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A biodiversity metric for interpreting outputs of models of atmospheric nitrogen pollution impacts on habitats

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Executive summary

As a signatory party to the Convention on Long Range Transboundary Air Pollution (CLRTAP), the UK has been requested to provide biodiversity metrics for use in assessing impacts of atmospheric nitrogen (N) pollution. In response to this request, different metrics can be provided for different habitat classes, defined at EUNIS Level 3 or Level 2. Habitat specialists at the Statutory Nature Conservation Bodies (SNCBs) were consulted to ascertain the best basis for such metrics.

Nitrogen tends to accumulate in ecosystems and cause delayed and cumulative effects. For this reason, dynamic soil-vegetation models are used to assess the impacts of N pollution scenarios. Models of soil and vegetation responses to N pollution can predict changes in soil chemistry (such as pH or plant-available N), and effects on habitat suitability for individual plant and lichen species. Models are also available that predict cover (abundance) of individual species or of groups of species such as *Sphagnum* mosses or forbs (broadly, wildflowers). However, the latter models are thought less reliable than models that predict habitat suitability. The best model currently available for the UK is MultiMOVE, which predicts habitat suitability for more than 1200 plant and lichen species. The current study aimed to assess how metrics of biodiversity or habitat quality can be calculated from the outputs of currently available dynamic models.

The study was restricted to widespread habitats known to be affected by N pollution – bogs, grasslands, and heathlands. The habitat specialists were asked to discuss the reasoning behind their evaluation of sites as good, poor or degraded examples of these habitats, in a series of semi-structured interviews. The specialists were also asked to rank a set of examples of their habitat. These parallel sources of evidence were used to assess potential metrics, such as those based on the number of species, cover of species-groups, or presence of indicator-species. Likely responses to the request for biodiversity metrics from other countries were also canvassed in an email survey.

The habitat specialists made frequent reference to Common Standards Monitoring (CSM) guidance, a set of criteria for assessing habitat condition. The guidance was developed to be applicable across the UK, and identify key attributes of a habitat that indicate its condition. The criteria often include thresholds for the abundance of groups of plants, for instance in a heathland there must be sufficient cover of subshrubs. Lists of species that indicate favourable or unfavourable condition are also included for many habitats.

Interview responses revealed that vegetation composition is very important for assessing habitat condition. Scarce species are considered important for biodiversity conservation, and sites are often designated because they support populations of scarce species. However, these scarce species tend to occur on few sites, and may be hard to see or identify, so assessments are generally made on the basis of species or groups of species that are distinctive for the habitat but not extremely scarce. These species are usually those listed in the CSM guidance, although species are often added to these lists for particular sites or regions. Additional species have also been recommended as suitable for detecting and monitoring effects of N pollution.

Several metrics calculated from the species lists in the habitat examples were shown to be related to the criteria used by the specialists to assess habitat quality. Of these, the most consistently and clearly related was the number of positive indicator-species, as identified in the CSM guidance. The evidence provided by quantitative and qualitative analysis of the habitat specialists' responses clearly points to the use of positive indicator-species as the basis for a biodiversity metric for use in this context. A prototype metric based on mean MultiMOVE predictions of habitat suitability for positive indicator-species was shown to be responsive to key environmental indicators of N pollution.

Using the MultiMOVE floristic model implies that cover values for species cannot be predicted, and so abundance-based metrics cannot be calculated. This limitation is hard to avoid, since models that predict changes in cover are currently unproven. Another limitation presented by basing a metric on habitat suitability for positive indicator-species is that lists of these species may change – for example, refined indicator-species lists are currently being developed by JNCC. However, in principle the habitat suitability for positive indicator-species provides a robust basis for a metric of habitat quality. It is recommended that such a metric be derived using CSM indicator-species lists in order to meet the Call for Data, but that the method should be adaptable to future changes in the lists of species used. The sensitivity of metric values to such changes needs to be explored. Typical and threshold values for the metric should be established using real habitat examples.

Contents

1. Introduction

Atmospheric pollution by reactive nitrogen (N) has chronic and acute effects on ecosystems, such as stimulating plant growth and so changing the competitive balance between species, and acidifying the soil. Nitrogen is tightly cycled and retained in most ecosystems, so effects of N pollution can be cumulative, persistent and progressive. For this reason, effects are often considered using dynamic models of soil and vegetation biogeochemistry, to account for delayed responses to changes in N deposition rate. In recent years, these models have been used to drive models of floristic response, i.e. which plant and lichen species are likely to increase and which decrease in response to a given N deposition scenario. A major gap in understanding how soil-vegetation-floristic models should be applied has been the lack of agreed methods for interpreting floristic change in terms of habitat quality and nature conservation objectives. This project aims to fill this gap.

Under the Convention on Long Range Transboundary Air Pollution (CLRTAP), the Co-ordination Centre for Effects (CCE) is responsible for the development of modelling and mapping methodologies for the integrated assessment of European air pollution effects. The CCE issued a "Call for Data" in November 2012, which was aimed at enabling the calculation of country-specific biodiversity indicators for assessing changes in biodiversity driven by atmospheric deposition. The ultimate aim of the CCE is to assess the extent to which "no net loss of biodiversity" is achieved, under air pollution scenarios, using suitable biodiversity endpoints as a measure.

The 'indicators' to be provided in response to the call will be referred to in this report as 'metrics', to avoid confusion with indicator-species, although the latter might be used in defining a suitable metric. Biodiversity metrics must be able to be calculated from the output variables of soil-vegetation models. The Call for Data specifies that a signatory party such as the UK may provide different indicators for different habitats, defined at EUNIS Level 3.

The aims of the study were to:

- Select a small set of habitats for which to develop an approach.
- Assess which are the key aspects of habitats used to assess biodiversity by habitat specialists at the Statutory Nature Conservation Bodies (SNCBs).
- Propose methods for deriving a metric from outputs of soil-vegetation models for assessing impacts on 'biodiversity'.
- Consult Defra and the SNCBs on the proposed metrics.
- Recommend and justify an approach for defining metrics for habitats.

There is now strong evidence that plant and lichen species have been lost from areas of the UK as a result of anthropogenic N deposition. Even when N deposition rates are already above critical load, a further increase of N deposition can lead to the loss of further species (Emmett et al., 2011). Species that are negatively affected by N include many with conservation designations. However, some species increase in prevalence in response to N, and this group includes a few species with conservation designations, such as certain *Sphagnum* species (Stevens et al., 2011). It is therefore necessary to evaluate changes in species composition as a whole, to help assess the effects of different N deposition scenarios on UK habitats.

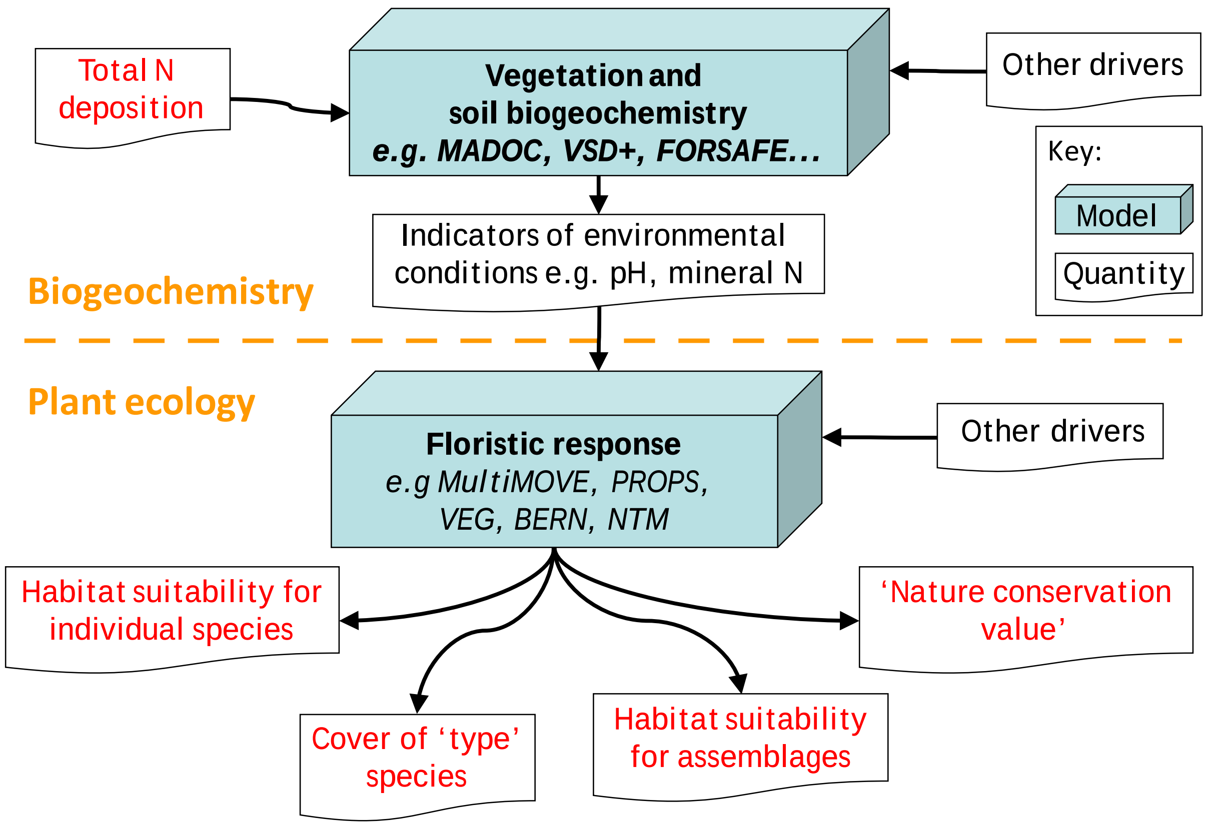
The impacts of acidifying pollutants can be assessed using convenient indicators such as soil pH or ionic concentrations, but there is no equivalent easily-measurable metric for N saturation and eutrophication. In early studies, a decline in C/N ratio was seen as indicating N saturation, but it is now appreciated that C/N can increase with N deposition because of stimulated production of litter with a large C/N ratio compared to older soil organic matter. Increases in plant-available N in soil are difficult to detect directly, since plant-available N is often at low concentration due to rapid plant uptake, and concentrations can fluctuate wildly with mineralisation and rainfall events. More realistic measurements of N availability such as mineralisable N or resin-sorbed N are promising, but have not been applied to sufficient sites to determine the ecological importance of a given measured value. The most promising measurable indicator of N impacts on ecosystems is N concentration in moss tissue (Rowe et al., 2013), which reflects current deposition since mosses mainly obtain N from atmospheric inputs rather than from the soil. However, the connection between moss N content and biodiversity value is not obvious, and metrics which more closely reflect the ways in which habitat value is judged would be useful for developing biodiversity endpoints and damage thresholds.

Considerable efforts have been expended on developing models of soil, vegetation and floristic change in response to N pollution. These models also respond to other drivers and to site conditions. It is worth noting here the various forms of output that are generated (see also Figure 1):

- Soil pH, C/N ratio, plant-available N and other biogeochemical metrics (e.g. ForSAFE, VSD, VSD+, N14C, MADOC)
- Suitability of the habitat for individual species (MOVE, MultiMOVE, PROPS)
- Cover of individual species (VEG)
- 'Biodiversity value' (NTM)
- Suitability of the habitat for phytosociologically-defined plant communities (BERN)

This report examines how the outputs from such models can be related to biodiversity targets or endpoints and to concepts such as habitat quality, nature conservation status and habitat damage.

Figure 1. General schema for models currently used to assess nitrogen pollution effects on habitat biogeochemistry and floristic response.



The evidential basis for the study was provided by consulting with habitat specialists of the SNCBs, using semi-structured interviews and, in parallel, a ranking exercise. The methods used to identify these key informants and use their views to inform the development of habitat quality metrics are explained in the next section. In section 3, results of a qualitative analysis of interviews with habitat specialists are presented, along with analysis of the exercise in which habitat examples were ranked. Section 4 discusses the options for deriving metrics in the light of these analyses of informants' views, and develops a method for deriving a metric from model outputs. Conclusions and recommendations are given in Section 5.

2. Methods

2.1 Overview of methods

Many different approaches could be taken to defining biodiversity value and habitat quality. High quality could be defined in terms of habitat structure, presence of scarce or declining species, presence of species that are important to the structure, function or integrity of the habitat, absence of atypical or otherwise undesirable species, abundance of species-groups such as subshrubs or mosses, or similarity to a target assemblage of species, among other criteria. Species scarcity could be defined with reference to global, national or local populations. Undesirable species could be defined as those that are non-native (whether determined nationally or locally), competitive, invasive, or not previously recorded in the habitat. Emphasising particular ecosystem functions or ecosystem services may argue for defining habitat quality in terms of visual appeal, ability to support pollinators, beneficial influence on ecosystem greenhouse-gas budgets, and a host of other considerations. Many of these functions and services are dependent on particular species.

Plausible scientific justifications can be made for many of these criteria, but ultimately the balance of criteria used to define habitat quality depends on the value-system and priorities of whoever is making the judgement. For this reason, it is necessary to base any decision on the most appropriate metric of habitat quality on consultation and open discussion, rather than by invoking scientific considerations. A key part of the current study, therefore, was a consultation with habitat specialists of the SNCBs, as described in detail in the following sections. The consultation comprised a semi-structured interview, and a ranking exercise in which habitat examples were compared against each other.

In parallel to the consultation, potential metrics were developed. There is some potential to direct the development of soil-vegetation models towards predicting new aspects of habitats, but there is limited time before the UK is due to respond to the Call for Data, so it is probable that the recommended metrics will have to be based on existing models. The final choice of metric will have to be pragmatically based on available model outputs. A key aim of the study was therefore to determine whether such model outputs can be related to the criteria which habitat specialists use to assess habitat quality. This was done using results of both a qualitative analysis of interview responses and a quantitative analysis of the ranked examples.

The study was restricted to three main types of habitat, as defined at EUNIS Level 1. These were D: mires, bogs and fens; E: grasslands and lands dominated by forbs, mosses or lichens; and F: heathland, scrub and tundra. This was partly to reduce the scale of the task, and partly because evidence of N impacts on habitats mainly relates to these habitats. Nitrogen pollution is probably affecting woodland to some extent, particularly by decreasing the time taken for succession after clearance or gap-formation, but effects of N were not observed in a large-scale study of European woodland (Verheyen et al., 2012). Other classes such as coastal habitats and sparsely-vegetated habitats were excluded from the study because of a lack of research data on N impacts, and/or because models of N impacts have not yet been developed for these habitats.

The examples ranked by the habitat specialists were quantitative descriptions (see Section 2.3) of single plots on real sites. Metrics were calculated from the same examples for comparison with the specialists' judgements (Section 2.5). However, the necessary model inputs were not available for these examples, and model outputs were not directly comparable with these plot descriptions, so an alternative set of sites was used to illustrate metric calculation from model outputs, as discussed in Section 4.2.

2.2 Semi-structured interviews of habitat specialists

2.2.1 Selection of participants

In any survey, the choice of participants can greatly influence the outcome. It could be argued that value judgements are a matter for society at large, and therefore that citizens' jury or fully-representative survey approaches should be applied. However, while a significant proportion of the public have an appreciation of nature and are aware of the importance of nature conservation, in general decisions about specific conservation targets are entrusted to experts in governmental and non-governmental (NGO) organisations. Numerous NGOs are active in UK conservation debates, so it would be difficult to canvas views from all interested parties. It is more feasible to identify experts from governmental organisations with relevant expertise. The SNCBs – Natural England (NE), Scottish Natural Heritage (SNH), Natural Resources Wales (NRW), the Northern Ireland Council for Nature Conservation and the Countryside (NICNCC) and the Joint Nature Conservation Committee (JNCC) – are responsible for nature conservation in the UK. In consultation with the Defra Project Officer and steering committee, 16 habitat specialists were identified within the SNCBs with expertise in one or more of the three EUNIS Level 1 habitats targeted in the study. The specialists were contacted initially via e-mail, which included a briefing note to provide background to the project, and invited to participate in a semi-structured interview and a ranking exercise of habitat examples. Of 16 specialists contacted, 14 were able to participate – four from SNH, four from NRW, one from NICNCC and the remaining five from NE (Table 1).

Table 1. Affiliations and specialisations of the habitat specialists consulted in the project. Habitat specialisations were related to EUNIS Level 1 Habitats: D = Mires, bogs and fens; E = Grasslands and lands dominated by forbs, mosses or lichens; F = Heathland, scrub and tundra.

Interviewee code	Affiliation*	Habitat specialisation	Corresponding EUNIS Level 1 habitat(s)
I1	SNH	Grasslands	E
I2	SNH	Peatland, bogs, fens, marsh and swamp	D
I3	SNH	Peatlands (and uplands generally)	D
I4	SNH	Uplands (general) and lowland heaths	D, E, F
I5	NRW	Upland and lowland heath	F
I6	NRW	Wetlands	D
I7	NRW	Montane heaths	F
I8	NRW	Lowland grasslands	E
I9	NINCC	All terrestrial habitats	D, E, F
I10	NE	Lowland semi-natural grasslands	E
I11a	NE	Uplands	D, E ,F
I11b	NE	Uplands	D, E ,F
I12	NE	Lowland bogs and fens	D
I13	NE	Lowland heathlands	F

* SNH = Scottish Natural Heritage; NRW = Natural Resources Wales; NICNCC = Northern Ireland Council for Nature Conservation and the Countryside; NE= Natural England

2.2.2 Interview design & delivery

The semi-structured interview comprised of six main topics relating to the assessment of habitat quality in the UK (Table 2). Broadly, these were: general features of habitat quality; species value; plant and lichen indicator-species; other taxa; species-groups; and reference communities. Guidance questions were devised for each theme (Table 3) but the interview allowed for considerable variation in questioning, including additional questions and two-way dialogue. This approach retains the benefits of having a clear structure (aiding the analysis process and keeping the research focused) whilst also providing the flexibility needed to collect rich qualitative data.

Table 2. Topics covered by semi-structured interviews.

