter tend to be more subtle. Moor grips are often cut as long, straight or gently curving lines through existing water-tracks and flushes. Sometimes they are laid out in a herringbone network. They are usually about 0.3 m deep, though they may erode deeper than this, and at 20 m - 30 m spacing. However, erosion may make them deeper and the spacing can range from 10 m - 50 m. The effect of drains is exacerbated if they become deeper through scouring. Sometimes drains are cut to eliminate bog pools which may be perceived as a threat to livestock. This destroys one of the most important elements of the blanket bog habitat.

To understand the effects of drainage one needs to know something about bog structure. The surface 2 cm - 5 cm of undisturbed blanket bog consists of living photosynthetic plant tissue. Ninety percent of the volume is void and water moves rapidly through its porous structure. Below this is a zone of relatively undecomposed plant material 30 cm - 50 cm deep through which water still moves relatively rapidly. Below this again a narrow zone is encountered where bulk density increases five to ten fold. Water penetrates only slowly through this more compacted zone. The sum of these zones forms a protective surface cover over the main mass of peat. The properties of the main peat mass are quite different from those of the surface layer. Seepage of water occurs at very low rates, lack of oxygen (due to waterlogging) is permanent, and decay is extremely slow. The surface layer modulates water seepage and runoff according to rainfall: when rainfall is plentiful water is released relatively freely by lateral flow, while in periods of water shortage it provides a "mulch" layer which prevents excessive drying of the underlying peat mass. In periods of drought the water table gradually lowers until it reaches the boundary with the deeper saturated peat when further decline becomes exceedingly slow.

Were it not for the free movement of water in the surface layer and the fact that peat is relatively unstable when exposed to the air, it is possible that drainage would have rather limited effects because water moves so slowly through the deep peat. However, drains increase the frequency and duration of periods when the upper few decimetres of the bog surface become comparatively dry and well aerated. Such episodes encourage oxidation (aerobic decay) and reduce the capacity of the bog to respond elastically to such disturbances. Certain *Sphagnum* species, which are major functional components of the surface layer, can only tolerate dry conditions for limited periods of time: for example, under experimental conditions the major peat-former *S. papillosum* fails to recover after only 2 weeks of desiccation. Possible damage can be recognised by pronounced bleaching of the *Sphagnum*. Initial changes to the vegetation after drains are cut may appear to be rather few, and the bog may appear to remain "wet" for most of the time, but the long-term effects of drainage include the replacement of the wet "lawn" component by modified dry ridge vegetation. The bog surface becomes dominated by mixtures of *Calluna vulgaris*, *Eriophorum vaginatum*, and an assortment of hypnaceous "feather" mosses more characteristic of dry heaths, with only occasional cushions of *S. capillifolium*. Even old, poorly maintained, and possibly barely perceptible drains will have some effect. Equally, periods of waterlogging can still occur so plants of dry heaths and grasslands do not necessarily flourish either, except immediately adjacent to the drains, although they are likely to increase their representation to some extent. Close to grips and drains *Myrica gale* often becomes more dominant, *Molinia caerulea* becomes both more vigorous and tussocky, and *Calluna vulgaris* becomes taller and denser. Trees and shrubs (*e.g. Betula* and *Salix* spp.) may also invade the edges of drains where hydrological conditions are less stagnant. As they grow these will increase drying and oxidising effects and this may initiate succession towards wet scrub or woodland.

If drains have been closely spaced and have been well-maintained, or are self-maintaining through scouring, often the only diagnostic feature to identify the land as having once been blanket bog is depth of peat. This may be determined by looking in drains, along stream courses, and within erosion features. The peat depth may be determined quite simply with a bamboo garden cane which can be pushed easily through peat but will meet resistance when it hits mineral ground. The surface of well drained bog tends to be firm and dry to walk over in the summer.

The spread of bracken into other habitats

Bracken is a widespread species in the uplands, particularly at lower altitudes around the edges of upland areas. It can potentially invade a variety of other habitats. If this happens, and the bracken becomes dense and dominant, the habitat value for many species declines. The degree of invasion which occurs is related to the vigour of the bracken.

A stand of bracken is more likely to spread into surrounding vegetation if it is composed of vigorous rather than weak bracken. Colonisation is slow in the absence of a vigorous parent colony. If the stand is increasing in vigour it may also be expanding but this will depend on how vigorous the stand is in relation to the suitability of the soil, the degree of exposure, the intensity of damaging agents, and the competitiveness of the surrounding vegetation. Some types of vegetation such as dense *Nardus* and *Molinia* swards, and possibly vigorous *Calluna vulgaris* or *Vaccinium myrtillus*, seem to be difficult for bracken to invade. A crest of vigorous bracken may not necessarily indicate an advancing front. It may also occur in a zone of favourable soil conditions, reduced competition, or lower grazing pressure between two other vegetation types *e.g.* at the interface between *Nardus* and *Agrostis-Festuca* grassland. In many areas, although there is still scope for spread of bracken, much of the most suitable ground has already been colonised. Declines in bracken vigour do also occur. However, this is more likely to lead to a thinning or increased patchiness of the stand rather than a reduction in extent. Noticeable changes in the amount of frond litter are likely to lag behind observable changes in frond vigour and this may permit some assessment to be made of whether the vigour of a bracken stand is increasing or decreasing.

Bracken plants spread vegetatively and can form large, genetically identical clones. These clones can persists for a long time, probably for hundreds of years and possibly for over a thousand years. Clones may extend over distances of at least 400 metres. A clonal patch may degenerate eventually but it seems likely that scattered parts may survive, become rejuvenated, and gradually recover. New plants can arise from spores. Spores are produced in huge numbers (as many as thirty million per fertile frond when conditions are right) and are very widely dispersed in the air. A lack of late spring frosts and a warm, dry period in August to September, resulting in some late summer moisture stress, are the conditions which seem to encourage spore production. Some stands may produce spores almost every year while other stands are very rarely fertile. There is some limited evidence that more vigorous plants may be more likely to produce spores abundantly. The distinctive but inconspicuous young sporeling plants are very rarely found in the uplands. However, they could be more widespread than is usually assumed. Limited evidence shows that bracken patches may be made up of a number genetically different individuals suggesting that establishment from individual spores can occur. It takes about three years for a new plant to develop from a spore to an adult form, but it may take twenty to thirty years for a whole stand of bracken to develop from a weak colonising state to a mature and vigorous condition.

Both the density of bracken fronds and their size tend to increase with increasing vigour. In very vigorous bracken the density of fronds tends to decline again but this is more than made up for by the increase in frond size. Stressed bracken produces small fronds which tend to unfurl faster and also die back up to one month earlier in autumn (dieback normally occurs during September), although there may also be a high proportion of fronds which both emerge and unfurl late. Stunted, tougher and thicker fronds with fewer frond segments and relatively more fibrous support tissue are produced in response to the stress of low moisture availability.

The thick and extensive rhizomes provide a large food store and reserve of frond buds from which new fronds can grow should the above-ground parts of the plant be damaged. When fronds are damaged but the rhizome remains unharmed fronds often resprout more densely than before, although frond size is reduced. The large reserve capacity of the rhizome system makes the plant very resilient to damage unless this occurs repeatedly over many years.

Severe weather

General

Damaging effects of severe weather are usually the result of desiccation of plants. This can occur at any time of year and is not just restricted to summer drought. In fact, effects are more often observed in late winter or early spring. Effects are most often and conspicuously seen in ***Dwarf-shrub heath*** but ***Wind-clipped summit heath***, ***Scrub*** and ***Bracken*** can also be affected. Nearly all habitat types can be affected during exceptional summer droughts.

Dwarf-shrub heath

Sustained spells of strong drying winds can produce "browning" (followed by "greying") of foliage, with subsequent partial dieback of shoots. Rarely, the dwarf-shrub canopy is completely killed. Effects of drying winds occur most frequently, and are often most severe, during the winter half of the year when wind speeds are higher and low soil temperatures make uptake of water more difficult for plants. Near the coast the effects of salt spray can exacerbate the desiccating effects of the wind. However, on very shallow soils and around the edges of rock outcrops similar desiccation "browning" may occur during summer droughts in the absence of strong winds. Wind-browning effects may cover many square kilometres but they always show a consistent pattern of occurrence on slopes facing the direction from which the drying winds came. Within affected patches the tallest and most exposed parts of plants are worst affected. Patches which are very short and have a smooth upper surface are much less affected. Although the leaves and shoots may die, the effects are rarely so severe as to kill whole stems and the plants usually survive and resprout from their lower parts. Where such conditions occur regularly every year the vegetation will form a short, dense mat (often less than 10 cm deep) in which the stems and branches of the dwarf-shrubs grow more or less horizontally, and more or less parallel to the prevailing direction of drying winds, benefiting from mutual shelter and lower wind speeds close to the ground. In extreme cases the effects of wind may be so severe that the vegetation is reduced to strips at right angles to the direction of the prevailing wind, separated by bare gravel or soil. This is quite a common feature in ***Wind-clipped summit heath***.

Prolonged snow-lie has a number effects on dwarf-shrub vegetation. Stems and foliage are crushed to a greater or lesser degree by the weight of the snow, and both this and any movement of the snow pack may break stems. Plants also are partially deprived of light for the duration of the drift. The more shade tolerant dwarf-shrubs like *Vaccinium myrtillus* and *Vaccinium vitis-idaea* survive this better than *Calluna vulgaris* and are more abundant than *Calluna vulgaris* where snow accumulates regularly. Such patches are found in obvious snow-holding areas. Heavy snow falls can produce similar physical effects in ***Scrub***. On the other hand, snow cover does protect plants from the effects of drying winds, frost and blasting by wind borne ice crystals.

Bracken

Bracken survives the winter by relying on its extensive underground rhizome system. Winter frosts which deeply penetrate the soil (though rarely occurring at the altitudes within which bracken is usually found) may damage the rhizomes, while late spring frosts can damage the emerging fronds. Generally the frond litter provides very effective insulation. Where it is absent, fronds may emerge later due to winter frost damage to the rhizomes and colder soil temperatures in spring. Sporadic frosting is unlikely to severely affect a bracken stand in the long term. Frost is often more frequent and severe in the east of the country, where it more rigorously determines the distribution of bracken, but frost damage is more often *seen* in the west because there bracken can establish in potential frost hollows from which it would be eliminated in the east. In soils where rooting is restricted and the rhizomes rise up into the decaying frond litter they may become more vulnerable to frosting if the insulating litter layer is disturbed or removed.

Droughting effects on soils with very free drainage and poor moisture holding capacity can be exacerbated by wind exposure. Wind also produces mechanical damage and, if persistent, it may mechanically weaken fronds (particularly at the neck of the frond).

Fungal disease

General

Effects are usually most conspicuous in ***Dwarf-shrub heath***. However, root-rots can affect a wide variety of plant species in many different habitats although the effects are usually not very conspicuous. Rusts can also be common particularly on trees and shrubs, *e.g. Gymnosporangium clavariforme* forms conspicuous orange fruiting bodies and swollen nodes on the stems of juniper, weakening or more rarely killing them. "Snow mould" can kill or damage patches of grassland sward although again its effects tend to be most noticeable in ***Dwarf-shrub heath***. In ***Blanket bog*** one can often observe small patches of blackening and dieback of *Sphagnum* moss dieback which do not seem to be related to any obvious management impact and may be due to fungal disease.

Dwarf-shrub heath

A number of fungi can cause dieback of dwarf-shrubs. Some, such as the facultatively parasitic *Marasmius androsaceous*, can directly attack the aerial parts of *Calluna vulgaris*. "Snow mould", found on plants weakened after prolonged snow-lie, also may kill shoots directly. More frequently various root-rots can lead to the death of stems. Where dwarf-shrubs are "layering" the production of new roots on more distant parts of trailing stems may allow parts of the plant to survive for some time as the rot slowly travels up the stem from its origin in the oldest parts of the stem and root system. Individual dwarf-shrub plants of the same species seem to vary in their susceptibility to fungal attacks. Sometimes apparently completely healthy plants can be found growing immediately adjacent to severely affected ones. Usually, only scattered plants are affected but occasionally affected patches may extend over several hectares.

Bracken

Bracken also is susceptible to a number of diseases caused by parasitic fungi such as "curl-tip disease", "pinnule blight disease", and "leaf curl or tar spot disease". The last of these is uncommon in Britain. These rarely cause progressively damaging effects on bracken stands. Trampling by large herbivores and strong winds can mechanically damage fronds, particularly weakening the neck of the frond, and plants may be made more susceptible to diseases after such mechanical damage.

Agricultural improvement

Smooth grassland

Grasslands within this habitat type are the most likely targets for pasture improvement to increase agricultural production. Varying intensities of treatment may be applied to bring this about. Controlled heavy grazing, with concomitant high rates of dunging and increased mineral cycling and availability, may bring about a gradual change to a more productive (though usually less species rich) type of sward. This effect may be bolstered by regular dressings of lime, phosphorus, nitrogen, or (more rarely) applications of balanced fertilisers. Fertiliser responses of swards of indigenous species can be very variable though increases in production of 100% or more are possible. Sometimes the process may be taken further by top seeding with palatable and productive mixtures of *Lolium perenne* and *Trifolium repens* (sometimes also with some *Phleum pratense*). The most extreme form of improvement, which is likely to occur more rarely and only on better soils on the margins of the uplands, involves destruction of the original sward by ploughing, or herbicide application followed by surface tillage, and reseeding. Reseeded pastures are likely to need repeated applications of up to 80 kg N $ha^{-1}yr^{-1}$ and 10 - 20 kg P $ha^{-1}yr^{-1}$ to maintain productivity and prevent reversion. If lime and fertiliser applications are not maintained (as has happened to many improved hill grazings) then substantial reversion can occur within five years, although high species richness may require decades to fully develop if soil fertility declines only slowly. The *Trifolium* content of the sward can be maintained for a considerable time, with concomitant higher sward productivities, by judicious grazing management. Lime dressings have tended to be reduced or become more infrequent in recent decades since agricultural grants for liming were discontinued in the 1970's. A further treatment which may be applied is the use of pesticides against species which may reduce sward productivity *e.g.* application of chlorpyrifos to control leatherjackets (Tipulid larvae).

Effects on the associated flora and the structure of the habitat largely depend on the balance between increased vegetation productivity, increased offtake by livestock, and increased disturbance by grazing and trampling. There may also be direct effects from fertiliser and pesticide applications. Many plants will tend to grow larger and flower more profusely if fertilised but this is likely to be counteracted by increased grazing offtake and increased trampling by higher stock densities. If stock densities and trampling are not increased in proportion to the increased sward productivity then slower growing and smaller plants are likely to be lost from the more competitive sward environment which results. Lime and fertiliser dressings as low as 3 tonnes ha^{-1} of calcium oxide (CaO) equivalent and 25 kg N $ha^{-1}yr^{-1}$ have been found to reduce plant species diversity in some circumstances.

The fauna may not be affected in quite the same way. Improved nutrient quality of plant material returned to the soil is likely to increase soil invertebrate diversity unless the fertilisers used also produce a strong acidifying effect. Disturbance through increased rates of removal of plant material and trampling by domestic livestock will counteract the possible increases in the number of species, fecundity and population sizes of above-ground small mammals and invertebrates which might otherwise occur. Deleterious disturbance effects are likely to be most pronounced for larger, more slowly maturing and reproducing invertebrates such as the larger ground beetles and spiders. Any pesticide use obviously will have destructive effects on the associated invertebrate fauna but the degree of impact will depend on the frequency of use and to some extent on the timing of application. For example chlorpyrifos is often applied in early spring before some elements of the fauna are active, *e.g.* ground beetles, and the effects on these species may be less than expected.

Pollution

General

Air pollution could potentially affect most upland habitats. However, observable effects are most likely to occur in ***Wind-clipped summit heath***. The effects here are mainly due to nutrient enrichment by nitrogen deposition although acidifying effects may also be significant, particularly in snow-beds and high altitude ***Flushes***. At lower altitudes some limited areas of ***Dwarf-shrub heath*** may also be affected by nitrogen deposition: where *Calluna vulgaris* grows in competition with *Molinia caerulea* this will tend to favour the *Molinia*. We do not yet have definitive evidence which would allow us to say how widespread these effects are. The effects of air pollution could make field diagnosis of grazing impacts on vegetation less certain.

Wind-clipped summit heath

Deposition of nitrogen compounds from the atmosphere, as a result of air pollution, may affect vegetation composition in a similar way to dung from grazing animals. The frequent occurrence of cap-cloud and mist on montane ground greatly increases rates of deposition. This pollution could be significant in areas south of the Great Glen, particularly parts of the Cairngorms, south-west Highlands and the Southern Uplands. Mountain tops in these areas may experience deposition rates as high as 8 - 18 kg N $ha^{-1}yr^{-1}$, sufficiently high to be likely to produce long-term effects on vegetation composition such as the spread of grasses at the expense of the moss *Racomitrium lanuginosum*.

Part 5: How to plan and undertake an impact survey

Planning and prior preparation

The objectives for the site

The first thing which should be considered are the site management objectives. These will determine which habitats require to be surveyed or, if all are to be surveyed, then the objectives will help to prioritise how survey effort should be applied across the habitats. Survey planners should remember that even if only some of the habitats are of direct interest it can still be useful to obtain information for others: a more complete picture of the pattern and behaviour of impacts makes them easier to interpret and makes it easier to translate the results of the survey into site management prescriptions. Site management objectives also have a strong bearing on the type of output required from the survey, most importantly on the scale of spatial resolution required and the most appropriate form of reporting of the survey results.

