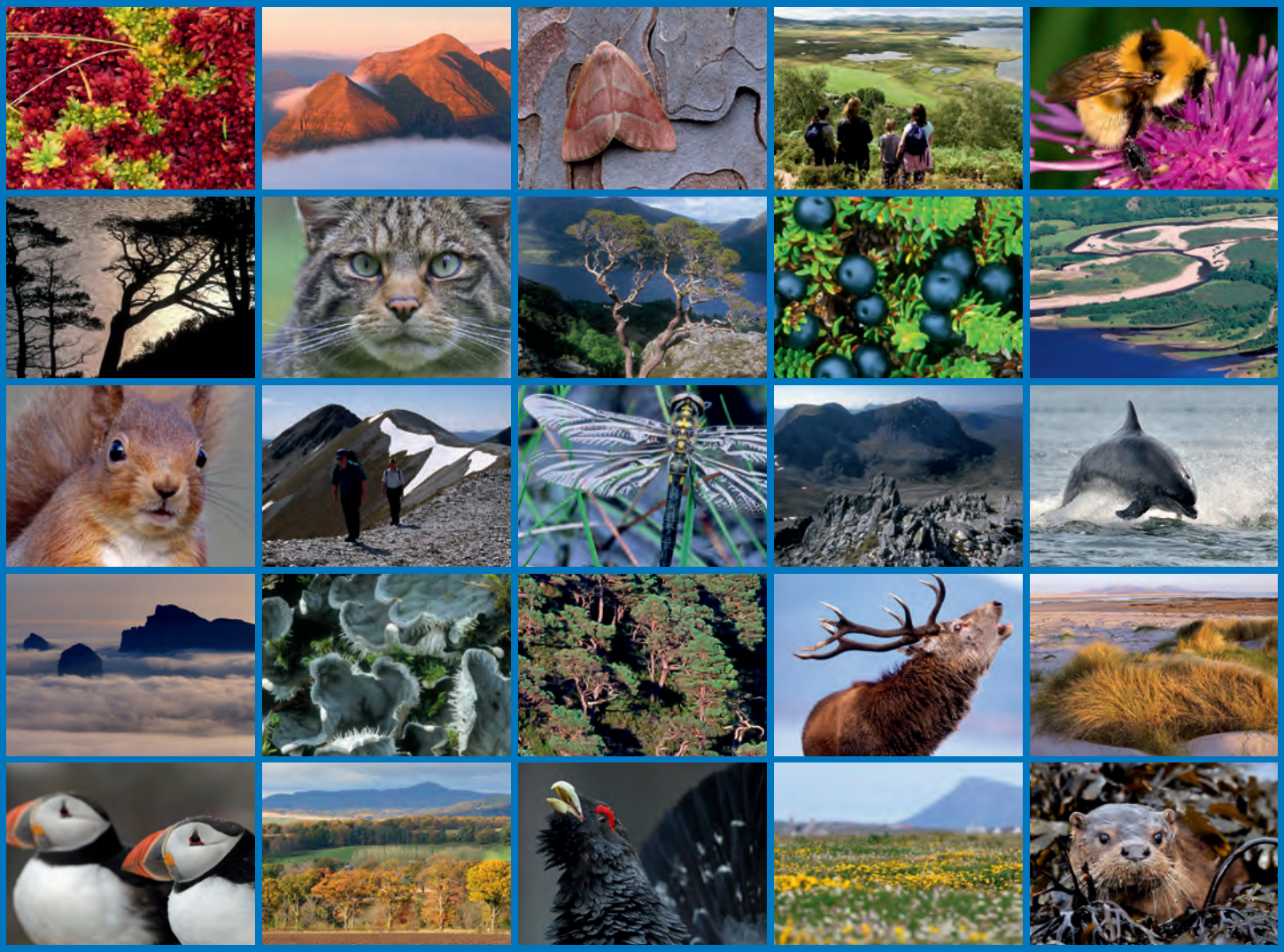
Scottish Natural Heritage
Commissioned Report No. 701

Scotland's peatland - definitions & information resources



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COMMISSIONED REPORT

Commissioned Report No. 701

Scotland's peatland - definitions & information resources

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COMMISSIONED REPORT

Summary

Scotland's peatland - definitions & information resources

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Keywords

Peat; soil; peatland habitat; bog; definition; classification; Scotland.

Background

This report describes the state of Scotland's peatland, using available information on peatland extent and location, vegetation and land cover, land use and management, and environmental pressures. It is a revised and updated version of the JNCC Report No. 445 *Towards an assessment of the state of UK Peatlands*, focusing on the Scottish context. It also reports, where possible, on the attributes of the peat material itself. Information on all these aspects of peatlands can be drawn from a wide range of sources, which have been gathered using different approaches and for many different purposes. Reconciling the various descriptions and classifications to provide a coherent picture of the state of UK peatlands represents a significant challenge.

The report addresses how we define, delineate and describe peatlands, and critically consider the sources of available information. It also briefly describes the likely impact of peatland management on the ecosystem services that peatlands deliver and describes the information available on the state of peatlands for Scotland (further detail on these issues are part of the UK JNCC report 445 *Towards an assessment of the state of UK Peatlands*). This report underlines the important association of biological and geological diversity, particularly in the role of storing carbon and emitting greenhouse gases.

In addition to the information extracted from the 2011 JNCC research report No 445, this report sets out the context of peatlands and carbon-rich soils in Scotland, as these are relevant to the identification of natural heritage issues of national interest in development proposals and other casework activities. The definitions of peat, carbon-rich soil and peatland are important in relation to the guidance which sets out SNH's approach to determining whether impacts on natural heritage interests raise issues of national interest.

Many peatlands will include species and habitats of outstanding conservation importance and will therefore be of national interest on conservation grounds. Species and Habitats of outstanding conservation importance include:

- Habitats and species of EU interest as listed in Annexes I, II, IV & V of the Habitats Directive;
- UKBAP priority habitats or species; and
- Scottish Biodiversity List habitats and species

Peatlands are also important for their geodiversity values. Important examples are designated within Geological Conservation Review (GCR) sites. The important functional role of rare soil types and all carbon-rich soils outwith designated sites is highlighted in the SNH Guidance Notice on "Identifying Natural Heritage Issues of National Interest in Development Proposals" (SNH, 2011b).

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Acknowledgements

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Matthew Shepherd	-	Natural England
Richard Weyl	-	Northern Ireland Environment Agency

1. WHAT ARE PEATLANDS? – SCOTLAND'S PERSPECTIVE

The Ramsar Convention (1971) proposed a definition of peatlands as:

> *"ecosystems with a peat deposit that may currently support a vegetation that is peat-forming, may not, or may lack vegetation entirely. Peat is dead and partially decomposed plant remains that have accumulated in situ under waterlogged conditions"*

The Convention defines active peatlands as areas where peat is currently forming and accumulating but also recognises inactive peatlands lacking current peat formation. Inclusion of the latter category is vital because inactive peatlands respond to management and environmental pressures to deliver ecosystem services, such as food or timber, or generate problems such as greenhouse gas emissions or discoloured water. Currently inactive peatlands are widespread in the UK, but the palaeoecological and historical record contained in peat show that peatlands go through active and inactive periods during their development (Lindsay 2010). Favourable management can result in resumed peat growth (e.g. Lloyd 2006; Wichtmann and Joosten 2007; Waddington *et al* 2011).

There are some points to note on using the Ramsar Convention definition.

- Vegetation typically associated with peatlands can occur over organic deposits that may be too thin to be defined as peat based on conventional pedological criteria. It is proposed here that the presence of peat-forming bog vegetation, irrespective of the depth of the underlying organic layer, is also useful in indicating the location of peatlands. Some types of peat-forming fen vegetation can also occur on mineral substrate (e.g. reedbeds on estuarine sediment, tufa forming systems), and so have not been used to indicate peatland;

- The Ramsar definition would exclude peatlands where a former peat deposit has been lost (e.g. peat extraction, human-induced peatslides, wildfire, severe erosion exacerbated by overgrazing, pollution, burning, or agricultural wastage of peat). Under restoration management, these areas may be suitable for peat formation in the future. While such areas may no longer be true 'peatlands', they represent both historic and potential future peatlands, and should be included and assessed when considering the state of the Scotland's peatlands;

- Not all peaty deposits are present on the surface of the soil. Some peaty deposits are overlain by mineral deposits such as marine or alluvial sediment, or deposits of tufa from calcareous springs, and peat may 'outcrop' occasionally at the surface. These buried peats are important carbon stores, store historic and palaeo-environmental information and continue to influence hydrology but are rarely seen in Scotland. For this reason they should be included in the broad definition of peatlands but may present few or no opportunities to recreate peat forming habitats.

1.1 Peat and Peat Formation

Peat is defined as the partially decomposed remains of plants and soil organisms which have accumulated at the surface of the soil profile. Peat accumulates where the rate of input of organic material from the surface exceeds the rate of decomposition and 'turn-over' of this new material. Under UK climate conditions, this happens under seasonal or year-round water-logging and is exacerbated by cold temperatures.

Because of the very low mineral content of peat, it is much less dense than any other soil materials, with most of its volume being occupied by water when wet. The organic matter fraction in peat material is very high and varies from anything above 20-25% organic matter

for ‘peaty’ soil, to more than 50-60% for ‘peat’. Soil with peat layers typically has dry bulk densities ranging from between 0.06g cm^{-3} to 0.4g cm^{-3} depending on the level of humification, compaction or mineral content. Lindsay (2010) has reported that, in the UK, the typical carbon content of peat is around 52% carbon by dry weight.

The range of organic compounds that form during decomposition of living organisms makes peat a material with some unique characteristics. When peat becomes very dry, it can form a water-repellent barrier making the peat difficult to rewet and thus leave it prone to erosion by wind and water (Dekker and Ritsema 2000). If peat ceases to be waterlogged, decomposition is no longer retarded and the peat gradually decomposes. This process results in the release of greenhouse gases to the atmosphere, and dissolved organic carbon to adjacent streams and water bodies – both of which represent significant environmental concerns.

a) Blanket bog
The Flow country, Caithness and Sutherland

b) Raised bog
Flanders Moss NNR, Stirlingshire

c) Fen
Whitlaw Mosses NNR, Scottish Borders

Figure 1. Example of peatlands in Scotland a) Blanket bog, b) Raised bog, c) Fen

The waterlogging that encourages peat formation can result from high precipitation and poor drainage, or where there is a more or less constant supply of ground water and/or surface runoff. The origin and quality of the water supply are important determinants of the broad type of peatland that develops. Interactions between geology, soil properties, topography and climate also strongly influence the peat formation.

Peatlands which receive all their water from precipitation are **bog peatlands**. Where such peat forms across a hilly landscape it is known as a **blanket bog peatlands** (Figure 1a). In the lowlands, such bogs can form on wet floodplains or in basins, often on the surface of existing fen peats, and because they rise up slightly above the surrounding landscape are known as **raised bogs** (Figure 1b). Those which formed under the influence of ground- and/or surface-water supply are **fens** (Figure 1c). A peatland landscape can display a complex combination of these types; upland blanket bogs are often interspersed with nutrient poor fens, and raised bogs can grade into fringing 'lagg' fens.

The character of peat-forming vegetation strongly influences the character of peat soils. Peat soils formed from bog mosses are often reddish-brown and fibrous. Reed or sedge peat can vary from fibrous to well-humified, while peat formed from purple moor-grass tends to be well humified black-material. Though all peat retains water, bog moss peat retains more because the moss's cells are adapted to store water. Waterlogging coupled with the importance of rainfall as the dominant water source for many of our peatlands generally results in nutrient-poor soils.

Active bog peatlands have been described as exhibiting a two-layered structure (Ingram 1983; Clymo 1992). The lower layer, which is almost continually waterlogged is known as the catotelm and represents older peat material (Figure 2).

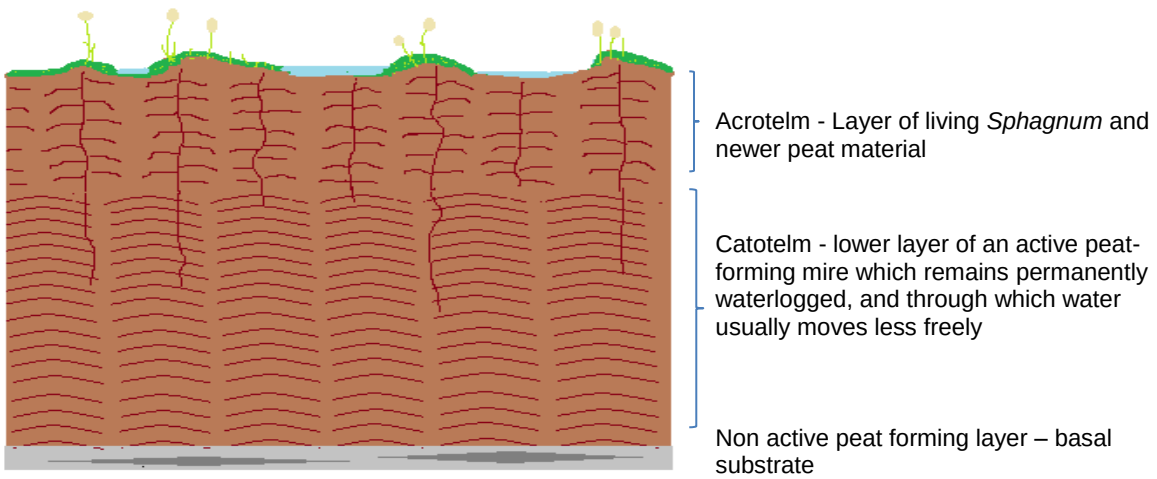


Figure 2. Drawing of two-layered structure of active bog peatlands above the non-active peat forming layer

The layer above the typical lowest water table is called the acrotelm. This layer contains newer plant and peat material and includes any living mat of mosses present. Bog surfaces can be patterned with mosaics of pools, hummocks, ridges and lawns. Lindsay (1995, 2010) provides a comprehensive description of the functional units of bogs and describes different types of bogs.

The extent to which this two-layered model applies to fens is much less clear, though it probably applies quite well to many 'bog-like' poor fens. Fen peatlands may take the form of

infilled water bodies, floating mats of vegetation and wetlands associated with springs. Because of their topography, floodplain fens may receive deposits of alluvial or marine mineral sediment generating a banded structure of peat and mineral layers. McBride *et al* (2010) provide descriptions of fen flora, fauna and hydrology, while the much more detailed Wetland Framework project (Wheeler *et al* 2009) provides an exhaustive account of the varied water supply mechanisms which operate across fens in England and Wales, and based upon this a typology ideally suited to assessing a wide range of hydrological impacts.

2. DESCRIBING PEATLANDS – THE DIFFERENT APPROACHES

The Ramsar definition of peatlands is internationally accepted, but some assessments of peatland extent in the UK pre-date the Ramsar definition. There are key differences in the approaches that have been historically used in UK to define and delineate the peatlands. For example, definitions of peatlands have been based on soil and geological descriptions and definitions, or inferred from information on vegetation descriptions and hydrological processes. Past and current approaches to defining and recording these different features have implications when assessing the extent and state of peatlands.

Peatlands can be described and classified according to

- Soil typology,
- Vegetation-based typology, and
- Geological and process-based typology.

2.1 Soil-based definition of peatlands

Peatlands have been most commonly defined by the presence of peat or peaty soil types. Soils have been studied and mapped in the UK since the early 1940s. In Scotland, the National Soil Survey Institute of Scotland sought to adapt existing classification systems to describe the range of soils they encountered (Soil Survey of Scotland, 1984). All soil classification systems used in the UK evolved from the Avery soil classification (1980) and are based on the field observation of individual soil profiles and the recognition of their texture and morphological characteristics, in particular the nature and sequence of soil layers or horizons (Figure 3). The identification of a specific soil type does not depend on any horizon exceeding a specific thickness, except in the case of peaty and peaty soil types where both the depth of peaty material and the organic matter content of that material are used as identification criteria.