Topic	**Subtopic**
T1. Main features of habitat quality	*a) Combination of features* *b) Habitat structure* *c) Vegetation composition and structure* *d) Geographical and temporal variability* *e) Ecosystem services* *f) Applicability and practicality*
T2. Value of individual species	*a) Structural and functional species* *b) Scarce species* *c) Invasive species* *d) Historical context* *e) Comparative values of species*
T3. Plant & lichen indicator-species	*a) Characteristics of positive indicator-species* *b) Characteristics of negative indicator-species* *c) Context of indicator-species*
T4. Taxa other than plants and lichens	*a) Importance of other taxa* *b) Management conflicts* *c) Barriers to using other taxa* *d) Proxy indicators of suitability for other taxa*
T5. Species-groups	*a) Pros and cons of using species-groups* *b) Identifying useful species-groups*
T6. Reference communities	*a) Defining a reference community* *b) Potential reference community definitions*

Table 3. Guide used for semi-structured interviews of habitat specialists in the UK

Theme	Example (guide) question	Purpose/ justification of question
Habitat quality (1)	What are the main features of a habitat that you would look for when assessing habitat quality? *[Prompt: is it the presence, abundance, or absence of specific species, or is it about other aspects of the habitat?]*	Determining the general aspects of habitat quality
Species value (2)	Should more value be attached to some species than others (for example those that are CSM indicators, nationally scarce, or globally scarce, declining, distinctive for the habitat, nitrogen-sensitive)? If so, how should 'high value' species be selected? How much relative importance should they be given compared to other species? Should invasive or non-native species be viewed as reducing habitat quality *per se*, or only when they cause a decline in habitat suitability for target species?	Exploring attitudes towards species value (native and non-native) and identifying the most important factors when considering habitat quality
Plant and lichen indicators (3)	What types of plant and lichen species would lead you rank a site a having high quality? *[prompt: for example locally or globally scarce species, distinctive species, or species important for habitat structure]* What types of plant and lichen species would lead you to rank an example as having low quality? *[prompt: for example non-native or invasive species]*	Developing an understanding of what are 'desirable' and 'undesirable' plant and lichen species (which can also be used to understand the quadrat rankings).
Other taxa (4)	Can habitat quality be assessed on the basis of presence or abundance of *just* plants and lichens? If not, what other taxonomic groups are important in *habitat x?* How important are they compared to the most important plants and lichens?	Determining how necessary it is to include other taxonomic groups in soil-vegetation models, and if it is necessary, identifying which groups/species are important.
Species groups (5)	How important is the presence of species groups (such as forbs, shrubs or ericoids) for assessing the habitat quality of *habitat x*?	Determining how important species groups are for assessing habitat quality – and identification of these species groups.
Reference communities (6)	If habitat quality was to be based on the similarity to a reference community, how should this reference be chosen? How problematic do you think regional differences are for choosing a suitable reference community?	Determining how to select reference communities for the habitats and how far reference communities can be generalised.
Other	Do you have any other comments?	Identification of other relevant issues that might not have been covered by previous questions

All interviews were conducted in person by two of the project researchers, between 28th August and 5th September 2013, with the exception of the interview with the NICNCC specialist in Northern Ireland which was conducted by phone. Following the semi-structured interview, the participants were asked to rank a set, or sets, of habitat examples (Section 2.3).

2.2.3 Qualitative analysis of interview responses

The habitat specialists' responses were analysed under predefined topic and subtopic headings (Table 2). The interviews were transcribed and then analysed using Atlas Ti software. Data were coded according to each of the six topics and by habitat. Within each of the six topics, key themes were identified using an approach based on grounded theory, where themes are allowed to emerge from the data. Responses were summarised and supported with example quotations. Results are presented according to the six topics of the interview, with consideration of the differences and similarities between habitats and countries. Key messages for each topic are summarised at the end of each section.

2.3 Ranking of habitat examples

Following the interview, the habitat specialists were given a set of examples of their habitat and asked to rank these in order of 'habitat quality'. These examples consisted of individual 'relevés' i.e. lists of all the plant and lichen species that were present in a defined area or 'quadrat'. It was explained to the specialists that the examples should be assessed in relation to the definition of the EUNIS class (see below) in question. For example, a relatively species-rich relevé with very low subshrub cover would not be considered a high-quality example of a heathland.

The habitat examples for ranking were taken from the database of 31,261 examples that were originally used to develop the National Vegetation Classification (NVC), and for the habitats considered in the current study were usually derived from 2 x 2 m quadrats. The cover for each species was indicated using the DOMIN scale and species were placed in descending order of abundance without distinguishing vascular plants, bryophytes and lichens.

All of the examples in the database were automatically assigned to the nearest NVC community using the MAVIS program (Smart, 2000). These NVC subcommunities were mapped onto EUNIS Level 3 and Level 2 classes using correspondences published by the National Biodiversity Network and JNCC. The EUNIS classes considered in the study are listed in Table 4. However, the habitats covered by the specialists did not always clearly match the EUNIS classification, and in most cases the specialist covered several Level 3 classes. We allowed the specialists to choose one or more of the sets of examples prepared for Level 2 and Level 3 classes. This resulted in uneven coverage of the classes, but was thought necessary to ensure that each specialist was making assessments using familiar criteria.

Table 4. Types of habitat considered in the study, as defined in the EUNIS system.

EUNIS Level 2		EUNIS Level 3	
Code	Name	Code	Name
D1	Raised and blanket bogs	D1.1	Raised bogs
		D1.2	Blanket bogs
D2	Valley mires, poor fens and transition mires	D2.2	Poor fens and soft-water spring mires
E1	Dry grasslands	E1.2	Perennial calcareous grassland and basic steppes
		E1.7	Closed non-Mediterranean dry acid and neutral grassland
		E1.9	Open non-Mediterranean dry acid and neutral grassland, including inland dune grassland
E2	Mesic grasslands	E2.1	Permanent mesotrophic pastures and aftermath-grazed meadows
		E2.2	Low and medium altitude hay meadows
E3	Seasonally wet and wet grasslands	E3.4	Moist or wet eutrophic and mesotrophic grassland
		E3.5	Moist or wet oligotrophic grassland
F4	Temperate shrub heathland	F4.1	Wet heaths
		F4.2	Dry heaths

The original aim in collecting the NVC dataset was to sample from the full range of British habitats, and examples were recorded from protected sites including some of the best examples of particular habitat types, as well as from more agriculturally improved sites. This made the dataset particularly useful for our purposes. When assessing the correlations between the mean ranking assigned to habitat examples by habitat specialists and rankings derived using different algorithms, it is important to sample the upper and lower ends of the habitat quality range. These examples have stronger leverage, i.e. they affect the correlation more than do examples from the middle of the range. For this reason, we adopted a stratified random sampling scheme to choose examples from the set available for a given habitat. For this stratification, a preliminary metric was calculated, using two measures that it was thought might be related to habitat specialists' criteria. The species-richness of each example was determined, and assigned a rank-score. The geographical scarcity (proportion of UK hectads where the species occurs) of the most scarce species in the example was also determined, and assigned a rank-score. These rank-scores were both normalised to values in the range 0 – 1, and the sum of these two values calculated as the preliminary metric. The habitat examples were then ordered according to this preliminary metric, and one example was chosen from each of 12 strata.

The degree of correlation between the quality ranking given to the examples by the habitat specialists and the ranking according to calculated metrics was used to assess these calculated metrics. Correlation was assessed using Kendall's Tau.

2.4 Available models

The metric must be able to be calculated from the outputs produced by the current generation of soil-vegetation models that are being applied to assess air pollution impacts. These models have been developed by different groups across Europe, and have been applied mainly within their country of origin, although there are increasing efforts by some groups to develop and apply their models elsewhere. All the models predict effects of N (and other drivers, including sulphur pollution) on the biogeochemistry of soil and vegetation. However, while soil pH can be related to habitat quality in a relatively straightforward way, biogeochemical outputs related to N availability are less obviously related to conventional measures of habitat quality. The dynamic biogeochemical models have therefore been chained to models of floristic response, i.e. the likely composition of vegetation in terms of species. In principle these floristic models could each be driven using several of the available biogeochemical models. In the current study we focus on the outputs from the floristic models.

In this section we firstly describe the main types of model that have been developed, and then recommend a model and provide justification for this choice. This choice imposes some constraints on the types of metric that can be calculated from the model outputs. However, when considering potential metrics we also assessed those requiring other model outputs, since if there was a strong recommendation that other types of output were necessary to assess habitat quality, it would be possible to apply alternative models.

2.4.1 Types of model

Models predicting habitat suitability for individual species (MOVE, MultiMOVE, PROPS)

This class of models is highly empirical, i.e. based on observations, since the models are obtained by statistical analysis of a species' prevalence in relation to several environmental gradients. Some of these gradients are defined using direct measurements or climatic datasets, and some are defined using mean values of plant traits such as 'Ellenberg N'. Since the publication of the original MOVE model (Latour and Reiling, 1993), developments in the UK led to the similar GBMOVE model (Smart et al., 2010), and more recently to MultiMOVE (Henrys et al., in prep) in which niche models were obtained for 1217 UK plant and lichen species by averaging fits from an ensemble of statistical models.

The PROPS model is being developed from large European floristic datasets including UK datasets. The intention is to develop models for species with ranges that extend beyond the Netherlands, and to assess species occurrence in relation to direct physical measurements without using trait-means. Wieger Wamelink and the other PROPS developers advocate this approach to reduce the uncertainty involved with translating from biophysical measures to trait-means. However, it has some disadvantages. Training datasets that lack biophysical measurements alongside floristic data cannot be used for model-building, and most floristic datasets are of this type. More seriously in relation to N effects work, there is no standardised method for measuring N availability in soil, and so in PROPS prevalence is related to the sum of estimated N deposition and modelled N availability, which reduces the empirical basis for the model.

Models predicting cover of individual species (VEG)

The VEG model works in a different way to the above models. The environmental preferences for each species are related to current conditions to determine the 'competitive strength' of the species. The actual cover of each species in a given year depends on the outcome of dynamic competition among all the species. This approach allows simulation of 'biological delays' to impacts and recovery. However, attempts to relate cover of UK species to habitat suitability have shown weak relationships. Some species never occur at high cover values even when the habitat is highly suitable. Conversely, species that are sometimes dominant can also occur at only low cover values, even when the site is highly suitable for them. Predicting cover is inevitably less certain than predicting occurrence. Although some evidence has been presented for Swedish situations that VEG predictions of species cover match observations (Sverdrup et al., 2007), attempts to apply the model beyond its original range have been less successful. The model is most accurate at simulating interactions among a relatively small set of species, and the developers advocate using species to represent types or growth-forms. Such an approach should be applied with caution, since superficially similar species, such as different *Sphagna*, can have very different environmental requirements.

Models predicting 'Biodiversity value' (NTM)

The NTM model directly predicts biodiversity value, as a function of site environmental conditions such as vegetation height, soil pH and soil fertility. The model was calibrated for the Netherlands by assigning biodiversity values to particular vegetation types. Similar relationships could be derived for the UK, in that low-fertility, higher-pH habitats tend support more species than relatively eutrophic, acid habitats. However, some neutral and acid habitats are assigned high value in the UK, and conservation priorities are not identical.

Models predicting suitability of the habitat for phytosociologically-defined plant communities (BERN)

The model applied by the National Focal Centre for Germany, BERN, is essentially a niche model in which environmental suitability is related to several environmental axes. Suitability for plant communities, rather than individual species, is predicted. Niches for communities can generally be defined more tightly than niches for species, since the conditions for co-occurrence of the component species are more constrained. Objections to this approach are based on the view long-prevalent in the UK that species are affected individually by the environment, and species-assemblages result from the totality of these influences. This contrasts with the phytosociological view that a set or community of species forms a harmonious unit that is acted on collectively by the environment. A more pragmatic objection is that actual species-assemblages inevitably differ from a standard community description, which introduces extra uncertainty.

2.4.2 Choice of model

For calculating example metrics, it is necessary to make a choice from the models that could potentially be applied to simulate N effects on UK habitats, as outlined in the previous section.

The NTM and BERN models are based on habitat quality criteria used in the Netherlands and Germany. The NTM model depends on establishing direct relationships between environmental conditions and biodiversity value. As noted above, such relationships can be nuanced, and considerable new research would have to be done to establish functions that could be used. The BERN model is based on concepts such as the harmonious plant community, and would not easily be adapted to UK criteria.

The VEG model has the great advantage of predicting abundance (cover) of plant species rather than prevalence or habitat-suitability. Cover proportion, particularly of species-groups such as ericoid subshrubs, is widely used in conservation assessment and appears frequently in Common Standards Monitoring (CSM) guidance. However, little evidence is available that VEG predictions of cover are reliable, particularly for areas beyond the region (Sweden) where the model was developed. Also, since there is a limit to the number of species that can simultaneously be modelled, it is necessary to use species to represent species-types, for example using the preferences of *Calluna* to predict responses of all ericoid subshrubs. The model has potential to be applied in the UK, and some progress has been made in establishing VEG response functions for UK species, but it is unlikely that model outputs would be available in time to meet the Call for Data.

Models trained on species prevalence data and therefore predicting habitat suitability (but not abundance) for individual species are thought to be more reliable. The current versions of these models (PROPS and MultiMOVE) have been developed in parallel and with considerable discussion between the teams of developers. It is difficult to make an impartial choice of model since several of the authors of this report have been involved in developing of MultiMOVE. Nevertheless, we are confident that MultiMOVE is the most suitable model currently available for predicting responses of the UK flora to N deposition. This is because MultiMOVE:

- Was trained on UK floristic data
- Predicts habitat-suitability rather than attempting to predict cover
- Includes models for a substantial proportion of UK plant and lichen species

However, it is important to recognise the constraints that this choice imposes, as will now be discussed.

The MultiMOVE model does not predict the abundance (i.e. cover) of species, but only the suitability of the habitat for the species. This is because it is trained on prevalence data, and as noted above there seems to be a rather weak association between prevalence and cover. Although work is continuing to try to resolve these issues and generate cover predictions, it is doubtful whether this will result in a predictive model in the near future and in time to meet the Call for Data.

Although many UK plant and lichen species are included in MultiMOVE, many are not. Niche models are only reliable when sufficient observations are included in the training data, and those species with < 12 observations in the floristic datasets were automatically excluded. This means that models are less likely to be available for scarce species. Also, species with predominantly coastal distributions, where salinity is likely to be a key control, were excluded. There has been some work on developing niche models for scarce species, and current work at the Centre for Ecology and Hydrology under the 'Resilience' project aims to fill the gap for coastal species. However, in the near term only the 1217 species currently included in MultiMOVE can be used for metric calculation. This set includes many species that are used in habitat monitoring, but model outputs will not be available for the more scarce species.

In conclusion, choosing the MultiMOVE model makes it impossible to generate habitat quality metrics that are based on the cover of species or species-groups, such as grass/forb cover ratio; and habitat quality metrics that are based on the suitability of the habitat for very scarce species. These disadvantages must be set against the relatively high degree of confidence with which habitat suitability can be generated for 1217 species, and the inclusion within this set of many of the species that are currently used for monitoring habitat condition.

2.5 Potential habitat quality metrics

The aim of the current study was to establish a method for calculating a metric of habitat quality that reflects the views of habitat specialists. Many different methods for calculating such a metric have been proposed, and we attempted to include the full range of methods in the assessment. Although some methods would be difficult or impossible to apply to metric calculation from currently-available model outputs, it was thought important to assess these as well, as they might lead to recommendations for model development. In this section we provide a summary of the reasoning behind different approaches, and outline methods used to calculate metrics using each approach. For some approaches, several distinct methods for calculating metrics may be appropriate.

The main methodology used for monitoring the condition of designated sites in the UK is described in a series of documents known as the Common Standards Monitoring (CSM) guidance, and we have made use of this guidance in developing several of the metrics. It should be noted that the CSM guidance was designed for rapid site assessment by surveyors without specialist taxonomic skills.

Also, impacts of N on habitats were not widely appreciated at the time the guidance was developed, so specific methods for monitoring for N impacts were not included.

The documents include guidance on the features of a site to be monitored, definition of conservation objectives, and how to judge the condition of the interest features (JNCC, 2004c). Features of interest may include scarce species, as described in the guidance for vascular plants (JNCC, 2004b) and for bryophytes and lichens (JNCC, 2005). However, models that predict floristic change do not currently include scarce species. Also, the CSM guidance for species is not clearly related to particular habitats. These sections are therefore of limited relevance for the current study. Metrics derived from model outputs are likely to be more easily related to the CSM guidance for habitats, which is set out in the sections on lowland grassland (JNCC, 2004a), lowland wetland (JNCC, 2009b), lowland heathland (JNCC, 2009a), and upland habitats (JNCC, 2006). There is not an exact match between the habitat classes used in CSM and the EUNIS classes for which metrics need to be derived, but CSM guidance for the most relevant class was selected for each EUNIS habitat.

The CSM guidance is based on assessing attributes of habitats. Some of these attributes would be difficult to relate to outputs from current soil-vegetation models used to predict N impacts. These models simulate a point or stand rather than a large area, so attributes related to spatial extent or the pattern of different habitats within an area cannot be predicted. Attributes based on species, whether individual indicator-species or groups of species such as subshrubs or grasses, are more closely related to model outputs. However, many of the models predict likely prevalence or habitat suitability for a species rather than cover. As noted above, the relationship between habitat-suitability and observed cover is weak. Where attributes include cover thresholds, there is little alternative when applying such models to using habitat-suitability as a proxy for cover, but this uncertainty should be borne in mind when assessing metrics derived in this way.

The aspects of CSM guidance most easily interpreted in terms of metrics that can be calculated from the available models are: species-richness; lists of species that indicate favourable or unfavourable habitat condition; and targets for species-groups. As well as these types of indicators we will consider some metrics that are not directly related to CSM guidance, either because they are being considered by other signatory parties to the CLRTAP (scarcity of present species; similarity to a reference assemblage; likely species-composition under future climate) or because they have been shown to be related to N impacts (fertility scores, i.e. 'Ellenberg N', for present species).

For each type of metric, we propose methods for calculation from actual examples of quadrat data. All methods were designed to produce a positive correlation with habitat quality.

2.5.1 Species-richness

Species-richness, or the number of species present within a defined area such as a 2 x 2 m quadrat, is more relevant for some habitats than others. In calcareous and neutral grasslands and certain other habitats, high species-richness is generally considered a positive attribute, although additional species that are invasive or otherwise negative indicators would not be positive. Many acid habitats naturally have few species of flowering plant, and an increase in species-richness in such habitats can imply deteriorating condition. In all habitats there is a range in species-richness even among high-quality examples, for example between different subtypes of the habitat, or across gradients of latitude, altitude or rainfall. Despite these caveats, species-richness is often seen as a positive attribute, and is easy to explain to non-specialists, so it will be considered as a potential metric.

Metric 1: Species-richness. Number of vascular plant, bryophyte and lichen species.

2.5.2 Indicator-species

The CSM guidelines include, for many habitats, lists of indicator species. These are grouped into species whose presence (and sometimes abundance or frequency of occurrence across the site) indicates favourable condition, which we will refer to as positive indicator-species, and species that indicate unfavourable condition, i.e. negative indicator-species. Although positive indicator-species provide the most obvious basis for a metric, it could be argued that negative indicator-species would be more suitable since these are fewer in number and have more consistent traits across habitats.