Deciding on the type of assessment unit and output required

Generally, impact information will be most useful in map form. Not only do maps allow direct visual appreciation of the size of areas affected by different impacts, and the proportion of a site affected in total, but they also show the location and pattern of specific impacts. *Where* impacts are occurring can be as important as how much ground they affect.

It will generally be most useful for coverage of the ground to be as complete as possible. However, it is unrealistic and unnecessary to directly assess and record every square metre of ground. The survey planner must decide on a sensible spatial resolution for recording and assessment. This should be such that any impacts which are of a size to significantly influence achieving the objectives of the site will be registered in the survey results while avoiding producing more information than is strictly necessary or interpretable. The most appropriate spatial resolution will vary according to the practicalities of plotting at the map scale desired, the size of the habitat features of interest, the size of the site, and possibly the scale at which management can influence impacts on the features of interest. Even at 1:10,000 scale it is difficult to accurately plot and label areas smaller than about 0.1 ha, while at 1:25,000 the same applies to areas smaller than 0.25 ha. (Very small features of high importance or interest can be referred to by target notes). Also, the smaller the assessment unit the greater will be the potential for large errors in location relative to the size of the assessment unit, making repeat surveys (for quality checking or monitoring) more difficult to interpret. In terms of seeing the overall pattern of impact, and translating this into management implications, it is probably not worth assessing and mapping areas smaller than 1 ha where sites, or areas of habitat, cover less than a couple of square kilometres. For larger sites or habitats up to 10 km^2 a minimum assessment unit of about 4 ha is likely to provide sufficiently detailed information for overall site assessment and management planning, while for very large sites of several hundred square kilometres units of up to 0.25 km^2 may be more appropriate. However, units should not exceed 0.25 km^2 as above this size the individual mapping units are likely to be so internally heterogeneous, with respect to both habitats and impacts, that discrimination of important patterns of impact intensity will be seriously compromised .

The question of the most appropriate spatial resolution for mapping and recording is also influenced by whether a raster format or vector format is adopted. Raster format involves dividing up the site into a regular grid of squares, most usually based on the National Grid. Each square represents an assessment unit for which impact assessment information is gathered and recorded. Vector format involves the identification of areas of homogeneous impact which are then recorded and mapped as closed polygons. Each polygon is an assessment unit and these can vary greatly in size and shape. Both raster format and vector format approaches have their strengths and weaknesses, which are described in more detail in the remaining paragraphs of this section. Which approach you adopt will be influenced by how you want to use the results.

In raster format the regular grid ensures a uniform coverage of the site or habitats of interest. It also allows the results to be fed into a database and printed out as a map overlay (most easily through a geographical information system) without the time consuming and expensive stage of digitising boundaries as is required when the results are in vector format. The results can be recorded on data sheets and/or displayed as a map overlay on which the grid squares are coded or coloured in various ways to indicate impacts.

However, a number of problems and complications can arise. Firstly, the boundaries of the grid squares need to be identified on the ground. This usually involves interpreting the grid lines on published topographic map in terms of ground features. This can be difficult to do accurately in relatively featureless terrain. Secondly, since the raster squares are arbitrary relative to impact patterns it is possible for an individual square to have more than one applicable impact class. This can be dealt with in a number of ways: the simple presence/absence of all classes may be recorded, the proportions of the square affected by each class present may be recorded, or an average based on the relative amounts of the different impact classes may be recorded. The simple presence/absence solution can lead to a rather uninformative and not easily interpretable picture (*e.g.* the odd heavily grazed plant or small patch can often be found in most squares regardless of the overall grazing impact), and it can be difficult to devise a scheme for labelling, colouring and coding which is consistent and not potentially misleading. Problems of coding and display can also occur when the proportions of different impact classes in a square are used, but the recorded data for each unit are less ambiguous and more clearly interpretable. An average assessment for the square can be more easily displayed and is more simply recorded but the relative proportions of the different impact classes still need to be estimated in order to determine the average and it would be a waste of effort and information not to record them. Retaining this information also gives the option of drawing attention to the existence of high intensity, but small-scale, impacts (*e.g.* supplementary winter feeding locations for livestock) which the averaging process will tend to obscure. However, in order to keep data collection within practical and useful limits we recommend recording only those impact classes covering more than 20 % of an assessment unit. Finally, some types of impact do not fit easily into the raster format and are more naturally recorded as polygons. For example, where the habitats concerned only occur as small patches or where an impact, such as recent burning, affects relatively few, but clearly discernible, patches varying greatly in size and shape and for which the dimensions of affected patches are an important impact characteristic.

The vector format approach is very similar to the procedure used in the surveying of vegetation types. This is potentially a more efficient way of recording impact information since large uniform areas can be recorded as one large polygon, replacing several raster format recording units. Also, because homogeneous areas are used to define polygons, the number of items of information which need to be recorded for each unit should be less than for the arbitrarily defined raster format grid squares.

But this approach also has its problems. These can arise, for example, when broad impact gradients are encountered. It can be difficult for field surveyors to decide where to draw a boundary, which reduces the precision and repeatability of the survey, and the forced classification of continuous variation can potentially mislead anyone interpreting the results. Also, output cannot automatically be printed out as map overlays without first digitising the boundaries of the field maps and entering the data into a geographical information system.

One of the most problematical features of this approach is how the surveyor identifies a homogeneous area. (The raster approach, by using arbitrary units, evades this problem.) Homogeneity is a relative concept. An area is only homogeneous relative to specific features, specific magnitudes or rates of change in those features, specific spatial scales, and the specific number of classes used. Impacts are often very patchily distributed, sometimes simultaneously over a *range* of spatial scales. This particularly applies to grazing and browsing impacts: over a given area of ground grazing intensity can consistently differ between the parts of an individual plant, between individual plants of the same species in the same patch, between plants of different species, between patches of the same vegetation type in different topographic locations, and between patches of different vegetation types. Other types of impacts do not show such pronounced multi-scale variation. For example, burnt patches usually form discrete polygons which can be clearly distinguished from the surrounding matrix, although there can still be considerable internal variation in intensity of burning and burnt patches can vary greatly in size and shape. Where homogeneity could potentially be assessed at a number of different spatial scales it can make sense to choose a scale best suited to the scale of human perception. This will increase survey precision and repeatability, although it should always be remembered that this may not be the scale which is most important for the activities of the flora and fauna of the habitat.

Although human visual perception is very good at discriminating edges or boundaries in the visual field, and thus indirectly identifying homogeneous areas, the process of doing this is rarely made explicit. Even experienced surveyors can be unclear about what they are doing when they define homogeneous areas on the ground. A repeatable survey method requires explicit criteria to help individual surveyors be consistent in their choice of boundaries and to help them explain to other surveyors, and to those using the results of their work, why they have mapped particular areas as homogeneous.

The field indicators given in the second volume of this guide, coupled with the guidance on the size of assessment units, provide part of such a set of explicit criteria for habitat impact assessment. One problem is that you may not know which impact criteria are applicable until you have defined an area and walked over it ! The resolution of this paradox is to adopt a "bootstrapping" approach. Prior knowledge of the distribution of factors which influence impacts, *e.g.* soil type or exposure, coupled with large-scale field indicators, can be used to rough out a description both in terms of homogeneous areas and impact classes. Then, both the boundaries of the sketched areas and the impact descriptions can be checked, refined and modified if necessary, after closer inspection at smaller spatial scales using all applicable field indicators.

While doing this you also need to be aware of how to use your visual system to best advantage. Although, while looking straight ahead, you may be aware of things within a field of view of up to 180°, clear vision only occurs within a much narrower angle of about 30° to 40°. (For comparison the angle of view of a standard 50 mm lens on a 35 mm camera is about 46°.) Even a 30° to 40° view can be difficult to assess consistently and accurately because you have to move your eyes and head around and your brain has then to piece together all these different "views" in order to try to come some sort of integrated assessment. We recommend that you make your assessment of homogeneity based on apparent uniformity of colour and texture (or regular pattern of colour and texture) within a field of view of about 19° to 28°. This will be the case when you gaze straight ahead at a patch from a distance of between two and three times the width of the patch. It is then relativley easy to assess the whole of an area with very little eye movement. To assess larger areas you need to stand further back from them. How far away you are then determines the amount of detail you can see clearly and therefore what types of features you can identify reliably and use to assess homogeneity.

Using existing sources of information to help in planning survey field work

Once the type of survey and output have been decided work can begin on planning in detail how the survey should be undertaken on the ground. It makes sense to use any existing information which may help in planning the most effective way of covering the ground to be surveyed. Geological, soil, and topographic maps can all help to determine where some habitats are most likely to occur and what the pattern of impacts (particularly grazing and browsing) is most likely to be. National Vegetation Classification maps, if available, can also be interpreted to provide similar information. For example, in general, grazing impact is likely to be least on the wettest and/or most acid soils, and in high altitude or in very exposed locations, while areas of lime-rich soil are likely to attract heavy grazing impact. This can help to highlight areas which may provide critical tests of impact levels over the site, as well as helping to start the process of identifying areas of homogeneous impact. Up-to-date aerial photographs, if available, can be a great boon for surveyors both to facilitate locating themselves, both on the ground and with respect to topographical maps, and also as an aid to plotting impact polygons.

Management information should be used with caution when undertaking a survey. There is a risk that some kinds of information, particularly stock numbers, will bias a surveyor's assessments through his or her prior assumptions about the consequences of particular stocking densities or stock management practices. It is therefore better to carry out the impact survey without such knowledge, collecting it only after the survey has been completed in order to interpret the results and formulate any necessary management responses. However, information on stocking densities can be useful to the survey planner when deciding whether an impact assessment is likely to be worthwhile or not. In Part 4 we have provided some indicative guidelines on stocking densities to help determine if impact assessment will be a useful exercise. If this decision is made by someone other than the person undertaking the survey, as will often happen, then risk of bias should not be unduly increased.

Timing

Time requirements

For a survey of all habitats and all potential impacts, the average rate of ground coverage on an average hill for a Phase 1 Impact Survey will probably be about 1 - 2 km^2 hr^{-1}, while for Phase 2 Impact Survey it will be about 0.5 km^2 hr^{-1}. On very difficult ground, very broken topography, and/or complex patterns of impact, these rates may need to be halved. This excludes time taken to travel in to the area of ground being assessed.

When to carry out surveys

Habitat	*Optimum time of year*	*Comments*
Smooth grassland	July - August	Grazing effects on plants will be most easily observed in mid to late summer when plants have achieved their full height, most species will have flowered if they are going to, and signs of grazing will be more apparent as the herbivores begin to eat into the accumulation of herbage produced during the very rapid growth of spring and early summer.
Flush	June - July	Optimum time is uncertain but assessment is probably best done during the flowering season of herbs, though some degree of assessment should be possible at any time of year provided the flush is not covered by snow or ice. Poaching may well be more severe at other times of year.
Tall herbs	July - August	Assessment is best done during the height of the growing and flowering (and grazing) season for most of the herbs, though some degree of assessment should be possible at any time through summer to autumn.
Scrub	March - early May (July - September for the field layer)	(a) *Browsing, grazing and trampling*. Conifers such as juniper are most likely to be browsed over winter but the timing of browsing of deciduous, broad-leaved species can be more variable. Although broad-leaved species might be expected to be browsed more in summer, *Betula* spp. and *Myrica gale* are sometimes browsed more in winter. Heavy trampling and browsing resulting from animals seeking shelter is most likely in the winter but observable effects should persist through to late summer. Generally, the best time for assessment of the woody component of the habitat will be late winter to spring but the

		herbaceous field layer would be better assessed in late summer. (b) *Burning.* Probably best assessed at the same time as browsing, grazing and trampling.
Blanket bog	June - July	(a) *Drying.* Can probably be assessed at almost any time of year but avoid drought periods or very wet periods when discrimination between different states becomes much more difficult. (b) *Burning.* Burning is most likely to occur over winter but some may occur (illegally) during the summer. If assessment is delayed to later than mid-summer then the assessment will often be able to include observations on plant survival and regeneration (a delay of six months to a year is even better for assessing regeneration). (c) *Grazing and trampling.* Impacts are most easily observed in the mid-summer period when there will be the greatest difference in stature and flowering/fruiting success of the indicator herb species. Avoid drought or very wet periods. Low altitude bogs may be more heavily used in winter, high altitude bogs in summer.
Wind-clipped summit heath	July - August	Assessment is best done towards the end of the summer growing and grazing season. Late July to late August is likely to be the optimal time for making observations as this will give an indication of usage for the majority of the year.
Tussock grassland	July - August	Grazing effects on plants will be most easily observed in mid to late summer when plants have achieved their full height, most species will have flowered if they are going to, and signs of grazing will be more apparent as the herbivores begin to eat into the accumulation of herbage produced during the very rapid growth of spring and early summer.

Dwarf-shrub heath	March - early May	(a) *Browsing*. Evidence of browsing on dwarf-shrubs usually is most easily observed in late winter or early spring. This is at the end of the period when most browsing will have occurred but before the dwarf-shrubs have made much new growth. It may still be possible to make an assessment at other times of year but this will be more difficult, due to unbrowsed new growth obscuring past browsing, and the results will provide a less reliable indication of current browsing pressure. (b) *Burning*. Assessment of fire intensities is best carried out soon after fires have occurred. This could be conveniently done in the same late March to May period as for browsing assessment since many management fires will be set during the statutory winter muirburn period. However, fires outside this period are not infrequent whenever prolonged dry spells occur. It can be useful to wait for six to twelve months after the fire before carrying out a survey as it is then easier to assess post-fire regeneration.
Bracken	July - August	Some degree of assessment can be done at any time of year as long as the ground is not snow covered. However, a comprehensive assessment ideally should include observations throughout May to September, since rates of spring frond unfurling, the final size and healthiness of fronds, and the timing and rate of autumn frond death are all important indicators. Some trend indicators may be more easily observed after the fronds have died down. If only one observational visit is possible then sometime during July to August, when fronds have reached their maximum size, is probably best.

Phase 1 Impact Survey: reconnaissance

This is the simplest form of impact survey which is likely to be sufficiently informative to be of use in site management decision making. Much of the assessment work in this phase is undertaken from vantage points providing views of several square kilometres using Large-scale Field Indicators. Binoculars, or even telescopes, and recent aerial photographs (if available) are helpful aids. Any relevant pre-existing information is also used to help determine the most likely pattern of impacts, as described previously, as well as observations of habitat structure and distribution which may influence the pattern of impact.

The surveyor should pay particular attention to potential hydrological units and any physical evidence of drains or erosion (particularly for bogs), the likely wetness of ground, the occurrence of very broken and rocky ground, steep slopes, and the pattern of shelter and exposure provided by the topography, all of which will all influence the pattern and intensity of grazing and burning impacts.

The surveyor should make some closer observations to check on the interpretation of impact deduced from afar. In particular critical habitat types and situations should be checked. For grazing and browsing impacts at least some representative areas of ***Smooth grassland***, ***Flush***, ***Tall herbs*** and ***Scrub*** (if any of these are present) should be visited and checked. If these are found *not* to be heavily grazed/browsed it is highly unlikely that any other habitats will be heavily grazed/browsed. A representative selection of ***Blanket bog*** and ***Wind-clipped summit heath*** areas should also be checked. If these *are* found to be heavily grazed then it is highly likely that all other habitats will also be heavily grazed. Recently burnt areas should also be walked through to check for fire intensity and vegetation recovery.

The result of Phase 1 Impact Survey is a first approximation to describing the pattern of impacts. At the end of Phase 1 the surveyor should have a good knowledge of the range of variation of impacts on the site and be able to produce a coarse resolution, impressionistic description of habitat impacts in both map and narrative form. The results of a Phase 1 survey may be sufficiently clear cut that a fuller Phase 2 survey will not be necessary but this is unlikely to happen often.

Phase 2 Impact Survey

Phase 2 assessment involves walking through and checking each of the raster format grid squares or polygons of homogeneous impact identified during Phase 1 Impact Survey.

Heterogeneity at a scale below the chosen minimum size of assessment unit should be averaged out in making an assessment for each polygon or grid square, although it may help subsequent interpretation if any impact classes covering more than 20% of an assessment unit are also recorded. For vector format polygons, if more than 20% of the area could be classified differently from the rest then you should reconsider if the polygon really is homogeneous, particularly if the scale of variation is greater than the minimum assessment unit size.

An informal, subjective assessment of the overall impact will already have been made in the course of Phase 1 Impact Survey and in refining the boundaries of homogeneous areas. However, this needs to be checked with more detailed and systematic observations. This usually means some sort of averaging of a number of "point" estimates scattered across the polygon. Point samples involve making assessments for one or more field indicators for a small patch of ground, of about a square metre, immediately in front of the surveyor (see the discussion in the last paragraph of the section **Deciding on the type of assessment unit and output required**). Some indicators may only be applicable to larger areas, perhaps even the whole polygon, but this should be obvious from the indicator descriptions. For each polygon or grid square close observations should be made at ten sample points at least (preferably more), well scattered across the polygon or grid square to ensure that a representative assessment is obtained. The more sample points used the more precise and reliable will be the assessment. Averaging can be by mental running average as one walks over the ground, or more formally, by written recording and mathematical averaging of data from each sample point. The latter is slower, more cumbersome and more expensive but it does provide more information, reduces the possibility of bias in estimation, and is probably less mentally fatiguing for the surveyor since the averaging can be done later at the data collation stage.