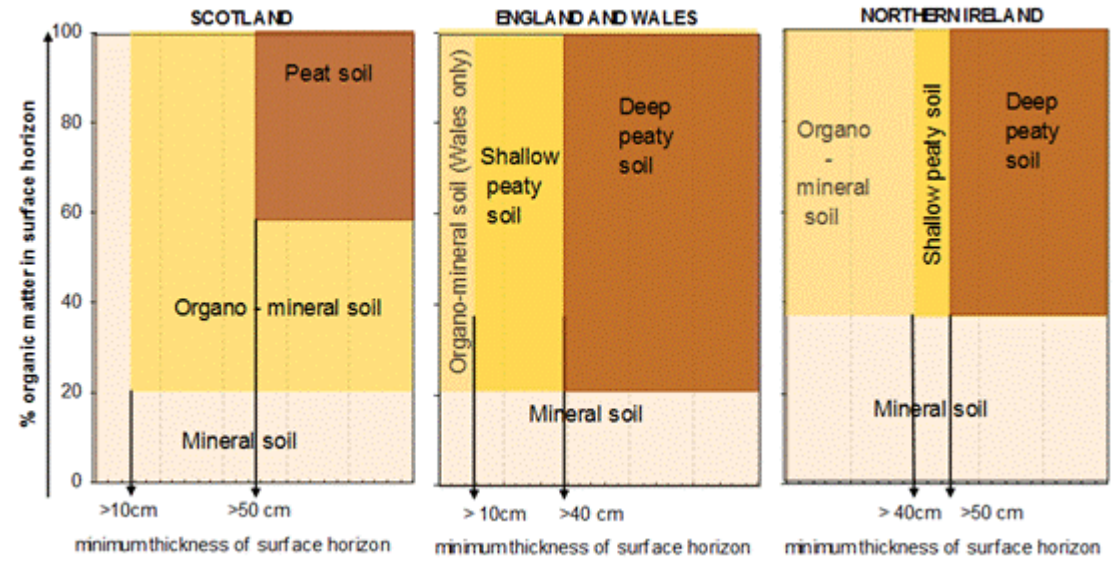


Figure 3. Minimum depth and % organic matter content threshold used for differentiation between mineral, peaty (organo-mineral) and peat soils in Scotland, England and Wales, and Northern Ireland soil classification schemes (adapted from JNCC 2011)

Recent work towards a harmonised international standard in soil classifications has led to the development of the World Reference Base (WRB) soil classification. This system is now used by EU institutions for reporting on soil conditions and has been used to derive 1:1,000,000 soil and risk maps in Europe. It identifies soil by the presence of diagnostic horizons but does not record the depth of the peat layer. There is some correlation between

‘histosol’ type (characterised by more than 40 cm of peat with more the 20-30% soil organic content) and the UK deep peat concept but no clear link between other WRB soil types and UK peaty soil classes. Soils in the UK have never been mapped with these definitions in mind and WRB maps are a reinterpretation and translation of UK national soil maps.

Consensus on classification and definition is not essential as long as information is collected and mapped in a consistent manner that enables cross checking to existing reference systems.

2.2 Vegetation-based definition of peatlands

The presence of peat-forming vegetation, dominated by species adapted to the waterlogged and generally nutrient-poor conditions, is a useful indicator of active peatlands (Figure 4). It should be noted that this definition of peatlands includes areas of vegetation that currently is not actively forming new peat.

Surveys of peat-forming vegetation are undertaken for biodiversity purposes and not specifically for determining the extent or condition of peat soils. However, where soil surveys are based on information from soil pits and auger samples, the extent of soil types between sample points is often inferred using a combination of topography and vegetation cover.

Figure 4. Examples of species associated with peatland types

The absence of peat-forming vegetation does not mean that peat itself is absent, and unless soil information is available it may be hard to recognise true peatlands. Furthermore, some vegetation associated with deep peat is also found on shallower peaty deposits (such as blanket bog vegetation over shallow peat) or even over mineral soils (such as reedbeds in estuaries).

This extended definition includes bog vegetation over ‘shallow peaty’ soils, which means that maps showing this vegetation type can be used to identify peatlands. However, the

presence of peat forming, semi-natural vegetation, or even any vegetation at all, should not be used to indicate, on its own, the full extent of peatlands.

2.3 Geological-based and ecological definitions of peatlands

Because of the timescale involved in the formation of deep peat (over 1000's of years), some peatland areas are also identified as Quaternary geological deposits. Since the late 19th century, the survey of superficial geological deposits in the UK has recognised the occurrence of peat deposits extending to >1m below the ground surface, among other Quaternary superficial geological features (McMillan and Powell 1999). Extensive areas of peat have formed since the end of the last glaciation (around 10,000 years BP); peat is also present as interbeds or 'pocket peat' within earlier deposits.

The superficial geology mapping was intended to show material underlying the modern soil profile, and so British Geological Survey (BGS) mapping does not map peat deposits that occur entirely within 1 metre of the ground surface, and therefore only shows deeper deposits or buried peat.

2.4 Definitions based on peatland functional characteristics

Peatlands have also been defined as an ecological construct, which considers together vegetation, morphological and hydrological characteristics to define the range of functioning peatlands (e.g. Lindsay 1995, 2010; Wheeler *et al*, 2009). Such schemes offer a potentially sophisticated understanding of peatland function and provide an important means to both evaluate sites for statutory protection and also for understanding the potential of management and restoration to restore active peatland.

Information on peat functions can be derived from the interpretation of soils/ geological and vegetation data. For example, information on peatland hydrological functions have been derived from the Hydrology Of Soil Type classification (HOST) (Boorman *et al* 1995) which is based on the physical properties of soils and their effects on the storage and transmission of soil water, but which does not include consideration of vegetation cover. HOST Peat class information was taken from the 1:250,000 soils maps in the case of England, Wales and Scotland and the 1:50,000 soil maps in Northern Ireland. The presence of peaty surface layers (defined as having more than 20% of organic matter) is one of the soil properties used in the HOST classification.

Similarly, information on peatland carbon storage can be derived from models of bog peat depth. Peat depth modelling in relation to climate and topography has shown some success for undisturbed peatlands, and, while this fails to recognise the impacts of land management on peat depth (and more hydrological information is required to model fen peat location), such approaches may be useful in indicating where different depths of peaty material would be expected to accumulate. Such a model was developed for the ECOSSE project (Scottish Executive 2007), and tested against field measurements for peatlands in Wales and Scotland.

The functional wetland habitat typology for Scotland (SNIFFER, 2009) is also used as a classification system from some of the Scottish peatlands habitats. The classification which includes 11 main types (type 1 to 11) considers the nature of soil type alongside hydrological and vegetation information to define landscape setting criteria and habitat type criteria which when combined form the basis of this typology. Many of the wetland classes are associated with both peat and mineral soil indicators i.e. **Other wet woodland (1b), Marshy grassland (2a), Fen (4), Swamp (5), Reedbed (6), Wet Heath (7)**. Only **Bog Woodland (1a)**, **Peat Bog (8a)**, **Quaking bog (8b)** are unambiguously associated with peat soil.

3. PEATLAND VEGETATION, LAND USE, PEAT FUNCTIONS AND ENVIRONMENTAL PRESSURES

As well as knowing the location, extent, depth and origin of peatlands, it is also important to understand the external factors that affect how peatlands function. Many of the functions of peatlands are influenced by its vegetation, land cover and land management, as well as environmental pressures, and the condition of the peat itself (for example the state of decomposition or severity of erosion). Considering these factors together, it is possible to derive a wide variety of information relevant to policy and environmental management, such as current likely carbon loss, GHG flux and costs of restoration, as well as to identify likely stakeholders in policy development and land management.

The following sections describe the range of land cover, land management, environmental pressures and functions relating to peatlands. They include a review of available data sources across Scotland.

3.1 Peatland vegetation and land cover types

All peatlands in the UK have developed under peat-forming vegetation, but a wide range of other vegetation types occur over peatlands as a result of land management. This section describes the range of vegetation typically associated with active and inactive, or otherwise degraded, peatlands and defines these with reference to some of the common vegetation communities described in the National Vegetation Classification (NVC) system (Rodwell 1991a, 1991b, 1992, 1995). Examples of vegetation types are shown in Figure 5. The association between NVC and the EC Habitats Directive Annex 1 peatland habitats (Council of the European Communities 1992) is given in Appendix 1.

Other information on peatland vegetation and land cover is available from large-scale mapping (often derived from remote sensing) or sample-based surveys. These can be augmented by more detailed vegetation surveys.

3.1.1 Peat-forming vegetation

A suite of vegetation types is associated with wet conditions that are conducive to peat formation, and these represent peatlands in their most active and least damaged state. Most UK peatlands are bogs, receiving all their water from precipitation, and these have a characteristic range of **bog vegetation**, which is similar for both blanket bogs and raised bogs. The restricted diversity of bog vegetation reflects the harsh environment, which is fed by rain water naturally poor in nutrients. Vegetation in this situation is slow-growing and often dominated by bog mosses *Sphagnum* spp. or cotton-grasses *Eriophorum* spp.), with dwarf shrubs including common heather *Calluna vulgaris* and cross-leaved heath *Erica tetralix,* and grasses such as purple moor-grass *Molinia caerulea*. The NVC communities M17-20 define the core range of bog expanse vegetation in the UK, with the representation of the bog-pool communities (M1-3) varying in relation to climate and land management.

The type and productivity of **fen vegetation** reflects the relative influence of plant macro-nutrients (notably ~N, P and K), base cations and pH. So-called 'rich-fen vegetation' (including M9, M10, M13, M14, S24) develops at locations subject to the influence of calcareous, but nutrient-poor, water and its distribution is strongly correlated with outcrops of calcareous bedrock or drift. The vegetation is often species-rich and commonly includes a significant brown-moss element, with an over-storey of forbs and a wide range of graminoids. More productive swamp and tall-herb fen vegetation, dominated by common reed *Phragmites australis* and other tall graminoids (including S25, S26) develops at locations with relatively enriched substrates, including periodically inundated floodplains. Nutrient-poor, acidic water promotes a bog-like **poor fen** (including M4-M8 and M21) vegetation of bog mosses, sedges (*Carex spp*.), cotton-grass and dwarf shrubs (McBride *et*

al 2010). Many examples of poor fen occur as soligenous features (flushes and springs), often in association with bog or marshy grassland vegetation. **Wet woodland** habitats (W1-W7) are part of the natural succession process in fens, and many (possibly most) fens have layers of woody peat showing how woodland was part of fen landscapes periodically in the past.

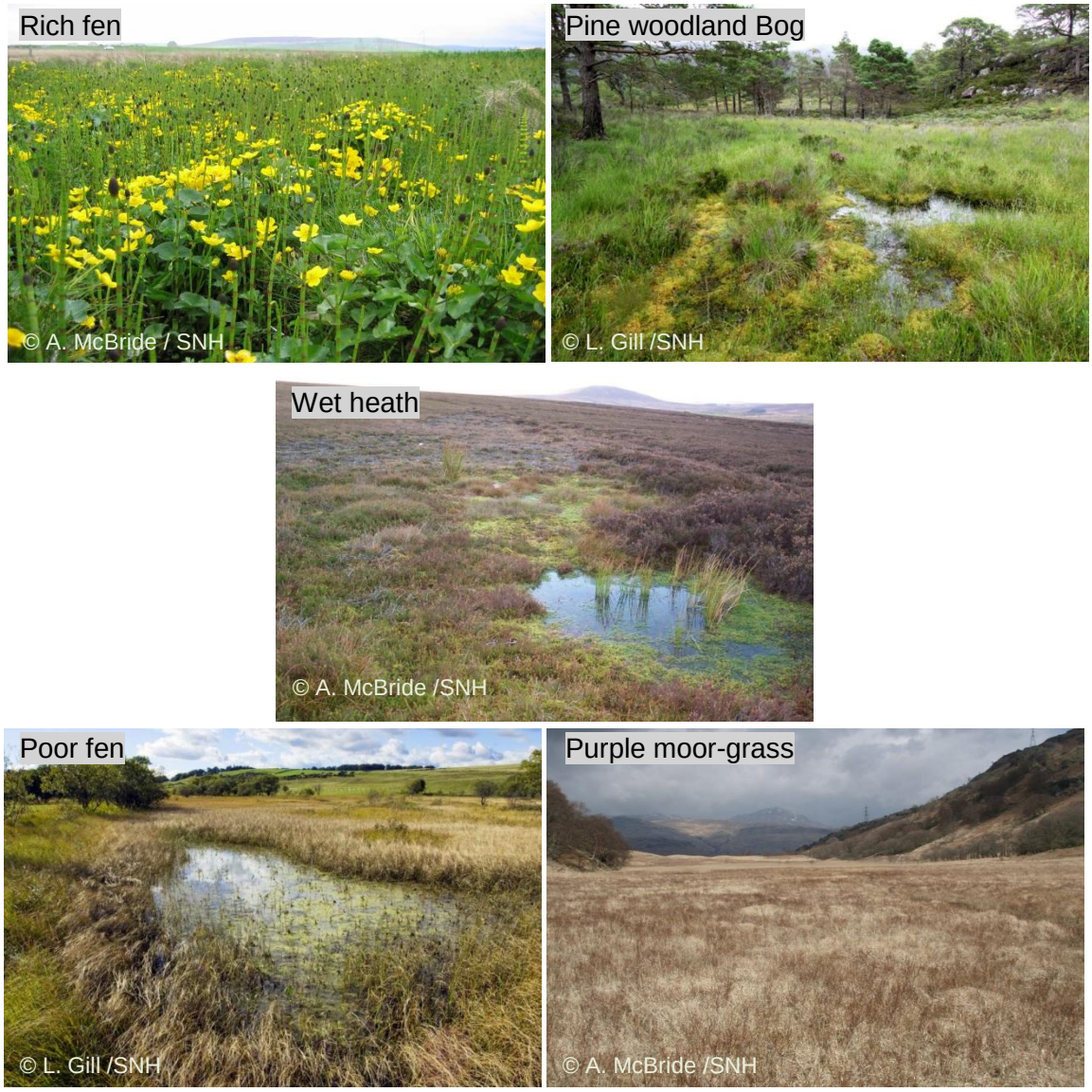


Figure 5. Examples of peatland vegetation types

Many bog and fen vegetation types are recognised under the EC Habitats Directive as Annex 1 habitats (Council of the European Communities 1992) and as UK Biodiversity Action Plan Priority Habitats.

Purple moor-grass *Molinia caerulea* is a deciduous grass and a natural component of bog and poor fen vegetation. Under certain drainage and burning management, such peatlands can become almost completely dominated by this species (NVC M25). The annual build-up of purple moor-grass litter does form peat, especially where it accumulates in pools, and it appears as sub-fossil remains in the palaeoecological record. However, the extent to which purple moor-grass-dominated vegetation is important in on-going peat formation is not known.

Wet heath vegetation (NVC M15, M16) is dominated by cross-leaved heath, deer-grass and bog moss. This is most widespread on shallow peaty soils, but can also occur on deeper peats influenced by partial drainage, burning and peat-cutting.

Bog woodland (W18/M19, W2b, W4c) is a rather rare vegetation type in the UK. The structure and function of this habitat type is finely balanced between tree growth and bog development.

3.1.2 Other peatland vegetation types and land cover

Other types of semi-natural vegetation which are not associated with the formation of waterlogged peat can also occur over peaty soils as a result of management and environmental impacts.