In all cases we assembled lists of species from the CSM guidance for an appropriate habitat. The CSM guidance used for specific EUNIS Level 3 habitats is outlined in Table 5. Positive and negative indicator-species were selected from the guidance summary for the habitat, from both the text descriptions and lists of indicator species. The species used for each habitat in the study are presented in Appendix 3. For Level 2 habitats, the lists of indicator species for component Level 3 habitats were combined. Some species were excluded since they appeared as both positive and negative indicators for different sub-types of the habitat in question.

Table 5. Common Standards Monitoring Guidance referred to for specific EUNIS classes

EUNIS	EUNIS class	CSM guidance used	Notes
D1.1	Raised bogs	Lowland wetlands (Table 3 Lowland raised bog and lowland blanket bog). Upland Habitats (Table 14.6 Blanket bog and valley bog – upland).	*Cirsium vulgare* and *C. arvense*, included as negative indicators, but not scarcer *Cirsium* species. *Sphagnum recurvum* not included as an indicator. *Cladonia* spp. included as positive indicators to represent non-crustose lichens. Pleurocarpous mosses not included since suitable species are not defined.
D1.2	Blanket bogs	No specific relevant guidance.	
E1.2	Perennial calcareous grassland and basic steppes	Upland Habitats: (Table 14.8 Calcareous grassland – upland). Lowland grassland (Table 4 Lowland calcareous grasslands).	“Fern species excluding bracken” were not included. It would probably be appropriate to reduce the list of *Carex* species used as positive indicator-species to only those found in dry calcareous sites, e.g. based on Ellenberg scores.
E1.7	Closed non-Mediterranean dry acid and neutral grassland	Upland Habitats: (Table 14.1 Acid grassland – upland). Lowland grassland (Table 3 Lowland dry acid grasslands).	Upland guidance indicates that >10% cover should be of forbs, but the specific species are not indicated.
E1.9	Open non-Mediterranean dry acid and neutral grassland, including inland dune grassland	No specific relevant CSM guidance.	

EUNIS	EUNIS class	CSM guidance used	Notes
E2.1	Permanent mesotrophic pastures and aftermath-grazed meadows	Lowland grassland (Table 2 Lowland meadows and upland hay meadows).	All orchids listed in PlantAtt included.
E2.2	Low and medium altitude hay meadows	As above.	As above
E3.4	Moist or wet eutrophic and mesotrophic grassland	Lowland grassland (Table 5 lowland purple moor grass and rush pastures).	*Molinia caerulea*, *Juncus effusus*, *J. conglomeratus* and *J. inflexus*, although characteristic for the habitat, can be over-dominant so were excluded. *Salix repens* was selected as a positive indicator, but other *Salix* species were assumed to be scrub-forming, negative indicators.
E3.5	Moist or wet oligotrophic grassland	As above.	As above
F4.1	Wet heaths	Lowland Heathland (Table 2 Lowland Wet Heath). CSM Guidance for Upland Habitats (14.27 wet heath – upland).	Species excluded since listed as both positive and negative indicators (for different wet heath types): *Carex panicea*; *C. pulicaris*; *Rhynchospora alba*; *Trichophorum cespitosum*. *Cladonia* spp. included as positive indicators to represent non-crustose lichens. Pleurocarpous mosses not included since suitable species are not defined.
F4.2	Dry heaths	Lowland Heathland (Table 1 Lowland Dry Heath). CSM Guidance for Upland Habitats (14.23 Subalpine dry dwarf-shrub heath).	'Desirable species' listed for limestone and dune heaths included, since they are unlikely to be negative condition indicators for other heath types.

We considered three metrics based on indicator-species, based on: positive indicator-species; negative indicator-species; and both sets of indicator species.

Metric 2: Positive indicator-species. Number of positive indicator-species present.

Metric 3: Negative indicator-species. -1 × number of negative indicator-species present.

Metric 4: Positive and negative indicator-species. Number of positive indicator-species present, minus number of negative indicator-species present.

2.5.3 Species-groups

Aspects of habitat structure are often expressed in terms of cover proportion of species-groups, such as grasses, forbs or subshrubs. The percentage cover of subshrubs (ericoids and small leguminous shrubs) is a defining characteristic for heathlands. Grass to forb cover ratio is considered a useful condition measure for grasslands, and has been shown to be increased by N deposition, although it may be difficult to judge reliably in a rapid visual assessment. Grass and forb cover proportions can simply be converted into a cover ratio, but this results in an infinite value for examples with no forbs. We therefore adopted a more mathematically robust measure, which increases with greater forb cover: forb cover / total cover. The presence and cover of *Sphagnum* moss species is a key attribute for bogs.

The habitat examples included cover estimates made using the DOMIN scale. All cover-based metrics were calculated by conversion of DOMIN scores to the midpoint of each DOMIN cover class (Table 6).

Table 6. Assumed cover percentages corresponding to DOMIN scores.

DOMIN	%	DOMIN	%	DOMIN	%	DOMIN	%	DOMIN	%
1	1	3	3	5	18	7	42	9	83
2	2	4	7	6	29.5	8	63	10	95.5

Metric 5: Subshrub cover (heathlands only). Total cover of subshrubs, including *Myrica*, *Ulex minor*, *U. gallii* and all *Genista*, but excluding *Ulex europaeus*, all *Rubus* and all *Salix*.

Metric 6: Forb to total cover ratio (grasslands only). Total cover of forbs (including all herbaceous species of vascular plants, bryophytes and lichens apart from *Graminae*) / Total cover of all species. Forbs were assumed to be all herbs apart from *Graminae*, and included sedges and allies (e.g. *Eriophorum* and *Luzula*), rushes, horsetails and ferns, and partially woody genera such as *Helianthemum* and *Hypericum*. Taxa not included as forbs were grasses, trees, shrubs (including all *Rubus*), subshrubs (including *Myrica*), mosses and lichens.

The metrics of habitat quality being applied in the Netherlands draw heavily on Red List criteria, i.e. the scarcity and rate of decline of species (van Dobben and Wamelink, 2009). Species that are very scarce may form the feature of interest for which a site is designated, and the presence of scarce species is likely to increase the perception of habitat quality. However, the scarcity of such species makes them difficult to use widely in site condition assessment, and they are covered by CSM guidance on vascular plants (JNCC, 2004b) or lichens and bryophytes (JNCC, 2005) rather than guidance on habitat assessment. More seriously for the current study, scarce species are less likely to have MultiMOVE models, since these are only derived when more than 30 occurrence records exist in the training dataset. This bias effectively precludes calculation of metrics related to species scarcity.

2.5.5 Similarity to a reference assemblage

Vegetation science in the UK has relied mainly on an 'individualistic' view of vegetation dynamics, in contrast to the phytosociological approaches often adopted by some other European countries. The concept of the plant community as a unit of natural selection is problematic since there is little evidence that competition processes affect consistent sets of species rather than individual species, and also since assemblages of species are usually unique. However, the National Vegetation Classification (NVC) (Rodwell, 1991-2000) for the UK was developed using objective statistical methods and has proved very useful as a set of standards to which habitat examples can be compared. Extensive use is made of NVC categories for conservation assessment, and the occurrence of some NVC communities or sub-communities is taken to be an indicator of habitat quality in CSM guidance. The similarity of a set of species to a reference assemblage has been proposed as an indicator of habitat quality (Reinds et al., 2012). Important considerations are the choice of reference, and the method used to calculate similarity.

Reference communities recommended by the CCE could be chosen on the basis of similarity to pristine or pre-industrial examples of the habitat (Max Posch, *pers com.*). This similarity may have to be inferred or assumed, since pre-industrial data on vegetation composition are scarce. Typically, examples from the mid to late 20th century from sites that are relatively unpolluted and have received conservation-sensitive management are used as the reference. Those NVC communities that are considered good examples of a habitat might also be appropriate references. To calculate a metric of this type, we identified target NVC communities using correspondences published by the National Biodiversity Network and JNCC (Table 7). There was one exception, due to an apparent error: the correspondence given for E2.2 "Low and medium altitude hay meadows" is the NVC class MG1, which is a grassland type dominated by rank grasses such as *Arrhenatherum elatius*, generally considered to result from too low a management intensity and therefore of limited nature conservation value. The CSM guidance for lowland grassland suggests that NVC communities corresponding to "Lowland meadows and upland hay meadows" are MG3, MG4, MG5 and MG8. Therefore, these NVC communities were assumed to correspond to the EUNIS class E2.2 and the higher-level class E2, and MG1 was deleted from the correspondence list for these EUNIS classes.

Table 7. National Vegetation Classification communities used as references for selected EUNIS classes in the current study.

Code	EUNIS class	Corresponding NVC communities
D1	Raised and blanket bogs	M2, M3, M17, M19, M20, M18, M21
D1.1	Raised bogs	M2, M3, M18, M21
D1.2	Blanket bogs	M17, M19, M20
D2	Valley mires, poor fens and transition mires	M6, M31, M32, M33, M35
D2.2	Poor fens and soft-water spring mires	M6, M31, M32, M33, M35
E1	Dry grasslands	CG1, CG2, CG3, CG4, CG5, CG6, CG7, CG8, CG9, CG10, CG11, U1, U2, U3, U4, U5
E1.2	Perennial calcareous grassland and basic steppes	CG1, CG2, CG3, CG4, CG5, CG6, CG7, CG8, CG9, CG10
E1.7	Closed non-Mediterranean dry acid and neutral grassland	U2, U3, U4, U5, CG11
E1.9	Open non-Mediterranean dry acid and neutral grassland, including inland dune grassland	U1
E2	Mesic grasslands	MG3, MG4, MG5, MG6, MG8*
E2.1	Permanent mesotrophic pastures and aftermath-grazed meadows	MG4, MG5, MG6, MG8
E2.2	Low and medium altitude hay meadows	MG3, MG4, MG5, MG8*

Code	EUNIS class	Corresponding NVC communities
E3	Seasonally wet and wet grasslands	M22, M23, M24, M25, M26, M27, M28, MG9, MG10, MG11, MG12, MG13, OV28, OV29, U6
E3.4	Moist or wet eutrophic and mesotrophic grassland	M22, M23, M27, M28, MG9, MG10, MG11, MG12, MG13, OV28, OV29
E3.5	Moist or wet oligotrophic grassland	M24, M25, M26, U6
F4	Temperate shrub heathland	H1, H2, H3, H4, H5, H6, H7, H8, H9, H10, H12, H16, H18, H19, H20, H21, H22, OV34, M14, M15, M16
F4.1	Wet heaths	M14, M15, M16, H4, H8
F4.2	Dry heaths	H1, H2, H3, H4, H5, H6, H7, H8, H9, H10, H12, H16, H18, H19, H20, H21, H22, OV34

*** MG3, MG4, MG5 and MG8 were substituted for MG1 in these EUNIS classes. See text.**

Similarities of each habitat example to all corresponding NVC types were calculated using the Czekanowski index (Reinds et al., 2012), i.e.

$$CzI = 1 - \frac{\sum_{i=1}^{n} | x_i - y_i |}{\sum_{i=1}^{n} (x_i + y_i)}$$

where xi and yi (i=1,···,n) denote the species abundances in the habitat example (x) and the NVC community (Y). This index lies in the range between 0 and 1, and is 1 if the example and NVC community are identical. The NVC tables include species from a large number of quadrats, and so cannot be taken as indicating species richness likely in a single quadrat. For this reason, pseudo-quadrats were generated for each NVC class for the similarity calculation, as explained in Tipping et al. (2013).

For most EUNIS classes, several corresponding NVC types are listed, and it would be hard to justify selecting one of these as more valuable than another. We therefore applied two methods for calculating the appropriate similarity: the maximum similarity of the example to any corresponding NVC class, and the mean similarity to all corresponding NVC classes.

Metric 8: Similarity to a NVC subcommunity assemblage.
8 a) Maximum Czekanowski similarity to a corresponding NVC community.
8 b) Mean Czekanowski similarity to all corresponding NVC communities.

Plausible scenarios for climate change within the current century include major changes in temperature, precipitation pattern and the frequency of extreme weather events. It has been argued that these changes mean that it will be impossible to preserve habitats as they are, and so that biodiversity targets should be set that take into account these changes. This might mean, for example, accepting that within a grassland, species that are currently near the southern edge of their range will be supplanted by species which are currently typical further south in continental Europe. The FORSAFE-VEG model has been applied to predicting impacts of climate change on species composition, and its developers advocate basing biodiversity targets on the predicted composition when allowing for climate change but assuming that deposition rates of N and S were never elevated above pre-industrial levels. However, large uncertainties must be attached to such predictions, not least because it is unclear what climatic conditions will prevail after climate changes have stabilised. Although the effects of climate change are likely to be increasingly taken into account when determining nature conservation priorities and targets, methods and scenarios for this have not yet been fully developed. It was therefore decided not to include a habitat quality metric based on future climate in the current study.

2.5.7 Fertility scores (Ellenberg N) for present species

Scores have been assigned to UK vascular plants and bryophytes according to where they are likely to occur in relation to different environmental axes. Although these scores were derived algorithmically from UK occurrence data by Mark Hill and colleagues (Hill et al., 2007; Hill et al., 2004) they are still referred to as 'Ellenberg' scores after the originator of this system. The most relevant score for this study is that representing an axis of fertility or plant productivity, the Ellenberg N score. The mean value for present species of this score has been shown to respond to the rate of N deposition (Emmett et al., 2011).

Metric 9: Ellenberg N score. Mean Ellenberg N score for plant species present, not cover-weighted.

2.6 Assessing approaches taken by other signatory parties

All 23 National Focal Centres for signatory parties to the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP), and representatives of three associated parties, were contacted by email in July 2013 to request information on the metric they intend to apply for the Call For Data 2012-2014. A summary of responses is presented in section 3.4.

3. Results

3.1 Qualitative analysis of interview responses

In this section, the habitat specialists' responses are summarised under the pre-defined topic headings (see Table 2). For each sub-topic, example quotations are tabulated, and comments have been added to these tables to summarise the responses. A more extensive summary of the interview responses is provided in Appendix 1.

T1 Main features of habitat quality

Habitat specialists were asked to describe the main features that are looked for when assessing habitat quality. Results are summarised in Table 8.

Table 8. Key themes emerging from habitat specialist consultations in relation to Topic 1, Habitat Quality *(Example question: What are the main features you look for in assessing habitat quality?)*

Themes	Comments	Example quotations
Combination of features (T1.a)	A combination of features is often used to assess habitat quality – such as species extent and composition, vegetation and habitat structure, and management impacts.	*"Species composition would be the most obvious one, both in terms of species that are there and species that aren't, relative proportions of those species… And broadly, the impacts of land management would be probably the other major area I can think of to determine condition."* ***I4 Heaths, Wetlands, Grasslands [Scotland]*** *"The first things we'd be looking at are obvious signs of management, as in drainage and burning; then I would look at the amount of heather across the site, the amount of Sphagnums present; cotton-grass; trying to get a feel for the balance between dwarf shrubs and other plants…"* ***I11b Wetlands [England]***
Habitat structure (T1.b)	Habitat structure – such as management impacts, water conditions, depth of peat – can be the key feature of habitat quality assessment. Functionality is also often considered important.	*"So if you come across an area that has quite pronounced humps and hollows and pools, and bog pool complex, that's quite scarce, in NI anyway. And that in itself would certainly merit strong consideration for selection as an ASSI. So surface topography is very important."* ***I9 Wetlands [Northern Ireland]*** *"…it comes back to the functionality of the habitat. If the habitat isn't functioning and in three dimensional way, just a two dimensional approach to looking at it, then you will end up where you just have species disappearing, because you're not taking into account the dynamism of that habitat"* ***I2 Wetlands [Scotland]***

Themes	Comments	Example quotations
Vegetation composition and structure (T1.c)	Vegetation composition and/or structure can be the key feature of habitat quality assessment. Factors considered include the relevance of species assemblages compared to individual species, uniqueness of the vegetation composition, limitations of species richness as a metric, and species acting as a proxy of the environmental conditions.	Structure*: "The [vegetation] structure is one of the important things. …So we don't want to see the whole site very homogeneous looking, mature or degenerate, but a diversity of the stages."* ***I13 Heaths [England]*** Assemblages*: "Generally [we're] not looking for specific species, looking more for diversity of a certain level."* ***I1 Grasslands [Scotland]*** Uniqueness: "*If it's unique – I've never seen something quite like that before, that adds to your conservation value."* ***I8 Grasslands [Wales]*** Species richness: *"...species richness, although it has some value, you have to be cautious, don't you, because it's the kind of individual nature of the species that ultimately matter, rather than the actual number."* ***I10 Grasslands [England]*** Proxy for environmental conditions: *"My view is that the species that we use in CSM should be closer linked to sets of environmental conditions rather than a list of species from the NVC, which can indicate all sorts of things."* ***I12 Wetlands [England]***
Geographical and temporal variability (T1.d)	It can be important to consider geographical and historical variation in habitat quality assessment. Habitats are also often naturally dynamic and therefore quality assessment needs to be flexible.	Geographical variation: *"There would obviously be altitudinal, geographical, bio-geographical differences as well."* ***I4 Heaths, Wetlands, Grasslands [Scotland]*** Temporal variation: *"It will have to quite flexible within that to take into account local variation, and I think that's the thing. It's the flexibility, because one of the things when we are monitoring for example, or designating, we are not at the moment… the way we look is not flexible enough, it's too rigid, it's not dynamic – habitats are dynamic."* ***I2 Wetlands [Scotland]***
Ecosystem services (T1.e)	The provision of ecosystem services, in addition to biodiversity, can be an aspect of habitat quality assessment.	*"If you're faced with choices, and if I was looking at the total peatland resource in Scotland, I would prefer that that total resource had the capacity to deliver a number of key services, of which biodiversity is not necessarily the most important. If I'm looking at individual sites then the biodiversity is important in that it is part of the value of that site to society. But I wouldn't expect all bog or peatlands to have that. The priorities are going to change depending on whether we're talking about the resource as a whole or discrete sites within the resource."* ***I3 Wetlands [Scotland]***

Themes	Comments	Example quotations
Applicability and practicality (T1.f)	Common Standards Monitoring (CSM) indicator lists are usually used in habitat quality assessment. However, there are limitations to CSM and lists may be modified for pragmatic and applicability reasons.	CSM limitations: *"That was one of the problems with Common Standards Monitoring, is that we've tried to fit in the whole of the UK into it....It's too broad."* ***I7 Heaths [Wales]*** Modification of indicator lists for applicability reasons: "*When the JNCC Common Standards were published we wrote our own kind of Welsh translation of it, just added a bit more flesh to the bones really, and perhaps made it a little bit less generic."* ***I6 Wetlands [Wales]*** Modification of indicator lists for practical reasons: *"…the lowland grassland [modified indicator species list] was designed it so that the officers could go out and do it in half a day. And you wouldn't find anything too difficult, so there's no grasses for example in the list of positive indicators.*" ***I1 Grasslands [Scotland]***

T2 Value of individual species

Habitat specialists were asked if some species should be valued more than others, to explore the basis for such evaluations. The specialists were also asked whether invasive species should be considered negative *per se*. Results are summarised in Table 9. The term 'invasive species' is a broad term that may encapsulate both non-native and native species that are colonising new localities. Although 'invasive species' are often considered as those having some sort of negative impact, here we use the term in a broad sense to mean species (whether native or non-native) that are 'invading' where they weren't previously present.