It is important not to rely on just one or two indicators when doing Phase 2 Impact Survey. The lists of field indicators cover a range of different features, and vary somewhat in their reliability and discrimination. For some of them it may be difficult sometimes to decide what is the most appropriate impact class. Also, indicators are likely to vary somewhat in how they divide up the range of variation in impact which may lead to some disagreement in the impact classes as assessed by different indicators. These potential problems can be dealt with by basing the overall assessment on whichever impact class is closest to the average for all the indicators used. This solution will be most robust when many indicators are involved. The greater the number of indicators used the greater is the scope for cross-checking and corroboration. Assessments based on more indicators are likely to be more reliable, more justifiable and more repeatable than assessments based on few indicators.

Recording the results

We recommend that surveyors make detailed and systematic records of routes taken (plotted on a map), viewpoints from which general assessments are made, time of year (and state of vegetation development), weather conditions (visibility, and whether vegetation was wet or dry), and which field indicators were used at each assessment unit or patch. Photographs (prints) of typical high, moderate and low impact situations for the more qualitative field indicators used will greatly help to maintain consistency in any repeat survey.

The results of assessment should be systematically recorded on field maps and data recording sheets. Recording sheets should be designed with tick boxes so that as little writing as possible is required in the field. Not only does this make field recording easier but it also reduces the risk of errors due to illegible writing or miscopied symbols, codes or descriptions. Each assessment unit (grid square or polygon) should have its own recording sheet. Examples of model recording cards are provided at the end of this volume. (Printed A5 copies of these are available from SNH Publications). Fair maps should be produced for each habitat and impact type and should be drawn up from the field maps, preferably at the end of each day of survey.

Where raster format maps are being produced the colouring and coding system adopted should be as visually consistent and informative as possible. This can be difficult to achieve where there are mosaics or gradients of impact. The following scheme for colouring and coding is presented as one possible solution. Assign a colour to each of the main impact classes *e.g.* red for high, orange for moderate and yellow for low. Apply this colour wherever the relevant impact class covers more than 33% of an assessment unit. If the areas covered by these impact classes are within 20% of each other then apply the relevant colours in equal amounts by hatching or stippling but if the difference between classes is greater than 20% apply half the amount of the relevant colour for the less widespread class. Any impact classes which cover more than 20% but less than 33% of the assessment unit should be indicated by a superimposed letter code. This type of scheme should allow someone looking at the map to easily see broad patterns of impact without loss of useful detail.

Where there are broad impact gradients it can be helpful if these are indicated on the impact map with arrows running from the lowest to the highest impact end of the gradient. The gradient, and arrow, may run across one to several polygons or grid squares. It can be difficult for surveyors to precisely locate a boundary between impact classes where there are broad gradients of continuous variation in impact. Indicating where these situations occur will alert anyone looking at the map that boundaries between classes may be somewhat arbitrary.

We recommend that this comprehensive recording procedure is always undertaken since it makes the methods and results much more interpretable, transparent and justifiable, makes it easier carry our quality checks on survey work, and makes the results of more potential use for future monitoring.

Part 6: Predicting the future state of habitats

Smooth grassland

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Heavily grazed. Gross characteristic features probably stable. Erect-growing herb component may decline in long term. Increased mineral nutrient cycling but increased losses by leaching also possible. Greater probability of erosion being initiated on steep slopes.	Moderately high diversity of characteristic flora maintained unless grazing very intense when it will decline. Uncertain long term persistence of annual species or potentially taller growing species which never get a chance to flower. Restricted flowering and lack of seedling establishment of some herbs may reduce the long-term resilience of their populations through loss of genetic variation.	Favourability for foraging Ring Ouzels and Wheatears maintained or increased, but low or declining favourability for small mammals. Low or decreasing diversity of above-ground invertebrates, although small, rapidly breeding, mobile, invasive species may be or become quite abundant. Moderately abundant and diverse soil fauna, probably including earthworms.
Moderately grazed. Stable, though may suffer periodic disturbances due to vole eruptions.	High diversity of characteristic flora maintained. Plants which grow taller and more erectly than the ground-hugging, creeping and cushion-forming species stand some chance of flowering without being grazed, probably enhancing long-term resilience of their populations.	Maintenance of species composition and structural variation in the vegetation is likely to ensure that most characteristic animals will continue to be present, including nectar and pollen feeding insects. Moderate abundance and diversity of soil fauna, possibly including earthworms,

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
		likely to be maintained.
Lightly grazed or not grazed. Possibly unstable (over many decades): loss or reduced vigour of very small stature or annual species, and possible invasion by dwarf-shrub/shrubs in some situations. Unpredictable effects from slug grazing and periodic severe vole grazing. Increased plant litter accumulation, somewhat reduced decomposition rates and possible, though not certain, reduction in availability of mineral nutrients.	When lightly grazed, continued moderately high diversity and persistence of most of the characteristic flora but annual species (*Gentiana* and *Euphrasia* spp.) may become uncommon and the diversity of grass species is likely to decline. When ungrazed, overall diversity likely to decline except in very nutrient-poor or exposed situations. At high altitudes near crags small, montane willows or dwarf-shrubs as well as taller herbs, may become established, particularly if suppressed plants were initially present in the sward.	Taller sward may be less attractive to characteristic birds such as Ring Ouzels and Wheatears but small mammals and herbivorous invertebrates (including slugs, and nectar and pollen feeding insects) may become abundant. Abundances of above-ground invertebrates may become more equitable. Possible but not certain decrease in activity, and possible decline in abundance and diversity, of soil fauna. Some decomposer species with a high moisture requirement, *e.g.* Tipulid larvae, may benefit.
Heavily modified (agricultural improvement). Simplified and more homogeneous structure and plant composition, heavily disturbed (by	Low species diversity maintained, or slow increase in species diversity if high fertility not maintained and reversion occurs.	May be used by characteristic birds for feeding. Other vertebrates likely to be very sparse or absent. High degree of disturbance from high

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
grazing and trampling), but relatively highly productive. Structure and composition will become more complex if heavy grazing and fertiliser treatments not maintained.		densities of livestock (and possible pesticide use), and a short sward with little structural variation, leads to low diversity and low to moderate abundances of above-ground invertebrates. Small, rapidly reproducing, invasive species (more characteristic of lowlands) are favoured. Dung, provided livestock have not been treated with anti-parasitic drugs, may provide an additional habitat resource which counteracts the general loss of invertebrates. Soil fauna diversity and activity likely to be relatively high.
Lightly modified, reverted or agriculturally unimproved. Stable. Plant composition and small-scale patch structure varied and in dynamic equilibrium, though vertical structural variation limited. Plant productivity moderately high.	Moderate to high species diversity maintained.	Value for moderately diverse characteristic above-ground fauna likely to be maintained. High diversity and activity of soil fauna likely to be maintained.

Flush

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Heavily grazed and trampled. Loss of structural variation and tall herb component. Fragmentation of vegetation cover and erosion of the substrate may continue. Flushed area may become larger, more diffuse, and/or drier but may stabilise if erosive water flows are infrequent.	Low to moderate species diversity and abundance of plants due to physical disruption, loss of suitable growing conditions, and prevention of flowering. Rushes may subsequently become abundant.	Low to moderate species diversity and abundance of invertebrates due to loss of cover, possible drying, and physical disturbance. Heavily grazed flushes with little or no cover are avoided by black grouse. Rushes (up to 15% cover) may enhance habitat value for waders.
Moderately grazed and trampled. May be both localised degradation and recovery. Substrate structural diversity maintained but possibly some long term loss of tall herb structure. Succession to scrub is unlikely even at lower altitudes due to continued browsing and grazing.	Diversity high, especially in lime-enriched flushes at lower altitudes. However, some tall species may be absent or weak. Grassland species and rushes indicative of past heavy usage may persist.	Moderate to high diversity and abundance of fauna. Rushes (< 15% cover) may enhance habitat value for waders.
Lightly grazed and trampled. Generally stable at high altitudes, and where very wet. At lower altitudes	Plants are able to grow to their full stature and their flowering is unconstrained. Plant species diversity very	High abundance and diversity of invertebrates. Tall cover favours Black Grouse broods but may

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
(below 300 m in the far north and west to below 700 m in the central and eastern Highlands and Southern Uplands), likely to be loss of structural diversity, with vegetation becoming taller, more closed, and less diverse. Small plant species may be lost. Occasional disturbance by unusually high water flows may temporarily reverse this trend. Possible succession to scrub over decades (length of time depends on nearness of seed sources) as high as 900 m altitude (montane willows).	low to moderately high: high in lime-enriched, but not eutrophic, flushes which are periodically disturbed through natural physical instability; low where substrates are stable, moderately acid or eutrophic. High diversity of characteristic species maintained at high altitudes.	be less attractive to some waders.

Tall herbs

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Heavily grazed. Rapid loss of gross habitat characteristics, vegetation structure and diversity of characteristic species, if recent. If long-established then stable in highly impoverished state, or slow further deterioration.	Low and declining diversity of characteristic plants. Stands likely to become increasingly impoverished the longer grazing continues. Total plant diversity may remain moderately high on lime-rich substrates.	Information sparse. Low or declining populations and diversities of small mammals and some groups of invertebrates.
Moderately grazed. Partial impoverishment if recent. If long established possibly stable. Some taller vegetation components likely to be maintained. Occasional fluctuations in grazing pressure, or in the patchiness of grazing, may help to maintain taller vegetation elements.	Moderate diversity of characteristic species maintained. Total plant diversity is likely to be high over lime-rich substrates. Occasional fluctuations in grazing pressure, or the patchiness of grazing, which permits intermittent flowering and reproduction will contribute to the long-term persistence of populations of characteristic species.	Information sparse. Some food and cover for wood mice, voles and shrews. Invertebrates likely to be moderately diverse and abundant, benefiting from the diversity of plants and plant structures, food mass and shelter provided by the moderately large standing crop of plant material.
Lightly grazed or ungrazed. If recent, standing crop and flowering of tall herbs likely to increase. If long-established, stable	Possible, but not certain, increase in diversity of characteristic plants which can reach their full stature and	Information sparse. In large patches, sufficient to sustain local populations, small mammals and invertebrates are likely

Tall herbs

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
at high altitudes above the treeline (above 300 m in the far north and west to above 700 m in inland parts of central and eastern Highlands and Southern Uplands). At lower altitudes likely to be invaded by trees and shrubs over two to three decades. Rate of succession will depend on (a) presence or absence of suppressed saplings in the vegetation, (b) nearness of tree and shrub seed sources and (c) occurrence of some disturbance to create openings in which seedlings can establish.	flowering potential. However, some small species may not be able to compete in tall dense vegetation. Plant diversity is likely to be, or become, less than when moderately grazed.	to be diverse and abundant, benefiting from the diversity food sources, food mass and shelter provided by the large standing crop of plant material.

Scrub

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Heavily browsed/grazed. Rapid loss of gross characteristics of habitat, vegetation structure and diversity of characteristic species in less than a decade. If long-established then stable in highly impoverished state, or slow further deterioration. Low or much reduced nectar, pollen and seed resources. May be recoverable by reduction in grazing/browsing in one to three decades if impact is relatively recent (within one to two decades). If extreme, and/or long established may be irreversible, or only partially reversible, due to soil disturbance, eutrophication from dunging, and elimination of more sensitive and less mobile species.	Low or declining diversity of characteristic plants in all structural layers through suppression of both vegetative growth and flowering and fruiting, at variable rates according to species. Some bryophytes may appear to become more dominant if impact is not extreme but this is often due to their being unmasked by removal of forbs and dwarf-shrubs, and species diversity may be lower than in less used scrub. Impoverishment will be progressive the longer grazing continues although total plant diversity may remain moderately high on lime-rich substrates.	Low or declining populations and diversities of characteristic birds and small mammals (only Wood Mouse may remain). Larger herbivores, responsible for the changes, likely to continue to use area. Invertebrate abundance and diversity of most groups reduced: through competition with larger herbivores for shoot tips of plants (and incidental predation); loss of nectar and pollen resources required by adults of many insects; loss of large woody stems for bark-boring and dead wood specialists in the longer term; disturbance to the litter layer and its associated decomposer organisms; and deterioration of the sheltered microclimate required by many species.

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Moderately browsed/grazed. Structural and species diversity are likely to be at their greatest in relation to grazing/browsing. Not very stable dynamic equilibrium, possibly sustainable over periods of several decades, but could easily move towards reduced structural diversity if browsing/grazing either slightly too high or slightly too low. Fluctuations in grazing/browsing will help maintain structural diversity: intermittent trampling disturbance and patchy grazing/browsing may facilitate seedling regeneration and maintenance of maximum species diversity across all structural layers. Stability should be judged over periods of one to two decades.	Moderate diversity of characteristic species maintained. Total plant diversity is likely to be high, especially over lime-rich substrates (vascular plants) or in humid, western areas (bryophytes). Occasional fluctuations in grazing pressure, or the patchiness of grazing, which permits intermittent flowering and reproduction will contribute to the long-term persistence of populations of characteristic species in all structural layers.	Variation in physical structure is likely to favour a wide range of characteristic bird species according to size and geographical and topographical situation of the stand. The presence of a moderately well developed field layer will provide cover for small mammals. Invertebrates are likely to be moderately diverse and abundant, benefiting from the diversity of plants and plant structures, food mass and shelter provided by the moderately large standing crop of plant material and only limited competition and disturbance from large herbivores.
Lightly, or not, browsed/ grazed. If recent, probable increases in field layer standing crop	Greatest diversity and abundance of species most characteristic of humid, sheltered conditions, *e.g.* many	Characteristic birds are likely to be moderately abundant and diverse. In large patches, sufficient to sustain

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
(probably mainly due to an increase in height) and flowering of plants. Shrub/tree layer is likely to increase in height and density. Substantial changes within a decade. If shrubs/trees become dense then the field layer may become suppressed and structural and total species diversity will be reduced. If long-established, stable at high altitudes above 600 m in inland parts of central and eastern Highlands and Southern Uplands and from near sea level in the far north and west. At lower altitudes likely to become woodland over two to three decades. The rate of succession will depend on (a) presence or absence of suppressed tree saplings in the vegetation, (b) nearness of tree seed sources and (c) the occurrence of some disturbance to create openings in which seedlings can establish.	bryophyte species and woodland vascular plants, or sensitive to grazing *e.g.* many tall herbs. However, total species diversity is likely to be less than under moderate browsing/grazing if shrub/tree layer becomes very dense and dominating. If shrubs/trees do not form a continuous canopy tall herbs and dwarf-shrubs in the field layer will flourish.	local populations, small mammals and invertebrates are likely to be diverse and abundant, benefiting from the diversity of food sources, food mass and shelter provided by the large standing crop of plant material. Invertebrates which feed on field layer dwarf-shrubs and herbs will benefit from much reduced competition (and incidental predation) from large herbivores. If shrubs/trees become very dense, eliminating sheltered open spaces and suppressing field and ground layers, total faunal diversity is likely to decline but the most characteristic species requiring humid, undisturbed conditions are likely to be favoured. However, although bark-boring and dead wood specialists will benefit from increased amounts of woody stem material any reduction in field layer flowers will reduce habitat suitability for the

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
		adults of many of these species.
High intensity burning. Destruction of most or all of the ground, field and shrub/tree layers and loss of characteristic features of the habitat. May be an increase in availability and cycling of mineral nutrients but also a possibility of erosion of soil and loss of nutrients. In most situations recovery of ground and field layers within a decade and substantial recovery of shrub/tree layer in one to two decades, but if fire very severe damage may be permanent. High altitude stands likely to be permanently damaged or be very slow to recover.	Temporary, or possibly long-term, elimination of more shade tolerant species requiring humid conditions *e.g.* many bryophytes. Epiphytic flora destroyed with many decades required to restore suitable conditions and for subsequent recolonisation. May be an increase in diversity of species, particularly herbs, if varied seed sources are nearby but if this is not the case then species diversity is likely to be reduced.	Extreme disturbance to all parts of the fauna, possibly including the soil fauna. Direct mortality, and subsequent loss of shelter and cover, as well as of food resources, will affect nearly all species. Recovery may be long-delayed particularly for some of the more characteristic and specialised species of invertebrate which may not be very mobile. This is exacerbated by the small size and isolation of many stands of scrub.
Moderate intensity burning. Partial destruction in most structural layers but survival, relatively undamaged, of some parts of the ground, field and shrub/tree	Will tend to enhance species diversity of vascular plants due to the provision of opportunities for post-fire seedling establishment coupled to substantial	Some of the characteristic fauna may survive the fire in unburnt or superficially burnt parts of the stand. Small animals, invertebrates and

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
layers means that physical characteristics of the habitat may be retained in parts. Dead wood may even increase in amount. There may be some short-lived increase in availability and cycling of mineral nutrients. Recovery of the vegetation and habitat characteristics is likely to occur quite rapidly with substantial recovery in less than ten years, possibly less than five years depending on the nature of the scrub at the time of burning. Recovery at higher altitudes may take longer. Structural and plant species diversity is likely to be similar or greater once stands have recovered.	vegetative survival of pre-existing species. Herbs and dwarf-shrubs are most likely to benefit. Epiphytic flora will tend to be reduced in diversity and abundance.	perhaps small mammals, in the litter and burrowing in the substrate, may survive and recolonise provided populations have not been reduced to below viability. Recovery may be delayed by the reduction in sheltered, humid conditions and disruption to vertical structure and cover of shrubs. Summer fires will have more drastic effects than winter fires.
Low intensity burning. Damage relatively superficial and patchy in most components of the habitat with substantial recovery within five years. Dead wood component likely to be little affected.	Probably little effect on existing vascular plant species diversity but may be some deleterious effects on bryophytes in the ground layer and on the epiphytic flora.	Much of the invertebrate fauna is likely to survive, particularly in the litter and soil, though populations are likely to be reduced. Some small mammals may also survive. Sheltered conditions are likely to