On blanket bog and shallow peatlands, drainage, rotational burning, grazing and air pollution can be responsible for the development of **dry heathland** vegetation (H8-H10, H12) dominated by common heather *Calluna vulgaris*. This vegetation is more usually associated with the formation of thinner organic soils in freely draining areas, and is unlikely to form deep peat under our current climate. Where there is heavier grazing, often alongside drainage, **acid grasslands** (U2, U4-U6) can develop over peatlands, dominated by mat-grass (*Nardus stricta*), heath-rush *Juncus squarrosus*, or bents *Agrostis* spp. and fescues *Festuca* spp.. These vegetation types are more commonly associated with thinner organic or acid brown earth soils. Drainage and fertiliser application in lowland peatlands can result in **semi-natural grasslands** mostly MG8-MG11, with MG12, MG13 and M22 only recorded once in Scotland. Other semi-natural, non-peat forming vegetation that can occur on drained peatlands includes **bracken** (U20, W25), scrub (W21-W24) and **dry woodland**.

Following wildfires, erosion or severe overgrazing, upland peat can be left completely without vegetation. The surface of bare peat can rapidly dry out and become hydrophobic, and the dry peat particles are susceptible to erosion, which can expose the underlying mineral substrate. Eroded peat may be redeposited in basins, where it can be colonised by common cotton-grass *Eriophorum angustifolium*, which helps to trap more eroded peat. Some upland peat erosion complexes may be natural long-standing features, but many are the product of adverse past management and/or atmospheric deposition of pollutants.

As well as changing the character of semi-natural vegetation, land management can also establish completely artificial vegetation on peatlands. Drainage, and cultivation or harrowing followed by reseeding and applications of fertiliser and lime, can create agriculturally **improved grasslands** dominated by sown forage species such as perennial rye-grass or white clover (MG7). In lowland peatlands, increased drainage and intensity of agricultural use enables cultivation for cereals, field vegetables, or root crops. This also leaves the peat surface bare for periods of the year.

Forestry planting on peatlands usually results in a cover of coniferous trees, although fragments of original bog vegetation may survive in open areas. In the UK the main species planted are Sitka spruce *Picea sitchensis* and Lodgepole pine *Pinus contorta*.

Bare peat is also a dominant land cover during peat extraction, but is normally replaced by another land cover once extraction ceases. This can include agricultural crops or forestry, or be flooded, resulting in areas of open water. For restoration of bog vegetation, water needs to be kept very shallow, still, acidic and nutrient poor, and the influence of ground water excluded. Some peatlands have also been built over with buildings, roads or other infrastructure, while others may have been removed for quarrying of the mineral resources beneath.

3.2 Degradation states of peat and link to peatlands functions

Peatland characterisation has traditionally focused on vegetation, hydrological and developmental criteria, but peatlands can also be described according to their degree of degradation (Figure 6). This can extend to consideration of the extent of erosion or decomposition of the peat itself and the behaviour of the water table. Lindsay and Immirzi (1996) provide a description of different states of degradation of bogs. A simplified version of this system can also be applied to fens and recognises five categories of peat state / function (active, degraded, bare, archaic and wasted/lost).

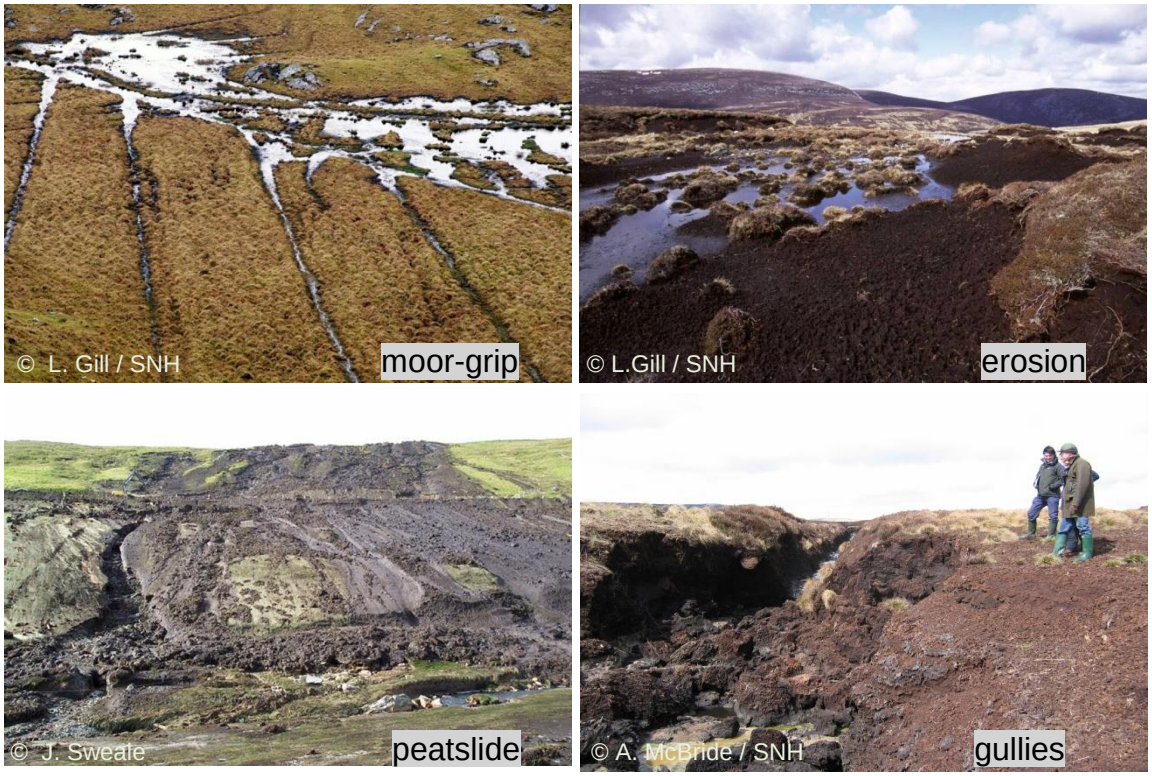


Figure 6. Examples of types of peatland degradation a) moor-grips, b) erosion, c) peatslide, d) gullies and peat burst

These are summarised below and their relevance to hydrological and carbon issues is discussed.

- **active peatlands** are characterised as likely to be peat-forming because of the quality of the vegetation cover and largely unmodified hydrology. This may include formerly degraded surfaces in cases where management has successfully restored near-surface water levels;

- **bare peat** has had all its vegetation removed (e.g. by erosion) but has not been affected by a significant change of land use. This contrasts with **archaic peat** which may still have significant soil peat depth but is under other land use (e.g. cultivation);

- **wasted peat** has lost both its peat-forming vegetation and a significant depth of peat soil;

- All intermediate stages between active and bare peat are described as **degraded peat.** This resource retains a semi-natural vegetation cover, but with dominance either by graminoids or ericoids.

The location and extent of peatlands falling into the categories above are normally inferred from land management or vegetation information. Agriculturally wasted peatlands are thought mainly to occur in England and are not widespread in Scotland.

In addition to the above framework, it is possible to recognise other important features of peatlands, in particular the pattern by which a degraded or bare peatland erodes.

Gullies are fluvial erosion channels which cut into a peat mass, resulting in loss of peat and significant dehydration of adjacent *in situ* peat. They are naturally occurring features of peatlands, and occur where blanket peats spread to the heads of valleys. However, they also occur where artificial drainage features become eroded, and where other pressures such as wildfire, overgrazing or pollution reduce vegetation cover and exacerbate erosion. As gullies erode and branch, adjoining gullies can meet. This results in isolated 'islands' of peat called 'haggs'. Severe erosion of this type results in a mixture of degraded or bare peat. It can also result in the re-deposition of eroded peat into secondary peatlands, which capture peat material are re-colonised by peatlands vegetation and may start to form new peat again *in situ*.

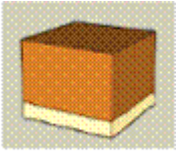
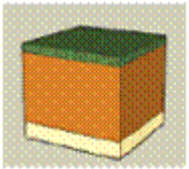
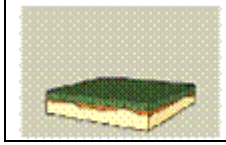
Natural erosion processes of peat (especially blanket peat) can extend over large areas and remove large amounts of peat material. The geomorphology of peat damage is an important area of research in its own right.

Several sources of data are available to indicate the extent of hagging and gullying in Scotland (e.g. Scottish Peat Soils Map, Lilly *et al* 2009). The Defra partnership peat project (Defra, 2008) also provides information on the extent of areas of hagged or gullied peatlands.

Peatlands are also subject to environmental pressures not directly related to site management, with atmospheric deposition of pollutants and climate change representing the key pressures. Deposition of nitrogen (as ammonia or nitric acid from nitrogen oxides) is an ongoing problem, but during the last two centuries peatlands have also been subject to deposition of sulphuric acid rain from fossil fuel burning, soot particles and heavy metals from transport, industry and warfare. Fen peatlands are also often affected by pollution of groundwater, particularly by plant macro-nutrients from agricultural fertilisers or domestic or industrial waste.

The 'critical loads' of some pollutants, above which habitats are damaged, have been calculated following the Bern Convention. The deposition of ammonia and other pollutants is monitored under a national scheme (CEH 2008). National modelling (NEGTAP 2001) suggests that many of our peatlands are subject to critical load exceedance as shown in the UK Air Pollution Information System (APIS).

Table 1. Categories of peat, based on function, and their relation to vegetation management, water table and organic matter dynamics. Extract from JNCC Report 445 (based on Lindsay and Immirzi (1996) and Lindsay (pers comm.)).

Peat Category	Structure, Vegetation and Management	Water table	Organic matter dynamics
Active 	Semi-natural vegetation cover of bog mosses, cotton grasses and dwarf shrubs (bogs, poor-fens) and medium-tall graminoids, forbs and hypnoid mosses (other fens). Might include Purple moor-grass dominated vegetation in some circumstances. Diplotelmic structure in case of bogs and some fens, with true acrotelm of living bog mosses and/or recently deposited plant litter Sympathetically managed and restored mires.	Water table mostly fluctuates within acrotelm rooting zone. Catotelm /deeper peat remains more or less permanently waterlogged.	Organic matter fixed and starts to degrade in acrotelm, releasing some CO_2 New peat material enters long-term storage at top of catotelm – little CO_2 released, slow release of CH_4. Acrotelm may oxidise some CH_4 into CO_2. Optimal state for long-term storage of carbon in catotelm
Degraded 	Semi-natural vegetation, but with balance of graminoids/forbs/ericoids and bryophytes changed by adverse/lack of management. Acrotelm absent or impacted. Could include forestry if some bog flora remains. Associated with burning, drainage, afforestation of peatland.	Water table fluctuates within previously accumulated catotelm peat. Taller vegetation draws water from peat surface layers.	Falling litter degrades at peat surface, or in upper peat layers. Little new organic matter reaches area of permanent waterlogging. Upper catotelm peat degrades into CO_2 and becomes more decomposed (humified). More CH_4 is oxidised in upper peat layers. Can be subject to peat shrinkage.
Bare 	No true acrotelm. No vegetation. Associated with peat cutting, wildfire, pollution, overstocking or cultivation of peatlands. Some erosion complexes are long-standing and apparently natural.	Water table fluctuates within previously accumulated catotelm peat. Upstanding dry haggs alternate with lower wetter but periodically dehydrated peat.	No new litter entering system. Catotelm peat degrades into CO_2 but extremes of temperature probably retard degradation. CH_4 emissions may increase – mechanism unknown. Much peat lost through erosion by wind and water.
Archaic 	No true acrotelm Agricultural vegetation (grassland/ cropland) including cultivated land Forestry where no bog flora remains. Usually deep drained.	Water table controlled by ditch system, often with under-drainage Held typically at ~40-80cm below peat surface in catotelm May be brought closer to surface during winter in grasslands.	Plant litter degrades at peat surface or in upper layers. Upper catotelm peat degrades into CO_2 and becomes more decomposed (humified). Cultivation of soil increases oxidation of organic matter releasing more CO_2. Little CH_4 released – dry surface peat may oxidise atmospheric CH_4. Peat surface rapidly lowers due to decomposition and erosion of peat.
Wasted or Lost 	No true acrotelm or catotelm. Most peat has been lost or removed. Agricultural vegetation (grassland/cropland).	Water table mainly fluctuates within underlying mineral soils.	Peat organic matter increasingly mixed with soil mineral material. Some peat material stabilised. Decomposition of organic matter slows releasing less CO_2. Little CH_4 released and some atmospheric CH_4 oxidised.

Groundwater abstraction is a key pressure for some fen peatlands but groundwater impacts can also result from surface drainage and the resultant interruption of key groundwater supply pathways. Abstraction is an issue for some lowland raised bogs which are dependent on a high underlying groundwater table. Any alterations to the local hydrogeological regime can result in adverse impacts on mire hydrology and consequently conservation status and ecosystem service provision.

Climate change is one of the greatest threats facing our peatlands. A recent study (Clarke *et al* 2010) examined the current topographic and climatic conditions in the areas where upland peats occur in the UK. This study noted that, under the most recent climate change projections, these conditions would become more restricted geographically in 50 or 100 years time. This does not necessarily mean that peat will not survive in the future. Bog mosses have a much wider tolerance of climatic conditions than those projected in this study, and the essential factor in peat formation – the ability to retain water – cannot easily be modelled using this sort of approach. However, it does indicate that peatlands in the future will be under greater climatic pressure than they are currently. The best adaptive response to climate change is to secure favourable management and ultimately condition for the peatlands resource; this also offers the best and most efficient route for retaining or even bolstering their ecosystem functions.

3.3 Describing peatlands land use and management

Land management can affect peatlands by modifying their hydrology, changing their geochemical conditions, changing their surface vegetation or disturbing or removing the peat material itself. Some key land uses of peatlands are described in the National Ecosystem Assessment (UNEP WCMC, 2011). These land uses are briefly described here, along with some additional management practices affecting peatlands specifically (Figure 7).

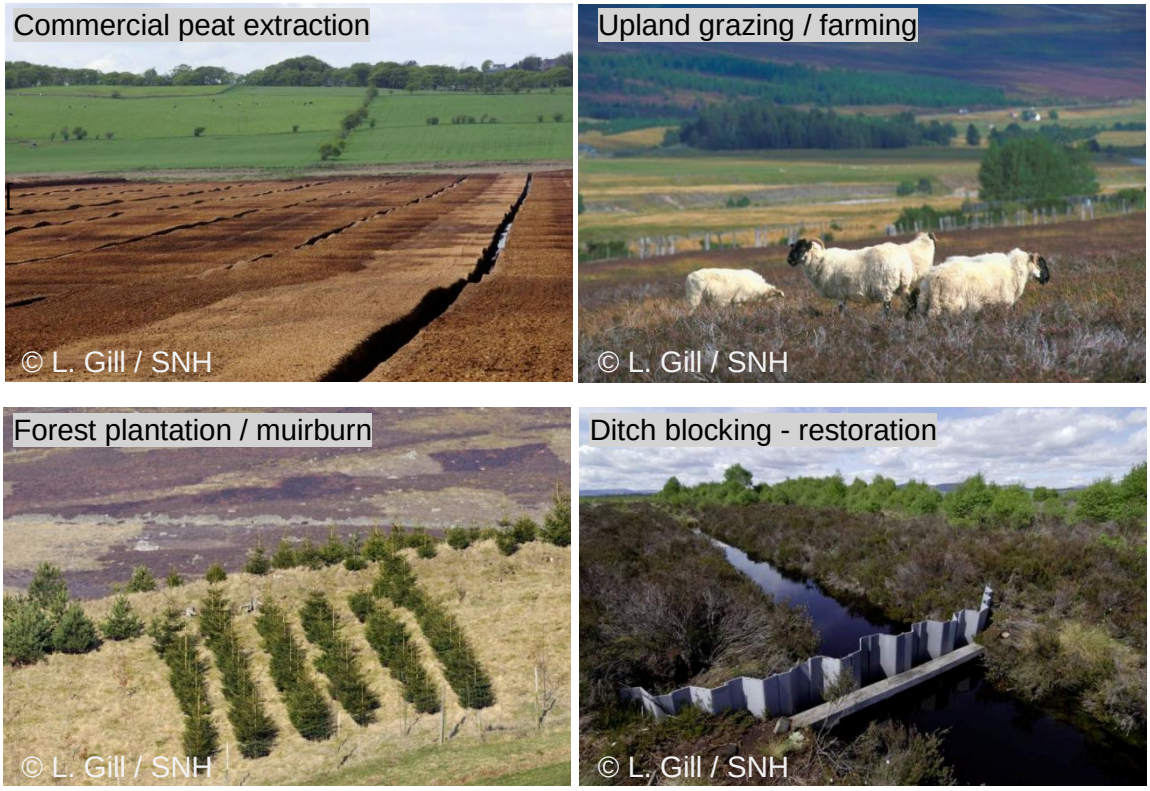


Figure 7. Land use practices impacting on peatlands

Some peatlands are unmanaged, although it is very rare to find a peatland that is not still influenced by the impacts of past management and land use. Without significant grazing by herbivores, many lowland peatlands are subject to some level of invasion by scrub and ultimately the development of woodland. Intact bog peatlands are an exception and present a hostile environment to most native tree and scrub species, with slow rates of succession. Unmanaged fen peatlands are more likely to support trees, which may then collapse into the peat forming layers of woody debris. Many peatlands remain impacted by past land management, such as drainage, or are influenced by other environmental factors, such as nutrient pollution, which promote graminoid dominance and the replacement of oligotrophic Sphagna by minerotrophic species or even hypnoid mosses.