Table 9. Key themes emerging from habitat specialist consultations in relation to Topic 2, Species Value ***(Example question: Should more (or less) value be attached to some species than others?)***

Themes	Comments	Example quotations
Structural and functional species (T2.a)	Structurally and functionally significant species can be important for habitat quality, although these may be dynamic or interchangeable . Resilience to climate change is of particular importance.	*"With something like montane heaths, it will be* Racomitrium lanuginosum*, which is almost like a keystone species in that it forms the structure with which other stuff grows and supports, so it's a very important key species."* ***I7 Heaths [Wales]*** *"We see* Sphagnum *as a priority for the accumulation of peat, basically."* ***I11b Wetlands [England]*** *"So a priority for us is that with climate warming we're trying to get bogs to function naturally so they are then more resilient to warming"* ***I11b Wetlands [England]***

Themes	Comments	Example quotations
Scarce species(T2.b)	Scarce species are generally considered to provide added value to a habitat, but are not necessarily an important or an effective way of assessing habitat quality. However, they may be important for site designation.	*"Obviously they are of interest in their own right because they are scarce and we like scarce things…"* ***I12 Wetlands [England]*** *"...generally you're going to think about the habitats, the species that are found in all or most examples of those habitats. That doesn't mean the others aren't important at a local level."* ***I4 Heaths, Wetlands, Grasslands [Scotland]*** *"So if you have a particularly large population of some rare or scarce species, that might qualify, regardless of what the grassland is like."* ***I8 Grasslands [Wales]*** *"And the next thing was that we tried to avoid things which were not particularly common or quite rare, because although they might be telling you that where they occur that that's an absolutely perfect site, because of the hydrology of the soils or whatever is right, they are not very useful in terms of an overall assessment of the condition of a site."* ***I10 Grasslands [England]***
Invasive species (T2.c)	Species invading a habitat (whether non-native or native) are generally not considered negative *per se*, but rather due to high cover and competition with other species, although their impact is not always known. In some cases invasion is considered natural and positive. Pragmatics of being able to remove the species may also influence attitudes.	*"…what is wrong about alien species? The thing that's wrong about them is that they can become invasive and take over from native vegetation. So if they are doing that then that's bad, but if they are not, they're just there at very low cover, then from a vegetation point of view I don't think you'd worry."* ***I8 Grasslands [Wales]*** *"You have to look at the context and the chance of spread. The odd spruce isn't going to do a lot. It's more how the invasive species behaves."* ***I3 Wetlands [Scotland]*** *" if they [species not native to Scotland] are moving in naturally we think of that as a positive thing e.g. the comma butterfly."* ***I1 Grasslands [Scotland]*** *"Other things you're maybe slightly more relaxed about, depending on how much you have of them, and how feasible it is to remove, the desirability of removing them."* ***I9 Grasslands [Northern Ireland]***
Historical context (T2.d)	The historical reference point for habitat conservation can be important, in order to ensure appropriate management goals.	*"...are some of the scarce species typical species which are now scarce because of past management? So, I can think of heathlands in this area, lowland heathland, where we now have very scarce species, but they could be historically quite widespread…. Things like* Viola lactea *… those kind of species, which are associated with a certain set of structures within the heathland. So scarce species can be important because they are actually typical."* ***I5 Heaths [Wales]***
Comparative values of species (T2.e)	Valuing some species more highly than others has challenges and potential conflicts. Society and conservationist may also value species differently.	*"...it's the displacement of those species that we see as more valuable, over those species that tend to become more dominant over the diminutive types of species. So, in some respect we're sort of playing god, by trying to keep that balance…. I think one of the problems occurs when we don't have any control over that, for example diffuse pollution is a massive problem..."* ***I2 Wetlands [Scotland]*** *"The public view of grasslands is not necessarily our view of grasslands."* ***I1 Grasslands [Scotland]***

T3 Plant & lichen indicator-species

Habitat specialists were asked what plant and lichen species would lead them to rank a site as having high or low habitat quality. It is useful here to distinguish 'typical' species that are commonly found in the habitat, from 'distinctive' species that only or mainly occur in the habitat. Typical species are not always distinctive. Results are summarised in Table 10.

Table 10. Key themes emerging from habitat specialist consultations in relation to Topic 3, Plant and Lichen Indicators *(Example question: What types of plant and lichen species would lead you to rank an example as having high/ low habitat quality?)*

Themes	Comments	Example quotations
Characteristics of positive indicator-species (T3a)	Characteristics of positive indicator species include species that are distinctive or typical for the habitat, and those that act as a proxy for good environmental conditions	Distinctive species: *" I suppose we are looking for those particular species which are niche species of that particular habitat"* ***I2 Wetlands [Scotland]*** Distinctive species: *"...the majority of the ones that you would use to infer habitat quality are more or less confined to peatland, so if you've got that then... Like for example* Eriophorum vaginatum*, seems pretty much an obligate indicator of peat at 40cm"* ***I6 Wetlands [Wales]*** Typical species: *"So again, with the Common Standards Monitoring you are looking at a range of associate species, which I suppose we can call typical species, and so that will be grasses, and then some very common species like* Potentilla*, and other common heathland species really. You do expect to see them in the mix."* ***I5 Heaths [Wales]*** Environmental conditions: *"I mean, basically we tried to select those species that are really indicative in telling you the conditions are right for the maintenance of that grassland, so we would not choose, for instance, species which are indicators of semi-improved or eutrophic conditions."* ***I10 Grasslands [England]***
Characteristics of negative indicator-species (T3b)	Characteristics of negative indicator-species include competitiveness, those that act as a proxy for poor environmental conditions, and potentially those that have negative impacts on ecosystem service delivery.	Competitiveness*: "The worst negative indicators are the ones that take up most space.. And then species that react to high nutrient levels ...So it's species that take up space at the expense of a greater variety of non-competitive things."* ***I1 Grasslands [Scotland]*** Environmental conditions*: ""We've got the other group we call the coarse grasses, which would be like Holcus and others like that which just indicate eutrophication."* ***I13 Heaths [England]*** Ecosystem services*: "My slight hesitation is because it, Eriophorum vaginatum, is one of these species that transports methane to the atmosphere. So the fact that we know that it's shunting all this methane up into at the moment is maybe not quite so good."* ***I3 Wetlands [Scotland]***

Themes	Comments	Example quotations
Context of indicator-species (T3c)	Geography, altitude, past management and natural variation in habitats can make it difficult to define positive and negative indicators and suitable species assemblages. The scale at which management takes place may also be of concern.	Geography*: "The difficulty is that peatlands are incredibly variable. In the Grampians you get relatively dry, species-poor bogs. In the west you get wet, species-rich bogs. You still have the same species groups but the balance is quite different"* ***I3 Wetlands [Scotland]*** Geography*: "I think the subshrub depends on where you are, what your soils are, and to a certain extent, past management."* ***I5 Heaths [Wales]*** Scale*: "That's one of the problems when … it gets down smaller and smaller, and micro-management, but really we should be looking at the whole, the ecosystem as a whole."* ***I2 Wetlands [Scotland]***

T4 Taxa other than plants and lichens

Habitat specialists were asked whether habitat quality can be assessed on the basis of presence or abundance of just plants and lichens, and if not, what other taxonomic groups are important– results are summarised in Table 11.

Table 11. Key themes emerging from habitat specialist consultations in relation to Topic 4, Other Taxa (Example question: Can habitat quality be assessed on the basis of presence or abundance of just plants and lichens? If not, what other taxonomic groups are important?)

Themes	Comments	Example quotations
Importance of other taxa (T4a)	Other taxa are important for a habitat, but vegetation is usually the primary focus. However, other taxa can be significant for site designation and may therefore be assessed under some circumstances, often by specialists.	*"So we do have peatlands that are designated for their bird, dragonfly, moth assemblages. These aren't the only things for which they are designated but they are designated features in their own right. So those things are taken into account."* ***I3 Wetlands [Scotland]*** *"… we tend not to [assess other taxa], it tends to be … vegetation, but on sites that are notified for certain species or groups, then obviously they will be assessed." I***12 Wetlands [Wales]** *" If it's an SSSI and it's designated for the habitat and also the birds or invertebrates, then somebody would look at the population trends or there will be some monitoring of other species, but I, or the training I give to the advisors, doesn't include directly the invertebrates or birds. But they are very important."* ***I13 Heaths [England]***

Themes	Comments	Example quotations
Management conflicts (T4b)	There is potential for conflict in managing different types of taxa and maintaining good habitat quality – but often the differences can be accommodated.	*" …occasionally breeding waders and species-rich grassland would potentially have some conflicts, we tend to be able to iron those things out."* ***I9 Grasslands [Northern Ireland]*** *"There's a huge issue in the north in particular, the balance with the amount of red deer we've got."* ***I3 Wetlands [Scotland]*** *"Golden plover and blanket bog is probably the classic example … the issue would be some of the sites where golden plover is a feature, as well as the blanket bog, and to manage the blanket bog for the golden plover would effectively render it unfavourable as far as blanket bog condition is concerned."* ***I9 Wetlands [Northern Ireland]*** *"You can integrate other things. In many cases, it's just a matter of knowing what you've got in a site and what they need, what the species need."* ***I13 Heaths [England]***
Barriers to using other taxa (T4c)	Limitations in resources, skills and knowledge, as well as potentially poor consistency of sightings, act as a barrier to the use of other taxa as habitat quality indicators.	Skills*: "I think that's always the difficulty is getting this balance between the information that you are collecting and the ability for people to collect that information. Ideally what we'd like is the standards to be raised higher so people could go in and identify some of those other species that are relevant and perhaps important, but we don't take account of."* ***I2 Wetlands [Scotland]*** Knowledge: *"You have to know quite a lot about the autecology of a species, I think, before you can start to draw conclusions."* ***I12 Wetlands [England]*** Consistency: *"Again you are dependent on the weather conditions when you go out, it's very much on what we see, so I think all these species they are important but it would be very difficult to record them on a consistent basis".* ***I1 Grasslands [Scotland]***
Proxy indicators for suitability of other taxa (T4d)	Other taxa may be monitored through using habitat structure and vegetation as a proxy.	"*Our role is habitat specialists. And we look at structure, so we look at the height of vegetation, and we look at the ages of ericoids, and we look at bare ground, so you look at elements of the habitat that invertebrates or reptiles might find useful or interesting. But our colleagues would be expected to pick that up."* ***I11a Heaths, Wetlands, Grasslands [England]***

T5 Species-groups

Habitat specialists were asked whether species-groups (e.g. forbs, subshrubs, graminoids, grasses, mosses, *Sphagna*) are useful for assessing habitat quality – results are summarised in Table 12.

Table 12. Key themes emerging from habitat specialist consultations in relation to Topic 5, Species Groups *(Example question: How important is the presence of species-groups, such as forbs, shrubs or ericoids, for assessing the habitat quality?)*

Themes	Comments	Example quotations
Pros and cons of using species-groups (T5a)	Species groups can be useful, particularly for verification and for assessing ecosystem services. However groups may not provide the level of detail necessary for habitat quality assessment.	Verification*: "…it's actually quite a useful check that you've made your original estimation quite good"* ***I9 Wetlands, Heaths [Northern Ireland]*** Level of detail: *"…we've got a lot of H16* Arctostaphylos *heath... we would definitely be thinking about the amount of* Arctostaphylos *that there is in those examples of the habitat, rather than just covering dwarf shrubs, that kind of thing, because it is a distinctive form of dry heath that has particular sets of species so particular management requirements as well."* ***I4 Heaths [Scotland]***
Identifying useful species-groups (T5b)	**(i) Forbs & herbs** – can be useful for grasslands, particularly in borderline cases.	Grassland*: "…on some of the grassland sites some of the primary things we'd be looking at is forb versus grass ratio"* ***I9 Grasslands [Northern Ireland]***
	(ii) Dwarf shrubs, ericoids and graminoids – can be useful for heathlands.	Heaths*: "You could go just in terms of groups if you don't want a full list, which will change a lot from site to site, so just looking at ericoids, graminoids, forbs and yeah non vascular species like mosses, that grouping could be useful."* **I13 Heaths [England]**
	(iii) Lichens and mosses – can be useful for wetlands and heathlands, although species-level observations can be more useful.	Wetlands: *"...in terms of going out and doing the assessment, you might just clock that there's three species [of* Sphagnum*] and in terms of the assessment that's all you need to know, but in a wider sense it's nice to know what the species are."* *I**11b Wetlands [England]*** Heaths*: "I would have thought looking at* Cladonias*, for example, would be quite important. Particularly for the coastal heathlands and the heathlands on things like secondary habitat … the* Cladonias *are really important, so those could be looked at."* ***I5 Heaths [Wales]***

T6. Reference communities

Habitat specialists were asked their opinion on a reference community approach to assessing habitat quality, where a site may be measured against an ideal or target example of the community. Results are summarised in Table 13.

Table 13. Key themes emerging from habitat specialist consultations in relation to Topic 6, Reference Communities *(Example question: What is your opinion of the reference community approach, and how should this reference be chosen?)*

Themes	Comments	Example quotations
Defining a reference community (T6a)	Despite some appeal of the concept, it is difficult to define a reference community, for example by using NVC communities, due to the natural spatial and temporal variation in habitats.	Temporal variation: *"Even change in the short-term, if you go back to the dry heath and the succession of stages, if you look at the species composition and even the presence of species will change over a 20 year cycle. So, as soon as you start thinking about a reference community, you start thinking, well, there are all these exceptions."* ***I4 Heaths, Wetlands [Scotland]*** Spatial variation: *"So I'd certainly be wary of having a single reference point, and saying 'that's the best and everything else should aspire to that, and something at the other end of the country, can't really aspire to be the same'. Something in the east wouldn't necessarily have the same species composition as something in the west. There's sound ecological reasons why it shouldn't have those things."* ***I9 Heaths, Wetlands, Grasslands [Northern Ireland]*** NVC communities: *"...we want a broader view than that, so I don't quite like NVC held up as an example of what a grassland should be."* ***I1 Grasslands [Scotland]***
Potential reference community definitions (T6b)	NVC may be a potential starting point for defining a community, however flexibility for habitat variation still needs to be incorporated. Use of quadrat data is hindered by paucity of records.	NVC: *I think the NVC is probably the closest you're going to get to have something that we all agree on that is relatively close to that single reference point, but around it there needs to be that grey area of a little bit of flexibility as well..."* ***I2 Wetlands [Scotland]*** Quadrat records: *"If you actually had old records for the site and could go back and compare, that would be very useful. I can't think of any instances where you are likely to have good enough old records that you would compare with. That would be useful but impractical."* ***I1 Grasslands [Scotland]***

3.2 Key messages from qualitative analysis

The key messages drawn out from the semi-structured interviews are summarised in Table 14.

Table 14. Key messages from semi-structured interviews.

Theme	Key message
Combination of features (T1a)	Habitat quality is viewed in terms of vegetation composition, but also more holistically as the result of a combination of features, including habitat structure and physical attributes such as water table dynamics.
Habitat structure (T1b)	Structural and functional aspects of habitats, such as water quality and quantity, surface topography, and management impacts, are highly important for wetlands in the assessment of habitat quality, but may also be of increasing importance in the future for

Theme	Key message
	other habitats.
Vegetation composition and structure (T1c)	Vegetation, both in terms of composition and structure, is the dominant factor in habitat quality assessment for grasslands and heathlands. Species assemblages are typically more important for habitat quality assessment than individual species, although both can act as a proxy for environmental conditions.
Geographical and temporal variability (T1d)	Habitat quality assessment may need to reflect geographical differences in condition – whether caused naturally or by historical anthropogenic causes – as well as the temporally dynamic changes that may occur in a habitat.
Ecosystem services (T1e)	Ecosystem services, such as water and climate regulation, have the potential be included as an additional factor to biodiversity conservation objectives in habitat quality assessments.
Applicability and practicality (T1f)	The Common Standards Monitoring guidance acts as the key framework for much of the habitat quality assessment; however, some tailoring of CSM indicator-species lists has improved local applicability and practicality for use by local monitoring officers.
Structural and functional species (T2a)	Species that are structurally or functionally important have particular value, especially in wetland habitats. They may have increasing relevance to other habitats in the face of climate change.
Scarce species (T2b)	Scarce species provide added value to a habitat, and can be important for site designation. However, they are not usually a dominant criterion for assessing habitat quality, in part because they do not occur on enough sites to be widely applicable as indicators.
Invasive species (T2c)	Invasive species, whether native or non-native, are generally considered negative when they out-compete or cause other detrimental impacts to valued native species, rather than being considered negative *per se*. Feasibility of removal, and whether invasion is a natural part of range expansion, are also taken into consideration.
Historical context (T2d)	The historical context of a habitat or a particular site can influence the management goals with regards to species assemblage, potentially resulting in over-valuing or undervaluing species.
Comparative values of species (T2e)	Valuing some species more highly than others has challenges and potential conflicts, for example over which species to conserve.
Characteristics of positive indicator-species (T3a)	Criteria for selecting positive plant and lichen indicators include being distinctive for the habitat, typical for the habitat, or indicating good environmental conditions.
Characteristics of negative indicator-species (T3b)	Negative indicator-species are typically those that out-compete desirable native species, but they also may be those that indicate poor environmental conditions such as heavy grazing and eutrophication. Some species may become negative indicators if they reduce delivery of ecosystem services.
Context of indicator-species (T3c)	The use of species-indicators can be complex and requires flexibility to take into account variation in geographical factors (including scale and altitude), natural habitat variation, and other factors such as past management.
Importance of other taxa (T4a)	Plants and lichens are typically considered more useful for the assessment of habitat quality than other taxa. However, other taxa can be an important feature for site designation, in which case the species will typically be monitored by specialists in those taxa rather than as part of routine habitat quality assessment.
Management conflicts (T4b)	In some cases other taxa require management conditions that are not compatible with high habitat quality; however these different requirements can normally be accommodated, particularly on larger sites.
Barriers to using other taxa (T4c)	There are a number of barriers to using other taxa in habitat quality assessment, including limitations in resources, time, skill, knowledge of species autecology, and consistency of sightings.
Proxy indicators for suitability of other taxa (T4d)	The quality of a habitat with respect to other taxa may be inferred through using environmental conditions, such as habitat structure and vegetation composition, as a proxy.