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Recovery at higher altitudes may take longer.		be quickly restored so recovery should be relatively rapid and complete. Summer fires are likely to have more damaging effects than winter fires.
High frequency fires. Impoverishment of habitat structural and species diversity, especially in the shrub/tree layer and in the amount of live and dead wood of larger dimensions. Much less effect on field layer and may rejuvenate dwarf-herb and tall herb plants. Very frequent fires may encourage dominance by bulky graminoids or bracken and reduce flowering herbs and dwarf-shrubs, the availability of nectar and pollen resources, and slow rates of recovery of shrub/tree component. Dead organic matter resources in the plant litter and in the soil may be reduced.	Little effect overall on vascular plant diversity. Diversity among field layer herbs and dwarf-shrubs is likely to be enhanced, but fire sensitive shrub species dependent on seed regeneration may be eliminated if there are no nearby seed sources. Also, there may be some decline in the more delicate and sensitive bryophytes, and the epiphytic flora is likely to be prevented from developed to any extent.	Much of the more characteristic and specialised fauna will be eliminated or much reduced in diversity and abundance. Species most affected are likely to be those which require a well developed canopy of shrubs/trees, a thick litter layer, or wood (living and dead) in larger dimensions. Birds and invertebrates are most likely to be affected but small mammals are likely to recolonise and maintain good populations between fires.
Moderate frequency fires. Slight	Possibly some overall loss in diversity of	Some of the more characteristic and

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
impoverishment of habitat structural and species diversity, perhaps most markedly in the amount of live and dead wood of larger dimensions. The field layer is likely to be diverse if shrubs/trees are patchily distributed but if they are uniform and dense then the field layer will be suppressed by dense shading from the "fire coppiced" shrubs/trees. Field layer diversity, and nectar and pollen resources, therefore, may either increase or decrease.	vascular plants. Diversity among field layer herbs and dwarf-shrubs may decline due to suppression and loss between fires of short-lived, light-demanding species, and fire sensitive shrub species dependent on seed regeneration may still be eliminated if there are no nearby seed sources. Delicate and sensitive bryophytes, and the epiphytic flora will be able to develop to some degree but are unlikely to achieve maximum abundance and diversity.	specialised fauna will be survive although the maximum diversity and abundance of these species is not likely to be attained. Less mobile species may not recolonise sufficiently rapidly to produce viable populations between fires. More common and less demanding species are likely to be well represented, though less so if the shrub/tree layer becomes very dense and continuous.
Low frequency fires. Potentially, full development of all habitat features, although if shrubs/trees are dense there may be a lower structural and species diversity than under moderate frequency burning due to suppression of the field layer. Large dimension live and dead woody material likely to be well represented, except in	Full range of characteristic shrub/tree species likely to be present including fire sensitive species unless fires are very large. Well developed epiphytic flora. Field and ground layer diversity may be reduced if a dense shrub/tree layer develops.	Full representation of the more characteristic and specialised members of the fauna. May be a loss of small mammals and some birds and invertebrates if presence of open spaces or a field layer is suppressed by shrub/tree growth.

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
very exposed or high altitude situations. However, accumulation of large potential fuel mass between fires may increase the possibility of fires being of high intensity when they do occur.		

Blanket bog

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Heavily drained. If continues and/or large amounts of peat removed then marked modification or destruction of habitat in less than a decade. Lost or declining open water pool features, *Sphagnum* cover, rate of peat formation, and increased oxidation of surface peat. Increase in density and height of woody or grass structural components (depending on grazing pressure). Conversion to wet heath or damp grassland, or in extreme cases something approaching dry heath or moderately dry grassland. May recover in decade(s) if drainage ceases.	Elimination of populations of characteristic species. May be replaced by moorland flora characteristic of heaths or grasslands but if peat also removed then even these may be eliminated.	Elimination of populations of characteristic species. Waders, divers, and amphibians likely to be eliminated through damage to pools and water-tracks. May be replaced by moorland fauna characteristic of heaths or grasslands but if peat also removed then even these may be eliminated.
Moderately drained. Marked but not complete modification of habitat over decades with scattered patches relatively unmodified.	Many characteristic bog species will survive in limited areas and may be relatively abundant in patches. Dwarf-shrubs, grasses and herbs favoured in	Many characteristic bog species will survive in limited areas and may be relatively abundant in patches. Any damage to pools and water-tracks will

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
	relation to sedges, *Sphagnum* and hepatic species. Overall diversity may be relatively high due to influx of species from drier habitats.	particularly affect waders and divers, and amphibians. Overall diversity may be relatively high due to influx of species from drier habitats.
Lightly drained. Localised modification or more widespread but subtle changes (over decades) in vegetation composition and structure. May recover in a decade if drainage ceases.	Moderately high diversity. Most characteristic bog species will survive, many will remain abundant and will be little affected, while there is likely to be a small influx of species from wet heath and damp grassland.	Moderately high diversity. Most characteristic bog species will survive, many will remain abundant and will be little affected, while there is likely to be a small influx of species from wet heath and damp grassland. Terrestrial invertebrate diversity is likely to be low to moderate (aquatic invertebrate diversity is likely to be moderately high) although some species (*e.g.* Tipulid flies) may occur at high population densities.

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Heavily burnt. Recovery slow to very slow. In extreme cases revegetation of any kind may take decades (possibly up to four) and considerable erosion may occur. Extensive increase in oxidation of surface peat which may be temporary or more prolonged. Re-established vegetation may differ from that originally present. May be damage to open water pool systems (temporary eutrophication, altered water flows and breaching of pool margins). Recovery of pre-fire habitat characteristics may take a considerable time (particularly if the water table has been affected).	The diversity and abundance of nearly all types of plants will be low for many years. At moderate to high frequencies of burning there is likely to be a long-term substantial loss of species.	The diversity and abundance of nearly all types of animals will be low until the area substantially revegetates. Damage to pools and water-tracks will particularly affect waders, divers, and amphibians even if revegetation occurs. At moderate to high frequencies of burning there is likely to be a long-term substantial loss of species.
Moderately burnt. Recovery moderately slow (one to two decades). Some temporary increase in oxidation of surface peat in the first few years after fire in small scattered patches.	If fires are relatively small and occur at low frequencies a wide range of characteristic flora will be little affected. If fires are large and frequent bryophyte diversity is likely to be	Vertebrates and more mobile invertebrates will recolonise rapidly unless the fire is very large. Many invertebrates will survive in unburned moss and plant litter in wetter hollows. If fires

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
Recovery most rapid if no associated increases in the amount of drainage so that the water table remains unaffected.	impoverished, while the variety and abundance of dwarf-shrubs, herbs and grasses will be increased.	are relatively small and occur at low frequencies a wide range of characteristic fauna will be little affected. If fires are large and frequent the fauna will be impoverished.
Lightly burnt. Rapid recovery (< 10 years) of vegetation cover and pre-fire vegetation composition (provided no associated drainage), though may take one or two decades to return to pre-burning structural state. Little or no oxidation of peat.	Recolonisation is likely to be rapid. Many species will survive the fire and will regrow vegetatively. Very delicate plants, *e.g.* many liverworts, which require constant high humidity, may be damaged by either the heat of the fire or dry post-fire conditions.	Vertebrates and more mobile invertebrates will recolonise rapidly unless the fire is very large. Many invertebrates and some small vertebrates will survive in unburned moss and plant litter. Small mammals, reptiles and amphibians may be moderately abundant.
Frequently burnt. Reduced or declining cover of dwarf-shrubs, *Sphagnum* and other bryophytes, and lichens. High, or increasing, dominance of grasses, sedges and herbs. Perhaps increase in oxidation of surface peat. Increase in grass and sedge seeds as a food resource. Reduced	Low diversity with an absence or loss of species most characteristic of bogs (other than pool flora), those which are relatively slow growing (*e.g.* woody species and lichens).	Loss or absence of breeding by most moorland bird species. Twite and Skylark may benefit from increased availability of grass and sedge seed. Small mammals likely to become moderately abundant except where vegetation is heavily grazed. Frequent disturbance and increased

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
cover, more variable and extreme microclimate and increased disturbance. Reduced fire intensities due to limited build-up of fuel but surface layers of soil may be damaged by heat due to reduced insulation from the thinner moss and plant litter layer. Reduced capacity to absorb and hold water in surface layers of vegetation and peat. Increasing impact with increasing heaviness of burning.		fragmentation of undisturbed patches is likely to reduce invertebrate diversity and abundance.
Moderately frequently burnt. Little effect on the substrate, or its hydrological properties, provided fires are not heavy. Persistence of most habitat components (*Sphagnum*, other bryophytes, lichens, grasses and sedges, herbs and dwarf-shrubs) in moderate, though possibly reduced, amounts. Increasing impact with increasing heaviness of burning.	Most characteristic species present but may be somewhat reduced in abundance, especially if fires are heavy. Lichens likely to be reduced in abundance. Some influx of species more characteristic of heaths and grassland. Highest overall diversity but reduced populations of bog surface specialists.	Most characteristic species present but may be somewhat reduced in abundance, especially if fires are heavy. Some influx of species more characteristic of heaths and grassland. Highest overall diversity but reduced populations of bog surface specialists.

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Infrequently burnt. Little or no effect on substrate characteristics or vegetation composition or structure. Relatively unrestricted expression of growth potential of bryophytes, particularly *Sphagnum* (drainage and trampling permitting), dwarf-shrubs and sedges, providing a variety of moderately tall tussocky to tall woody structures (> 1m tall where *Myrica gale* present)as well as more open moss hummock and moss "lawn" surfaces. Increased impact with increasing heaviness of burning.	Moderately high diversity overall. Highest diversity and abundance of bog-surface specialists.	Moderately high diversity overall. Highest diversity and abundance of bog-surface specialists. Small mammals, reptiles and amphibians may be moderately abundant.
Heavily trampled and grazed. Reduced or declining average vegetation height, and depth of bryophyte hummocks and mats, leading to progressively more severe loss of structural diversity and increasing instability	Low diversity and abundance of species most characteristic of the bog surface (pools may be less affected). Vascular species may be slightly more diverse than in less heavily browsed situations because of the reduced dominance	Loss of animals associated with taller vegetation cover and those specifically dependent on dwarf-shrub species for food. Much reduced food and nesting opportunities for grouse, raptors (small mammal prey), and

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
of environmental conditions. Low dwarf-shrub and *Sphagnum* cover or significant decline over a decade or less. Progressive damage to vegetation of water-tracks and pools, and to pool edge features. Risk of erosion of peat.	of dwarf-shrubs, bryophytes and lichens. Significant influx of species from dry heaths and acid grasslands. Diversity and abundance of bryophytes and lichens will be low.	small passerines except for those which feed on soil invertebrates or dung invertebrates. Small mammals, reptiles and amphibians scarce. Low numbers and diversity of those invertebrate species most characteristic of bogs. Deleterious effects on waders, divers and amphibians may be prolonged if there is damage to pools and water-tracks, even if trampling and grazing pressure is reduced.
Moderately trampled and grazed. Potentially some reduction in cover, depth and diversity of *Sphagnum* and other bryophytes. Deterioration in shaded and humid conditions required by many bog species. Possibly localised microerosion. Impact patchy so some areas less affected. In sloping situations change may be more uniform and rapid	Moderately high diversity of plants. Maximum total diversity of species in relation to trampling and grazing but species most characteristic of bogs, although mostly present, will have reduced populations. Small influx of species from dry heath and acid grassland.	Maximum total diversity of species in relation to trampling and grazing but species most characteristic of bogs, although mostly present, likely to have reduced populations.

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
degradation (within a decade). Moderately wide variety of food sources for leaf-feeding herbivores. Moderate risk of erosion, particularly if peat cutting, fire, or natural erosion expose bare peat.		
Lightly, or not, trampled and grazed. More or less unrestricted growth of bryophytes, particularly *Sphagnum* (drainage and fire permitting), dwarf-shrubs and sedges, providing a variety of moderately tall tussocky to tall woody structures (> 1m tall where *Myrica gale* present), more open hummock and moss "lawn" surfaces, and well vegetated small pools. Loss of variety of food sources for leaf-feeding herbivores. Shaded and humid conditions well developed, or increasingly well developed. Low risk of erosion.	Mosses, liverworts and lichens likely to be abundant and diverse, vascular plants less so.	If long established will favour animals which require undisturbed, moist, sheltered conditions and to a lesser extent tall vegetation cover. Small mammals, reptiles and amphibians may be moderately abundant.

Wind-clipped summit heath

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Heavily grazed or trampled. Substantial loss of the mat element, and the development of a sward of grasses and herbs over several decades (two to three decades if extreme). Rate of change likely to be slow but may accelerate. Potential increase in rate of initiation of erosion.	Partial or complete loss of *Racomitrium lanuginosum* and lichens, possibly also reduction in dwarf-shrub species. Grasses and herbs likely to increase. Diversity of plant species may increase but at the expense of those which are most characteristic of this habitat.	Reduced productivity, and possibly loss of, characteristic specialised species through trampling of nests and loss of suitable nesting and feeding sites *e.g.* Dotterel and Ptarmigan, and loss of cover for invertebrates.
Lightly grazed or trampled. Little change, provided climate remains stable.	Low to moderate total diversity of plant species but high diversity of those Arctic-Alpine species adapted to the harsh conditions of the exposed summits.	Vegetation suitable for nesting and feeding of characteristic birds. Full complement and diversity of appropriate montane invertebrates.
Burnt. Substantial destruction with very slow recovery over many decades, or much longer if erosion initiated.	Severe loss of species. Possibly slow recovery over the long-term.	Severe loss of species. Some invertebrates which live under stones and in the soil may be little affected. Slow recolonisation of other animals from adjacent unburnt ground provided fires are small.

Dwarf-shrub heath

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Heavily browsed. Low or declining average vegetation height, structural diversity and food source diversity for herbivores. Low or substantially declining dwarf-shrub cover over a decade or less and greatly reduced availability of pollen, nectar, berry and seed resources.	Vascular species may be slightly more diverse than in less heavily browsed situations since the reduced dominance of dwarf-shrubs will encourage the growth of grassland plants. Diversity of bryophytes and lichens will be low, although certain mosses may become abundant.	Loss of animals associated with taller vegetation cover and those specifically dependent on dwarf-shrub species for food. Much reduced food and nesting opportunities for grouse, raptors (small mammal prey), and small passerines except for those which feed on soil invertebrates, dung invertebrates and, possibly, grass seeds. High vulnerability of nests to predation and trampling. Small mammals scarce, but rabbits and hares may be abundant. Both numbers and diversity of the more characteristic above-ground invertebrates, both herbivores and predators, are likely to be low. Soil invertebrates are likely to be relatively abundant and diverse, encouraged by herbivore dung.