The most common land use for peatlands is probably livestock grazing. Most active peatlands can only sustain light seasonal grazing due to the low productivity of the vegetation. Where there is too much grazing livestock, the peat forming vegetation is modified and typically becomes dominated by graminoids; bare peat can also result. Overgrazing became a problem for many upland peatlands during the late 20th century because headage-based subsidy payments encouraged unsustainable stocking rates; area-based payments have now removed much of the incentive to overgraze. Conversely, in many lowland peatlands historic grazing has ceased, due to changes in the local farming systems, resulting in succession to scrub and the challenge is to re-establish sustainable grazing. However, overgrazing and trampling by red deer remain a significant concern in some upland areas. Some upland peatlands are regularly burnt during the late winter to encourage spring growth of grass. This practice favours the deciduous purple moor-grass *Molinia caerulea*, because winter burning only removes its dead leaves, but damages winter green plants such as hare's tail cotton-grass *Eriphorum vaginatum*.

In the mid-late 20th century the drive towards agricultural productivity resulted in government subsidies for drainage, the most widespread results of which are the frequent shallow drains (grips) excavated across vast tracts of upland peatlands. Grips drain the peat surface layers, and deeper peat next to the channel, but also divert water flow away from areas downslope of the grip; they can also initiate or exacerbate peat erosion. Ironically, the benefit of gripping in terms of increased agricultural productivity remains largely unproven (Stewart and Lance 1983). Some areas of upland peatlands are affected in a similar way by the legacy of historic peat cutting for fuel, sometimes on a very large scale. Although still practised, the scale of cutting is now much less than it once was.

Many upland peatlands are subject to grouse moor management. Regular burning (muirburn) has been used to encourage artificially high populations of red grouse *Lagopus lagopus scoticus* by providing a mosaic of younger and older heather for grouse feeding and nesting cover respectively. This management can replace blanket bog with vegetation more akin to dry heath.

Extensive areas of upland peatlands have been deep ploughed and planted with non-native coniferous trees, particularly Sitka spruce *Picea sitchensis* and lodgepole pine *Pinus contorta*. Current forestry policy does not support further tree establishment on peat and many areas are now being restored back to peatlands habitats.

Large areas of lowland peatlands are managed for agriculture as improved grassland or cropland. In both cases the land is drained, limed and subject to fertiliser application, and crop plants or forage grasses are sown. Peatlands with arable or root crops are normally subject to deeper drainage than those producing grass. Large areas of shallow peaty soils fringing our uplands have also been converted to pasture.

Lowland peatlands have also been cut for fuel and animal bedding in the past, but current mechanised extraction is principally to produce horticultural growing media. Lowland peat

cuttings were often abandoned to develop into scrub or heath, or to fill with water. Later they may have been used for landfill, or converted to agricultural use, but more recently the emphasis has been more towards the restoration of some form of wetland cover. Peatlands may also be subject to activities to remove or bury the peat to enable infrastructure development or mineral exploitation.

More recently, there has been a growing interest in restoring peatlands to encourage more natural peatland functions and characteristics. This can involve re-establishing vegetation on bare peat to slow on-going erosion, or raising the water table through dams or sluices to restore peat-forming conditions.

The Green Stimulus Peatlans Restoration Project is a Scottish Government initiative to reduce carbon released into the atmosphere by helping to restore degraded peatlands. It is part of a substantial programme of peatland restoration across Scotland which aims to restore peatland functions to provide benefits to biodiversity, the water environment, and the economy, and to play a critical role in the fight against climate change (http://www.snh.gov.uk/climate-change/what-snh-is-doing/green-stimulus-peatland-restoration/).

Renewable energy generation represents a comparatively recent pressure, focused predominantly on upland peatlands. Impacts include direct loss of peatland habitat through wind farm infrastructure overlap but also possible longer-term degradation, due primarily to the hydrological effects of tracks cut through or 'floated' over peat. These impacts are poorly quantified and there is a need to adopt consistent monitoring and investigation practices. A voluntary approach to estimate the impact of wind farm developments on the soil carbon stocks held in peats has been developed under contract to the Scottish Government (Nayak *et al* 2008, Scottish Government 2011b).

4. SOURCES OF DATA / INFORMATION ON PEATLANDS

This section reviews the data sources available to indicate the location and extent of peatlands and describes how these have been used to draw conclusions about peatland coverage. Mapping of peatland vegetation, management and function is described in later sections.

There is a wide range of sources that are useful in different ways to characterise peatlands in the UK and to infer information on their location and states. These include:

- National surveys of peat, soil or vegetation, which were largely conducted to provide information for mapping of UK resources;
- Maps of soil, vegetation, geology, other environmental functions (e.g. HOST classification system) and thematic maps derived from them (SNH carbon rich mapping unit);
- Research and experimental manipulation sites; these sources provide information on the processes and dynamics of change in peatland ecosystems and inform judgements of the state of the peatland resource; and
- Soils, biodiversity and environmental monitoring schemes, which provide information on trends in state of peatlands interests but are often point-based and cannot be used to map peatlands extent.

The depth of the peat layer is a key part of peatland classifications in the UK; consequently, any actual peat soil maps will help indicate the location of peatlands, and vice versa. However, historical maps and older soil surveys should be treated with caution as they may only indicate the likely presence of peatlands. The depth of the peat layer may have changed since the survey. Soil types also change over short distances, reflecting the complex interaction between soil parent material, landform, climate, vegetation and past land use. Furthermore, some areas are more variable than others. Soil maps aim to delineate areas where the soil profiles are relatively similar, but extensive and detailed survey is not always a practical option for large-scale mapping of soils and will be constrained by a range of methodological factors.

In recent years, many soil research activities have been driven by the policy requirement to understand and quantify the state and functions of UK soils and their responses to climate and environmental changes. These have given rise to different methods to represent similar information in the various UK countries. There has been increasing activity to understand the extent and location of organic-rich soils (referred to as peat or peatlands in many policy statements); the ECOSSE project to improve our understanding of carbon storage and carbon emission from carbon-rich soils in Scotland and Wales (Scottish Executive 2007) is a prime example. The NERC EA-QUEST programme also gathered peatland location information in order to explore potential climate change impacts in the uplands (Gallego-Sala *et al* 2010).

The importance of peatlands to the character and economy of Scotland, and the need to manage and safeguard this resource, is driving policy and research activities in Scotland. Scottish Government and other public bodies have overlapping interests in peatlands and other carbon-rich soils and have been supporting research initiatives to review and improve our understanding of the extent, condition and function of Scotland's peatlands (Chapman *et al* 2009a).

The State of Scotland's Soil report published in 2011 (Dobbie *et al*. 2011), provides an up-to-date assessment of the state of Scotland's soil resource including its carbon rich soils. It has contributed to the wider understanding that soils are a vital part of our economy, environment and heritage, which need to be protected for present and future generations and helps to review information on the soil resource across Scotland. Under the INSPIRE

(Scotland) Regulation (Scottish Government 2011a), spatial data agreements for Scottish Public Sector access have been signed which will enable easier access to soil and other environmental data.

Most of the soil information held by the James Hutton Institute (Hutton) and others in the Scottish public sector has been digitised and can be accessed on-line on the Scottish Environment Website (SEWeb) and its soil daughter web site (Scottish Soil Website, http://www.soils-scotland.gov.uk/). Downloads of digital datasets are strictly restricted to non-commercial users. Similarly BGS soil data (soil being here defined as a geological construct) can be visualised on the NERC soil portal (https://www.bgs.ac.uk/nercsoilportal/).

4.1 Peat survey, databases and point sources information

4.1.1 Large-scale peat surveys

Information on the location, extent and depth of individual peatland bodies or on transects across the landscapes have been recorded since the mid-20th century as part of the development of the national soil surveys discussed below. Specific peatland surveys have also been produced to assess the potential value of commercial exploitation of peatlands in the UK and, more recently, in the development of renewable energy proposals).

In Scotland, peat surveys were conducted in the 1940s and 1950s for the Scottish Peat Committee (DAFS 1962, 1964, 1965a, 1965b, 1968). The information was later reviewed in 1990 and a peatlands database compiled (Birnie and Ward 1991). This information, together with data from the peat survey maps, commercial extraction surveys and Forestry Commission site survey reports was geo-referenced in the National Soil Inventory of Scotland (NSIS) database.

The *National Peatland Resource Inventory (NPRI)* is an historical composite georeferenced database of lowland peatland information including survey reviews in Lindsay and Immirzi (1996) and supplement data from FenBase and BogBase (Money and Wheeler 1995; Shaw and Wheeler 1995; Shaw and Wheeler 1997; Shaw *et al* 1998). Peat polygons were digitised in Arc-GIS based on BGS 1:50,000 Drift Maps. The NPRI polygons were then allocated to mire type; lowland raised bog, blanket mire, intermediate raised/blanket bog, and fen. The NPRI is thus GIS-based geo-information system for the whole extent of deep peat within Britain (not the UK). For the raised bog polygons, assessments were made of the extent of different land-cover categories. This was summarised by Lindsay and Immirzi (1996).The report includes land-cover information for lowland raised bogs (and detailed land cover maps for Scotland). Most sites include digitised mapped boundaries, although some are still represented by circles of the same area as the feature.

4.1.2 National soil database and countrywide soil data

The *National Soil Inventory of Scotland (NSIS)* (the James Hutton Institute) also recorded a range of chemical, physical and contextual information to inform on the properties and state of the soils at the time of sampling on a 5km grid based on the National Grid of GB. The systematic survey of Scotland's soils by staff from the then Macaulay Institute for Soil Research started in the 1940s and by the 1970s around 50% of the country was covered by detailed 1:25,000 scale field maps. This was published as a colour map at 1:63,360 (1 inch : 1 mile) scale. Additional mapping effort in the 1970's and 1980's provided a full coverage of Scotland at 1:250,000 for soil and land capability maps. Provisional black and white maps for some of the area not covered at the 1:63,360 scale were also produced. Some 1:10,000 scale maps are also available for limited parts of Scotland. A partial resampling of this original inventory was undertaken over the last few years, providing some information on change in soil and soil carbon in Scotland (Chapman *et al* 2009b).

The *Countryside Survey*, undertaken by the Centre for Ecology and Hydrology (CEH), is a stratified random monitoring scheme of a national network of sites across Great Britain, representing the main types of landscape, land cover and soil groups. The Countryside Survey applies a rigorous, consistent methodology which includes characterising soil and vegetation. Unfortunately, restrictions mean that it is not possible to identify locations of sampling points with sufficient accuracy to relate these to mapped areas of peatland. Furthermore, the analyses of soil characteristics and broad habitat data available are only comparable at the scale of the 1km squares within which they are measured and the soil data only refers to measurements in the top 15cm of soil, and thus cannot be used to infer information about peat depth. Notwithstanding these limitations, it is possible to use these data to identify those 1km squares which are dominated by highly organic soils, and examine the cover of broad habitats in these squares, to give an indication of peatland cover and, by inference, land use.

4.1.3 Thematic / site specific soil and peat deposit information

A considerable amount of data is now being gathered by organisations such as National Parks as well as part of impact assessments of new planning development. There is an urgent need to ensure basic standards of consistency in terms of both data collection and storage, and also better coordination of effort. A number of administrative obstacles (i.e. OS copyright for derived data, software licencing issues) have historically prevented this from happening.

Soil maps are also produced at various scales from surveys conducted for specific management purposes. For example the Forestry Commission has undertaken a systematic soil survey of many of its forest holdings resulting in 1:10,000 scale soil maps employed *inter alia* for *Ecological Site Classification (ESC)* decision support (Forestry Commission 2003). The classification system used by ESC is different form the Soil Survey of Scotland classification and is not discussed here (Bathgate 2011).

Soil and peat mapping produced for Environmental Impact Assessments for planning applications (particularly for wind farms) also represent a significant new source of data for many peatland sites but much of this data is not readily accessible or collated at a suitable scale.

Remote sensing techniques including LiDAR and satellite surveys have been used in recent years to assess the extent and state of peatland vegetation (Evans *et al* 2005) and some soil features (Scottish Government 2009a, 2009b). Outcomes of these surveys have been used to revise modelled estimates of peatland extent and condition.

The Geological Conservation Review (GCR) also provides some valuable information on peat deposits associated with geological and geomorphological features of interests. SNH is responsible for the maintenance of the *GCR Scottish site* database. Digital site boundaries for all Scottish GCR sites and associated attribute tables are available free of charge from the SNH download portal (NaturalSpace - https://gateway.snh.gov.uk/natural-spaces/index.jsp).

4.2 Map and country wide information

Many of the UK's peatlands are complex mosaics of wetland habitats, have gradual transitions between soil types, are remote, may overlie different rock types, and are agriculturally of lesser importance than most mineral soils. This means that, with regard to soil survey, most UK peatlands are less likely to have been intensively surveyed and mapped at larger scales, and soil maps are therefore more prone to inaccuracies.

Even where more detailed mapping is available (generally as paper maps), these have been scaled up to 1:250,000 scale in readily available digitised versions. Peatland units mapped at this scale are therefore likely to encompass a variety of peat and non-peat soils. This heterogeneity creates problems when assessing the extent to which peatlands deliver certain ecosystem services on broad geographical scales.

Information on the status of peat has often been derived from historical archives on land use and land management (Rodwell 1986; Harrison 2003). More recently, contextual information has been recorded at the time of soil survey. This includes vegetation cover information and signs of erosion or damage to soil if present at time of observation (Lilly *et at* 2009). Erosion may be reported on soil maps as an eroded soil type but this does not inform on the type and intensity of erosion affecting the soil units. Recent re-samplings of national soil survey are providing a new opportunity to assess changes in soil depth.

The following sections briefly outline the approaches taken to map soils and peat in Scotland.

4.1.1 Soil maps

The typological classification adopted for all UK soils is based on the description of the vertical arrangement of soil layers or 'soil profile'. The thresholds to characterise peat and peaty horizons are different between countries. Based on profile description only, 10 major soil groups are recognised in the UK which are divided into 45 soil groups and 116 soil sub-groups to form the basis of soil classification (Avery 1980).