Theme	Key message
Pros and cons of using species-groups (T5a)	Assessing cover of species-groups can be a useful tool for inferring habitat quality. However, species-groups may not always provide the level of detail necessary, for example for rare sub-communities or as a proxy for environmental conditions.
Identifying useful species-groups (T5b)	Cover of species-groups can be useful in habitat quality assessment, such as forbs, herbs and graminoids for grasslands; dwarf shrubs, graminoids, mosses and lichens for heathlands; and mosses for wetlands, but a group such as 'graminoids' can include negative and positive indicator-species.
Defining a reference community (T6a)	There is considerable variation in the examples of each habitat that are seen as high quality, so it would be very difficult to define a reference community.
Potential reference community definitions (T6b)	The NVC tables, or past records where these exist, could be used to define a reference community at site level, or a set of reference communities covering the variation in high-quality habitat.

3.3 Comparison of specialists' rankings with rankings derived from potential metrics

3.3.1 Habitat specialists' rankings

The habitat specialists were given a choice of sets of examples to rank, so variable numbers of rankings were obtained for the habitat classes (Table 15). Rankings were available for a total of nine habitat-classes. For each set of examples that was ranked, the mean habitat specialists' ranking was calculated, for comparison with rankings derived using different metrics.

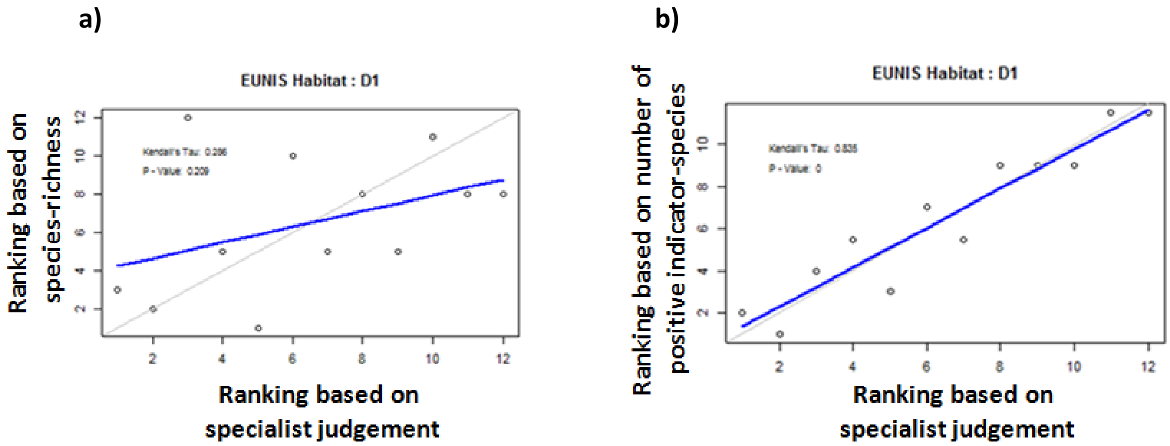
Table 15. Number of rankings obtained for each EUNIS class.

EUNIS Level 2			EUNIS Level 3		
Code	Name	Num	Code	Name	Num
D1	Raised and blanket bogs	3	D1.1	Raised bogs	0
			D1.2	Blanket bogs	1
D2	Valley mires, poor fens and transition mires	1	D2.2	Poor fens and soft-water spring mires	0
E1	Dry grasslands	3	E1.2	Perennial calcareous grassland and basic steppes	0
			E1.7	Closed non-Mediterranean dry acid and neutral grassland	0
			E1.9	Open non-Mediterranean dry acid and neutral grassland, including inland dune grassland	0
E2	Mesic grasslands	2	E2.1	Permanent mesotrophic pastures and aftermath-grazed meadows	0
			E2.2	Low and medium altitude hay meadows	0
E3	Seasonally wet and wet grasslands	2	E3.4	Moist or wet eutrophic and mesotrophic grassland	0
			E3.5	Moist or wet oligotrophic grassland	0
F4	Temperate shrub heathland	5	F4.1	Wet heaths	2
			F4.2	Dry heaths	2

3.3.2 Correlations between habitat specialists' rankings and metric rankings

The rankings of habitat examples provided by the habitat specialists provided parallel evidence to the qualitative analysis presented in the previous section. The specialists' rankings will be referred to as 'habitat quality' in this section, for brevity. The degree of correlation between the ranking of the examples when evaluated using an algorithmic metric, such as species richness, and the ranking of these same examples by a habitat specialist, gives an indication of how similar the algorithm is to the specialist's assessment criteria. For example, assessing examples of "raised and blanket bog" using the number of positive indicator-species resulted in a closer correlation with specialists' rankings than did ranking by species-richness (Figure 2).

Figure 2. Correlations of habitat specialists' rank scores for a set of 12 examples of raised and blanket bog with rank scores based on: a) species richness; and b) number of positive indicator-species.



The overall pattern of correlations with alternative metrics (Table 1; the reader is also encouraged to look at the graphs presented in Appendix 2) corroborated the qualitative analysis, and provided additional information which allows metrics to be assessed.

Table 16. Coefficients for correlations between habitat specialists' rankings of examples of bog (D), grassland (E) and heathland (F) EUNIS classes and rankings based on algorithmic metrics.

Metric	D1	D1.2	D2	E1	E2	E3	F4	F4.1	F4.2
	Correlation coefficient								
SR	0.29^{ns}	0.38^{ns}	0.06^{ns}	0.52^{*}	0.50^{*}	0.80^{***}	0.25^{ns}	0.80^{***}	0.60^{**}
positive spp.	0.85^{***}	0.09^{ns}	n/a	0.72^{***}	0.81^{***}	0.85^{***}	0.61^{**}	0.78^{***}	0.52^{*}
negative spp.	0.13^{ns}	-0.25^{ns}	n/a	-0.18^{ns}	0.32^{ns}	-0.12^{ns}	-0.10^{ns}	-0.35^{ns}	-0.35^{ns}
positive – negative spp.	0.84^{***}	0.04^{ns}	n/a	0.74^{***}	0.66^{**}	0.74^{***}	0.34^{ns}	0.67^{**}	0.55^{*}
Subshrub							0.12^{ns}	0.29^{ns}	0.39^{ns}
Forb/Tot				0.02^{ns}	0.39^{ns}	0.15^{ns}			
Sphagnum	0.53^{*}	0.62^{*}	0.52^{*}						
MaxSimil	0.58^{**}	0.43^{ns}	0.29^{ns}	0.63^{**}	0.48^{*}	0.12^{ns}	0.54^{*}	0.64^{**}	0.08^{ns}
MeanSimil	0.42^{ns}	0.71^{**}	0.29^{ns}	0.53^{*}	0.61^{**}	0.58^{**}	0.30^{ns}	0.63^{**}	0.30^{ns}
Ellenb N	0.49^{*}	0.25^{ns}	0.11^{ns}	0.47^{*}	0.73^{***}	0.36^{ns}	0.63^{**}	0.57^{*}	-0.05^{ns}

SR = Species-richness; positive spp. = number of positive indicator-species; negative spp. = number of negative indicator-species; positive – negative spp. = number of positive indicator-species minus number of negative indicator-species; MaxSimil = greatest Czekanowski similarity to corresponding National Vegetation Classification communities; MaxSimil = mean Czekanowski similarity to corresponding National Vegetation Classification communities. ns = not significant (*P* > 0.05); * = *P* < 0.05; ** = *P* < 0.01; * = *P* < 0.001; blank cells = not applicable to the habitat; n/a = not possible to calculate due to lack of specific corresponding Common Standards Monitoring guidance.**

The number of positive indicator-species, as identified in CSM guidelines, was consistently correlated with habitat quality. For most of the EUNIS classes for which rankings were available, this metric was the most highly correlated. The exception was the D1.2 (blanket bogs) class, where the best metric appeared to be the mean similarity with corresponding NVC communities. However, in this case the reference ranking was provided by one specialist, and the 12 examples were grouped into only four quality classes. This does not seem provide sufficient evidence to justify using an alternative metric for this EUNIS class, particularly since the habitat quality of the higher-level EUNIS Level 2 class (D1 Raised and blanket bogs), based on a larger set of rankings, was best reflected by positive indicator-species.

The number of negative indicator-species was in no case significantly correlated with habitat quality, and, when subtracted from the number of positive indicator-species, mainly decreased the degree of correlation.

Species-richness was significantly associated with habitat quality in grassland habitats and heathlands, although not in bogs. Correlation coefficients were however mainly lower than with positive indicator-species, which probably reflects the positive effect on species-richness of invasive species, which were often considered by the habitat specialists to reduce habitat quality (see section 3.1).

Similarity to reference NVC communities was significantly correlated with habitat quality for most sets of grassland examples and for dry heathland, although not for bogs. In some cases the correlation was closer when using similarity to the most-similar corresponding NVC class, but in some cases the mean similarity to corresponding NVC classes better reflected habitat quality.

Mean 'Ellenberg N' score was also significantly correlated with habitat quality for several EUNIS classes, although not consistently so in bog, heathland or grassland.

In conclusion, the metric which most clearly and consistently reflected the habitat specialists' ranking was the number of positive indicator-species, as listed in CSM guidance.

3.4 Responses from other National Focal Centres

A total of 11 responses were received to the request for information on how National Focal Centres (NFCs) of other signatory parties intend responding to the Call for Data. Responses received from Ireland, Germany, Japan, Poland, Ukraine and Romania stated that discussions in these countries are ongoing. The more detailed responses are summarised in Table 17.

Table 17. Summary of responses to the question of how the Call for Data 2012-14 will be addressed by different National Focal Centres (NFCs).

NFC	Response Summary
Austria	A project has been running since May to apply a range of models (VSD+, Landscape-DNDC, PROPS, VEG and BERN) to about 50 Austrian long-term monitoring sites. Metrics will be discussed when the results of this model intercomparison are available.
Finland	A recent report on metrics of ecosystem services (Kniivilä et al., 2013) includes a description of indicators applicable for monitoring biological diversity. These indicators have been used primarily for the evaluation of the national biodiversity strategy and the Finnish reporting to the Convention on Biological Diversity. So far, nitrogen effects have not been included in Habitats Directive reporting, partly due to the diffculty of distinguishing effects of nitrogen and climate. Finland has not participated in the Atlantic seminars, only in the Boreal seminars, and nitrogen has not been an issue in the Boreal seminars. However, work plans under the International Cooperative Program on Integrated Monitoring include VSD+ vegetation modelling for selected IM sites. Two Finnish sites, Valkea-Kotinen and Hietajärvi, will probably be included. No decision has been made as to what metric will be applied.
France	Have assessed alternative metrics (species-richness; Shannon index; Czekanowski similarity) calculated for 12 ICP-Forest sites. It is not clear what reference was used to calculate Czekanowski similarity. Species-richness and the other metrics were strongly influenced by the species of dominant tree. Species-richness was greater in mixed than in pure tree stands. Species-richness was considered the most promising of these metrics, although the study was only a first step. The VEG model is likely to be applied in meeting the Call for Data.
Netherlands*	- Habitat types (using Dutch classification) have been selected on the basis of a) relevance to Natura2000 and b) sensitivity to N deposition.

NFC	Response Summary
	- For these habitats, lists have been defined of a) 'characteristic and typical' species, and b) 'competitive' species. - Prevalence of these species has been modelled using PROPS, and indicators derived. Promising indicators: a) sum of normalized change of occurrence of typical species; b) relative occurrence of typical and competing species. Less promising: a) indicators based on number of species; b) Simpson Index. A final decision on the habitat quality metric to be used in the Call for Data 2012-14 has not yet been made.
Norway	The focus will be on aquatic ecosystems, as these are most relevant for Norway. A project is exploring indicators of ecological status, and looking for linkages between chemical parameters (pH, ANC, P, N) and changes in species (benthic algae and invertebrates) composition. This will allow assessment of - taxon-specific couplings between nutrient and acidity traits - the degree of consistency between different biotic indices, separately for nutrients and acid conditions - the impact of acidity on nutrient indices, and nutrients on indices of acid conditions
Sweden	The Swedish EPA have decided not to respond to the Call for Data, and instead are reviewing the strategic direction of Critical Loads work. There has been a recent shift in focus from assessing pollution effects on production forests, to looking more at protected sites. There is an ongoing debate about which method for calculating critical loads for N is most likely to lead to emissions cuts. Funding is being sought for a project to examine what data are available for protected areas that might be suitable for calculating critical loads, and comparing these with previously calculated critical loads for forests and lakes.
Switzerland	Only forest sites have been assessed so far. The VEG model, whether driven by the Forsafe or VSD+ biogeochemical model, has not yet produced consistently accurate predictions of vegetation occurrence. Consequently, rather than model individual species it was decided to use species-groups based on nutrient-value-scores, comparable to 'Ellenberg N' scores. Oligotrophic species (with scores of 1 or 2) were defined, and the predicted percentage cover of such species could be used as a habitat quality metric. However, confidence in these predictions is also low, and the use of empirical relationships between nitrogen deposition and either species-richness or occurrence of oligotrophic species is being considered for defining a metric.

* A more detailed description of progress in the Netherlands follows.

For the implementation of the Habitat Directive, the Dutch Ministry of Economic Affairs has characterised habitats in terms of typical species, plant associations and abiotic conditions (http://www.synbiosys.alterra.nl/natura2000). These lists of typical species are used for monitoring habitat quality. The list contains species from a wide range of taxa (e.g. birds, mammals, higher plants, butterflies). Species are often characteristic for a particular habitat type, and more or less restricted to a habitat type. These species are often target species for Dutch nature policy, and were selected because they were rare, had negative trends, or were protected by national or international policies (Bal et al., 2001). Protection of these species largely depends on the protection of the habitat types. Most of the typical species are also Red List species. In addition, indicator species are added which indicate good abiotic or biotic (e.g. vegetation structure) condition.

For vegetation modelling, this list has limited value because the rare species are often difficult to model. The relatively low number of plant species mentioned also limits the possibility to calculate robust biodiversity indicators. However, the link with the Dutch vegetation system in the description of protected habitat types offers another source of plant species which can be used to describe habitat quality. Each habitat type is also characterised in terms of plant associations which should be present when conditions are favourable. The complete species composition of these plant associations are in turn described with the Dutch vegetation database (Hennekens and Schaminee, 2001) and Synbiosys (www.synbiosys.alterra.nl). These plant species can be used to add to the list of typical species. Information on species composition was also used by van Dobben et al (2006) to calculate critical loads of nitrogen for Dutch plant associations. For vegetation modelling, two groups of species were added to the list of typical species:

- Positive indicators of complete plant associations (i.e. species characteristic or restricted to the associations)
- Negative indicators of complete plant associations (i.e. species that are known to increase when the plant associations decrease in quality). This group contains species such as *Deschampsia flexuosa* in heathland and *Juncus effusus* in grassland.

Based on this information, the Dutch NFC is currently aiming to deliver policy-relevant and meaningful biodiversity indicators for 20 habitat types. On average, these have 96 plant species, of which 24 are considered negative indicators, and either 10 (based on Natura 2000 monitoring schemes) or 63 (based on species-associations) are considered positive indicators. Initial calculations were presented in recent CCE reports. Probably the indicator chosen will focus on the (absolute or relative) difference between modelled chances of occurrences of both positive and negative indicator-species.

4. Discussion

In this section, the criteria used to make a final selection of the metric are discussed, and the potential metrics described in Section 2.5 are assessed. A recommendation is made for a metric that reflects these criteria, and can be calculated from the recommended MultiMOVE model. Its advantages and limitations are discussed. The steps necessary to improve and fully operationalise the recommended metric in preparation for meeting the Call for Data in March 2014 are described.

4.1 Criteria for recommending a metric

The responses to the semi-structured interviews form a good basis for assessing the most appropriate metric to be applied in meeting the Call for Data. The interviews were generally open and free-flowing, and the habitat specialists seemed in the main to appreciate the opportunity to discuss the basis for their assessments. The requirement for a habitat quality metric to be applied in the context of air pollution policy was understood. The analysis of interview responses by theme allowed the specialists' priorities to be assessed.

The purpose of ranking examples of each habitat was also understood, and most of the specialists were enthusiastic about this exercise and responded promptly. However, there were some issues with the examples provided, mainly resulting from the automatic assignation to NVC communities. This assignation uses presence and cover data for all the species present in the example, but does not necessarily correspond to criteria used in habitat definition such as having >25% cover of subshrubs. The habitat class to which unusual or intermediate examples are assigned can be somewhat arbitrary. Most sets therefore included examples which the specialists considered not to belong to the EUNIS class in question. Also, several specialists first classified the set into different types, and then ranked each type separately. Despite these difficulties, nearly all rankings were usable in some form.

If a metric recommended in the UK response to the Call for Data has certain characteristics, it is likely to be used in analysis of biodiversity impacts of air pollution at European scale and in integrated effects modelling. The modellers at the CCE envisage a single metric for each habitat (EUNIS Level 3) which varies continuously between a high value for the biodiversity endpoint, i.e. the target, and a low value for a very damaged or degraded example of the habitat. This low value might for instance correspond to the point where a site would no longer be classified as an example of that habitat. If the metrics developed for UK habitats are to be used within the CCE process for dynamic modelling of critical load exceedance and recovery, and integrated assessment, these metrics must take this form, i.e. have a single dimension.

Somewhere along the line between the biodiversity endpoint and the damaged or degraded example, a threshold value below which the habitat is seen as damaged and above which it is undamaged or recovered may need to be defined, although this is not required for the current Call for Data. For individual species, thresholds for their likely occurrence can be estimated as the lowest habitat-suitability at which the species has been observed. This could form the basis of automated threshold-setting for metrics derived from species-level predictions. Such an approach would introduce uncertainty, however, and it may be more appropriate to define damage thresholds using expert judgment, or by calculating values of the metric for real examples of the habitat that have borderline favourable condition. The ease with which a damage/recovery threshold can be defined could be considered when selecting a metric, but this criterion was not included in the overall assessment.

In summary, the criteria used to make a final metric selection were:

- Correspondence with key methods for site condition assessment as identified in the interviews with habitat specialists.
- Correlation of ranking of habitat examples determined using the metric with ranking by habitat specialists.
- Feasibility of calculation using currently-available soil-vegetation models, in particular MultiMOVE.

The potential metrics are assessed according to these criteria in Table 18. All of these metrics satisfy the condition of having a single dimension.

Table 18. Assessment of potential metrics against selection criteria.