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
Moderately browsed. In the longer term (> 10 years) possibly some loss of dwarf-shrub cover and structure. Maximum expression of the patchiness of browsing, with a small scale pattern of both heavily browsed patches and lightly browsed patches (sometimes even within a single dwarf-shrub bush), giving considerable variation in height and openness.	Moderately high diversity of plants, mostly dwarf-shrubs and bryophytes but with some admixture of species from acid grasslands.	Maximum diversity of characteristic species in relation to browsing pressure. Most of the characteristic species are likely to be present in extensive areas unless these are recently established and have been previously heavily browsed. Moderately high numbers and diversities of invertebrates, both above-ground and in the soil, are likely.
Lightly browsed. Unrestricted expression of growth potential of dwarf-shrubs. Allows development of moderately tall but open, woody structures. Loss of variety of food sources for leaf-feeding herbivores but abundant pollen, nectar, berry and seed resources. Increase in shaded and humid conditions. If suppressed trees and shrubs are present these may become	Vascular plants will not be diverse if dwarf-shrubs have become very tall and dense. Bryophytes and lichens likely to be abundant and diverse.	If long established will favour animals which require tall vegetation cover or moist, sheltered conditions. Red Grouse may decline if the vegetation becomes uniformly tall but this will suit nesting by raptors and some passerines. Small mammals may be moderately abundant. Reptiles may be present but are unlikely to be abundant, but amphibians (particularly toads) may be moderately abundant if wet areas

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
dominant in one to two decades. If trees and shrub seed sources are nearby (< 1 km) then these are likely to colonise and become dominant over one to three decades. Light-seeded, wind-dispersed species like birch and willows may be slow to establish if fires have been light and infrequent.		nearby. Likely to be large populations and high diversities of above-ground and litter layer invertebrates, including some species also found in woodland.
Heavily burnt. Recovery slow to very slow. In extreme cases revegetation of any kind may take decades (possibly up to four) and considerable soil erosion may occur. Re-established vegetation may differ from that originally present. Possible loss of mineral nutrients from system.	The diversity and abundance of nearly all plants will be low until the area substantially revegetates. At moderate frequencies of burning there is likely to be a long-term substantial loss of species.	The diversity and abundance of nearly all types of animals will be low until the area substantially revegetates. At moderate frequencies of burning there is likely to be a long-term substantial loss of species.
Moderately burnt. Recovery rapid to moderately slow (< 10 years). Rate of recovery is affected by weather conditions in the growing seasons immediately after	If fires are relatively small and occur at moderate frequencies a wide range of characteristic species will survive and thrive. If fires are large and frequent the diversities	Vertebrates and more mobile invertebrates will recolonise rapidly unless the fire is very large. Some invertebrates will survive in unburned moss, plant litter or

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
burning. Species composition and structural features are likely to remain constant when averaged over many patches burnt at different times provided browsing is light to moderate.	of both dwarf-shrubs and bryophytes are likely to be impoverished.	soil. Soil organisms may be temporarily stimulated by the influx of mineral nutrients from ash but are otherwise likely to be only slightly affected. If fires are relatively small and occur at moderate frequencies a wide range of characteristic fauna will benefit. If fires are large and frequent the fauna will be impoverished.
Lightly burnt. Rapid recovery (< 5 years) of vegetation cover and pre-fire vegetation composition, though may take decades to return to pre-burning structural state.	A moderately high diversity of bryophytes and lichens is likely to survive but vascular plants, and pioneer species which colonise and flourish where vegetation cover has been largely removed, will be uncommon and of low diversity. If light fires are frequent the diversity of all elements of the flora will be impoverished.	Vertebrates and more mobile invertebrates will recolonise rapidly unless the fire is very large. Many invertebrates will survive in unburned moss, plant litter or soil. Invertebrate species requiring large patches of bare ground with very short, sparse vegetation will not be favoured by light burning but those which require undisturbed, sheltered conditions are likely to survive. Soil organisms are likely to be little affected. Infrequent light fires

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
		are likely to impoverish the vertebrate fauna.
Frequently burnt. Low or declining dwarf-shrub, bryophyte and lichen components and high or increasing dominance of herbs. Increase in grass seed as a food resource. Reduced evergreen cover and woody structural elements, more variable and extreme microclimate and increased disturbance. Reduced fire intensities due to limited build-up of fuel. Possible loss of mineral nutrients from system, particularly if heavily burnt.	Low to moderate diversity with an absence or loss of those species more directly sensitive to fire (*e.g.* juniper and clubmosses), those which are relatively slow growing (*e.g.* woody species and lichens), and those which require sheltered, humid conditions (*e.g.* many mosses and liverworts). On more base-rich mineral soils herb diversity may be high.	Loss or absence of breeding by most moorland bird species. Twite and Skylark may benefit from increased availability of grass seed. Voles are likely to become abundant, where the vegetation is not heavily grazed by larger herbivores, due to the increased cover of grasses. Frequent disturbance and increased fragmentation of undisturbed patches is likely to reduce invertebrate diversity and abundance. Soil organisms likely to be abundant and diverse except if very heavily burnt.
Moderately frequently burnt. Provided fires are not extensive this produces a varied habitat composed of mixtures of grasses and "sedges", herbs, dwarf-shrubs, bryophytes,	High diversity but with a low abundance of those species more directly sensitive to fire (*e.g.* juniper and clubmosses), those which are relatively slow growing (*e.g.* woody species and	Most moorland bird species are likely to be present, breeding and abundant. Small mammals moderately abundant. Above-ground invertebrates abundant and diverse. Soil organisms likely

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
lichens and small patches of bare ground. This will persist more or less indefinitely unless fires are very heavy or very light.	lichens), and those which require sheltered, humid conditions (*e.g.* many mosses and liverworts). On more base-rich mineral soils herb diversity may be high.	to be moderately abundant and diverse except if very heavily burnt.
Infrequently burnt. Likely to be stable over two decades to a century in structure and composition unless heavily browsed or if there is a large input of seeds from nearby trees and shrubs. Colonisation by species with light, wind-dispersed seeds is likely to be slow. In the absence of browsing a dense, deep, and stable mat of bryophytes, lichens and layering dwarf-shrubs may develop. Any gaps are likely to be quickly colonised by vegetative expansion of adjacent plants. Nutrients likely to become increasingly immobilised in vegetation and humic soil material.	Vascular plant diversity is likely to be moderate to low, particularly if dwarf-shrubs have become very tall and/or dense. More restricted, fire-sensitive species likely to benefit. Juniper will benefit from infrequent fire (bushes survive to reproductive maturity) but not from the complete absence of fire (reduced regeneration). Bryophytes and lichens are likely to be abundant and diverse.	The abundance and diversity of species is likely to be limited by a lack of open spaces and short vegetation. Moorland birds will use such areas for nesting, most (other than raptors) at low density. Variable small mammal abundance: low for voles but shrews and wood mice may be abundant. Above-ground and litter invertebrates likely to be abundant and moderately diverse, particularly in patches with an uneven structure and where some trees and bushes are present. Both the biomass and diversity of soil invertebrates is likely to be lower than when fires are moderately frequent.

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
Insect damaged. Outbreaks tend to appear, build up to a peak, then collapse over 1 to 4 years. Complete recovery often in < 5 years, without intervention, but occasionally may take one to two decades. More rarely, severe damage may lead to the vegetation becoming dominated by grasses and "sedges", or mosses.	Vascular plant diversity usually low both prior to and after an outbreak. Less palatable dwarf-shrubs such as *Erica* spp. may become more abundant as may grasses such as *Molinia caerulea*.	Larvae of insects whose populations undergo outbreaks provide an abundant food resource used opportunistically by a variety of birds, small mammals and invertebrate predators and parasitoids. However, habitat quality for many species may be reduced for a number of years after a severe outbreak.
Fungi damaged. If severe and extensive may precipitate a change to grass and sedge dominated vegetation, particularly if also grazed, within < 5 years. Duration of outbreaks uncertain.	Plant diversity is likely to be slightly increased.	Usually very localised effects on habitat. There are unlikely to be any large scale effects on larger animals, unless very extensive, and a more open vegetation structure may enhance the diversity of small vertebrates and invertebrates.
Weather-blasted. Likely to recover provided grazing and browsing is light to moderate. Substantial recovery after one growing season is normal but may take in	The diversity of vascular plants and bryophytes may be reduced but lichen cover and diversity may increase. Some mosses may increase in abundance.	Both the diversity and abundance of characteristic species are likely to be reduced except where this condition only affects small scattered patches. The short

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
excess of five years if damage has been very severe (killing most of the dwarf-shrub canopy).		vegetation produced by regular wind-clipping may be suitable for some montane species.

Tussock grassland

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
Heavily grazed. Gross characteristics more or less stable if grazing is by sheep and dominant plant is *Nardus stricta*, but slightly less stable if dominants are other species. If grazing is by cattle or goats then likely to lose characteristic structural features such as well developed tussocks (particularly on more nutrient -rich soils) and may become more like ***Smooth grassland***. Increased mobilisation of mineral nutrients.	Reduced diversity due to increased dominance of less palatable species if grazing by sheep. If grazing is by cattle or goats plant diversity is likely to increase (at least in terms of equitability of species abundances).	Decreased favourability for characteristic birds and small mammals due to high levels of disturbance from grazing animals. High vulnerability of nests to trampling and predation. High or increased diversity of soil fauna. Low or decreased diversity and abundance of above ground invertebrates (though species of herbivore dung may benefit). Loss of litter and tussock wintering sites may reduce invertebrates.
Moderately grazed. Stable, though may suffer periodic disturbances during to vole eruptions.	The range of characteristic species is likely to be maintained.	Maintenance of plant species composition and structural variation in the vegetation is likely to ensure that most characteristic animals will continue to be present. Moderate abundance and diversity of soil fauna likely to be maintained.

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
Lightly grazed or not grazed. Possibly unstable (more than two to three decades): loss or reduced vigour of small species in inter-tussock vegetation, and possible invasion by dwarf-shrub, shrub or tree component in some situations. Unpredictable effects from periodic severe vole grazing.	Reduction in diversity of flora unless invasion by, for example, wood species or tall herbs occurs. More palatable species will show some expansion, including species such as *Molinia caerulea* and *Deschampsia flexuosa* which may become more dominant. If suppressed taller herbs or dwarf-shrubs are present these may be able to develop more fully and reproduce.	Small mammals and herbivorous invertebrates may be abundant or increasing, except for those species dependent on small herbs. Low levels of disturbance favour larger and more slowly reproducing invertebrates, such as the larger ground beetles and spiders (also favoured by better developed vertical vegetation structures), and more sedentary species. Probably low or decreasing activity, and possible decline in abundance and diversity, of soil fauna.
Heavily burnt. May be complete or partial destruction of characteristic tussock structural features plus destruction of inter-tussock vegetation. This may be temporary or longer-term. Tussock size likely to be reduced. May recover within a decade. May be some instability due to post-	If severe enough to cause erosion, likely to lead to reduced diversity and abundance of plant species. Otherwise, may result in increased diversity as a consequence of increased incidence of seedling establishment during vegetation recovery, and greater ease of invasion and	Reduced abundance of associated birds and other vertebrates until vegetation recovers. Above-ground invertebrate abundance and diversity likely to be reduced as a result of loss of shelter, cover and plant biomass, and loss or damage to wintering sites. May be long term loss of more sedentary

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
fire invasion by plants characteristic of other habitats (*e.g.* woody species) if fires are infrequent. Possible loss of mineral nutrients from the system.	establishment by plants from outside the burnt area.	invertebrates. May have deleterious effects on soil fauna if severely burnt.
Moderately burnt. Partial temporary loss of some structural features (*e.g.* accumulated litter) but rapid recovery likely in less than 5 years. Some mobilisation of mineral nutrients.	Maintenance or slight increase in diversity. Many plants will survive and will be able to regenerate vegetatively but there is also likely to be some opportunity for establishment of new plants from seedlings.	Short-term reduction in above-ground fauna after each fire but in longer-term likely to help maintain diversity of associated species. Some invertebrates in litter and tussocks likely to survive the fire. Soil invertebrates are likely to show increase in activity and there may also be some increase in diversity.
Lightly burnt. Little impact, recovery within 1 - 2 years, more or less stable. Probable increase in tussock sizes.	Little impact on flora in the short-term but possible loss of diversity in long-term due to competitive exclusion by the more vegetatively vigorous species.	Little impact other than temporary disturbance to birds, small mammals and some invertebrates.
Frequently burnt. Stable, but structure and composition impoverished. Loss of plant cover, vegetation	Probable decrease in diversity and reduced equitability of species abundances, particularly when	Reduction in diversity and abundances of associated above-ground fauna due to loss of food and cover

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
height, litter depth, and possible reduction in vigour and size of tussocks. Increased nutrient cycling but also possible increased loss of nutrients by leaching.	lightly grazed or ungrazed, due to increased dominance by a small number of fire resistant, fast growing or fast colonising species.	and direct mortality. May be some increase in activity and diversity of soil fauna.
Moderately frequently burnt. Stable. Main characteristics remain unchanged over the long term.	Over the long-term likely to help maintain the full range of typical species.	Over the long-term likely to help maintain the presence of the full range of typical above-ground species. Probably little effect on the soil fauna.
Infrequently or not burnt. Tussock size and litter depth likely to increase. May be unstable over periods longer than two to three decades. Accumulation of dead plant material may lead to senescence of tussocks. Woody species may slowly invade.	Low and possibly declining diversity except where tall herbs or woody species present or invading.	There may be low or decreasing population of some small birds such as Meadow Pipit and Skylark, and in herbivorous mammals, if very dense vegetation containing a high proportion of dead material develops. Effects on invertebrates unclear. Possible increase in the diversity and abundance of litter dwelling decomposers and in larger, more slowly reproducing ground beetles and spiders.

Bracken

Habitat change	***Effects on associated fauna and flora***	
	Flora	*Fauna*
Very vigorous. Stable, or increasing bracken domination, over decades. High probability of invasion of adjacent habitats if environmental conditions suitable for bracken.	Low abundance and diversity of associated species.	Few vertebrate species associated with the most vigorous stands and generally low population densities for those species which do persists. Invertebrate diversity low to moderate.
Moderately vigorous. Extent and density likely to be fairly stable over decades. If increasing trend in vigour both extent and density may increase. If declining trend in vigour, density but not extent may decline. Unlikely to invade dense and vigorous *Nardus*, *Molinia*, *Calluna vulgaris*, or *Vaccinium myrtillus* unless vigour increases.	Low diversity but of variable composition. Provided the bracken canopy is not completely solid some vernal plants and/or scrambling, tall or vigorously sprouting species can grow under or through the fronds (mostly species usually found in woodland).	May be used for temporary cover or for breeding by a range vertebrates normally associated with woodland or moorland. Particularly of value for Whinchats. Will tend to be avoided by birds characteristic of open moorland unless very fragmented. Invertebrate diversity likely to be moderate, with low to moderate population densities (occasionally high for particular species).
Weak. If condition persists, extent and density of bracken likely to decline significantly over 5 - 20 years. If state due	The diversity of plants may be moderately high, in a moorland context, since characteristic moorland species and	May be used for temporary cover or for breeding by a range vertebrates normally associated with woodland or moorland,

Habitat change	*Effects on associated fauna and flora*	
	Flora	*Fauna*
to plants being young, or part of a pioneer front, vigour may increase followed by density and extent. State may be temporary.	plants more characteristic of semi-shaded woodland environments may both be present.	including (sparsely) species characteristic of open moorland. Particularly of value for Whinchats. Small mammals such as wood mice, voles and shrews may be quite abundant. Moderate invertebrate diversity and populations.

Part 7: Appendices

Glossary

assessment unit	A unit of ground, and recording, in which a single assessment of impact class is made (which may be based on an averaging of spot assessments) for each impact type which is appropriate.
back fire	A fire which burns against the wind. Usually travels slowly. Also known as a backing fire.
biotope	A class of living space or substrate required by a particular assemblage of plants and animals.
brown earth/soil	A soil which is not strongly acid, has mull humus, has little or no leaching of humic compounds, iron or other mineral from the surface layers, and is consequently has a fairly uniform "brown" profile.
browsing	The removal of foliage and shoots of woody plants by larger herbivores.
bryophyte	Moss or liverwort.
building phase	As applied to stands of dwarf-shrub vegetation, this means the stage of stand development during which the canopy of dwarf-shrubs reaches its maximum density and depth, but the plants have not yet reached their full stature.
cambial	Relating to the cambium, the thin layer of dividing cells near the surface of the stem of a woody plant which permits it to increase in girth.
canopy	This is a collective term for the entire assemblage of foliage and directly foliage-bearing shoots forming the upper surface of a plant or a patch of vegetation.
chronic	Occurring over a prolonged period of time.
condition	The state of the habitat judged against value criteria or management objectives.
cropping	Removal of plant parts, usually by herbivores.
dominant	As applied to plants in vegetation, the most prominent species in the vegetation. A dominant species is usually very much more widespread, larger and covers a greater proportion of the ground surface than other species. Usually a structural species which forms or modifies the environment of other, subsidiary (interstitial) species.
dwarf-shrub	Much branched woody plant, with a typical maximum potential height of less than 1 m. Often much shorter,

	and sometimes only present as a prostrate mat. In the uplands many of the dwarf-shrub species belong to the heath family (Ericaceae).
ecotope	A class of land type which is relatively homogeneous in physical conditions (of substrate and climate), in terms of potential ecosystem functioning, and in its potential assemblage of fauna and flora.
epiphytic	Growing on the surface of plants, usually on the bark of stems or branches of woody plants.
equitability	When used in relation to species diversity this refers to the similarity between the abundances of the different species present. Where equitability is low a small number of species contribute most of the individuals and the habitat will appear superficially to be species poor.
eutrophic	Rich (or enriched) in nutrients, particularly nitrogen and phosphorus.
feather moss	Moss with much branched shoots, often very regularly (so giving the impression of "feathers"), which form loose, horizontally layered, mats. *Hylocomium splendens* and *Pleurozium schreberi* are typical examples. Usually pleurocarpous mosses.
fertility	The degree to which a soil is rich in plant nutrients, particularly nitrogen and phosphorus.
field layer	The layer or stratum in the vegetation composed of herbaceous plants and dwarf-shrubs, usually less than 1 m tall.
flammability	The ease with which something will ignite.
floriferous	Abundantly flowering.
floristic	Relating to plant species composition.
forb	Any herb which is not a graminoid.
gleying	Within a mineral soil profile where there is poor drainage and relatively stagnant, poorly aerated conditions.
graminoid	Herbs which are grass-like in appearance and growth form. Includes plants belonging to the grass family (Poaceae) and sedge family (Cyperaceae).
grazing	The removal of foliage and shoots of non-woody, herbaceous plants by herbivores.
ground layer	The layer or stratum in the vegetation immediately above the soil surface composed of very short herbs, mosses, lichens and plant litter, usually less than 10 cm tall.
habitat	A class of persistent, or repeatable, circumstances in