The soil classification systems for the mapping and representation of soils have been adopted by the Soil Survey of Scotland (Macaulay Institute now the James Hutton Institute). The most detailed level of differentiation in this system groups soil profiles developed under similar conditions and similar parent materials. These are called 'soil series' and form the primary units of classification and mapping. They represent several thousand individual soil types across the UK. Mapping at high resolution (<1:50,000) is able to represent individual soil series and is broadly comparable between the UK countries. Soil series may be grouped into 'soil associations' which link all soil series with similar underlying parent material.

Figure 8. Soil profile type. a) peaty podzol b) peaty gley, c) Peat (© The James Hutton Institute)

Soil mapping approaches seek to apply definitions of soils that are applicable to similar soils regardless of management. However, the impact of management on peaty soils is often so severe that it can change the soil's horizon structure, and the characteristics of these horizons. Continued drainage and agricultural use also results in soils with peat layers that have become thin, or mixed with mineral deposits below, a process referred to as "wastage". Where evidence of such practices was observed at the time of the soil surveys, it may be recorded on soil maps as an additional feature on existing features (eroded peat).

The Soil Survey of Scotland developed the classification and soil mapping systems for Scotland (Soil Survey of Scotland 1984) for the production of the 1:250,000 soil map of Scotland. The 10 class Avery System is reduced to 5 'Divisions', 12 'Major Soil Groups' (MSG) and 37 'Major Soil Subgroups' (MSSG) (Figure 8).

Areas characterised by different combinations of one or more MSSGs from the same soil associations have been grouped to give 580 Soil Map Units, which are published on the 1:250,000 soil map of Scotland.

Table 2. Soil types associated with potential peatland soil

Soil type	Scotland Soil Classification
Peat (also referred to as Deep Peaty Soils elsewhere in UK)	**Soil Map Unit for 1:250,000 map** Unit 3 - Basin Peat (>0.5m) Unit 4 - Undifferentiated Blanket Peat (>0.5m) Unit 603 - Eroded Basin Peat (>0.5m) Unit 604 - Deep Blanket Peat (>1m) Unit 605 - Eroded Deep Blanket Peat (>1m) Unit 606 - Eroded Undifferentiated Blanket Peat (>0.5m) **Soil series name** Peat Basin peat Blanket peat Valley peat
Organo-mineral soils (also referred to as Shallow Peaty Soils elsewhere in UK)	**Soil series name** peaty podzol, peaty gley, peaty ranker, peaty lithosol, peaty alluvium
Undifferentiated may contain peat	**Soil series name** subalpine podzol, alpine podzol
Non peaty soils but with a deep organic surface layer	**Soil series name** Humus-iron podzol, Humus podzol, Humic gley;

Table 2 shows the equivalence between peat and peaty soils classes and peat depth in Scottish soil. Depth of surface horizon and organic matter content are key parameters in all peatland definitions. All soil types that show a peat layer are likely peatland candidates. However, soil information is often provided not as a map of single soil types but as a combination of soil types. This is especially relevant for the 1:250,000 soil map scale but also applies to larger scale maps where the spatial relationship between adjacent soil types cannot be explained at the scale of survey. The presence and relative importance of the peat

layer in those soil complex map units becomes more difficult to ascertain. SNH has developed a protocol to reclassify each soil mapping unit of the 1:250,000 scale map into 6 classes that reflect the likely presence of peat (SNH Information Note 318 2011a). This systematic reclassification provides a comparable and robust display of the soil carbon richness of soil across Scotland. In areas were digitised soil information is available at 1:25,000 a more detail map of soil carbon category is also available (see section 5.1).

Because of the commercial value of peat as fuel material and a horticultural medium, and a potential new market for GHG carbon off-setting, there has always been an interest in improving our understanding of the depth of peat deposits as well as their spatial extent. These elements are related where soil maps have used depth thresholds to identify peat, but such maps cannot indicate variations in depth of the peat mass across landscapes. An understanding of the spatial distribution of peat deposits is important, in particular to understanding the total amount of carbon the peatland stores, as well as being of value in understanding the hydrology of the peatland and its potential to store important palaeo-environmental features.

Most attempts to estimate the depth of peat in the UK have assumed a standard depth for all the peat mass and used simple assumptions on peat bulk density change over depth to convert carbon concentration measurement into carbon stock (e.g. Cannell *et al* 1993; Howard *et al* 1995; Milne and Brown 1997). The resampling of the National Soil Inventory in Scotland and recent related projects have greatly improved understanding of Scotland's peat depth and the bulk density and has enabled revised estimates of soil carbon storage (Scottish Executive 2007; Chapman *et al* 2009b). More recent works on the potential carbon abatement from peatland restoration has added to the body of evidence on soil carbon stock and emissions from peatland in different conditions (Artz *et al* 2012; Chapman *et al* 2012). This has led to the development of decision support tools for location of peatland sites suitable for restoration. (Artz *et al* 2013)

4.1.2 Geology mapping

The classification scheme for natural superficial deposits of the Quaternary age (traditionally described generically as 'drift') was developed by the British Geological Survey (BGS) to provide UK-wide 1:10,000 scale maps. The scheme identifies a broad class of 'organic deposits' divided into 'peat deposits' and 'biological deposits' (e.g. marine organic deposits). Peat deposits are subdivided into 6 sub-categories for more detailed mapping (basin peat, hill peat, blanket bog peat, fen peat, raised bog peat and peat flow). The terminology of the scheme emphasises the geographical setting, topography and drainage conditions as well as the origin of the peat-forming vegetation. The superficial geology mapping was intended to show material underlying the modern soil profile such as deep or buried peat, and does not include peat deposits that occur entirely within 1 metre of the ground surface (McMillan and Powell 1999). Hence the map of 'peat deposit' is not a proxy for peatland extent and underestimates the extent of UK peatlands (e.g. in the western parts of Northern Ireland and Wales).

The 1:625,000 scale UK geology map is freely available for download from the BGS OpenGeoScience website (http://www.bgs.ac.uk/opengeoscience/home.html). The Scotland 1:50,000 scale drift and hard geology map are also available on the Scottish Environment website map portal (http://www.environment.scotland.gov.uk/map.aspx).

4.1.3 Habitat and Vegetation mapping

Habitat and vegetation mapping, where available, generally provide good information on peatland extent. For example, blanket bog, raised bog and the core bog plant communities

are generally associated with peats greater than 0.5 m deep, and some forms of mapping (notably Phase I Habitat Survey, JNCC 2010) employ peat thickness as a mapping criterion.

Mapping of peatland habitat and vegetation cover is provided by either ground-based surveys at a range of scales, or by remote sensing. The main information sources are given in Appendix 3: USeful LinkS and online resources.

The UK Land Cover Map (LCM) 2000 and 2007, undertaken by CEH, uses satellite-derived imagery to identify land cover across the UK which has then been subsequently grouped into 26 broad categories which roughly equate to the UK Biodiversity Action Plan Broad Habitat classification. However there are a number of known issues with the accuracy of the classification which limit its uses for mapping peatland vegetation; for example LCM 2000's distinction of bog is based upon using other datasets for mapped peat depth where depth >0.5 m, and does not include examples on shallow peat with bog indicator species.

The information from the UK LCM 2000 was generalised and used to form the UK contribution towards the EU CORINE Land Cover Map for 2000 produced jointly by the European Commission and EU Member States.

The Land Cover Scotland (LCS88), produced between1987-1989, was the first national census of Scottish vegetation (MLURI 1993). It used the interpretation of medium-scale aerial photography covering the whole of Scotland, validated against field survey, to report on 127 different land cover types. Information provided by LCS88 is deemed more accurate than LCM 2000, though it is now dated. LCS88 is available under licence from the James Hutton Institute.

At present there are no comprehensive maps available of habitats with peat-forming vegetation across Scotland. SNH is, however, undertaking a project to produce a Habitat Map of Scotland to meet the requirements of the European Habitat and INSPIRE Directives, by 2019. This will map habitats based on the EUNIS (European Nature Information System) habitat classification (http://jncc.defra.gov.uk/page-3365), to give both broad habitat and Habitat Directive Annex I habitat level mapping across Scotland.

The National Vegetation Classification (NVC), as described in Section 3, forms the basis of detailed field survey and mapping. Only parts of the country have been field surveyed to NVC level, notably to provide information on habitat features of interest within designated sites or for more detailed planning requirements.

SNH holds a variable coverage of survey information on peatland vegetation from surveys undertaken on SSSI (Sites of Scientific Special Interest) and SACs (Special Areas of Conservation). Most of these surveys have been digitised and are available through SNH's download website (NaturalSpace). This information along with data from other organisations and new survey data will be used to build the Habitat Map of Scotland.

4.3 Describing peatland land use and management

The state of peatlands in the UK reflects their historical and on-going management for grazing, peat extraction for fuel and horticulture, forestry, nature conservation and more recently as a location for renewable energy schemes.

Land management can affect peatlands by modifying their hydrology, changing their geochemical conditions, changing their surface vegetation or disturbing or removing the peat material itself. Some land management types allow the on-going formation of peat, but many slow or stop it entirely. Different types of peatlands are subject to different types of

management, each associated with delivering a specific set of ecosystem services, but which may also adversely affect other ecosystem services as well as other peat functions.

Information on peatland land use and management can be based on extensive mapping of vegetation and land cover, or from similar information derived from a network of sample points. Further detail on UK data sources available is presented in Appendix 1 of JNCC Report 445 and in Appendix 3: USeful LinkS and online resources.

5. THE LOCATION AND STATE OF PEATLANDS IN SCOTLAND

Peatlands in Scotland extend over large areas of the Scottish uplands but are most extensive in the north and west in areas with gentle slopes and poor drainage. Blanket bog is the most extensive semi-natural habitat in Scotland, covering some 1.8 million hectares (see Table 6), or 23% of the land area. Blanket bog is a rare habitat globally and Scotland holds a significant proportion of the European and world resource. It is the habitat that dominates the landscape of gently undulating moorlands, particularly in the North Highlands and Western and Northern Isles. The peatlands of Caithness and Sutherland located across the northernmost parts of mainland Scotland form one the largest and most intact areas of blanket bog in the world. With its high rainfall and rugged, glaciated landscape, Scotland is also rich in other wetland habitats, from isolated lowland fens to the vast Insh Marshes near Aviemore and the lowland raised bogs of the Central Belt and Grampian Plain.

ECOSSE 1 (Scottish Executive 2007), ECOSSE 2 (Smith *et al* 2009) and Scottish Government Rural and Environment Research and Analysis Directorate funding for soils research under the "Environment – Land Use and Rural Stewardship" research programme provide a new model for organic soils and revised estimates for carbon stocks, but nothing new on soil structure. The Scottish Government commissioned an expert workshop in 2009 to establish the current state of knowledge on extent and condition of Scottish peatlands (Chapman *et al* 2009a). This information was used in the preparation of the Scottish Government's discussion paper on the Management of Carbon-Rich Soils (Scottish Government 2010).

Recent research has re-examined peat polygons from the digitised soil map of Scotland, and related these to measurements from peat survey transects in the early 1990s, state surveys of peatlands in the 1960s, data on bogs held by the James Hutton Institute (formally MLURI) from the Soil Survey memoirs, maps and other sources, commercial peat extraction data and Forestry Commission survey reports. These were used where possible to characterise soil map units in terms of peat depth, and generalised results for peat depth were applied to those where peat depth data were absent. The resulting peat depth map was combined with figures for peat bulk density and carbon content to estimate the carbon stored in peat soils (Chapman *et al* 2009a).

5.1 Soil-defined peatland extent

The only soil map covering the whole of Scotland is the 1:250,000 scale soil maps. Figure 9 shows the extent of peat soil (dark purple) and dominant soil types defined as peaty (light pink).

As previously discussed, there are limitations to estimating the national extent of peatlands using solely 1:250,000 soil maps (e.g. age of data, compounding of soil types linked to mapping scales). It is however possible to quantify, using the 1:250,000 scale map, the extent covered by different soil types likely to be associated with peatland systems in Scotland. Table 3 provides a national estimate of soil map units with occurrence of peat and peaty soil. This estimate is derived from work undertaken to assess the stock of carbon in Scotland, and combined soil and peat information from various sources and scales.

Table 4 is based solely on 1:250,000 soil data and has been provided as a GIS data layer for use in strategic and locational guidance. This evaluation has been developed by SNH for quick assessment of the likely carbon richness of soil map units (SNH, 2011a).

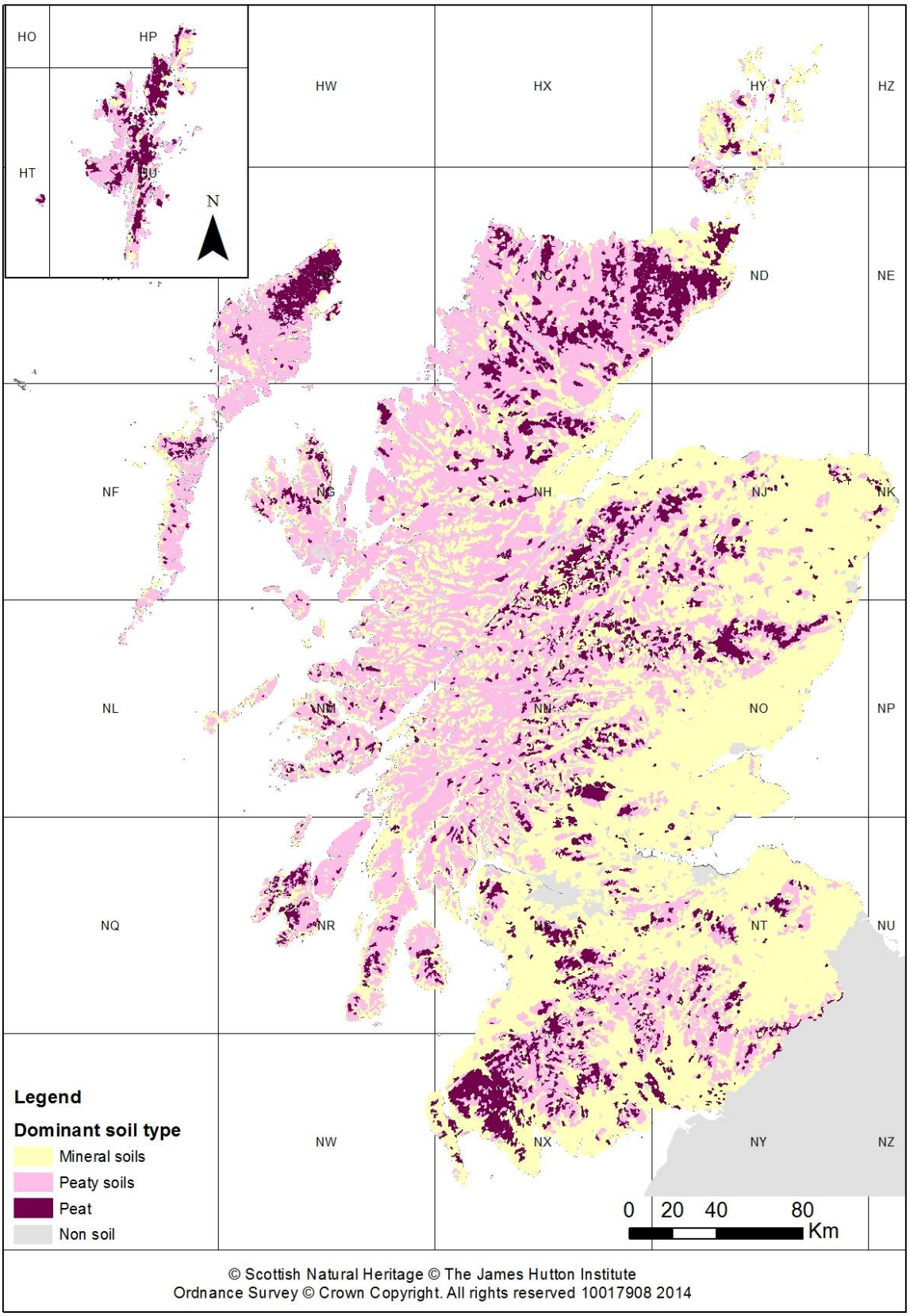


Figure 9. Location and extent of peat and peaty soils in Scotland, as identified from the Scottish Soils Map

The difference between these approaches is in part due to the accuracy of data and to differences in the interpretation of what may constitute peatlands. With the current state of knowledge and data available it is possible to prioritise one outcome to the detriment of another.