Potential metric	Correspondence with interview responses	Correlated habitats*	Feasibility of calculation from MultiMOVE outputs
1.Species-richness	Good for calcareous grassland, neutral grassland and possibly fen meadows / rush pastures. Less applicable to other habitats.	5 of 9	Theoretically possible, although method using MultiMOVE has not been tested
2. Positive indicator-species	Very good for all habitats, using species listed in CSM guidance	7 of 8	Easily calculated
3. Negative indicator-species	Good for all habitats, although perhaps less important than positive indicators	0 of 8	Easily calculated
4. Positive and negative indicator-species	Excellent for all habitats, since positive and negative indicators cover different aspects of habitat quality	6 of 8	Easily calculated
5. Subshrub cover	Very good for heathland; also relevant for bogs and grasslands, as maximum cover values.	0 of 3	Could be estimated, although habitat-suitability does not accurately reflect cover
6. Forb to total cover ratio	Very good for grassland, except acid grassland and fen meadows / rush pastures.	0 of 3	Could be estimated, although habitat-suitability does not accurately reflect cover
7. *Sphagnum* cover	Very good for bog, although eutrophic *Sphagna* should be excluded	3 of 3	Could be estimated, although habitat-suitability does not accurately reflect cover
8.a) Maximum similarity to reference assemblages	Very little correspondence	5 of 9	Could be estimated, using habitat-suitability as a proxy for prevalence.
8.a) Mean similarity to reference assemblages	As above	5 of 9	As above
9. Ellenberg N score	Some correspondence with the general categorisation of oligotrophic species as positive indicators	5 of 9	Easily calculated

*** Number of habitats for which rankings of habitat examples using the metric was significantly correlated with rankings by habitat specialists.**

4.2 Recommended metric – conclusions and limitations

It is now possible to make some recommendations as to the most suitable metric of habitat quality for use in this context, based on the interview responses and results of the ranking exercise, as summarised in Table 18.

Species richness is an appealing indicator, being clearly related to public perceptions of biodiversity value. However, an increase in species richness may reflect the invasion of atypical species, and this concern emerged frequently in the interviews, particularly when discussing bogs and heaths. Also, although correlative relationships have been established between for example species richness in grasslands and current N deposition (Stevens et al., 2004), there is currently a lack of models capable of predicting species richness in response to the dynamics of delays to damage and recovery. Species richness is potentially a suitable indicator for some habitats, if capacity to predict its changes in species richness is developed. However, it will not be applicable to other habitats, so species richness is not recommended as a suitable metric.

Metrics based on similarity to a reference assemblage were generally rejected by the specialists, mostly on the basis that there was too much variation in what is considered an ideal or target species composition for a particular habitat class. Despite this concern, rankings based on similarity to a reference were well-correlated with specialists' rankings for some of the habitats, such as E1 'Dry grassland' and F4.1 'Wet temperate shrub heathland' (Table 16). This correlation was somewhat erratic, however, for example there was no significant correlation when considering examples of F4.2 'Dry temperate shrub heathland'. For this reason, and since the specialists were not positive, this metric is not recommended.

Rankings based on mean fertility score (Ellenberg N) for species present in the example were also correlated with specialists rankings only for some habitats. There was little discernable pattern – for example, the correlation was marginal for E1 'Dry grasslands', clear for E2 'Mesic grasslands' and absent for E3 'Seasonally wet and wet grasslands'. This, together with the lack of widespread familiarity with Ellenberg N scores, led us to reject calculation of a metric based on Ellenberg N scores.

The cover of functionally important groups (forbs for grasslands, *Sphagnum* species for bogs, and subshrubs for heathland) was highlighted as an important factor by many of the specialists. However, rankings based on the total cover of these functionally important groups did not correspond to the specialists rankings, with the exception of *Sphagnum* cover for bogs. A habitat quality metric for bogs could be developed on the basis of *Sphagnum* cover, but given the difficulties with predicting cover (as opposed to habitat suitability) and the unsuitability of this metric for other habitats, metrics of this type are not currently recommended.

Negative indicator-species were discussed in many of the interviews, and were commonly seen as potential indicators of poor site conditions rather than being necessarily damaging in their own right. Although this emphasis might imply that such species are important for assessing habitat quality, there was no correlation between the number of negative indicator-species in the examples and the specialists' rankings. Also, it would probably be difficult to select negative indicator-species for use in an overall quality metric. There are many species that could indicate atypical site conditions – arguably, all species that are non-typical for the habitat. Conversely, some species are invasive precisely because they are well-suited to the environmental conditions typical for the habitat. For example, *Rhododendron ponticum* invades wet heaths not because they are degraded but because the environment is similar to that occupied by *R. ponticum* in its native range. A decrease in habitat suitability for such species is likely to coincide with worsening environmental conditions for target species for the habitat.

The specialists referred frequently and favourably to positive indicator-species as defined in the Common Standards Monitoring guidance. A metric based on the number of positive indicator-species gave the most consistently correlation with the specialists' rankings. Including negative indicator-species in the metric calculation worsened the correlations, presumably for the reasons outlined in the previous paragraph. Positive indicator-species were selected for inclusion in the CSM guidance on the basis that they are typical for the habitat and indicate favourable site conditions. This explains why their occurrence discriminates well the habitat quality of the examples. For this reason, and because niche models are available for most of these species, we recommend that the metric is based on occurrence of positive indicator-species.

Although the best approach currently appears to be to base the habitat quality metric on a list of positive indicator-species, the technical and pragmatic limitations of such an approach should be noted. These include:

- **Definition of positive indicator-species**. The species lists in CSM guidance have some ambiguities, in particular when groups of species are used as indicators. A group such as bryophytes, *Carex* or *Sphagnum* encompasses species with a large range of environmental requirements. The judgements made in section 2.5.2 about which species to include were made to the best of our ability, but have not been reviewed and agreed by specialists. There is ongoing work at JNCC to revise the lists of positive-indicator species for UK Priority Habitats, but this may not be resolved in time to meet the Call for Data. Whatever list is used, it will be subject to revision.
- **Habitat classification**. The CSM guidance relates to habitats defined according to the 'Guidelines for selection of biological SSSIs' (NCC, 1989), whereas the Call for Data response must be related to EUNIS categories.
- **Available niche models.** Niche models such as MultiMOVE or PROPS cover only a subset of UK species, and some indicator-species may not be included.
- **Aggregation method.** The value of a metric aggregated from the habitat suitabilities (HS) for a set of species will depend on the number of species included and the aggregation method, such as arithmetic or geometric mean, or the number of species with HS above a threshold value. The number of positive indicator-species varies among habitats, and if geographic filtering is applied (to exclude species for which the site is unsuitable due to climate; see section 4.3) this could also change the number of species. Typical values for habitat suitability vary among species. These issues are discussed in section 4.3, but further work is required to explore the sensitivity of metric values to the number and identity of the species included.

4.3 Development of a model-derived metric

If the recommended metric(s) are to be worked up as examples in time for the UK response to the Call for Data in March 2014, it will be necessary to base them on outputs from soil-vegetation models that can readily be applied to the UK. As discussed in Section 2.4, MultiMOVE is the model that has been most extensively applied in the UK, and is probably the most appropriate of those available. This model predicts habitat-suitability for particular species, and metrics that can be directly or indirectly calculated from these suitabilities are likely to be more practicable to calculate within the time available.

To help illustrate model outputs and potential derived metrics, the MultiMOVE model was applied to three sites representing the main habitat classes addressed in the study: bog, grassland and heathland. These sites consisted of 1 km squares selected from the Countryside Survey dataset on the basis that most of the individual plots assessed within the square had been assigned to a single habitat class. Key attributes of these sites, including those used as MultiMOVE inputs, are presented in Table 19. Only approximate locations are given since Countryside Survey locations are withheld.

Table 19. Attributes of locations where the MultiMOVE model was applied.

Broad Habitat	Location	July Max °C	January Min °C	Precip (mm)	EbR	EbN	EbF	GHeight
Neutral grassland	Lancashire	21.0	-4.6	884	5.2	4.6	5.8	2.8
Bog	Isle of Lewis	18.3	-1.6	2083	3.2	1.8	7.6	3.0
Heathland	North Yorkshire	19.5	-5.4	1017	2.7	2.2	6.7	3.6

Precip = annual precipitation; EbR = mean Ellenberg 'reaction' score for present species, reflecting soil pH; EbN = mean Ellenberg 'fertility' score; EbF = mean Ellenberg 'wetness' score; GHeight = mean Grime height score.

These attributes were used to generate habitat suitabilities (HS) at each site for the 1217 species for which MultiMOVE niches are based on >12 occurrences. The 'raw' HS values predicted by MultiMOVE are not directly comparable, since they are strongly dependent on the prevalence of the species within the training dataset. This issue can be overcome simply by dividing raw HS by the proportional prevalence (Albert and Thuiller, 2008), resulting in a rescaled habitat suitability, HSR. Results presented in the current study are based on these rescaled habitat suitabilities.

The HSR values as predicted by MultiMOVE for bog, neutral grassland and heathland sites are shown in Table 20, for the 24 species in each habitat that had the greatest HSR values. A filter was applied to exclude those vascular plant and bryophyte species that have not previously been recorded in the geographical area, defined as the vice-county in which the site occurred. In fact, only either zero or one species was filtered from the list for each site due to this criterion. Most of the species in each habitat list seem well-suited to the habitat at the geographical location in question. For example, the bog list includes such typical Hebridean bog species as *Campylopus atrovirens*, *Drosera longifolia* and *Carex pauciflora*. The mean and maximum values for HSR differed among the habitat types, due to the different numbers of examples from each habitat included in the training dataset, and/or the degree of specificity of the species for the habitat.

Table 20. The 24 species with greatest rescaled habitat suitability (HSR) as predicted by MultiMOVE, in Bog, Neutral grassland and Heathland habitat examples. The HSR value is shown for each species.

Bog (Isle of Lewis)					
Campylopus setifolius	51.8	*Myrica gale*	10.6	*Sphagnum auriculatum var.auriculatum*	8.7
Erophila glabrescens	28.4	*Carex pauciflora*	10.4	*Sphagnum palustre*	8.4
Campylopus atrovirens	21.1	*Pinguicula lusitanica*	10.3	*Menyanthes trifoliata*	8.2
Drosera intermedia	20.9	*Sphagnum imbricatum*	9.6	*Polygala oxyptera*	8.0
Pleurozia purpurea	19.9	*Carex limosa*	9.1	*Narthecium ossifragum*	7.7
Drosera longifolia	18.9	*Juncus cf. acutiflorus*	9.0	*Pedicularis palustris*	7.7
Breutelia chrysocoma	14.8	*Sphagnum auriculatum var.inundatum*	8.9	*Sphagnum tenellum*	7.2
Drosera rotundifolia	13.4	*Schoenus nigricans*	8.8	*Sphagnum compactum*	7.2

Neutral grassland (Lancashire)					
Geranium sylvaticum	10.7	*Rumex acetosa*	3.8	*Lotus pedunculatus*	3.0
Epilobium obscurum	7.0	*Ajuga reptans*	3.8	*Epilobium palustre*	2.9
Deschampsia cespitosa	6.3	*Achillea ptarmica*	3.7	*Eurhynchium striatum*	2.9
Holcus mollis	5.6	*Carex ovalis*	3.6	*Juncus effusus*	2.7
Cytisus scoparius	4.2	*Lathyrus pratensis*	3.6	*Viola riviniana*	2.7
Stellaria graminea	4.1	*Cirriphyllum piliferum*	3.3	*Plagiochila porelloides*	2.6
Cirsium palustre	4.0	*Vicia sepium*	3.2	*Poa pratensis sens.lat.*	2.6
Epilobium montanum	3.8	*Stellaria uliginosa*	3.0	*Geum rivale*	2.6
Heath (Yorkshire)					
Cladonia cornuta	9.7	*Listera cordata*	3.4	*Sphagnum palustre*	2.9
Genista anglica	9.6	*Plagiothecium undulatum*	3.3	*Cladonia floerkeana*	2.8
Juniperus communis	4.3	*Kurzia trichoclados*	3.3	*Sphagnum capillifolium*	2.8
Trientalis europaea	4.0	*Vaccinium myrtillus*	3.2	*Juncus cf. acutiflorus*	2.7
Calypogeia muelleriana	3.9	*Cladonia deformis*	3.1	*Deschampsia flexuosa*	2.7
Sphagnum recurvum	3.6	*Calluna vulgaris*	3.1	*Sphagnum girgensohnii*	2.7
Eriophorum vaginatum	3.5	*Sphagnum compactum*	2.9	*Cladonia digitata*	2.6
Aulacomnium palustre	3.5	*Polytrichum commune*	2.9	*Pleurozium schreberi*	2.6

The presence of some rather scarce species in these lists reflects rescaling by prevalence – the HSR value is a measure of the suitability of the site for the species, rather than likelihood of occurrence. This list includes one species that is atypical for the habitat (*Erophila glabrescens*, in bog, when this species is more typically found in open habitats on mineral soils). This suggests that there may be an issue with the model for this species. However, the predominance of species that would be considered typical for each habitat example gives confidence that the HSR values are comparable among species.

Some of the metrics outlined in Section 2.5 cannot currently be generated from MultiMOVE outputs, in particular those based on species cover. Although in principle the sum of habitat suitabilities for all species corresponds to a prediction of species richness, this prediction has not been tested, and a prediction of species richness was not made.

Several of the outlined metrics are based on the set of species that occur on a site, and for such metrics it would be necessary to interpret the set of MultiMOVE outputs in terms of a likely set of species. One approach would be to include all species for which HSR is above the threshold value at which they have been observed to occur. This approach has been explored by calculating the habitat suitability for each species at all Countryside Survey plots. In practice, the minimum value at which each species was observed does not seem well-related to the occurrence of species, since when suitabilities are calculated for a site, very many atypical species are found to be above their threshold. This is presumably due to the large number of reasons why a site can be unsuitable for a given species. Another approach would be to choose the set of species with the greatest HSR values, as for example in Table 20. This might result in a useful species set, although species do not necessarily occur even on highly suitable sites since occurrence is also controlled by dispersal and extinction rates and by presence in the local species-pool. Large HSR values do however provide a good indication that the species could occur and that the site is suitable. The list could be cut at a point corresponding to the likely number of species for the habitat.

Metrics that could be derived from an artificial species list, generated as described above, include:

- Number of positive indicator-species

- Number of negative indicator-species × -1
- Number of positive indicator-species minus number of negative indicator-species
- Mean Ellenberg N score

The number of positive indicator-species present would conform closely to the best metric as determined from the consultation, and would be fairly comparable among habitats, since it is based on relative rather than absolute values of HSR. However, such a metric has the disadvantage that it is discontinuous. This would the metric unresponsive to marginal changes in N deposition, and subject to abrupt change as the HSR value for sets of species surpassed those for other species.

The emphasis placed on positive indicator-species by the habitat specialists does however suggest that a metric derived from model outputs should also be based on these positive indicator-species. An approach that would give a continuously responsive metric would be to use the mean habitat suitability at the site for all positive indicator-species. Calculated values for this metric for the study sites are presented in Table 21. In this case, filtering out positive indicator-species that have not been recorded in the geographic area is more necessary than when choosing the top-ranked species, since some species might have low HSR values due to climatic unsuitability rather than effects of pollution. Lichen distributions were not available at the time of writing this report, so lichen species were excluded from this calculation.

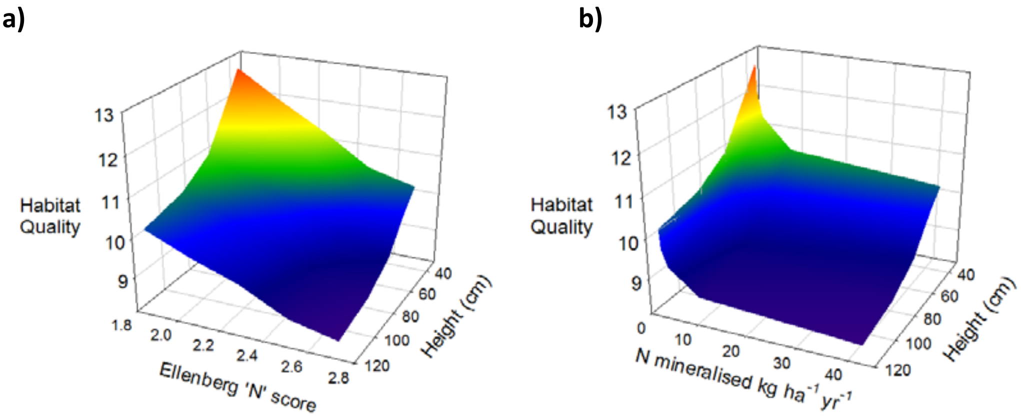
Table 21. Mean rescaled habitat suitability values for positive indicator-species at the study sites. Positive indicator-species were identified from Common Standards Monitoring guidance (see Appendix 3). Species that have not been recorded within the vice-county were excluded from the calculation, as were all lichen species.

Bog (Isle of Lewis)	Neutral grassland (Lancashire)	Heath (Yorkshire)
4.68	0.96	1.03

A metric calculated in this way is not immediately applicable, since these is clearly variation among habitats in the typical HSR value of their positive indicator-species. Further work will be needed to establish typical values of the metric for examples of habitats in favourable and unfavourable condition, and to assess how much geographical variation there is in these typical values. A useful focus for such work would be to define a threshold value, below which a site can be seen as damaged or in unfavourable condition, and above which the site is in favourable or recovered condition.

It is important that such a metric would be sensitive to changes in N pollution. Calculating the predicted effects of N pollution scenarios on midpoint indicators (such as soil pH, N availability, total C/N ratio and vegetation height) is beyond the scope of the current project, although biogeochemical models such as MADOC could be applied to this task. By varying the values of midpoint indicators, however, the responsiveness of the proposed metric can be assessed. A sensitivity analysis was carried out for the Yorkshire heathland site. The HSR value was determined using MultiMOVE for all vascular plant and bryophyte positive indicator-species for heathland (EUNIS F4) that have been recorded in the relevant vice-county. The mean HSR for these species was calculated under different scenarios that were defined by increasing and decreasing the mean Ellenberg 'N' score and the mean Grime height score, each by +/- 20% from observed values. For the purpose of illustration (Figure 3), mean Grime height score was converted to an estimate of actual vegetation height using the relationship defined in Rowe et al. (2011b), and mean Ellenberg 'N' score was converted to an estimated available-N flux using the relationship defined in Rowe et al. (2011a). Clearly, the HSR values for these positive-indicator species are strongly influenced by habitat properties that are known to be affected by N pollution.