	which specific plants and animals, or assemblages of plants of animals, are habitually found. In this guide defined broadly in terms of structure and compositional features of the topography, substrate, and associated flora and fauna.
head fire	A fire which burns with the wind rather than against it. Also known as a heading fire. Usually travels relatively quickly.
heath	Vegetation usually dominated by dwarf-shrubs, although also sometimes used to refer to rough grasslands or alpine vegetation dominated by *Racomitrium lanuginosum*, *Juncus trifidus* and *Carex bigelowii* in which there are usually at least some scattered dwarf-shrubs. *Erica* species are also termed "heaths".
herb	Any plant (excluding mosses, lichens and algae) without a woody stem or stems.
impact	A type of disturbance which produces observable effects on the habitat.
impact class	The classification of a particular type of disturbance into intensity or frequency classes, *e.g.* high, moderate and low intensity.
intensity	The degree of change caused to the structure and/or composition of the habitat by a particular impact *e.g.* the degree of vegetation destruction caused by a fire.
internode	The length of stem between the nodes at which leaves (or buds) occur on the stem.
layering	Applies to woody plants in which prostrate branches, in contact with the soil or buried by vigorous moss growth or litter accumulation, produce new roots at various points along their length. These may eventually come to replace the primary root system in supplying the plant with water and nutrients.
litter	See plant litter.
moorland	Unenclosed open rangeland, mostly covered by heaths, bogs and rough grasslands of various descriptions.
muirburn	The deliberate burning of moorland for management purposes.
mycorrhiza	A partnership between fungi and higher plants in which the fungal filaments penetrate the roots or form a sheath around them. They tend to increase the capacity of the higher plant to obtain certain nutrients, to protect itself against certain toxic elements and/or to resist root

	diseases. Very common and functionally very important.
oceanic climate	Climate with low but not very variable temperatures and, usually, high humidity for much of the time. Usually also windy.
offtake	Usually used in the sense of proportional offtake. The proportion of the annual production of a plant or stand of vegetation which is removed by herbivores.
order of magnitude	A power of 10. Used as in "two orders of magnitude larger", meaning of the order of a hundred times larger.
peat	Dark brown or black, acid material composed of partially decayed or undecayed plant material, often somewhat fragmented and compressed, which accumulates in oxygen poor, waterlogged environments. The mineral concentration is usually very low. "Peat soils" are defined, variously, as soils in which the surface peat is thicker than 40 cm or 50 cm. The latter has been used in soil surveys in Scotland. Soils in which the peat is deeper than 1 m are usually termed "deep peats".
pioneer phase	As applied to a regenerating dwarf-shrub stand this is the early stage of regrowth when individual dwarf-shrub plants are still separate, and the canopy of the stand has not yet reached its maximum density of fullness of coverage.
plant litter	Accumulated dead plant material (mostly dead leaves).
poaching	A traditional term to describe the effects of heavy trampling by livestock, particularly on wet ground, in which a heavily pock-marked and churned surface is produced.
podzol	A soil which is strongly acidified, often under conifers or dwarf-shrubs like *Calluna vulgaris*, characterised by strong leaching of humic compounds, iron and other minerals from the upper levels of the soil which become more or less bleached as a result. The leached compounds are often redeposited lower in the profile sometimes resulting in the formation of dense pan which can restrict drainage and root growth. The surface usually has poorly decomposed, mor humus which may sometimes form a thin peaty layer.
polygon	A shape with a closed boundary.
polyphagous	Having a broad diet. Not a specialist feeder.
precision	The converse of degree of "error" or uncertainty about an assessment.

pressure As in grazing pressure. This means the absolute amount of herbage removed by herbivores. A given pressure may remove a large or small proportion of the annual production of a plant or areas of vegetation. It is related to herbivore densities.

rangeland Open, unenclosed land over which domestic livestock and wild herbivores range freely.

ranker A thin, poorly developed soil, usually on siliceous, acid parent materials on steep slopes.

raster format Where survey and assessment recording is based upon a grid of identical, regular units, usually squares, for each of which an assessment is made.

reliability As applied to indicators this means the degree to which they are likely to produce repeatable, accurate and precise assessments.

rendzina Poorly developed, often thin soils on lime-rich parent materials.

repeatability The degree to which two or more independent assessments will produce the same result.

resilience This is the degree to which a feature can fully recover to its previous state after some temporary impact.

rhizome A stem which grows more or less horizontally at or below the ground surface, and persists for more than one growing season.

sapling A young tree and shrub, usually at least 2 years old, and more than 25 cm tall.

scouring Water erosion in which a flow of water cuts down into the substrate and deepens its channel.

"sedge" Plants belong to the Cyperaceae. Includes true sedges (*Carex*), cottongrasses (*Eriophorum*), bog-rushes (*Schoenus*), deer-grass (*Trichophorum*), and beak-sedges (*Rhynchospora*), among others.

shrub A much branched, woody plant, without a single main stem, with a typical maximum potential height between 1 m and 5 m.

solifluction Downslope soil creep.

stand As applied to vegetation, this means an area of vegetation with the same impact history and similar vegetation composition (the two usually being related), usually forming a unit of vegetation which is easily definable in the field.

state Of habitat, this means its describable form and

	composition (without any implication that this may be "good" or "bad").
sub-shrub	A creeping, sometimes small, plant which nevertheless has stems which are in part woody.
subsidiary species	Less dominant, or less structurally important species. Likely to be interstitial species rather than structural species.
susceptibility	The degree to which there is likely to be some particular impact. Probability of impact.
sward	The surface of a herbaceous turf, usually grassy, and usually less than 10 cm tall.
thatch	The accumulation of dead plant litter in the base of a herbaceous, usually grassy, sward.
tiller	A side shoot produced from the base of a plant.
tussock	A dense, usually roughly hemispherical, mass of closely packed shoots and tillers, usually of a grass or sedge. There is sometimes a hard, somewhat "woody" core.
unenclosed	Large areas of land largely unobstructed by fences or walls. Occasional fences or walls may occur but any enclosures resulting are several square kilometres in extent and usually include many different habitats.
uplands	The open rangeland, or moorland, above the level of permanent agricultural enclosure. Upland conditions can extend down to near sea level in the far north and west.
vascular plant	A plant with internal water conducting vessels. A "higher" plant including ferns, clubmosses, and all herbs and woody plants. Excludes algae, lichens and bryophytes.
vector format	Where areas of homogeneous impact are identified and mapped/recorded as shapes with a closed boundary (polygons).
vernal plant	A plant which makes most of its yearly growth, and flowers, in spring.
vulnerability	The degree to which something is likely to be wounded or damaged by some impact.
water track	A route taken by water draining naturally off an area, usually applied to a bog. Similar to a flush but usually not spring-fed so the flow of water is only intermittent.

Correlation Tables

Field Guide Habitats most appropriate to particular classes from various other land, habitat and vegetation classifications: key to the symbols used in the tables.

Symbols used in the tables

Classes from other land, habitat and vegetation classifications	Field Guide Habitat types	
	Generally the most approporiate FG type to use for assessment of impact	FG type which may be more appropriate in some situations, or transitions between FG habitats may apply.
Classes which are characteristic or typical of upland areas.	■	□
Classes which are more characteristic or typical of marginally upland or lowland areas.	●	○

Key to abbreviations of Field Guide Habitats

B = Bracken
TG = Tussock grassland
D = Dwarf-shrub heath
W = Wind-clipped summit heath
BB = Blanket bog
S = Scrub
TH = Tall herbs
F = Flush
SG = Smooth grassland

Field Guide Habitats most appropriate to Land Cover of Scotland 88 land cover types.

LCS88 Code	LCS 88 land types	SG	F	TH	S	BB	W	D	TG	B
76 - 78	Undifferentiated broadleaved woodland				□					
82	Undifferentiated low scrub				■					
110 - 117	Dry heather moor						□	■		
120 - 127	Wet heather moor					□	□	■		
130 - 137	Undifferentiated heather moor						□	■		
140 - 143	Undifferentiated coarse grassland								■	
150 - 153	Smooth grassland with rushes	□	■						■	
155 - 158	Smooth grassland with low scrub	■			□					
160 - 163	Undifferentiated smooth grassland	■								
170 - 173	Undifferentiated bracken	□								■
180 - 186	Blanket bog and other peatland vegetation					■				
220 - 223	Montane vegetation						■			

Field Guide Habitats most appropriate to NCC/EN Phase 1 Habitat Survey classes.

No. code	Letter code	Name	S G	F	T H	S	B B	W	D	T G	B
A 1.1.1	BW	Woodland, broadleaved, semi-natural				○					
A2.1	DS	Scrub, dense/ continuous				■					
A2.2	SS	Scrub, scattered				■					
B1.1	AG	Acid grassland, unimproved	■							■	
B1.2	SAG	Acid grassland, semi-improved	■								
B3.1	CG	Calcareous grassland, unimproved	■								
B3.2	SCG	Calcareous grassland, semi-improved	■								
B4	I	Improved grassland	●								
B5	MG	Marsh/ marshy grassland		□						■	
C1.1	CB	Bracken, continuous									■
C1.2	SB	Bracken, scattered	□						□		■
C2	Target note	Tall herb and fern, upland species-rich ledges			■						
C3.2	NR	Tall herb and fern, other non-ruderal			■						
D1.1	ADH	Dry dwarf-shrub heath, acid						□	■		

Field Guide Habitats most appropriate to NCC/EN Phase 1 Habitat Survey classes.

No. code	Letter code	Name	S G	F	T H	S	B B	W	D	T G	B
D1.2	BDH	Dry dwarf-shrub heath, basic						□	■		
D2	WH	Wet dwarf-shrub heath						□	■		
D3	LH	Lichen/ bryophyte heath						■	■		
D4	MH	Montane heath/ dwarf-herb						■			
E 1.6.1	BB	Blanket bog					■				
E 1.6.2	RB	Raised bog					●				
E1.7	WB	Bog, wet, modified					■				
E1.8	DB	Bog, dry, modified					■		□		
E2.1	AF	Flush and spring, acid/ neutral		■							
E2.2	BF	Flush and spring, basic		■							
E2.3	Target note	Flush and spring, bryophyte dominated		■							
E3.1	VM	Fen, valley mire		○							
E3.2	BM	Fen, basin mire		○							
E3.3	FPM	Fen, flood-plain		○							
E4	P	Bare peat					■				

Field Guide Habitats most appropriate to UK Biodiversity Action Plan

No. code	"Broad Habitat Type"	"Key Habitat Type"	SG	F	TH	S	BB	W	D	TG	B
1	Broad-leaved and Yew woodland	Upland oakwood Wet woodlands				□					
3	Native pine woodland	Native pine wood				□					
7	Improved grassland		■								
9	Acid grassland	Purple moor-grass and rush pastures	■	□						■	
10	Calcareous grassland		■								
11	Lowland heathland	Lowland heathland							●		
12	Grazing marsh			○						●	
13	Fens, carrs, marsh, swamp and reedbed	Fens		■			□			□	
18	Montane (alpine and sub-alpine types)		□		■	■		■	□		
19	Upland heathland	Upland heathland				□			■		
20	Blanket bog	Blanket bog					■				

Field Guide Habitats most appropriate to Natura 2000 habitat classes (EC Habitats and Species Directive 92/43/EEC).

N2K code	CORINE 91		SG	F	TH	S	BB	W	D	TG	B
4010	31.11	Northern Atlantic wet heath with *Erica tetralix.*					■		□		
4030	31.21	Sub-montane *Vaccinium* heaths							■		
	31.22	Sub-Atlantic *Calluna - Genista* heaths							■		
4060	31.45	Boreo-alpine Scottish heaths						■			
	31.49	Mountain avens mats	■					□			
4080	31.622	Sub-arctic willow scrub				■					
5130	31.88	*Juniperus communis* formations on heaths or calcareous grasslands				■					
6150	36.32	Silicious alpine and boreal grasslands						■			

Field Guide Habitats most appropriate to Natura 2000 habitat classes (EC Habitats and Species Directive 92/43/EEC).

N2K code	CORINE 91		S G	F	T H	S	B B	W	D	T G	B
6230	35.1 36.31	Species-rich *Nardus* grasslands on silicious substrates in mountain areas (and sub-montane areas, in continental Europe).	■								
6430	37.8	Eutrophic tall herbs. Hygrophilous perennial tall herb communities of montane to alpine levels of the *Betulo - Adenostyletea* class.			■						
7110	51.1	Active raised bog					□				
7120	51.2	Degraded raised bogs (still capable of natural regeneration)					□				
7130	52.1 52.2	Blanket bog (active only)					■				
7140	54.5	Transition mires and quaking bogs					□				

Field Guide Habitats most appropriate to Natura 2000 habitat classes (EC Habitats and Species Directive 92/43/EEC).

N2K code	CORINE 91		SG	F	TH	S	BB	W	D	TG	B
7220	54.12	Petrifying springs with tufa formation (*Cratoneurion*)		■							
7230	54.2	Alkaline fens		■							
7240	54.3	Alpine pioneer formations of *Caricion bicoloris - atrufuscae*		■							

Field Guide Habitats most appropriate to National Vegetation Classification plant communities.

NVC code	Name	SG	F	TH	S	BB	W	D	TG	B
CG10	*Festuca ovina - Agrostis capillaris - Thymus praecox* grassland									
	(a) *Trifolium repens - Luzula campestris* sub-community	■								
	(b) *Carex pulicaris - Carex panicea* sub-community	■	□							
	(c) *Saxifraga aizoides - Ditrichum flexicaule* sub-community	■	□							
CG11	*Festuca ovina - Agrostis capillaris - Alchemilla alpina* grass-heath									
	(a) Typical sub-community	■								
	(b) *Carex pulicaris - Carex panicea* sub-community	■	□							
CG12	*Festuca ovina - Alchemilla alpina - Silene acaulis* dwarf-herb community	■								
CG13	*Dryas octopetala - Carex flacca* heath	■						□		
CG14	*Dryas octopetala - Silene acaulis* ledge community			■						
H7	*Calluna vulgaris - Scilla verna* heath	○						●		
H9	*Calluna vulgaris - Deschampsia flexuosa* heath							■		

Field Guide Habitats most appropriate to National Vegetation Classification plant communities.

NVC code	Name	S G	F	T H	S	B B	W	D	T G	B
H10	*Calluna vulgaris - Erica cinerea* heath									
	(a) Typical sub-community							■		
	(b) *Racomitrium lanuginosum* sub-community						■			
	(c) *Festuca ovina - Anthoxanthum odoratum* sub-community							■		
	(d) *Thymus praecox - Carex pulcaris* sub-community							■		
H12	*Calluna vulgaris - Vaccinium myrtillus* heath							■		
H13	*Calluna vulgaris - Cladonia arbuscula* heath						■	□		
H14	*Calluna vulgaris - Racomitrium lanuginosum* heath						■	□		
H15	*Calluna vulgaris - Juniperus communis* ssp. *nana* heath						■	□		
H16	*Calluna vulgaris - Arctostaphylos uva-ursi* heath							■		
H17	*Calluna vulgaris - Arctostaphylos alpinus* heath						■	□		

Field Guide Habitats most appropriate to National Vegetation Classification plant communities.

NVC code	Name	SG	F	TH	S	BB	W	D	TG	B
H18	*Vaccinium myrtillus - Deschampsia flexuosa* heath									
	(a) *Hylocomium splendens - Rhytidiadelphus loreus* sub-community							■		
	(b) *Alchemilla alpina - Carex pilulifera* sub-community							■		
	(c) *Racomitrium lanuginosum - Cladonia* spp. sub-community						□	■		
H19	*Vaccinium myrtillus - Cladonia arbuscula* heath						■	□		
H20	*Vaccinium myrtillus - Racomitrium lanuginosum* heath						■	□		
H21	*Calluna vulgaris - Vaccinium myrtillus - Sphagnum capillifolium* heath					□		■		
H22	*Vaccinium myrtillus - Rubus chamaemorus* heath					□		■		
M1	*Sphagnum auriculatum* bog pool community					■				
M2	*Sphagnum cuspidatum/recurvum* bog pool community					■				
M3	*Eriophorum angustifolium* bog pool community					■				

Field Guide Habitats most appropriate to National Vegetation Classification plant communities.

NVC code	Name	S G	F	T H	S	B B	W	D	T G	B
M4	*Carex rostrata - Sphagnum recurvum* mire		■			□				
M6	*Carex echinata - Sphagnum recurvum/auriculatum* mire		■			□				
M7	*Carex curta - Sphagnum russowii* mire		■							
M8	*Carex rostrata - Sphagnum warnstorfii* mire		■							
M10	*Carex dioica - Pinguicula vulgaris* mire		■							
M11	*Carex demissa - Saxifraga aizoides* mire		■							
M12	*Carex saxatilis* mire		■							
M15	*Scirpus cespitosus - Erica tetralix* wet heath									
	(a) *Carex panicea* sub-community		■							
	(b) Typical sub-community					■				
	(c) *Cladonia* sub-community							■		
	(d) *Vaccinium myrtillus* sub-community							■		
M16	*Erica tetralix - Sphagnum compactum* wet heath (d) *Juncus squarrosus - Dicranum scoparium* sub-community							■		

Field Guide Habitats most appropriate to National Vegetation Classification plant communities.

NVC code	Name	S G	F	T H	S	B B	W	D	T G	B
M17	*Scirpus cespitosus - Eriophorum vaginatum* blanket mire					■				
M18	*Erica tetralix - Sphagnum papillosum* raised and blanket mire					■				
M19	*Calluna vulgaris - Eriophorum vaginatum* blanket mire									
	(a) *Erica tetralix* sub-community					■				
	(b) *Empetrum nigrum nigrum* sub-community					■		□		
	(c) *Vaccinium vitis-idaea - Hylocomium splendens* sub-community					■		□		
M20	*Eriophorum vaginatum* blanket and raised mire					■				
M23	*Juncus effusus/acutiflorus - Galium palustre* rush pasture		□						■	
M25	*Molinia caerulea - Potentilla erecta* mire		□			□			■	
M26	*Molinia caerulea - Crepis paludosa* mire		○	●					○	
M27	*Filipendula ulmaria - Angelica sylvestris* mire			●						
M31	*Anthelia julacea - Sphagnum auriculatum* spring		■							

Field Guide Habitats most appropriate to National Vegetation Classification plant communities.