Figure 10 shows the spatial distribution of the carbon rich mapping units listed in Table 3. In this system the area mapped as classes 5 and 6 will always be associated with peat soil (and therefore should support or be able to support peat forming vegetation). Classes 3 and 4 are rich in carbon but the shallower peat recorded at the surface may not be linked to active peatland vegetation other soil formation processes. Class 2 occurs where large areas of mineral soil are closely associated with pockets of peat soil but cannot be differentiated at the scale of mapping (e.g. hummocky moraine landform).

New information is coming to light from a recent resampling and review of soil information by the Hutton and others which may improve further the estimate of peatland extent. Historical survey data of peat depth gathered in the 1980's can also be used to map the presence of the recorded depth of peat across Scotland (Figure 11).

Table 3. Extent of peat map units based on the Soils Map of Scotland (based on Chapman et al 2009a).

Mapping Units	Area (in ha)	% Scotland (% UK)
Peat only mapping units		
Basin Peat	67,300	0.9 (0.3)
Eroded Basin Peat	800	0.0 (0.0)
Blanket Peat	371,100	4.7 (1.5)
Deep Blanket Peat	167,900	2.1 (0.7)
Eroded Deep Blanket Peat	30,900	0.4 (0.1)
Eroded Blanket Peat	125,900	1.6 (0.5)
Peat within other map units		
Basin Peat	5,400	0.1 (0.0)
Semi-confined Peat	542,300	6.9 (2.2)
Blanket Peat	415,500	5.3 (1.7)
Organo-mineral units		
Peaty soils	3,461,200	43 (14.0)
TOTAL	5,188,100	64.9 (21.1)

Table 4. Distribution of carbon rich soil map units based on 1:250,000 soil data only. (See Figure 10)

	Soil carbon mapping unit classes	Area (in ha)	Area (% Scotland)
1	Mineral soil	3,129,492	41.1
2	Mineral soil with occasion all peat	360,318	4.7
3	Organo-mineral (peaty) soil no peat	732,913	9.6
4	Organo-mineral (peaty) soil with occasional peat	462,168	6.1
5	Peat with Organo-mineral (peaty) soil	2,182,123	28.7
6	Peat only	764,689	10.0
Areas mapped with potential peat soil		3,749,198	49,5
All areas mapped		7,615,788	

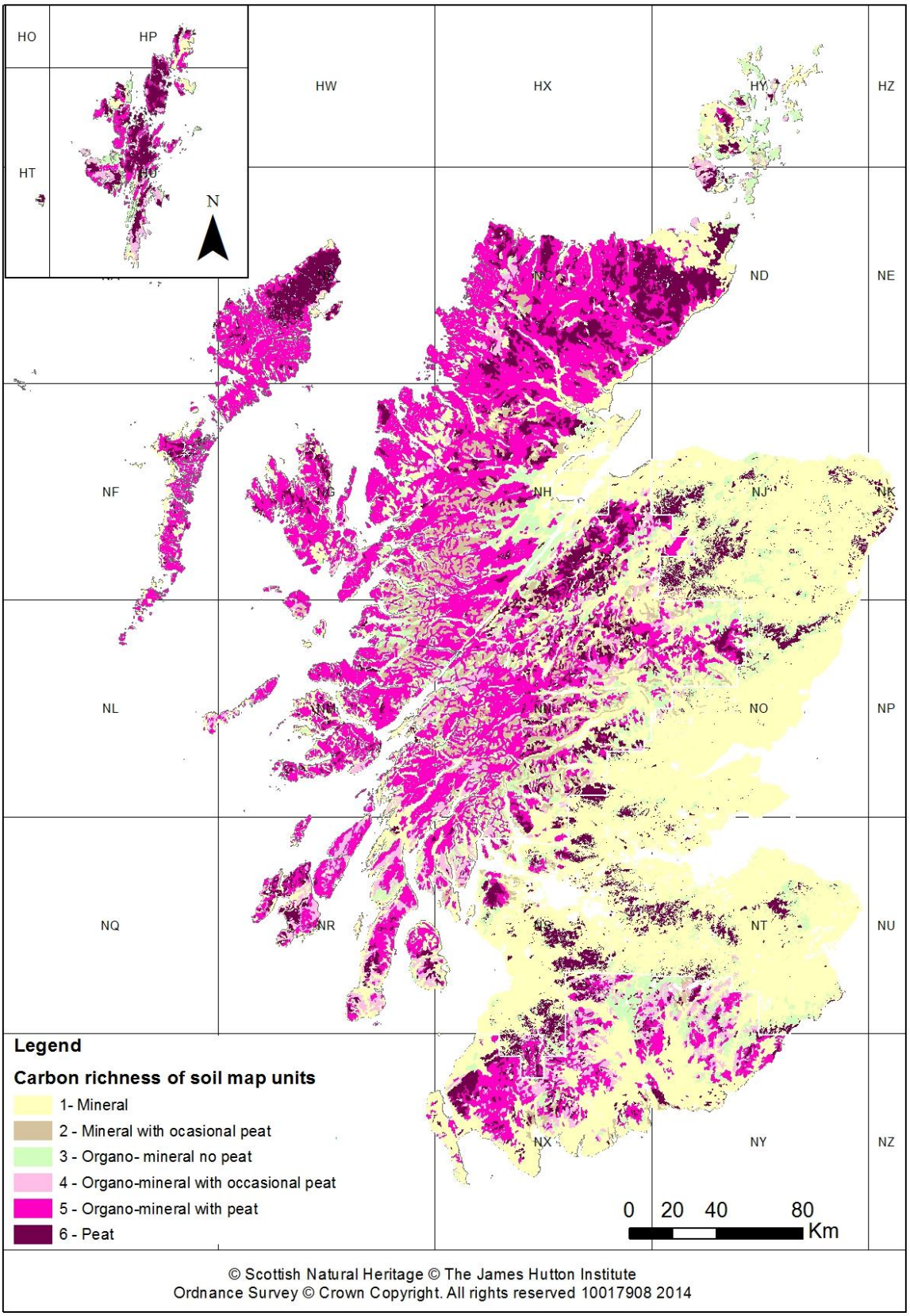


Figure 10. Carbon richness of soil mapping unit (1:250,000 and 1:25,000 scale data merged)

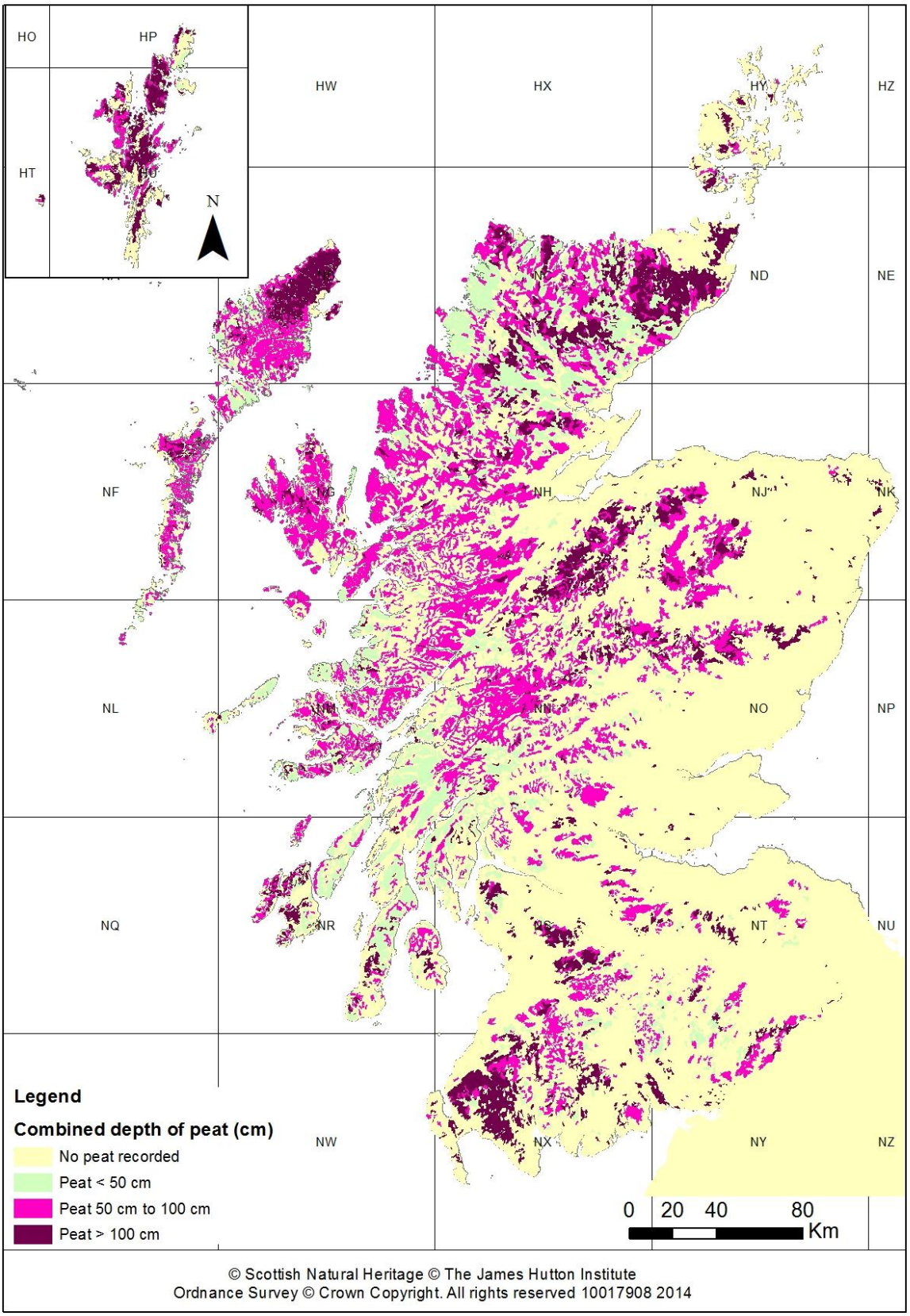


Figure 11. Peat depth in Scotland, as identified from the Hutton peat depth database

5.2 Extent of different habitat/land cover elements on peatlands

5.1.1 Peatland in Land Cover of Scotland 1988

The location of peat forming vegetation in Scotland can be indicated using LCS88 vegetation data. Land Cover of Scotland 1988 (LCS88) was the first **national** land cover census of Scotland and provided baseline information on rural land cover at a scale of 1:25,000. The classification system was developed specifically to provide information on semi-natural cover features, so that the greatest detail (at the lowest level in the hierarchy) relates to natural and management features within these cover types. LCS88 has 126 major classes. This was felt necessary to preserve the detail of the ground cover, especially in the upland and moorland areas – which cover some 80% of the land area. Mosaics, consisting of a dominant and subdominant class, were also permitted where the interpreter was unable to separate out different land covers.

An interpretation of LCS88 classification has been developed by SNH using information on primary and secondary vegetation types which are known to be associated with peatland systems. The methodology is described in Appendix 2: Reclassification of LCS88 Peatland categorIES and has been used to map areas likely to be peatlands (Figure 12).

Table 5. Distribution of vegetation types likely to be associated with peatland systems (based on LCS88 data and SNH reclassification V1.0 (See also Figure 12)

	Total area (in ha)	% all Scotland	% Scotland land/soil areas
Area mapped as “Bog and Peatland LCS88 classes” sole type	695,859	7.8	9.1
Area with “Bog and Peatland LCS88 classes” as dominant type	330,706	3.7	4.3
Area with “Bog and Peatland LCS88 classes” as secondary type	1,097,319	12.3	14.4
Area with other likely peatland type vegetation – wetter	509,149	5.7	6.7
Area with other likely peatland type vegetation – drier	397,928	4.5	5.2

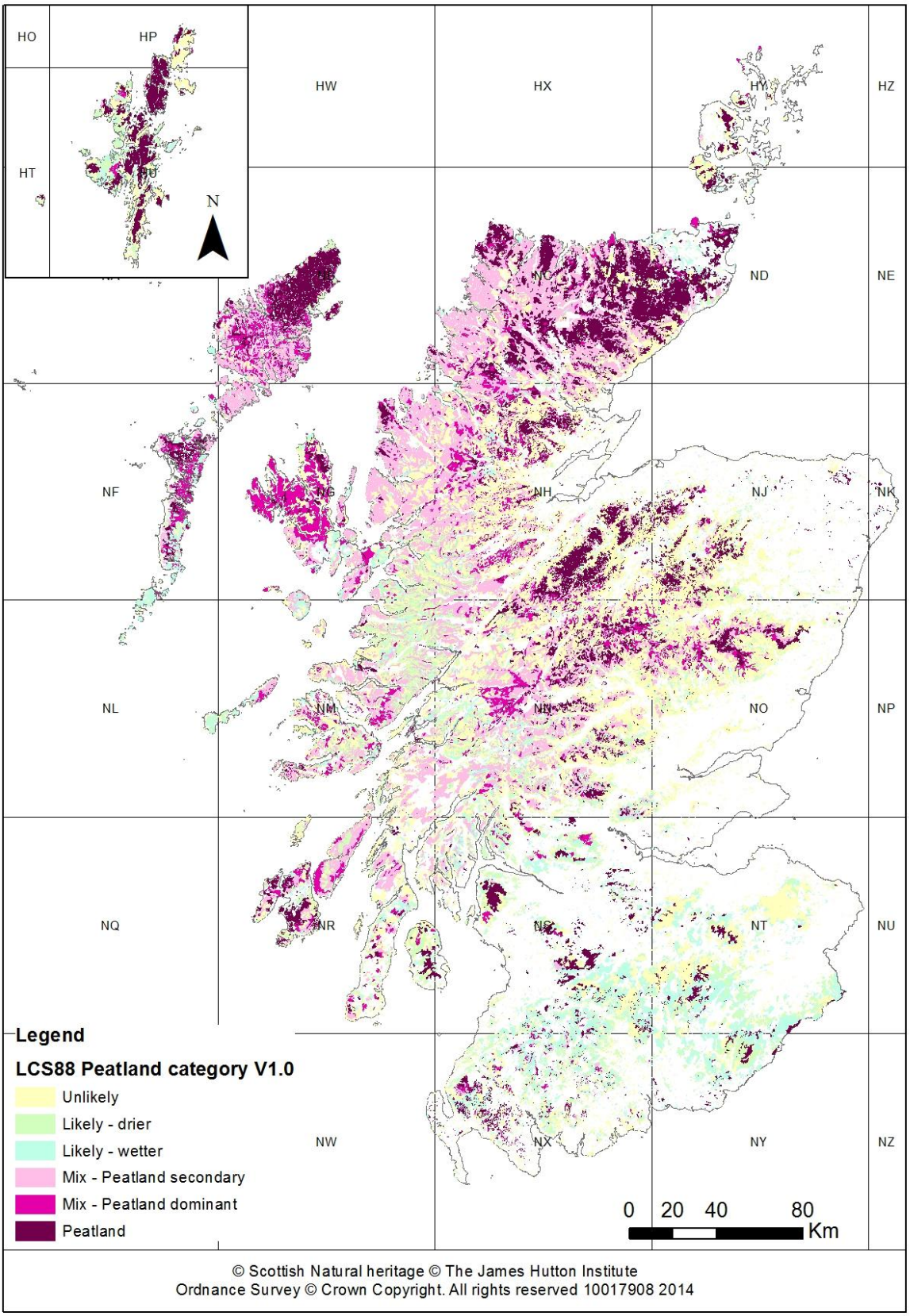


Figure 12. Land cover of Scotland 1988 (LCS88) – vegetation types likely to be associated with peatland habitats

5.1.2 Peatlands in BAP priority Habitats

The state of semi-natural peatlands described as BAP Priority Habitats (JNCC 2007) in Scotland was last reported via the BARS process (Biodiversity Action Reporting System), http://ukbars.defra.gov.uk/archive/plans/national.asp in 2008. Estimates on the extent and trends of peatland Priority Habitats for Scotland from the UK BAP reporting are given in Table 6. The UK Biodiversity Action Plan is now taken forward through a joint agreement between the 4 UK countries (JNCC and Defra 2012). Scotland is taking this forward under the '2020 Challenge for Scotland's Biodiversity' (Scottish Government 2013).