Figure 3. Sensitivity of Yorkshire heathland habitat quality (mean rescaled habitat suitability for positive indicator-species that occur in the region) to variation in vegetation height and in: a) mean Ellenberg 'N' score, a floristic indicator of eutrophication; and b) soil N availability, using the relationship with soil properties established in Rowe et al. (2011a) and assuming a C/N ratio of 35 g g^{-1}.



As well as being different for different habitat types, the mean HSR value will also be affected by the choice of positive indicator-species. Some uncertainties remain in which positive indicator-species should be used for a habitat on a particular site, due to:

- Nomenclature issues, such as name changes or the use of different taxonomic levels. For example, groups such as *Carex*, *Sphagnum* and *Cladonia* are listed as positive indicators for certain habitats, but MultiMOVE niche models have been developed for individual species, and clearly within a group such as *Carex* there is a wide range in environmental requirements.
- Uncertain transfers from habitat definitions used in CSM guidance to EUNIS classes.
- Regional differences in the relevance of particular species.

Geographic filtering may help to an extent with accounting for regional differences, but it is clear that whatever methods are used these must be adaptable for changes in the sets of positive indicator-species used, both before and after the Call for Data deadline on 3rd March 2014. Current work under the JNCC Plant Surveillance Scheme project aims to identify more clearly sets of indicator-species for UK Priority Habitats, and will report in March 2014. Although these lists are unlikely to be available in time to meet the Call for Data, they are likely to be directly useful and will help resolve many of the ambiguities in the current list.

Despite these caveats, we consider that a metric of this type can be recommended. The presence of positive indicator-species emerged from the consultation with specialists as a key basis for assessing habitat quality. The HSR value calculated by MultiMOVE is comparable among species, and gives an indication of habitat suitability that has a strong empirical basis. Assessing the HSR of all geographically-relevant positive indicator species avoids many potential problems with generating an artificial species list. Perhaps most importantly, a metric generated in this way is highly responsive to changes in N pollution.

5. Conclusions and recommendations

The consultation with habitat specialists provides an excellent basis for deciding on a suitable habitat quality metric. The habitat specialists referred frequently to Common Standards Monitoring guidance as providing a starting point for assessment, and did not substantially criticise or challenge the guidance. However, they did provide context and discussed limitations. Some of these limitations are inherent, resulting from the requirement for rapid assessment, in a single site visit and using non-specialist skills. These requirements have lead to the use of distinctive but comparatively common species for many diagnostic purposes, which, conveniently, largely corresponds to the subset of UK species for which models are available.

Several criteria that have been proposed as a the basis of a metric did not correspond to the views of habitat specialists as canvassed using semi-structured interviews and the ranking exercise, such as similarity to a reference community, or ecosystem service provision. The presence of scarce species was considered a very positive attribute, but was not consistent enough to be widely used in habitat assessment. Criteria based on the abundance of functionally important groups (forbs in grasslands, subshrubs in heathlands and *Sphagnum* in bogs) emerged from interview responses as important, but did not correspond well to the specialists' rankings of habitat examples. In any case, considerable uncertainty is attached to model predictions of species cover, so abundance-based metrics would be difficult to use.

The most reliable models available predict rescaled habitat-suitability (HSR) for individual species. By applying these models to predict habitat HSR for a large set of species at a given site and under a given N pollution scenario, appropriate metrics could be derived. An artificial species list could be assembled for a site for use in deriving metrics, but such a list would be subject to uncertainties about which and how many species should be included. A more promising approach is to assess HSR for all the appropriate indicator-species.

Negative indicator-species were sometimes used by the habitat specialists to assess site condition, and a metric incorporating negative indicator-species was proposed in early work on this topic (Rowe et al., 2008). However, negative indicator-species were usually not considered by the specialists to be damaging *per se*. A metric based on negative indicator-species was not correlated with specialists' rankings, and including negative with positive species slightly worsened correlations. The final recommendation for a metric is therefore based on positive indicator-species:

> *HQ = Mean habitat-suitability, rescaled by prevalence in the training dataset, for positive indicator-species at the site.*

This recommendation is not without caveats. Typical HSR values for positive-indicator species vary among habitats, so the typical *HQ* value will also vary. The number of positive-indicator species to be included for a given site is also subject to change. It is important not to include species for which the climate of the site is unsuitable, so filtering out species that have not been recorded in the vice-county would be advisable. The CSM guidelines also allow for and indeed encourage the definition of additional indicator-species for particular sites or regions. Revised lists of indicator-species have been prepared for Scottish grassland types (Jane Mackintosh, *pers com.*). Guidance on assessing lowland grassland has been extended for England to include positive indicator-species lists for specific grassland types (Robertson and Jefferson, 2000). Current work under the JNCC Plant Surveillance Scheme is aimed at producing revised positive indicator-species lists for UK Priority Habitats.

The limitations of the recommended approach (which are mainly related to uncertainties in the choice of indicator-species for a particular site and to the method for combining responses into an aggregate indicator; see section 4.2), are all likely to increase the uncertainty that must be attached to the metric. The implications of these uncertainties still need to be explored, for example by examining whether the metric values are stable in response to changes in the species-list from one geographic region to another and yet responsive to changes in N deposition rate. However, the current study has reduced a major uncertainty regarding the type of indicator most suitable for assessing habitat quality. Basing a metric on positive indicator-species is likely to result in a robust metric that reflects the views of habitat specialists reasonably well.

Making a response to the Call for Data would ensure that the UK retains its position among the more active members of the CCE, and applies the best science and models available for the UK. The Call for Data aims to meet the urgent demand for biodiversity indicators for use in integrated assessments, and the response will be used to develop upscaled predictions for impacts of N pollution on biodiversity at European scale. If a response is not made, there is a risk that the UK will be asked to apply models and metrics that have limited relevance within the UK, or that such models will be applied by the CCE. Biogeochemical models developed and tested outside the UK may not represent processes that are uncommon elsewhere, in particular nitrogen dynamics in peats and organomineral soils. Floristic models developed using non-UK datasets may not reflect the environmental ranges of species within the UK, and often do not include many of the relevant species.

If the MADOC-MultiMOVE model chain is to be applied to provide a quantitative response to the Call for Data, further work will first be necessary to determine typical values of the metric for a given set of positive indicator-species, and values corresponding to good, threshold and poor condition. Considerable method development will also be necessary, to simplify and streamline the application of the biogeochemical model to example sites, calculate changes in habitat suitability in response to pollution scenarios, and determine values for a habitat-specific metric. This work needs to be completed in time for the Call for Data submission deadline, 3rd March. This timescale does not allow for full exploration and discussion of the metric calculation method, but the Call for Data is intended in part to encourage signatory parties to engage with the development of such metrics, and there will be further opportunities to revise and refine the method used. Meeting the Call for Data would show commitment to the CCE process, as well as improving UK capacity to apply appropriate models and metrics.

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Appendix 1 Extended summary of semi-structured interviews

Topic 1: Main features of habitat quality

T1 a) Combination of features

Assessment of habitat quality often involves the consideration a number of different features, including habitat structure and condition, management impacts (for example grazing, drainage or burning) and vegetation characteristics, such as species extent, vegetation composition and structure. For example, water conditions are particularly important for wetlands in addition to vegetation composition:

> "*Water quantity and quality is one of the key things. And then vegetation quality…That's partly species assemblage, but also species of particular note as well, so they'll come into the factors of selection. Size as well, obviously from the point of view if you've got limited resources." I2 Wetlands [Scotland]*

Another stressed the importance of management and vegetation cover in relation to heathlands:

> *"…it would be signs of grazing intensity….How tall, how much dung, how much bare ground… proportion of graminoid species in the habitat, the amount of vegetation being pulled out, and that sort of thing." I7 Heaths [Wales]*

This combined approach to habitat quality assessment has applicability to all three EUNIS Level 1 habitats considered in this study, although apparently more so for wetlands, and to a lesser extent heathlands, than for grasslands.

T1 b) Habitat structure

Although a combination of features may be used in habitat quality assessment, for wetlands, habitat structure was stated as being particularly important. For example, referring to wetlands in Scotland, one specialist stated:

> *"…it's important that you've got these building blocks of good quality – in wetlands terms, you've got good quality water, you've got sufficient water supply to actually maintain the conditions." I2 Wetlands [Scotland]*

These sentiments were shared by wetland specialists from all four countries of the UK, who expressed the importance of surface topography such as humps, hollows and pools, water conditions, and depth of peat. The impact of management was also highlighted as significantly affecting whether wetlands pass their quality assessment, and indeed often failing due to occurrence of heavy drainage, burning or grazing. However, despite the sometimes poor vegetation quality of many wetlands in England and Wales, the existence of good structural potential often warrants that the site receives conservation attention, for example:

> *"It is surprising how often I'll go to a place and I'll rate it quite highly and our local officer will say 'but it doesn't have any bog moss' – but 'yeah, look, it's five metres of peat in the middle… it's domed…'" I6 Wetlands [Wales]*

The existence of the structural elements of a wetland habitat, such as deep peat, would also indicate that the habitat should be assessed as a wetland despite what vegetation may be currently growing upon it:

> *"So if you're on deep peat and you've got this heathland community… there shouldn't be a heathland community there should be a bog community. So we do use that to that degree. And if you're on acid grassland on deep peat, again ... we should be assessing it as degraded bog. And management should be moving towards getting back to a less degraded bog." I11a Heaths, Wetlands, Grasslands [England]*

Structural elements can therefore define the habitat classification, regardless of vegetation composition. Evidently habitat structure is crucial for wetlands, but one respondent did also draw attention to its increasing relevance for grassland habitats, especially under changing climatic conditions:

> *"This year I've seen a lot of bare ground caused by poaching by the very cold winter and cold spring. So I wouldn't like to suggest that structure is not an important aspect of that assessment…. It seems that this is an exceptional year, an exceptional problem of an exceptional year, but given that we must expect more exceptional years, it is something that we need to address." I1 Grasslands [Scotland]*

T1 c) Vegetation composition and structure

Vegetation, both in terms of composition and structure, emerged as the dominant factor in habitat quality assessment for grasslands and heathlands. The National Vegetation Classification (NVC) framework is often used as a starting point in quality assessment and for site designation:

> *"We rely quite heavily on the National Vegetation Classification framework… So, all of our SSSIs now, and have been for some time, unpinned by a survey of that level of detail, an NVC survey." I10 Grasslands [England]*

Beyond the NVC classification, assessment of the habitat vegetation can involve a number of deliberations, such as how the presence or absence of species may reflect the impacts, site condition, or conservation value, as expressed by one grassland specialist in Wales:

> *"It [the NVC community] is the first thing I'd home in on. But then you'd be thinking, is it good for this, is it good for that? And you wanted to know why, is it modified by enrichment or something, in which case you'd mark it down. And you'd be doing that largely on species presence or absence. Or is it transitional to something else? Or is it something completely unique that we've not seen before, but still has a diverse species component? So it's a guide to get us started, but it's not the final word in conservation assessment by any means." I8 Grasslands [Wales]*

Generally, species assemblages were considered more important for habitat quality assessment than individual species, because assemblages may be more representative and resilient, and also because most habitats do not necessarily rely on individual species for their functioning:

> *"Probably I would be less inclined in notifying individual species of importance, but a range of species, so I'm quite keen on species assemblages, because I think … it's more representative, and it's also more resilient to change." I2 Wetlands [Scotland]*

> And similarly:

> *"Generally [we're] not looking for specific species, looking more for diversity of a certain level… you can set site-specific requirements for particular species, but there aren't that many sites that are dependent on single species" I1 Grasslands [Scotland]*

However, both individual species and species-assemblages or groups of species can be useful for assessing habitat quality if they act as a proxy for environmental conditions, by for example providing some indication of water quality and quantity, nutrient loading or management such as burning:

> *"In most circumstances, if I'm looking at habitat quality, I would be looking at individual species or groups of individual species with … environmental requirements as some kind of proxy of the environmental conditions." I12 Wetlands [England]*

Given that species assemblages are important, a further consideration is how to measure these assemblages. Specialists of both grasslands and heathlands highlighted that species richness would not be a suitable metric for measuring quality in these habitats, due to the fact that the habitats can be naturally species-poor yet still of high quality:

> *"…heathlands in many cases are a species-poor habitat, so if you increase the number of species, the species richness, it usually means you are increasing the number of generalists, and usually this is a sign of neglect or unfit management. So if you increase the number of species by increasing bramble, bracken, ragwort or other species, you may be increasing the number of species but not the heathland species. So species richness is not a sign of quality." I13 Heaths [England]*

Another aspect to vegetation assessment is the relative importance of vegetation composition compared to vegetation structure. Although composition may be the dominant criterion, vegetation structure is also important as a habitat quality criterion:

> *"Vegetation composition and vegetation structure, I think those would be the most important. So, if we were assessing, we would probably start with a Phase 2 type survey and look at composition, but then we would also look the assessment of the structure of the vegetation as well…. I'd say they are equally important. I think, there has been a tendency to focus on the composition, but I think we are more and more thinking that structure is equally important in terms of heathland species, and association with particular structures, structure of the vegetation." I5 Heaths [Wales]*

T1 d) Geographical and temporal variability

When making an assessment about habitat quality, a number of respondents emphasised the need to put the assessment into geographical context. This reflects the fact that often different parts of the country or different altitudes will have natural variations in quality (whether vegetation or structure). The habitat may therefore be assessed with this in mind, although it may not necessarily be a dominating factor in quality assessment. For example:

> *"In terms of the community structure within the wider habitat, that sort of thing can be very variable, depending on the where you are in the country, so you've got longitudinal and latitudinal variation, but also altitudinal variation" I3 Wetlands [Scotland]*

> *"So what you regard as high quality in the north of Scotland, where there's a much smaller pool of species, might be a bit different from the south of Scotland. But we try not to skew our ideas of quality too much." I1 Grasslands [Scotland]*

However, in some cases, comparison of sites in different parts of the country in terms of quality (for example for SSSI designation) may no longer even be possible due to the rarity of the habitat, and instead a 'minimum standards approach' adopted:

> *"It all comes down to whether we take a kind of minimum standards approach or an exemplar approach. So those very rare habitats, provided that the grassland comes out as one of the unimproved types, then we wouldn't start to distinguish between say, an example in say Northeast Derbyshire and one in South Derbyshire and try and compare them…..grasslands are so rare now that for most of them we tend to take a minimum standards approach." I10 Grasslands [England*]

Related to geographical variation, it was also noted that some site have historical anthropogenic impacts that affect quality, which also may be factored in during site assessment:

> *"The problem with English blanket bogs is that there's a much greater history of intensive use, in some cases in the South Pennines going back a thousand years. And that use is basically grazing, historic wildfires have been a problem, and then rotational burning, for grouse and sheep management." I11b Wetlands [England]*

Just as a habitat may vary naturally depending on geographical factors, a habitat may also vary through time, showing natural dynamism. During habitat quality assessment, dynamism within a habitat may be allowed for, rather than achieving a fixed target of species composition and structure. For example, in relation to wetlands in Scotland, one respondent stated:

> *"…one of the things we're doing, all the time we're doing, is just taking snap shots, snap shots, snap shots, and sometimes, particularly the wetlands, they are very dynamic, if we let them be dynamic. And I've seen it where at certain stages you'll see something dominant, and then all of sudden it starts to disappear or decline …*
> *… the way we look is not flexible enough, it's too rigid, it's not dynamic. Habitats are dynamic." I2 Wetlands [Scotland]*

T1 e) Ecosystem services

Since the ecosystem services framework is currently favoured as an approach to supporting land management decisions, it is feasible that the capability of a habitat to deliver multiple ecosystem services such as climate or water regulation in addition to wild species diversity may be considered within habitat quality assessments. Ecosystem services did not emerge as a dominant theme from the consultations. However, there was some opinion that ecosystem services could be included in habitat quality assessment as an additional factor, or that the current approach already fits in fairly effectively to the ecosystem services framework:

> *"I think blanket bog fits quite well with ecosystem services… but notifying land as nature reserves, then obviously they need to be important for nature, if they are for ecosystem services then they should be called ecosystem reserves rather than if their biodiversity isn't… but there's not generally too much of a conflict in priorities… or there shouldn't be. Apart from perhaps recreation might be one… we work very closely with the water companies in the uplands in terms of producing good quality water, protecting carbon…" I11a Wetlands [England]*

> *"I'm not saying that these systems couldn't be valued using ecosystem service provision, but so far we haven't gone down that route. I'd see they'd have to be an add on, it wouldn't be an either/or, would it?" I10 Grasslands [England]*

T1 f) Applicability and practicality

The Common Standards Monitoring (CSM) guidance appeared to be widely used as the fundamental guideline for the monitoring the vegetation features of habitat quality. The use of the CSM guidance was raised by specialists from all habitats across all four countries, and in general the specialists considered that the guidance was useful and appropriate. Several specialists referred to their involvement in drawing up the CSM guidance and indicator-species lists.