NVC code	Name	S G	F	T H	S	B B	W	D	T G	B
M32	*Philonotis fontana - Saxifraga stellaris* spring		■							
M33	*Pohlia wahlenbergii* var. *glacialis* spring		■							
M34	*Carex demissa - Koenigia islandica* flush		■							
M37	*Cratoneuron commutatum - Festuca rubra* spring		■							
M38	*Cratoneuron commutatum - Carex nigra* spring		■							
MG6	*Lolium perenne - Cynosurus cristatus* grassland	●								
MG9	*Holcus lanatus - Deschampsia cespitosa* grassland								●	
MG10	*Holcus lanatus - Juncus effusus* rush-pasture		○			○			●	
U2	*Deschampsia flexuosa* grassland									
	(a) *Festuca ovina - Agrostis capillaris* sub-community	■								
	(b) *Vaccinium myrtillus* sub-community							■	□	
U4	*Festuca ovina - Agrostis capillaris - Galium saxatile* grassland	■								
U5	*Nardus stricta - Galium saxatile* grassland								■	

Field Guide Habitats most appropriate to National Vegetation Classification plant communities.

NVC code	Name	SG	F	TH	S	BB	W	D	TG	B
U6	*Juncus squarrosus - Festuca ovina* grassland									
	(a) *Sphagnum* sub-community					■				
	(b) *Carex nigra - Calypogeia trichomanis* sub-community					■			□	
	(c) *Vaccinium myrtillus* sub-community							■		
	(d) *Agrostis capillaris - Luzula multiflora* sub-community		□						■	
U7	*Nardus stricta - Carex bigelowii* grass-heath								■	
U9	*Juncus trifidus - Racomitrium lanuginosum* rush-heath						■			
U10	*Carex bigelowii - Racomitrium lanuginosum* moss-heath						■			
U13	*Deschampsia cespitosa - Galium saxatile* grassland		□	□					■	
U14	*Alchemilla alpina - Sibbaldia procumbens* dwarf-herb community	■	□							
U15	*Saxifraga aizoides - Alchemilla glabra* banks		■							
U16	*Luzula sylvatica - Vaccinium myrtillus* tall-herb community			■						

Field Guide Habitats most appropriate to National Vegetation Classification plant communities.

NVC code	Name	S G	F	T H	S	B B	W	D	T G	B
U17	*Luzula sylvatica - Geum rivale* tall-herb community			■						
U19	*Thelypteris limbosperma - Blechnum spicant* community			■						
U20	*Pteridium aquilinum - Galium saxatile* community	□			□			□		■
W4	*Betula pubescens - Molinia caerulea* woodland				□					
W9	*Fraxinus excelsior - Sorbus aucuparia - Mercurialis perennis* woodland				□					
W11	*Quercus petraea - Betula pubescens - Oxalis acetosella* woodland				□					
W17	*Quercus petraea - Betula pubescens - Dicranum majus* woodland				□					
W18	*Pinus sylvestris - Hylocomium splendens* woodland				□					
W19	*Juniperus communis* ssp. *communis - Oxalis acetosella* woodland				■					
W20	*Salix lapponum - Luzula sylvatica* scrub				■					

Field Guide Habitats most appropriate to National Vegetation Classification plant communities.

NVC code	Name	SG	F	TH	S	BB	W	D	TG	B
W23	*Ulex europaeus - Rubus fruticosus* scrub				●					

Names of vascular plant species mentioned in the text

Scientific name (Stace 1991)	Scientific name used in the National Vegetation Classification where different (British Plant Communities, Rodwell 1991, 1992)	Common name (Stace 1991, with one or two Scottish variations)
Achillea millefolium		Yarrow
Agrostis canina		Velvet bent
Agrostis capillaris		Common bent
Agrostis spp.		Bents
Agrostis stolonifera		Creeping bent
Agrostis vinealis	*Agrostis canina montana*	Brown bent
Alchemilla alpina		Alpine lady's-mantle
Alchemilla glabra		Lady's-mantle
Alchemilla spp.		Lady's-mantles
Alnus glutinosa		Alder
Anemone nemorosa		Wood anemone
Angelica sylvestris		Wild angelica
Antennaria dioica		Mountain everlasting
Anthoxanthum odoratum		Sweet vernal-grass
Arctostaphylos alpinus		Mountain bearberry
Arctostaphylos uva-ursi		Bearberry
Armeria maritima		Thrift
Athyrium distentifolium		Alpine lady-fern
Bellis perennis		Daisy
Betula nana		Dwarf birch
Betula pendula		Silver birch
Betula pubescens		Downy birch
Betula spp.		Birches
Blechnum spicant		Hard-fern
Botrychium lunaria		Moonwort

Names of vascular plant species mentioned in the text

Scientific name (Stace 1991)	Scientific name used in the National Vegetation Classification where different (British Plant Communities, Rodwell 1991, 1992)	Common name (Stace 1991, with one or two Scottish variations)
Briza media		Quaking grass
Calluna vulgaris		Heather or Ling
Caltha palustris		Marsh marigold
Campanula rotundifolia		Harebell
Cardamine flexuosa		Wavy bitter-cress
Cardamine pratensis		Cuckooflower
Cardamine spp.		Bitter-cresses
Carex bigelowii		Stiff sedge
Carex binervis		Green-ribbed sedge
Carex echinata		Star sedge
Carex flacca		Glaucous sedge
Carex nigra		Common sedge
Carex panicea		Carnation sedge
Carex pilulifera		Pill sedge
Carex pulicaris		Flea sedge
Cerastium fontanum		Common mouse-ear
Circaea x intermedia		Upland enchanter's-nightshade
Circaea lutetiana		Enchanter's-nightshade
Cirsium arvense		Creeping thistle
Cirsium heterophyllum	*Cirsium helenioides*	Melancholy thistle
Cirsium palustre		Marsh thistle
Conopodium majus		Pignut
Cornus suecica		Dwarf cornel
Corylus avellana		Hazel
Crataegus monogyna		Hawthorn
Crepis paludosa		Marsh hawk's-beard
Cynosurus cristatus		Crested dog's-tail
Cystopteris montana		Mountain bladder-fern
Cytisus scoparius		Broom
Dactylis glomerata		Cock's-foot
Danthonia decumbens		Heath-grass

Names of vascular plant species mentioned in the text

Scientific name (Stace 1991)	Scientific name used in the National Vegetation Classification where different (British Plant Communities, Rodwell 1991, 1992)	Common name (Stace 1991, with one or two Scottish variations)
Deschampsia cespitosa		Tufted hair-grass
Deschampsia flexuosa		Wavy hair-grass
Draba incana		Hoary whitlowgrass
Drosera spp.		Sundews
Dryas octopetala		Mountain avens
Dryopteris dilatata		Broad buckler-fern
Dryopteris expansa		Northern buckler-fern
Empetrum nigrum		Crowberry
Equisetum spp.		Horsetails
Erica cinerea		Bell heather
Erica tetralix		Cross-leaved heath
Eriophorum angustifolium		Common cotton-grass
Eriophorum spp.		Cotton-grasses
Eriophorum vaginatum		Harestail cotton-grass
Euphrasia spp.		Eyebrights
Festuca ovina		Sheep's-fescue
Festuca rubra		Red fescue
Festuca vivipara		Viviparous fescue
Filipendula ulmaria		Meadowsweet
Fraxinus excelsior		Ash
Galium aparine		Cleavers
Galium boreale		Northern bedstraw
Galium saxatile		Heath bedstraw
Galium verum		Lady's bedstraw
Genista anglica		Petty whin
Gentiana nivalis		Alpine gentian
Gentianella spp.		Gentians
Geranium sylvaticum		Wood crane's-bill
Geum rivale		Water avens
Geum urbanum		Wood avens
Gnaphalium supinum	*Omalotheca supina*	Dwarf cudweed
Hedera helix		Ivy

Names of vascular plant species mentioned in the text

Scientific name (Stace 1991)	Scientific name used in the National Vegetation Classification where different (British Plant Communities, Rodwell 1991, 1992)	Common name (Stace 1991, with one or two Scottish variations)
Helianthemum nummularium		Common rock-rose
Heracleum sphondylium		Common hogweed
Holcus lanatus		Yorkshire fog
Holcus mollis		Creeping soft-grass
Huperzia selago		Fir clubmoss
Hyacinthoides non-scripta		Bluebell
Hypericum pulchrum		Slender St John's-wort
Ilex aquifolium		Holly
Juncus acutiflorus		Sharp-flowered rush
Juncus effusus		Soft rush
Juncus spp.		Rushes
Juncus squarrosus		Heath rush
Juncus trifidus		Three-leaved rush
Juniperus communis		Common juniper
Juniperus communis nana		Common juniper (genetically prostrate)
Lathyrus linifolius	*Lathyrus montanus*	Bitter-vetch
Leontodon autumnalis		Autumn hawkbit
Linum catharticum		Fairy flax
Listera cordata		Lesser twayblade
Loiseleuria procumbens		Trailing azalea
Lolium perenne		Perennial rye-grass
Lonicera periclymenum		Honeysuckle
Lotus corniculatus		Common bird's-foot-trefoil
Luzula campestris		Field wood-rush
Luzula spicata		Spiked wood-rush
Luzula sylvatica		Great wood-rush
Lycopodium clavatum		Stag's-horn clubmoss

Names of vascular plant species mentioned in the text

Scientific name (Stace 1991)	Scientific name used in the National Vegetation Classification where different (British Plant Communities, Rodwell 1991, 1992)	Common name (Stace 1991, with one or two Scottish variations)
Melampyrum pratense		Common cow-wheat
Menyanthes trifoliata		Bogbean
Minuartia sedoides		Cyphel
Molinia caerulea		Purple moor-grass
Myosotis alpestris		Alpine forget-me-not
Myrica gale		Bog-myrtle
Nardus stricta		Mat-grass
Narthecium ossifragum		Bog asphodel
Oreopteris limbosperma	*Thelypteris limbosperma*	Lemon-scented fern
Osmunda regalis		Royal fern
Oxalis acetosella		Wood-sorrel
Oxyria digyna		Mountain sorrel
Persicaria vivipara	*Polygonum viviparum*	Alpine bistort
Phleum pratense		Timothy
Pilosella officinarum	*Heiracium pilosella*	Mouse-ear-hawkweed
Pinguicula vulgaris		Common butterwort
Pinus sylvestris		Scots pine
Plantago lanceolata		Ribwort plantain
Poa pratensis		Smooth meadow-grass
Poa spp.		Meadow-grasses
Polygalla serpyllifolia		Heath milkwort
Polystichum lonchitis		Holly fern
Populus tremula		Aspen
Potentilla crantzii		Alpine cinquefoil
Potentilla erecta		Tormentil
Primula vulgaris		Primrose
Prunella vulgaris		Selfheal
Prunus padus		Bird cherry
Pteridium aquilinum		Bracken
Pyrola media		Intermediate wintergreen
Quercus petraea		Sessile oak
Ranunculus acris		Meadow buttercup

Names of vascular plant species mentioned in the text

Scientific name (Stace 1991)	Scientific name used in the National Vegetation Classification where different (British Plant Communities, Rodwell 1991, 1992)	Common name (Stace 1991, with one or two Scottish variations)
Ranunculus spp.		Buttercups
Rhinanthus minor		Yellow-rattle
Rhynchospora alba		White beak-sedge
Rubus chamaemorus		Cloudberry
Rubus fruticosus agg.		Bramble
Rubus saxatilis		Stone bramble
Rumex acetosa		Common sorrel
Rumex spp.		Docks/Sorrels
Sagina procumbens		Procumbent pearlwort
Salix arbuscula		Mountain willow
Salix aurita		Eared willow
Salix caprea		Goat willow
Salix cinerea		Grey willow
Salix herbacea		Dwarf willow
Salix lanata		Woolly willow
Salix lapponum		Downy willow
Salix myrsinites		Whortle-leaved willow
Salix repens		Creeping willow
Salix reticulata		Net-leaved willow
Salix spp.		Willows
Saussuria alpina		Alpine saw-wort
Saxifraga aizoides		Yellow saxifrage
Saxifraga hypnoides		Mossy saxifage
Saxifraga oppositifolia		Purple saxifrage
Saxifraga stellaris		Starry saxifrage
Schoenus nigricans		Black bog-rush
Sedum rosea	*Rhodiola rosea*	Roseroot
Selaginella selaginoides		Lesser clubmoss
Senecio jacobaea		Common ragwort
Sibbaldia procumbens		Sibbaldia
Silene acaulis		Moss campion
Solidago virgaurea		Goldenrod
Sorbus aucuparia		Rowan

Names of vascular plant species mentioned in the text

Scientific name (Stace 1991)	Scientific name used in the National Vegetation Classification where different (British Plant Communities, Rodwell 1991, 1992)	Common name (Stace 1991, with one or two Scottish variations)
Stellaria media		Common chickweed
Succisa pratensis		Devil's-bit scabious
Thymus polytrichus	*Thymus praecox*	Wild thyme
Trichophorum cespitosum	*Scirpus cespitosus*	Deergrass
Trientalis europaea		Chickweed wintergreen
Trifolium repens		White clover
Trollius europaeus		Globeflower
Ulex europaeus		Whin or Gorse
Ulmus glabra		Wych elm
Urtica dioica		Common nettle
Vaccinium myrtillus		Blaeberry
Vaccinium oxycoccus		Cranberry
Vaccinium uliginosum		Bog blaeberry
Vaccinium vitis-idaea		Cowberry
Valeriana officinalis		Common valerian
Veronica officinalis		Heath speedwell
Veronica serpyllifolia		Thyme-leaved speedwell
Viola lutea		Mountain pansy
Viola palustris		Marsh violet
Viola riviniana		Common dog-violet

Model recording cards and feedback form

Habitat Impact Survey Field Indicator Recording Card

Smooth grassland

Surveyor's name		Date	
Recorder's name		Date	

Survey Unit Location and Type			
Ident. No.		Polygon	
OS Grid Ref.		Raster grid cell	
Observing conditions for survey unit			
Distance from survey unit (Phase 1)			

Clear visibility		Comments:	Vegetation wetness	
> 5 km			Wet	
1 - 5 km			Dry	
< 1 km				

Grazing

Phase 1 - Large-scale Indicators	**H**	**M**	**L**
Surface texture and colour of vegetation			
Sheep scars			

Grazing

Phase 2 - Small-scale Indicators	**H**	**M**	**L**
Sward height and texture			
Uprooted bundles of grass tillers			
Accumulation of dead plant material in sward			
Signs of grazing on unpalatable herbs (*Aa, Js, Ns, Pv, Sp, Tp*)			
Signs of grazing on palatable herbs (*Lc, Ll, Tr, Pl*)			
Signs of grazing on *Dryas octopetala*			
Flowering of grasses and forbs at > 3 cm			
Signs of grazing on most palatable grasses (*Ac, Ao, Dd, Df, Fr, H* spp, *P* spp)			
Signs of grazing on less palatable grasses (*Ac, Fo, Fv*)			
Signs of grazing on *Deschampsia cespitosa*			
Cover of mosses, particularly "feather" mosses			
Tree seedlings/saplings > 5 cm tall			
Breakage and uprooting of *Sa, Ms, Hs, Sh, Ss* (alpine)			
Density of shoots/ "weeding" of alpine cushion plants (*Sa, Ms*)			
Bare ground			
Dung			

Trend	**I**	**CH**	**D**	**CL**
Sward height vs other signs				
Flowering and vigour of taller herbs				
Cover and frequency of small, rosette, creeping, and mat herbs				
"Weedy" ruderal species				
Tree and shrub saplings				

Agricultural improvement		
Phase 2 - Small-scale Indicators	**H**	**L**
Presence of *Lolium perenne*		
Presence of *Datylis glomerata*		
Frequency and cover of *Cf, Cc, Hl* vs *Fo, Pe*		
Cover and frequency of *Tr* vs *Pe*		

Habitat Impact Survey Field Indicator Recording Card

Flush

Surveyor's name		Date	
Recorder's name		Date	

Survey Unit Location and Type			
Ident. No.		Polygon	
OS Grid Ref.		Raster grid cell	
Observing conditions for survey unit			
Distance from survey unit (Phase 1)			
Clear visibility	Comments:	Vegetation wetness	
> 5 km		Wet	
1 - 5 km		Dry	
< 1 km			

Grazing and trampling

Phase 1 - Large-scale Indicators	**H**	**M**	**L**
Bare peat or mud			

Grazing and trampling

Phase 2 - Small-scale Indicators	**H**	**M**	**L**
% of surface "poached"			
Disruption of bryophyte carpet			
Pulled mosses and other plants			
Height of vegetation			
% leaves of sedges/grasses showing signs of grazing			
Flowering heads of sedges remaining ungrazed			
Signs of grazing on *Juncus effusus, Equisetum spp, Erica tetralix*			
Amount of grazing of *Cardamine* spp.			
Flowering and vigour of tall herbs (*Cp, Fu, Sp, Vo*)			
Flowering of *Armeria maritima*			