Table 6. Extent and trends of the main peat forming vegetation in Scotland – BAP Priority Habitats.

UK BAP Priority Habitat	Area in Scotland (in ha)	Summary trend (from UKBAP 2008 Reporting)	Biodiversity Action Reporting System (BARS) links
Blanket Bog	1,759,000	Declining (slowing)	National action plan Blanket bog
Lowland Raised Bog	13,000	Declining (slowing)	National action plan - Lowland raised bog
Lowland Fens	8,585	Declining (slowing)	National action plan - Fens
Upland Flushes, Fens and Swamps	Not applicable	Not applicable	New Priority Habitat so not yet reported on

5.1.3 Peatlands in Annex 1 Habitats

The UK is required under the EC Habitats Directive Article 17 to report every 6 years on the conservation status of habitats listed in Annex I of the Habitats Directive. A European overview of the 2007 reporting round, notes that the conservation status of the habitat grouping of 'bogs, mires and fens' is particularly bad in the Atlantic and Continental bio-geographic regions (European Commission 2009).

Peatlands in Countryside Survey 2007
Table 8 presents results from the Countryside Survey 2007 data (Norton *et al* 2009) that have been used to infer change in peatlands. The Broad Habitat 'Bog' in Scotland represents over 85% of the known extent of this habitat in the UK. No significant change was detected in Scotland between 1998 and 2007, but a significant decrease of 2.5% was observed for the Lowlands Environmental Zone (EZ4). The mean plant Species Richness Score of Main Plots within the Bog Broad Habitat in Scotland decreased by 6% between 1998 and 2007.

Table 7 below gives the information that has been provided for the 2013 reporting round. Further details are available for the individual habitats at http://jncc.defra.gov.uk/page-6392. It should be noted that Article 17 reporting is for the whole of the Annex I habitat resource not just the habitat with in Special Areas of Conservation (SACs).

5.1.4 Peatlands in Countryside Survey 2007

Table 8 presents results from the Countryside Survey 2007 data (Norton *et al* 2009) that have been used to infer change in peatlands. The Broad Habitat 'Bog' in Scotland represents over 85% of the known extent of this habitat in the UK. No significant change was detected in Scotland between 1998 and 2007, but a significant decrease of 2.5% was observed for the Lowlands Environmental Zone (EZ4). The mean plant Species Richness Score of Main Plots within the Bog Broad Habitat in Scotland decreased by 6% between 1998 and 2007.

Table 7. Extent and Favourable Conservation Status of the main peat forming habitats in Scotland – EC Habitats Directive Annex 1 Habitats from UK 2013 reporting

Annex 1 Habitat	**Surface area in Scotland (ha)**	**Trend for Surface area within Scotland**	**Favourable Conservation Status Overall trend for UK***
H91D0 Bog woodland	1,000	Stable	Stable
H7110 Active raised bogs	5,600	Stable	Declining
H7120 Degraded raised bogs still capable of natural regeneration	1,490	Decrease	Improving
H7130 Blanket bogs	1,759,000	Stable	Declining
H7140 Transition mires and quaking bogs	1,420	Stable	Declining
H7150 Depressions on peat substrates of the *Rhynchosporion*	781	Stable	Declining
H7230 Alkaline fens	370	Stable	Improving

*The overall Favourable Conservation Status is based on assessments of the habitats for: Range; Area; Specific structures and functions and Future prospects. This is a combined assessment for the UK resource.

The Broad Habitat 'Fens, marsh and swamp' in Scotland represents around 54% of the UK stock of this habitat. No significant change was detected between 1998 and 2007. There was a significant change (23% decrease) in Species Richness Score between 1998 and 2007, and an 18% decrease between 1990 and 2007. Decreases between 1998 and 2007 appear to be particularly concentrated in the Lowlands (EZ4).

Table 8. Countryside Survey data for Scotland, showing Broad Habitat extent. (Extract form Countryside Survey – Scotland results from 2007- chapter 7)

	1990 Area ('000s ha)	1998 Area ('000s ha)	2007 Area ('000s ha)	Direction of significant trends 1998-2007
BH – Fens, marsh and swamp				
Total Scotland	289	261	238	
EZ4 (Lowlands)	58	72	71	NO SIGNIFICANT CHANGE
EZ5(Intermediate Uplands and Islands)	151	109	95	
EZ6 (true Upland)	80	80	72	
BH – Bog				
Total Scotland	1,922	2,039	2,044	
EZ4 (Lowlands)	158	160	156	DECREASING
EZ5(Intermediate Uplands and Islands)	832	872	890	
EZ6 (true Upland)	932	1,006	998	

The Broad Habitat 'Fens, marsh and swamp' in Scotland represents around 54% of the UK stock of this habitat. No significant change was detected between 1998 and 2007. There was a significant change (23% decrease) in Species Richness Score between 1998 and 2007, and an 18% decrease between 1990 and 2007. Decreases between 1998 and 2007 appear to be particularly concentrated in the Lowlands (EZ4).

5.1.5 Peatlands in Sites of Special Scientific Interest and un-notified GCR sites

Sites of Special Scientific Interest (SSSI) are those areas of land and water that Scottish Natural Heritage (SNH) considers to best represent our natural heritage - its diversity of plants, animals and habitats, rocks and landforms, or a combinations of such natural features. On 01 January 2011 there were 1,437 SSSIs in Scotland out of over 6,500 in Great Britain. They cover more than 1,020,000 hectares in Scotland (or about 12.7% of the land surface) and range in size from less than one hectare to almost 30,000 hectares. The notification of SSSI is a legal process that defines the natural features of interest specific for each SSSI. (http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/sssis/).

Peatland type features notified in Biological SSSI as natural features are listed below.

- Alkaline fen
- Basin fen
- Basin fen - Schwingmoor type
- Blanket bog
- Estuarine raised bog
- Fen meadow (NB peat forming vegetation may or may not be present)
- Fen woodland
- Flood-plain fen
- Hydromorphological mire range
- Intermediate bog (blanket)

- Intermediate bog (raised)
- Laggs of raised bog
- Open water transition fen
- Raised bog
- Saddle mire
- Transition ombrotrophic mire
- Transition open fen
- Valley fen
- Upland assemblage (NB peat forming vegetation may or may not be present)

The following wet habitat feature types are not considered as peatland types; Alpine flush, Montane assemblage, Spring fen, Spring-head, rill and flush, Springs (including flushes), Subalpine flushes, Transition grassland, Transition saltmarsh, Transition sand dunes.

Figure 13 shows the location of SSSIs containing notified features with peatland habitats. Note that the feature may only cover a very small part of the SSSI area, especially for Fen, marsh and swamp features. Some SSSIs are notified for more than one feature and may also contain peatland habitat types that have not been notified.

The total area of the SSSIs containing notified features with peatland habitats amounts to 5.6% of Scotland.

Some peatlands are also designated as Geological Conservation Review (GCR) sites and geological and geomorphological SSSIs (http://www.snh.gov.uk/protecting-scotlands-nature/safeguarding-geodiversity/protecting/geological-conservation/). 45 GCR sites relate to the *marine deposits and landforms* and *non-marine organic sediments* and are described in the GCR volume Quaternary of Scotland (Gordon and Sutherland, 1993). In most cases, the interglacial organic deposits are part of older sequences of mineral deposits (e.g. clay, gravel and sands) and may not reflect active processes. In other cases, peat deposits accumulated in hollow and depression features may be part of active peatlands if deposition processes have continued in the later Holocene. Some peat deposits, mostly associated with palaeosoil, have also been recorded in alluvial basins and active fluvial systems and are described in the Fluvial Geomorphology of Great Britain GCR volume (Gregory 1992). The GCR volumes provide information on all sites notified, including radiocarbon dates, fossil and pollen records, maps and cross sections of deposits.

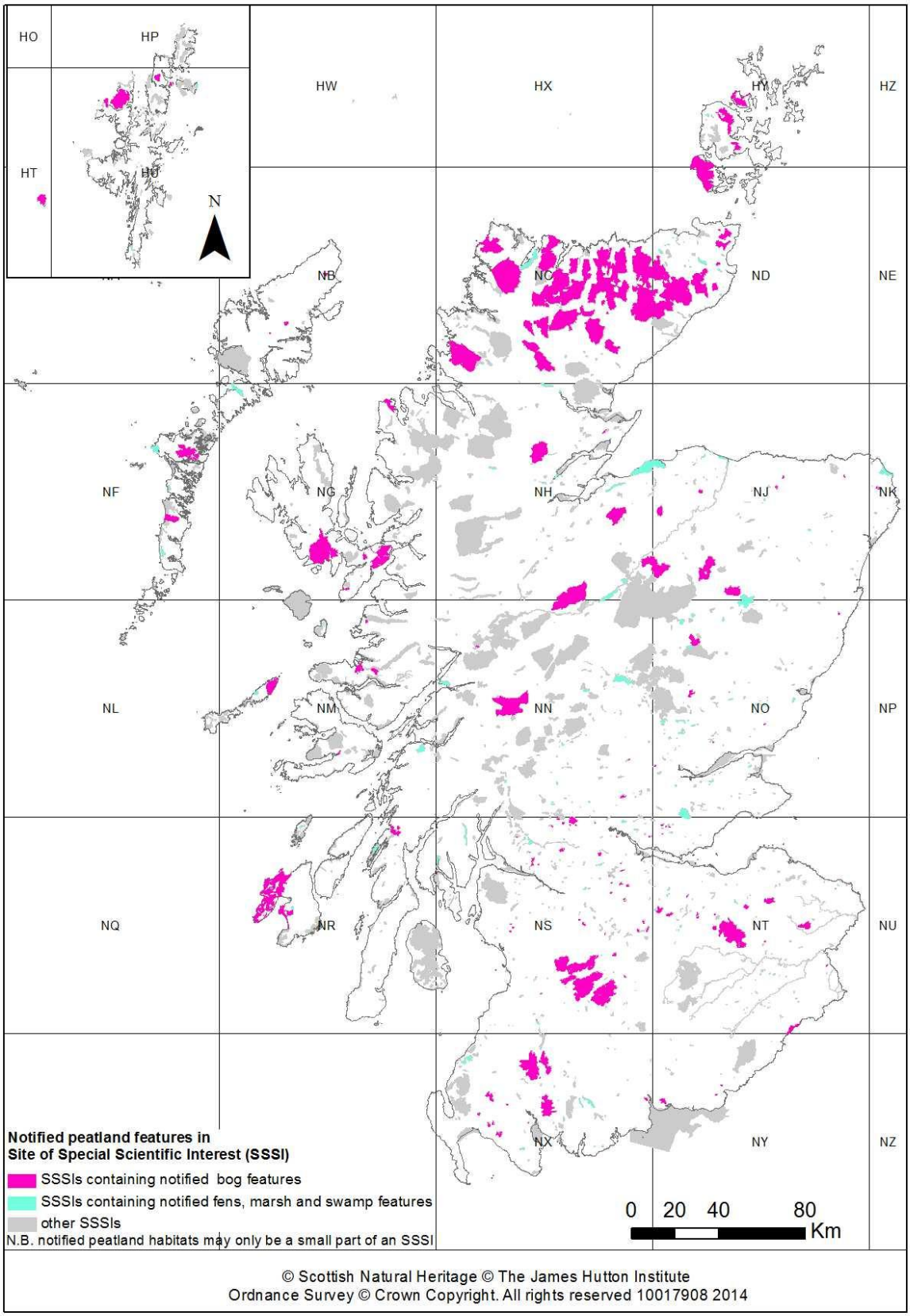


Figure 13. Sites of Special Scientific Interest containing peatland type features (March 2014)

5.1.6 Condition of peatland vegetation within designated sites

The condition of natural features on designated sites is monitored through Scottish Natural Heritage's Site Condition Monitoring (SCM) programme. Condition assessments of peat forming habitats within designated sites in Scotland has indicated that the proportion of blanket bog designated features in favourable condition (and unfavourable recovering condition) is 61.7% (9.6%); upland fens, flushes and swamps is 61.2 % (13.4%) and lowland raised bogs is 57.7% (18%) (Scottish Natural Heritage 2010).

In terms of differences between the regions of Scotland, the lowland raised bog features in the Central Belt were generally in better condition than in other areas. This probably reflected the fact that, compared with other areas of Scotland, designated sites in the Central Belt were chosen from a much larger sample of raised bogs.

There were also significant differences in the percentage of sites in favourable condition between the different areas of Scotland for lowland fens, marsh and swamp. Those sites located in northern Scotland had 80% of features in favourable condition. East and west Scotland were both below the overall average, with 59% of features in favourable condition.

The number of blanket bog features in favourable condition differed across Scotland. The blanket bog habitats in the west of Scotland were assessed to be in better condition than those located in the North, and the ones in the east were below the overall average.

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GLOSSARY

This glossary is extracted from JNCC Report 445 and set out to provide definitions to terminology used in this report (web links checked 11 December 2013)

Acrotelm	The surface layer of an active peat-forming mire, composed of the most recently deposited material, within which the water table fluctuates and where water moves more freely than in lower peat layers. See also **Catotelm**.
Active peat-forming	Describes peatlands subject to on-going peat formation, often inferred from the presence of vegetation that is normally peat-forming. Often abbreviated to "**Active**". See also Habitats Directive definition of active in relation to Annex 1 habitats 'Active raised bogs' and 'Blanket bogs' contained in European Commission, 2003. Interpretation manual of European Union Habitats. Version EUR 25. EC DG XI http://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf (p82-83).
Archaic peat	Term used in Lindsay and Immirzi (1996) to describe degraded peatlands with vegetation of agriculturally improved grassland or crops, or under built development.
Bare peat	Term used to describe areas of exposed peat.
Base-poor	Indicates low pH wetlands, deficient in base cations; pH range 4.5-5.5 (Wheeler et al., 2009a).
Base-rich	Indicates high pH wetlands, rich in base cations and often bicarbonate; pH range 6.5 or above (Wheeler et al., 2009a).
Bog	A mire which derives all its water supply from rain, snow or mist.
Bog (Gaelic)	Names in Gaelic include: bog; boglach; carr; fèithe; mòine; mòinteach; poll.
Blanket bog	Bog habitat which deposits expanses of peat that blanket the landscape. Includes both active and degraded versions of this habitat with semi-natural vegetation.
related definitions	'Blanket Bog' - UK Biodiversity Action Plan Priority Habitat (http://jncc.defra.gov.uk/Docs/UKBAP_BAPHabitats-03-BlanketBog.doc) 'Blanket bogs' H7130 Priority Habitat - Habitat directive Annex 1 (http://jncc.defra.gov.uk/Publications/JNCC312/habitat.asp?FeatureIntCode=H7130)
Blanket peat	aka Blanket bog peat. Peat deposits formed by blanket bogs.
related definitions	'blanket bog peat' – BGS sub-category of peat deposits mapping 'blanket bog peat' - NSRI soilscapes category.
Catotelm	The lower layer of an active peat-forming mire which remains permanently waterlogged, and through which water usually moves less freely. See also **Acrotelm.**
Condition assessment	A process for assessing the ecological condition of habitat features according to standardised criteria relating *inter alia* to species composition and structure (http://www.jncc.gov.uk/page-2217). The outcome of this assessment is used to assign features to a condition class.
Condition (of habitat)	The state of the feature at a particular point in time (each of which has subcategories relating to the change in condition since the previous assessment): a) favourable: maintained, recovered; b) unfavourable:

	recovering, no-change, declining; and c) destroyed: partially, completely.
Countryside Survey	The Countryside Survey is a stratified random monitoring scheme which provides a national network of sites across Great Britain, representing the main types of landscape, land cover and soil group. The Northern Ireland Countryside Survey uses similar methodology in Northern Ireland. These surveys have been repeated approximately every 8 years since 1978.
Broad habitats	A system to describe groups of similar habitats, which are defined in, and used by the UK Biodiversity Action Plan, and also used for reporting land cover for Countryside Survey. The Countryside Survey reports on two habitats relevant to peatlands; 'Fens, marsh and swamp' and 'Bog'.
Degraded habitat	Habitat which no longer supports its characteristic assemblage of species. Synonymous with unfavourable habitat condition See '**Condition**'.
Degraded peatland	Peatland supporting degraded habitat and/or peatlands and no longer peat-forming.
Deep peaty soil	In Scotland this corresponds to Peat soil mapping units characterised by the presence of surface peat layers containing more than 60% of organic matter and at least 50 cm thick.
Diplotelmic	Of active peat-forming bogs- having a two-layered structure comprising an **acrotelm** and a **catotelm**.
Ecosystem services	A term used to describe the goods, benefits and costs to society delivered through the functioning of an ecosystem.
Eutrophic	Nutrient-enriched (not necessarily also base-rich)
Fen	Mire which receives water from surface runoff and/or groundwater in addition to direct atmospheric precipitation.
Fen (Gaelic)	Names in Gaelic include: bog; boglach; botach; carr; fèithe; mòine; poll.
related definitions	'**Lowland Fens'** - UK Biodiversity Action Plan Priority Habitat. http://jncc.defra.gov.uk/Docs/UKBAP_BAPHabitats-27-LowlandFens.doc '**Upland Flushes, Fens and Swamps'** - UK Biodiversity Action Plan Priority Habitat http://jncc.defra.gov.uk/Docs/UKBAP_BAPHabitats-59-UplandFlushesFensSwamps.doc '**Transition mires and quaking bogs'** H7140 Habitats- Habitat directive Annex 1 http://jncc.defra.gov.uk/Publications/JNCC312/habitat.asp?FeatureIntCode=H7140 '**Alkaline fens'** H7230 Habitats- Habitat directive Annex 1 http://jncc.defra.gov.uk/Publications/JNCC312/habitat.asp?FeatureIntCode=H7230 '**Calcareous fens with Cladium mariscus and species of the Caricion davallianae'** H7210 - Habitats Directive Annex 1 (none known in Scotland) http://jncc.defra.gov.uk/Publications/JNCC312/habitat.asp?FeatureIntCode=H7210 **'Depressions on peat substrates of the *Rhynchosporion*'** H7150 Habitats- Habitat directive Annex 1 http://jncc.defra.gov.uk/Publications/JNCC312/habitat.asp?FeatureIntC

	ode=H7150 **'Petrifying springs with tufa formation (*Cratoneurion*)'** H7220 Habitats- Habitat directive Annex 1 http://jncc.defra.gov.uk/Publications/JNCC312/habitat.asp?FeatureIntCode=H7220 **'Alpine pioneer formations of the *Caricion bicoloris-atrofuscae*'** H7240 Habitats- Habitat directive Annex 1 http://jncc.defra.gov.uk/Publications/JNCC312/habitat.asp?FeatureIntCode=H7240
Fen peat	Peat deposited by fen habitats.
related definitions	'fen peat' – British Geological Survey sub-category of peat deposit mapping
'Lagg' fen	A fen immediately adjacent to a raised bog and separating it from adjacent habitats with mineral substrates.
Mesotrophic	With an intermediate input of nutrients
Mineral soil	Soil type mapping unit characterised by the presence of a surface layer containing less than 20% of organic matter (Scotland and Northern Ireland), less than 20-25% of organic matter (England & Wales).
Minerotrophic	Where nutrient supply is derived from mineral groundwater.
Mire	A wetland that supports peat-forming vegetation. Some authors use this term to include wetlands on mineral soils. See also '**Bog**' and **Fen**'.
Moorland	A term used to describe unenclosed upland areas dominated by a range of semi-natural vegetation. Not synonymous with peatlands.
Muirburn	A term used to describe rotational burning in Scotland.
Organo-mineral soil	in Northern Ireland by more than 20% of organic matter up to 50 cm deep and in Scotland by more than 20% of organic matter and more than 10 cm but less than 50 cm deep, or more than 10cm of surface horizon with 30-60% organic matter. For England and Wales see Shallow Peaty Soil.
Oligotrophic	Low fertility, nutrient poor (not necessarily also base-poor) (from Wetland Framework, Wheeler et al 2009b).
Ombrogenous	Derived from a water supply comprising precipitation alone. See '**Bog**'.
Ombrotrophic	Where nutrient supply is derived from precipitation (rain, snow or mist), also referred to as rain-fed.
Peat	Partially decomposed remains of plants and soil organisms which have accumulated, usually in waterlogged conditions, at the surface of the soil profile or as material infilling water bodies.
Peat (Gaelic)	The Gaelic word for peat is mòine
Peat soil	In the UK soil classification system, describes a type of soil which includes all organic-rich soils. (See deep peaty soil, shallow peaty soil).
related definitions	'**Peat deposits'** - a British Geological Survey class of organic deposit extending deeper than 1 metre below the ground surface. Sub-category included used on 1:25,000 and more detail soil survey map as a sub-category of soil peat include '**Basin peat**', **Hill peat**', **Peat flow',**
Peat-forming vegetation	Vegetation composed of species that are tolerant of waterlogged conditions and, as a result of these conditions, can form deposits of peat and thus sequester carbon.
Peatland	Land 'with a peat deposit that may currently support vegetation that is peat-forming, may not, or may lack vegetation entirely.' (modified from

	Ramsar Convention 1971).
Rain-fed	See **ombrotrophic**.
Raised bog	Bog habitat which is characterised by an accumulation of peat that rises above the surrounding landscape often in lowland wet floodplains and/or often over surface of existing fen peat. Includes both active and degraded versions of this habitat with semi-natural vegetation.
related definitions	'**Lowland Raised Bog**' - UK Biodiversity Action Plan Priority Habitat http://jncc.defra.gov.uk/Docs/UKBAP_BAPHabitats-31-LowlandRaisedBog.doc '**Active raised bogs**' H7110 Priority Habitat - Habitats Directive Annex 1 http://jncc.defra.gov.uk/Publications/JNCC312/habitat.asp?FeatureIntCode=H7110 '**Degraded raised bogs still capable of natural regeneration**' H7120 - Habitats Directive Annex 1 http://jncc.defra.gov.uk/Publications/JNCC312/habitat.asp?FeatureIntCode=H7120
Raised bog peat	Peat deposited by raised bog habitats.
related definitions	'**raised bog** **peat'** – a British Geological Survey sub-category of peat deposits mapping associated with raised bogs.
Shallow peaty soil	In England and Wales – Soil type characterised by the presence of a surface peat layer containing more than 20-25% of organic matter and at least 10 cm and no more than 40 cm thick . Term is not in use in Scotland or Northern Ireland but similar to Scottish Organo-mineral soil type.
Soil Organic Matter	Soil organic matter (SOM) refers to all organic material present in the soil including the remains of plants and animals at varying stages of decomposition and the living plant and animal material on and below the soil surface.
Soil Organic Carbon	Soil organic carbon (SOC) refers to the amount of carbon stored in the soil. It is often expressed as a percentage by weight or as g C/kg soil. SOC can be expressed into SOM through a simple multiplication factor, usually taken as equal to 1.72 in mineral soils and closer to 1.92 in organic soils.
Soil profile	Vertical arrangement of soil layers forming the basis of all UK soil classification system.
Soil series	Group of soil profiles developed under similar conditions and similar parental material in UK soil classification. Also the smallest unit of soil mapping.
Soil association	A characteristic grouping of soil series, used to map larger areas and normally bearing the name of the dominant series.
Waterlogging	Permanent or temporary saturation of the soil from high precipitation and poor drainage, or where there is a more or less constant supply of ground water and/or surface runoff, in basins, floodplains or springs.

APPENDIX 1: NVC VEGETATION FOUND IN HABITAT DIRECTIVE ANNEX 1 PEATLAND HABITATS

NVC found in peatlands	Bog woodland	H7110 Active Raised Bog	H7120 Degraded Raised Bog	H7130 Blanket Bog	H7140 Transition Mire & Quaking Bog	H7150 Depressions on peat substrates	H7230 Alkaline Fens
M1 *Sphagnum auriculatum* bog pool community		1		1	2	1	
M2 *Sphagnum cuspidatum/recurvum* bog pool community		1		1	2	1	
M3 *Eriophorum angustifolium* bog pool community		1	1	1			
M4 Carex rostrata – Sphagnum recurvum mire					1		
M5 Carex rostrata – Sphagnum Squarrosum mire					1		
M8 Carex rostrata- Sphagnum warnstorfii mire					1		
M9 Carex rostrata – Calliergon cuspidatum/giganteum mire					1		1
M10 *Carex dioica – Pinguicula vulgaris* mire							1
M13 *Schoenus nigricans – Juncus subnodulosus* mire							1
M14 *Schoenus nigricans-Narthecium ossifragum* mire					2	1	2
M15 *Scirpus cespitosus – Erica tetralix* wet heath		2	2	2		2	
M16 *Erica tetralix – Sphagnum compactum* wet heath		2	2	2			
M17 *Scirpus cespitosus – Eriophorum vaginatum* blanket mire	2		1	1		1	
M18 *Erica tetralix – Sphagnum papillosum* raised and blanket mire	1	1	1	1		1	
M19 *Calluna vulgaris – Eriophorum vaginatum* blanket mire	1	1	1	1			
M20 *Eriophorum vaginatum* blanket and raised mire		1	1	1			
M21 *Narthecium ossifragum – Sphagnum papillosum* mire						1	
M24 *Molinia caerulea – Cirsium dissectum* fen-meadow							
M25 *Molinia caerulea – Potentilla erecta* mire			2	1			
M29 *Hypericum elodes-Potamogeton polygonifolius* soakway						2	
S2 *Cladium mariscus* swamp and sedge-beds							
S24 *Phragmites australis – Peucedanum palustris* tall-herb							
S25 *Phragmites australis – Eupatorium cannabinum* tall-herb fen							
S27 Carex rostrata – Potentilla palustre tall herb fen					1		

1 = usually associated with Annex I habitat, 2 = occasional

For detail on the Habitat Directive Annex 1 habitats see JNCC http://jncc.defra.gov.uk/ProtectedSites/SACselection/SAC_habitats.asp

APPENDIX 2: RECLASSIFICATION OF LCS88 PEATLAND CATEGORIES

The table below identifies LCS88 classes which may be or may have been associated with peatland soil and habitats. These classes may appear either as a sole vegetation type or as primary or secondary types in complex units. The full list of available classes is available from MLURI (1993).

New code	description	LCS88 class from	LCS88 class to
1	Wetlands: with or without drains, scattered trees	200	203
2	Undifferentiated bracken: with or without rock outcrops, scattered trees	170	173
3	Smooth grasslands with low scrub: with or without rock outcrops, scattered trees	155	158
4	Dry heather moor: with or without rock outcrops, burning, scattered trees	110	117
5	Smooth grasslands with rushes: with or without rock outcrops, scattered trees	150	153
6	Undifferentiated heather moor: with or without rock outcrops, burning, scattered trees	130	137
7	Undifferentiated smooth grasslands: with or without rock outcrops, scattered trees	160	163
8	Undifferentiated coarse grasslands (*Nardus/Molinia*): with or without rock outcrops, scattered trees	140	143
9	Wet heather moor: with or without rock outcrops, burning, scattered trees	120	127
10	Blanket bog and other peatland vegetations	180	186
11	Recently ploughed land for afforestation / Land recently "ripped" for afforestation	83	83
		87	87
12	Undifferentiated montane vegetation: with or without erosion, rock outcrops	222	223
0	All other		

The various combinations of primary and secondary vegetation in the LCS88 identified above were reclassification into 7 types ranging from areas which are unequivocally peatland to areas unequivocally not peatland.

Peatland class	
7	Areas unequivocally peatland
6	Areas always including peatland vegetation as primary vegetation type
5	Areas always including peatland but as secondary vegetation type
4	Areas include vegetation type that may defined as peatland – wetter
2	Areas include vegetation type that may defined as peatland – dryer
1	Very unlikely to be peatland
0	Not peatland

The reclassification matrix is based on expert judgement.

		Primary vegetation												
		0	1	2	3	4	5	6	7	8	9	10	11	12
Secondary vegetation	0	0	1	1	1	1	4	1	1	1	4	6	1	1
	1	1	1	1	1	1	4	1	1	4	4	6	1	1
	2	1	1	1	1	1	4	1	1	4	4	6	1	1
	3	1	1	1	1	1	4	1	1	4	4	6	1	1
	4	1	1	1	1	1	4	1	1	4	4	6	1	1
	5	2	2	2	2	2	4	2	2	4	4	6	2	2
	6	1	1	1	1	1	4	1	1	4	4	6	1	1
	7	1	1	1	1	1	4	1	1	4	4	6	1	1
	8	2	2	1	1	1	4	2	2	4	4	6	2	2
	9	2	2	2	2	2	4	2	2	4	4	6	2	2
	10	5	5	5	5	5	5	5	5	5	5	7	5	5
	11	1	1	1	1	1	4	1	1	4	4	6	1	1
	12	1	1	1	1	1	4	1	1	4	4	6	1	1

APPENDIX 3: USEFUL LINKS AND ONLINE RESOURCES

Most of Scotland's environmental data can now be accessed via the Scottish Environment Web (SEWEB). http://www.environment.scotland.gov.uk/default.aspx [Accessed 12 December 2013]

Scotland's Environment website brings together information on Scotland's environment in an easily accessible and suitable form for all users. It allows a new, modern and dynamic approach to the presentation of environmental information. It is the first stop for anyone looking for reliable and accurate information on Scotland's environment from known and trusted sources.

The Scotland soil website has been developed to complement SEWEB and specifically provide access to soil information. http://www.soils-scotland.gov.uk/ [Accessed 12 December 2013]

The Forestry Commission - Ecological Site Classification Decision Support System (ESC-DSS) also provides information on some of the woodland soils in Scotland. http://www.forestry.gov.uk/esc [Accessed 12 December 2013]

In addition, Scottish Natural Heritage collects data and information on many aspects of Scotland's environment and has developed SNHi applications to allow easy access to information. http://www.snh.gov.uk/publications-data-and-research/snhi-information-service/ [Accessed 12 December 2013]

BGS soil data (soil being here defined as a geological construct) can be visualised on the NERC soil portal (https://www.bgs.ac.uk/nercsoilportal/) [Accessed 12 December 2013] and OpenGeoscience (www.bgs.ac.uk/opengeoscience/home.html). [Accessed 12 December 2013]

The following applications and websites provide information relevant to issues presented in the report.

Conservation – policy and monitoring

Information on Links to EC Habitats Directive Annex I habitats (listed under the Raised bogs and mires and fens section) [online]. Available from: http://www.jncc.gov.uk/Publications/JNCC312/UK_habitat_list.asp [Accessed 12 December 2013]

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