Trend	**I**	**CH**	**D**	**CL**
Frequency and abundance of rushes and "grassland" spp. (*Ac, Ac, As, Ao, Dc, Gs, Hl, Js, Mc, Ns, Pe, Je, Ja, Pc*)				
Height of bushes of *Myrica* or *Salix*				

Habitat Impact Survey Field Indicator Recording Card

Tall herbs

Surveyor's name		Date	
Recorder's name		Date	

Survey Unit Location and Type			
Ident. No.		Polygon	
OS Grid Ref.		Raster grid cell	
Observing conditions for survey unit			
Distance from survey unit (Phase 1)			
Clear visibility	Comments:	Vegetation wetness	
> 5 km		Wet	
1 - 5 km		Dry	
< 1 km			

Grazing

Phase 1 - Large-scale Indicators	**H**	**M**	**L**
Clumps, tussocks, patches visible from several 100's m away			

Grazing

Phase 2 - Small-scale Indicators	**H**	**M**	**L**
Height of vegetation			
Signs of grazing, vigour and flowering of commoner spp. (*A* spp, *As, Dc, Gs, Gr, Ls, Sr, Te, Hs*)			
Browsing of dwarf-shrubs			
Signs of grazing of ferns			

Trend	**I**	**CH**	**CM**	**D**	**CL**
Dominance of tall herbs vs grassland spp.					
Tree and shrub seedlings/saplings (*Sa, Bp, Pt, Fe, Jc*)					
Flowering of tall herbs vs form and vegetative vigour					

Habitat Impact Survey Field Indicator Recording Card

Scrub

Surveyor's name		Date	
Recorder's name		Date	

Survey Unit Location and Type			
Ident. No.		Polygon	
OS Grid Ref.		Raster grid cell	
Observing conditions for survey unit			
Distance from survey unit (Phase 1)			
Clear visibility	Comments:	Vegetation wetness	
> 5 km		Wet	
1 - 5 km		Dry	
< 1 km			

Browsing, grazing and trampling

Phase 1 - Large-scale Indicators	H	M	L
Browse line/growth form of saplings and bushes			

Browsing, grazing and trampling

Phase 2 - Small-scale Indicators	H	M	L
Evidence of browsing of trees and shrubs			
Bark stripping			
Presence and condition of seedlings and saplings			
Disturbance to field and ground layers			
Height of field layer herbs/ signs of grazing in field layer herbs			
Browsing of dwarf-shrubs in field layer			
Grazing of tall herbs in field layer			
Dung and tracks			

Trend	I	CH	CM	D	CL
Form and extent of shrub layer					
Extent of field layer					
Composition of herbs in field layer					

Burning: intensity of impact

Phase 2 - Small-scale Indicators	H	M	L
Effects on shrubs and trees			
Effects on field and ground layers			

Burning: frequency of fires

Phase 2 - Small-scale Indicators	**H**	**M**	**L**
Abundance and form of shrubs and trees			
Effects on dwarf-shrubs in field layer			
Effects on tussock grasses in field layer			

Habitat Impact Survey Field Indicator Recording Card

Blanket bog

Surveyor's name		Date	
Recorder's name		Date	

Survey Unit Location and Type

Ident. No.		Polygon	
OS Grid Ref.		Raster grid cell	

Observing conditions for survey unit

Distance from survey unit (Phase 1)	

Clear visibility		Comments:	Vegetation wetness	
> 5 km			Wet	
1 - 5 km			Dry	
< 1 km				

Drying and peat loss

Phase 1 - Large-scale Indicators	H	M	L
Spacing of slits, drains and trenches			
Depth of slits, drains and trenches			
Presence of an irregular pattern of small hummocks			
Extent of bare peat			
Extent and vigour of *Calluna*			

Burning: intensity of impact

Phase 1 - Large-scale Indicators	H	M	L
Extent of bare peat in the burnt patch			
Pattern of fire advance			
Colour of burnt patch immediately after burning			
Pattern of revegetation after burning			
Dominant moss patches or crusts of lichens or algae			

Burning: frequency of fires

Phase 1 - Large-scale Indicators	H	M	L
Extent of bare ground, moss patches, lichen or algal crusts			
Dwarf-shrubs vs graminoids			

Trampling and grazing

Phase 1 - Large-scale Indicators	H	M	L
Bare peat			
Sheep, deer and cattle paths			
Flowering of *Eriophorum*			
Colour of *Calluna* patches			
Luxuriance of vegetation on small islands			

Drying and peat loss

Phase 2 - Small-scale Indicators	H	M	L
Cracking of peat in walls of drains			
Water flow and scouring in drainage tracks			
Amount and composition in ditches and hollows			
Abundance and diversity of *Sphagnum*			
Softness/wetness underfoot			
Extent and vigour of *Calluna* vs *Erica tetralix*			
Presence of *J*, *Cp*, *Ns*, *Df*, *A* spp, *Pc*, "feather" mosses, *Rl*, bushy *Cladonia* lichens			

Trend	I	CH	D
Drain characteristics			
Location of greatest abundance of *Sphagnum*			
Extent of *Sphagnum* vs *Sphagnum* vigour			
Size of *Calluna* plants vs vigour of *Calluna* plants			
Dominance of *Calluna* vs *Sphagnum*			
Dominance of *Juncus squarrosus* vs *Sphagnum*			

Burning: intensity of impact

Phase 2 - Small-scale Indicators	H	M	L
Combustion or "cooking" of peat			
Dense mosses - amount of combustion or bleaching			
Loose mosses, lichens, plant litter - amount of combustion			
Amount of combustion of woody material			

Burning: frequency of fires

Phase 2 - Small-scale Indicators	H	M	L
Solidity and texture of peat			
Extent, diversity and luxuriance of *Sphagnum*			
Extent and luxuriance of *Racomitrium lanuginosum* and "feather" mosses			
Dominance of dwarf-shrubs vs graminoids			
Abundance of *Ac, Dc, Fo, Gs, Ns, Ps, Rc, Sp*			
Abundance and luxuriance of bushy *Cladonia* lichens			

Trend	CH
Abundance and dominance of graminoids	

Trampling and grazing

Phase 2 - Small-scale Indicators	H	M	L
Pool systems and water tracks			
Sphagnum hummocks and lawns			
Cover of *Sphagnum* and/or lichens vs "feather" mosses			
Hoof prints in bare peat			
Firmness of ground underfoot			
Browsing of *Betula nana*			
Signs of browsing of less palatable dwarf-shrubs (*Auu, En, Et, Vvi*)			
Amount of flower and fruit on *Rubus chamaemorus*			
Amount of flower and fruit on *Eriophorum*			
Growth form and signs of browsing of *Myrica*			
Browsing of *Calluna* and/or *Vaccinium myrtillus*			
Dung			

Trend	I	CH	CM	D	CL
Changes in growth-form of dwarf-shrubs					
Height of *Myrica*					
Height and cover of dwarf-shrubs vs graminoids					
Abundance and vigour of *Juncus squarrosus*					
Presence of "grassland" species (*Ac, Ac, Ao, Df, Fo, Ns*)					
Abundance of *Carex panicea* on drier "ridge" areas					

Habitat Impact Survey Field Indicator Recording Card

Wind-clipped summit heath

Surveyor's name		Date	
Recorder's name		Date	

Survey Unit Location and Type			
Ident. No.		Polygon	
OS Grid Ref.		Raster grid cell	
Observing conditions for survey unit			
Distance from survey unit (Phase 1)			

Clear visibility		Comments:	Vegetation wetness	
> 5 km			Wet	
1 - 5 km			Dry	
< 1 km				

Grazing and trampling

Phase 1 - Large-scale Indicators	**H**	**L**
Obvious evidence of grazing in associated flushes		

Burning

Phase 1 - Large-scale Indicators	**H**	**L**
Evidence of burning		

Grazing and trampling

Phase 2 - Small-scale Indicators		**H**	**L**
Signs of grazing on leaves of *Carex bigelowii*, *Juncus trifidus* and fine-leaved grasses			
Extent, location and size of patches of bare ground			
Dung of sheep or Red Deer			
Dung of Mountain Hare			
Signs of grazing on leaves of broader leaved grasses (*Ac, Av, Ao, P* spp.)			
Browsing of dwarf-shrubs			
Signs of grazing on alpine cushion/mat herbs (*Am, Ms, Sp, Sa*)			
Bare soil on face or flat of terraces			

Trend	**I**	**CH**	**D**	**CL**
Cover of *Galium saxatile*, *Potentilla erecta*, fine-leaved grasses				
Cover of broad-leaved grasses (*Ac, Av, Ao, P* spp.)				

Burning

Phase 2 - Small-scale Indicators	**H**	**L**
Signs of burning		

Habitat Impact Survey Field Indicator Recording Card

Dwarf-shrub heath

Surveyor's name		Date	
Recorder's name		Date	

Survey Unit Location and Type			
Ident. No.		Polygon	
OS Grid Ref.		Raster grid cell	
Observing conditions for survey unit			
Distance from survey unit (Phase 1)			

Clear visibility		Comments:	Vegetation wetness	
> 5 km			Wet	
1 - 5 km			Dry	
< 1 km				

Browsing

Phase 1 - Large-scale Indicators	H	M	L
Colour of *Calluna* patches			
Breadth of heavily browsed zone adjacent to grassland			
Sward height in associated grass patches			
Sheep scars			
Browsing of seedlings/saplings of deciduous tree and shrubs			

Burning: intensity of impact

Phase 1 - Large-scale Indicators	H	M	L
Newly initiated erosion			
Pattern of fire spread			
Colour of burnt patch immediately after burning			
Pattern of revegetation			
Extensive patches of mosses or crusts of algae or lichens			

Burning: frequency of fires

Phase 1 - Large-scale Indicators	H	M	L
Discrete, structurally variable, stands of dwarf-shrubs			
Height of dwarf-shrubs vs graminoids			
Extent of bare ground, moss mats, lichen crusts, algal mats			

Browsing

Phase 2 - Small-scale Indicators	H	M	L
Signs of browsing of less palatable dwarf-shrubs (*Auu, En, Et, Vvi* or associated *Ns*)			
Proportion of shoots browsed of *Calluna* and/or *Vaccinium myrtillus*			
Amount of flower or fruit on *Calluna* and/or *Vaccinium myrtillus*			

Browsing					
Phase 2 - Small-scale Indicators			**H**	**M**	**L**
Summer browsing of *Calluna*					
Type of shoot material removed					
Growth-form and signs of browsing on *Myrica*					
Uprooted dwarf-shrub seedlings in recently burnt patches					
Stem breakage					
Depth of carpet of bryophytes and "bushy" lichens					
Amount of bare ground					
Dung					
Spiders' webs					
Trend	**I**	**CH**	**D**	**CL**	
Growth-form of *Calluna* and/or *Vaccinium myrtillus*					
Changes on growth-form of dwarf-shrubs					
Presence of "drumstick", "topiary", "carpet" growth-forms					
Height and cover of dwarf-shrubs vs graminoids					
Sheep scars					

Burning: intensity of impact			
Phase 2 - Small-scale Indicators	**H**	**M**	**L**
Combustion or "cooking" of soil			
Amount of ash and size of charcoal fragments			
Degree of combustion of woody material			
Degree of combustion of plant litter, mosses, lichens			
Amount of regeneration and whether from seed or resprouting			
Survival of clubmosses and *Blechnum*			
Effects on trees and bushes			

Burning: frequency of fires			
Phase 2 - Small-scale Indicators	**H**	**M**	**L**
Relative abundance of different dwarf-shrubs			
Abundance of dwarf-shrubs in 2nd - 4th yr after burning			
Variation in height of dwarf-shrubs at small scales			
Structural dominance of dwarf-shrubs vs graminoids			
Extent and luxuriance of bryophytes and epiphytic lichens			
Abundance and luxuriance of "bushy" *Cladonia* lichens			
Size of plants/colonies of clubmosses and *Blechnum*			
Density of vascular plant species			
Abundance and diversity of forbs and grasses			
Solidity and texture of soil surface			
Abundance and form of trees and shrubs			
Trend		**CH**	
Abundance and dominance of graminoids			

Habitat Impact Survey Field Indicator Recording Card

Tussock grassland

Surveyor's name		Date	
Recorder's name		Date	

Survey Unit Location and Type			
Ident. No.		Polygon	
OS Grid Ref.		Raster grid cell	
Observing conditions for survey unit			
Distance from survey unit (Phase 1)			

Clear visibility		Comments:	Vegetation wetness	
> 5 km			Wet	
1 - 5 km			Dry	
< 1 km				

Grazing

Phase 1 - Large-scale Indicators	**H**	**M**	**L**
Sheep scars			

Burning: intensity of impact

Phase 1 - Large-scale Indicators	**H**	**M**	**L**
Newly initiated erosion			
Pattern of fire advance			
Colour of burnt patch immediately after burning			
Pattern of revegetation			

Grazing

Phase 2 - Small-scale Indicators	**H**	**M**	**L**
Signs of grazing on *Nardus* (sheep and Red deer)			
Signs of grazing on *Nardus* (cattle)			
Inter-tussock sward height			
Accumulation of dead plant litter			
Signs of grazing of less palatable spp. (*J* spp, *C* spp, *Gs, Pe,* mosses)			
Flowering of herbs in inter-tussock sward			
Signs of grazing on leaves of palatable spp. (*Ac, Ao, Dd, Df, Fr, H* spp, *P* spp, sedges)			
Signs of grazing on leaves of fine-leaved grasses (*Ac, Fo, Fv*)			
Signs of grazing on leaves of *Deschampsia cespitosa*			
Tree and shrub seedlings/saplings > 5 cm tall			
Bare ground			
Cover of *Polytrichum commune* and/or "feather" mosses			
Spiders' webs			

Trend	I	CH	D	CL
Inter-tussock sward height vs other indicators				
Flowering and vigour of taller herbs				
Abundance and vigour of *Juncus squarrosus*, rosette, creeping, mat, or dwarfed herbs				
Cover of mosses vs other indicators				
Tree and shrub saplings vs sward height				

Burning: intensity of impact

Phase 2 - Small-scale Indicators	H	M	L
Combustion or "cooking" of soil			
Amount of charcoal and ash immediately after burning			
Combustion of grass tussocks			
Effects on trees and bushes			

Burning: frequency of fires

Phase 2 - Small-scale Indicators	H	M	L
Height of grasses vs dwarf-shrubs			
Amount of dead plant litter and tussock senescence			
Size of tussock cores			
Diversity of herbs			
Abundance and form of trees and shrubs			

Habitat Impact Survey Field Indicator Recording Card

Bracken

Surveyor's name		Date	
Recorder's name		Date	

Survey Unit Location and Type			
Ident. No.		Polygon	
OS Grid Ref.		Raster grid cell	
Observing conditions for survey unit			
Distance from survey unit (Phase 1)			

Clear visibility		Comments:	Vegetation wetness	
> 5 km			Wet	
1 - 5 km			Dry	
< 1 km				

Vigour

Phase 1 - Large-scale Indicators	**H**	**M**	**L**
Timing and rate of emergence of fronds			
Timing of frond yellowing and dieback			
Continuity and density of frond canopy			

Vigour

Phase 2 - Small-scale Indicators	**H**	**M**	**L**
Disease or damage to fronds			
Frond height			
Diameter of frond stems			
Frond density			
Size of patches of uniform, unbroken canopy or frond litter			
Depth and continuity of frond litter			

Trend	**I**	**CH**	**D**	**CL**
Litter depth vs other indicators				
Identity and vigour of plants growing under fronds				
Form of edge of bracken patch				

A Guide to Upland Habitats
Surveying Land Management Impacts

Feedback Form

It would be very helpful if you would tell us about your experience of using this guide so that it can continue to be improved and made easier to use. The following questions are listed to help you but please feel free to comment on any aspect of the guide and to make more extensive comments than can be accommodated on this form.

	Yes	No
1. Are the descriptive sections intelligible and clear ?		
2. Are the guidance sections intelligible and clear ?		
3. Do you think it would be helpful to provide a more detailed and prescriptive methodology for carrying out an impact survey ?		
4. Would it be helpful to describe some examples of impact surveys ?		
5. Do you think the habitat concept used in this guide is useful ?		
6. Have you had any difficulties identifying habitats ?		
7. Are there any additional habitat types you think should be included ?		
8. Do you think there is sufficient knowledge about impacts on these additional habitats to assess them in the same way as the habitats included ?		
9. Are there any additional impact types you think should be included ?		
10. Are the field indicator descriptions intelligible and clear ?		
11. Are any of the field indicator descriptions inaccurate or misleading ?		
12. Have you had any serious difficulties in making assessments of impact due to inconsistencies between different indicators ?		
13. Are there any field indicators you think should be deleted ?		
14. Are there any additional field indicators you think should be included ?		
15. Do you think the layout of the text is satisfactory ?		
16. Is the size of the guide satisfactory for use in the field ?		
17. Were the illustrations helpful ?		
18. Do you think more illustrations are needed ? (Please specify below).		
19. Is the binding satisfactory ?		
20. Would it be useful to include a full list of references ?		

Further comments (cont.)

It would be useful if you would provide your name and address so that your comments can be discussed/clarified when the guide is revised, though if you would prefer to comment anonymously please do so.

Name:
Address:

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Please return to
Mr. A. MacDonald, Uplands Group, Advisory Services, Scottish Natural Heritage, 2 Anderson Place, Edinburgh EH6 5NP
Tel: 0131 446 2474

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