> *"I have found that, yes there are lots of things that you can criticise about Common Standards Monitoring, there always will be some things because it is so vast, we're trying to do such a vast job, but I think the approach, I think is good. It does give us a standardisation which allows us to make judgements in terms of a habitat at the level of Scotland…which I think gives us a good level of standardisation for some of our habitats … So I think that approach serves us well." I4 Heaths, Wetlands, Grasslands [Scotland]*

However, a common issue arising was that CSM, by attempting to be applicable to the whole of the UK, can be too generic and broad:

> *"…one of the issues with Common Standards Monitoring is that we've tried to include all four countries within one set of guidances, and for certain species it is not always appropriate for your location. But I would have thought it covers most of what we'd consider." I5 Heaths [Wales]*

As a consequence of the necessarily broad nature of CSM, the majority of specialists had modified indicator-species lists to improve their applicability to their country, to particular areas or even to individual sites. This includes removing species that are not considered applicable, and adding additional ones, for example ones that are locally distinctive. This can be useful for detecting local changes and potential negative impacts in an area, as explained below:

"On specific sites there may be more monitoring. On those sites that are very rich we'd expect the advisor to include a list of species that you would look for in subsequent years. Those species would not be listed on the generic UK form but would be added for that particular site to emphasise its species richness; and when they visited the site in six years time if they could detect obvious change then they should try and work out, why is that? And if the grazing seems to be okay and the burning is in hand, there's no drainage, then… that only leaves N deposition!" I11a Heaths, Wetlands, Grasslands [England]

A key consideration in drawing up the indicator-species lists for CSM guidance was practicality, i.e. whether species were easily observed and identified by surveyors without specialist knowledge:

"We tried also to concentrate on species that are easy to identify. So we tried to avoid, where possible, grasses and sedges – not always, we did use them sometimes. And we also tried to use species that were visible for a reasonable time during the season – you know things that appear and disappear very quickly are not so useful, because bear in mind the level of competency of the people who might be doing this." I10 Grasslands [England]

Even so, some specialists reported tailoring the lists to make them more practical for the local officers to carry out the monitoring, restricted by limitations in skill, experience or time. For example:

"In grasslands it [the modified indicator-species list] was developed to have generic attributes that are easy to apply to a site. This was so that the average Area Officer could go out and do it without specialist skills." I1 Grasslands [Scotland]

Furthermore, the formal guidelines are not necessarily the only way that the vegetation should be assessed, and there was some indication that local officers undertaking the habitat assessments should ideally being using judgement as well. However, lack of experience was cited as problem with this, as expressed below:

"I always, say 'use your judgement as much as possible' but people on the whole don't feel able to use their judgement. It's the same in England. You've got people who haven't worked on the habitat enough to feel that they can apply judgement. And so they tend to stick to the letter of the guidance rather too much, but it's never that clear-cut, is it?" I1 Grasslands [Scotland]

Topic 2: Value of individual species

T2 a) Structural and functional species

Specialists concerned with all three EUNIS Level 1 habitats considered in this study highlight the importance of species that are structurally or functionally significant. These species seem particularly important for wetland habitats, for example species that help to form peat and maintain the overall functionality:

> *"The other types of species that you could look at in terms of habitats like bogs for example, are the ones that are structurally important, or functionally important, peat forming species, the* Sphagna *and the* Eriophorum *in particular, could be ones that we would view of being of particular value and being particularly important in those habitats." I4 Wetlands [Scotland]*

It was also noted by some specialists that functional species are often interchangeable, and the specific genus or species may not be important:

> *"If all the* Sphagnum *was to go, that's potentially more significant. But bogs in the northwest often don't have Sphagna. What tends to happen is that* Sphagnum *is replaced by* Racomitrium*, and in the northwest by* Campylopus atrovirens*, which again seems to fulfil a similar role to what* Sphagna *does. It's not such a prolific peat former but it does form peat, it does help cover the surface. It impedes water flow… although if you were to lose your* Sphagna *in the east, you wouldn't get* Racomitrium *coming in. They are more equal in some places than others." I3 Wetlands [Scotland]*

Functional species are also important for other habitats, particularly if they help to maintain system resilience in the face of changing climate, as illustrated below with respect to grasslands:

> *"Particularly with climate change, we have to consider, what's their role in the resilience of that. They may not be the rarest but they may have a key function in the way that habitat functions and the stability of that habitat. And those things, we don't necessarily explore when it's sort of in bright lights that you must protect this species because it is rare." I8 Grasslands [Wales]*

T2 b) Scarce species

The general consensus was that scarce or rare species provide added value to a habitat, but are not usually a dominant criterion for assessing habitat quality, for example:

> *"I think that the mega-rare things are just used as a bonus evaluation. A site will stand on its own two feet because of the distinctive elements of it... I can't think of many terrestrial wetland sites where rare species are the main decisive factor, I can't think of any actually. It tends to be much more on the habitat intactness or assemblage of characteristics, even if they might actually be becoming rare." I6 Wetlands [Wales]*

However, there may be some circumstances where a rare or scarce species may be the defining part feature of a habitat, such as some montane habitats:

> *"Well there are some habitats where it's really the scarce species that are effectively the defining part of the habitat, so in montane willow scrub there are half a dozen rare dwarf willow species that are what basically what makes the habitat what it is." I4 Heaths, Wetlands, Grasslands [Scotland]*

Scarcity or rarity of a species depends on scale – whether the species is being considered with respect to local, national or international abundance and distribution. The reference scale used is likely to vary depending on context, however one specialist indicated that UK distribution was of particular importance:

> *"You can look at different scales for different purposes. I work on a Scottish remit so I am looking at .... Something that's uncommon down in the south, that adds value…possibly the UK distribution is more important than the Scottish." I1 Grasslands [Scotland]*

Scarce species may also be important for site designation, even if they are not an important part of the general habitat quality assessment:

> *"It [the presence of nationally scarce species] would carry a fair bit of weight if you were choosing to designate a particular site. I suspect it doesn't carry as much weight under our monitoring methodology." I1 Grasslands [Scotland]*

A number of specialists also emphasised that using scarce species as a means of assessing habitat quality is not appropriate. This may be because some scarce species have become so rare that they no longer provide useful information for quality assessment, but also because a scarce species may not be critical for the habitat functioning:

> *"The thing is, they are so scarce now that they can't really tell us a lot about our heathland because they no longer have those species. So scarce species may be important in a local context, where you know that that species still exists and is and should be there. But I don't know if you can use them across Wales, because so many parts of Wales now, as I say if you go to the Lleyn, there's only one or two sites which have some of these scarce species. So, that's why I don't know how you would use them more broadly" I5 Heaths [Wales]*

> *"If we take Dwarf birch,* Betula nana*…It's a nationally scarce species. If the* Betula nana *was to disappear or shrink its range, it's not going to affect the bog's capacity to do what the bog does. It's still going to capture carbon, it's still going to moderate water flows, all other things being equal – it's just the fact that that species has gone. So in that respect you could say that it's not that important for the habitat." I3 Wetlands [Scotland]*

T2 c) Invasive species

The prevailing attitude of the habitat specialists, from all habitat types, was that invasive species are not negative *per se*, i.e. not intrinsically negative, but rather they would usually only be considered negative if they caused some detrimental impact, usually through out-competing native species that are considered desirable. For example, one respondent stated:

> *"If you've got something that's invasive, even if it's a non-native, but it's not actually affecting the species composition otherwise, then I don't think you'd worry too much about it. It's something you'd note down obviously, and you wouldn't want it to increase...but if it's just there at low cover then so what? But when it builds in cover and is affecting other species, that's entirely different." I8 Grasslands [Wales]*

Nevertheless, there was some suggestion that alien (non-native) species are generically negative and should be eradicated if possible, although this sentiment may be in part a reflection of their experience of particularly detrimental species such as *Rhododendron,* which can be a serious, although localised, problem on heaths and wetlands:

> *"We tend to say that the exotics, we should try to eradicate if possible. So for example, for the heathlands it's* Rhododendron*,* Gaultheria*, those are the main species that cause problems, and they tend to spread and again out-compete the characteristic species, so if possible, less than 1% and if possible eradicated. Whereas the natives, we wouldn't say eradicate." I13 Heaths [England]*

Another factor that appears to be important with regards to invasive species is the feasibility of being able to remove or control the species. In cases where the invading species is so widespread that removing them it is not pragmatic, it was suggested that this may contribute to a more accepting view of the species, particularly if the impacts of the species are not well known – for example the New Zealand willowherb *(Epilobium brunnescens)* in upland habitats:

> *"Yes, I think it would be nice if we didn't have non-native species where we don't want them. If they are not causing damage to the habitat, which is not always easy to know, do you need to do anything about it? And I think if we can, and we can really easily then we should, but, in the example of the New Zealand willowherb, you wouldn't have a hope to do it....*
> *...do we actually know that it's having a negative impact, in that, is it actually occupying ground that would otherwise be occupied by other species?" I4 Heaths, Wetlands, Grasslands [Scotland]*

Invasion that appears to be part of a natural change in species range may be considered as neutral or positive, as they form part of natural habitat dynamism, for example the possible invasion of the tongue orchid to the south coast of England:

> *"We already get tongue orchid on the south coast, and nobody's really sure ....the seeds could have just blown across the channel, and if climate change has created the conditions that makes it more suitable, I'd say in that case, that's fine. That's part of dynamism, isn't it really? It's rather a different situation to your Himalayan balsam I guess, isn't it?" I10 Grasslands [England]*

T2 d) Historical context

The historical context of a site can be relevant when considering which species are of value to a habitat. For example, it may be important to define an appropriate historical reference point to use as a management goal – failure to do so may result in valuing species which historically were not present on that habitat, as explained below in the context of wetlands:

> *"The local importance is relevant, but you have to be careful that what you are seeing there that's local is representative of what you're actually trying to protect, because it could be what you see there now is not what was there 50 years ago, or the real function. It could be, for example, a swamp may be covered in reed sweet-grass, and that would be a response to the nutrients coming in to the site, and 50 years ago it wouldn't have even be recorded there. So you have to be careful that we're not automatically considering that reed sweet-grass is very good..." I2 Wetlands [Scotland]*

A similar issue was highlighted with respect to acid heathlands, which are particularly species-poor. This has resulted in debate over whether this paucity of species is natural or a result of past management, and as such, how it should influence management goals:

> *"It's the bulk of the heaths that are the acid heaths which can be incredibly species poor, and at the back of your mind you think 'are they species-poor because of past management or is that the way that they naturally are'? And we have this discussion constantly about acid heaths, because some of them are incredibly species-poor. But, our feeling is that maybe historically they weren't as species-poor as they are now, I think it's a combination of factors which has led to a decline of these associated species." I5 Heaths [Wales]*

T2 e) Comparative values of species

The valuing of some species over others is a potentially difficult issue. Although conflict did not emerge as a significant problem with respect to plant species valuation, in some cases such issues do arise. For example, preferences of the wider public may not reflect preferences of conservationists, or conflict may arise in the conservation of different scarce species that require conflicting management regimes, for example:

> *".. a site that's got globe flower, which quite likes grazing, and at the same time it's got, in the same grazing unit, it's got Scottish primrose.. It's how you arrive at a grazing regime that keeps both… So it's difficult to actually say 'no, we're abandoning the globe flower for the Scottish primrose'. You can't really say that." I2 Grasslands [Scotland]*

Topic 3: Plant & lichen indicator-species

T3 a) Characteristics of positive indicator-species

There are number of possible characteristics of positive plant and lichen indicator species. Specialists of both wetland and grassland habitats suggested that positive indicators may be distinctive species that are indicative of that particular habitat, for example those that indicate the presence of deep peat in wetlands such as *Eriophorum vaginatum*, or forb species which are unique to grassland sub-communities:

> *"…there are species that are indicative of particular habitats. If you think about a species that could be found in a range of habitats, so if what you are interested in is particular habitats, then the species that are indicative of those habitats are going to be the ones that you will use to value that habitat. If you think of grasslands, you get the same, or some of the same grass species,* fescues *and* Agrostises*, you'll get them both in acid grasslands and in calcareous grasslands, and it's the forbs that accompany them that are indicative of whether it's an acid grassland or a calcareous grassland. So, your method with the grassland, you would look at the forb species as ones that are indicative of that habitat." I4 Grasslands [Scotland]*

Positive indicators may also be species that are typical or common in the habitat. These are likely to be dominant for the habitat, and other accompanying species may be expected throughout the vegetation for it to be considered of high quality. This approach appears particularly useful for heathlands, as illustrated below with respect to montane heaths:

> *"It's the quantity [of* Racomitrium*] that you're really interested in, it's the dominant species for that, or most of the forms of that habitat – not all of them..... It needs other species on top of* Racomitrium*, I can think of about half a dozen species which would be useful to have... like stiff sedge,* Carex bigelowii, *and perhaps dwarf willow and species like that, and a range of lichens as well,* Cetraria islandica*,* Cladonia arbuscula*. I think you want them not necessarily in high cover but frequent occurrence throughout the vegetation." I7 Heaths [Wales]*

Another characteristic of positive indicators is that they can act as a proxy for good environmental conditions, for example, in wetlands, certain species may indicate high water levels or low nutrient levels:

> *"So in a bog it [useful indicators] would be something like* Sphagnum capillifolium*… not the more nutrient-responding species like* S. fallax *or some of the others. Or those that are indicative of long-term stability and clean water, high water levels. And equally in a more alkaline fen, again you're looking at bryophytes characteristic of high, constant flushing. And low nutrient status. So a lot of the curly brown mosses. And sedges that are indicative of low nutrient status and permanently high water tables." I12 Wetlands [England]*

> *"So I think you need to choose species that are sensitive to perturbation in some way, whether it be atmospheric pollution, or intolerance of some other factor." I10 Grasslands [England]*

It should be noted, however, that the species-indicators of environmental conditions that were included in the CSM guidance do not include those indicating atmospheric N pollution, since these have only recently become available (Stevens et al., 2009).

Furthermore, positive indicators in otherwise poor quality habitat can indicate restoration potential, which may be especially relevant for more the rare, or nationally declining, habitats, such as some grasslands:

> *"I know that when the grey dune becomes more and more grass-dominated, you tend to lose most of the species, but a couple of things like* Galium verum *and probably* Lotus corniculatus *will hang on. But that isn't the same as saying they aren't good indicators because … even those guys that will hang on still give you an indication that if you can get the management reversed and back in the right direction then that's probably going to be more restorable or restorable more quickly than something that doesn't have any of the indicators left." I9 Grasslands [Northern Ireland]*

T3 b) Characteristics of negative indicator-species

Negative indicators are typically those that out-compete other species (such as positive indicators and other valued species) in terms of physical space and proportion of cover, and therefore may often be invasive species (either native or non-native). For wetlands, this may include high proportions of *Molinia.* For heaths, invasive species such as *Rhododendron ponticum* are problematic, or too much cover of *Nardus*, *Juncus squarrosus, Juncus effusus*, *Deschampsia* and *Molinia* as well as non-native trees such as conifers. For grasslands, competitive negative species include species such as *Holcus* and bracken (as stated below):

> *"The worst negative indicators are the ones that take up most space. So bracken is probably the worst, just because it reduces the extent of the species-rich grassland. And then species that react to high nutrient levels – if you see lots of* Holcus *it's a bad sign. Again it's taking up a lot of space at the expense of other things. The interesting species probably like nitrogen as well but* Holcus *outcompetes them. So it's species that take up space at the expense of a greater variety of non-competitive things." I1 Grasslands [Scotland]*

Just as some positive indicators act as a proxy for good environmental conditions, similarly negative indicators can act as a proxy for poor conditions, such as heavy grazing, eutrophication, and the amount of cover, which are important considerations for grassland habitats:

> *"So some of the indicators are indicating that it's an open community and some are indicating that it's a more closed community. …You've also got the element of different management impacts and how they might be reflected in the species composition. So presence or absence of some of those indicators might indicate lack of grazing, or overgrazing. Some of them might indicate things like eutrophication. So the list is based on several factors that might indicate the condition of the habitat." I9 Grasslands [Northern Ireland]*

In some circumstances, ecosystem service provision may affect the choice of indicator species. For example, species that have been considered as positive indicators may have negative impacts on ecosystem service delivery such as climate regulation. Such a trade-off has been suggested for cotton-grass (*Eriophorum vaginatum)*, which is suspected of increasing methane emissions from wetland habitats, at least in some stages of its growth. Such as trade-off may not necessitate 'down-grading' the species to a negative indicator, but may be a consideration in habitat quality assessment:

> "*Well – I used to think so [that* Eriophorum vaginatum *is a positive indicator]. My slight hesitation is because it,* Eriophorum vaginatum*, is one of these species that transports methane to the atmosphere. So the fact that we know that it's shunting all this methane up into at the moment is maybe not quite so good." I3 Wetlands [Scotland]*

> *"Cotton-grass is still a peat-forming species, so you need to look at the balances. …. There may be a trade-off there [between cotton-grass and methane emissions] but at the moment I'm happier seeing cotton-grass on a bog than having it completely absent." I11b Wetlands [England]*

T3 c) Context of indicator-species

Although general characteristics of positive and negative indicators may be identified, a common theme expressed by the habitat specialists was that species indicators are very much context-dependent. For example, differences in location and altitude, soil type or past management may affect what would be expected, desirable or undesirable at a site, as illustrated below with respect to altitude of heathlands:

> *"I suppose compositions, even ericoid composition, is different between upland and lowland. We don't get* Vaccinium *in the lowlands for example, but it's a key component in the uplands, those kind of issues. And does it make a difference – much of our upland is shallow peaty type soils whereas our lowlands can be quite leachy soils." I5 Heaths [Wales]*

Natural variability in habitats and sub-communities can also make it difficult to determine which species may be important in terms of function and structure:

> "*When you start looking at fens, swamp and marsh… they can be broken down into more different types, they've each got their individuality ....It's hard to define which of those other species are actually important for that habitat to actually function, what their role is, and the importance of that role." I2 Wetlands [Scotland]*

Indicator species can also change from being positive to being or negative if they become very abundant and outcompete other species. In some examples of habitats, positive indicator-species may not occur, which can make habitat quality assessment difficult when other attributes suggest favourable condition:

> *"And so there's balance of negative species, they tend to be… they're interchangeable, they can be positive one minute and when they get to a certain state they become negative. So it's quite difficult." I2 Wetlands [Scotland]*

> *"But what do you do if you don't find* Rhynchospora*, when you're obviously in a nice, wet blanket bog? And sometimes you find it in places where you think, there's a raised bog just near here, and* Rhynchospora *comes out up there, it just doesn't seem the right conditions." I2 Wetlands [Scotland]*

The scale at which management and habitat quality assessment is made is may also be an issue with respect to species-indicators, as one specialist raised concern over an increasing trend to micro-manage, rather than considering the ecosystem as a whole.

Topic 4: Taxa other than plants and lichens

T4 a) Importance of other taxa

Other taxa were generally considered to have some importance for a habitat, and one specialist stated that they are an integral attribute:

> *"The quality of the habitat has to include fauna as well... you can't disassociate the two. They are an integral part.... It makes life easier if we do separate it down, but I don't think it's representative." I2 Wetlands [Scotland]*

However, the general message emerging was that plant and lichen species are most important for the assessment of habitat quality, but other taxa may be assessed in certain circumstances, particularly if the site has been designated based on the presence of other taxa:

"Well, our condition assessment will be features-based, so we're looking at the features, so if the site's declared as an example of grey dune, the assessment of grey dune is based on the plants essentially, but obviously the site could also be declared as an invertebrate assemblage, in which an independent assessment of the invertebrate assemblage would also be carried out. So it's very much based on the feature, and if the feature is a habitat, then the habitat assessment is largely based on the plants." I9 Grasslands [Northern Ireland]

Typically, other taxa will be assessed by specialists in those taxa, rather than the habitat specialists or officers, although some informal assessment may be carried out as part of the general habitat quality assessment, as explained below:

"I think we would look at the Section 42 species and we would definitely look at those [other taxa] in the context of evaluating, and there are certain species that have a close association with heathland, which we do look at, and we do consider. So things like silver-studded blue butterfly, those kind of things. For the lowlands and the coastal heaths, choughs are very important. So they are key in our assessment of heathlands and getting that balance between what choughs like and what we want from a heathland. So we definitely do look at them. But I don't think we have any systematic way of assessing, because Common Standards doesn't really cover the associated non-plant species very well. It's more a tick list I suppose. You know, this is a silver-studded blue site therefore it is important, rather than having an actual mechanism for grading sites based on their invertebrates or birds." I5 Heaths [Wales]

T4 b) Management conflicts

Conservation of other taxa can lead to conflict or tension when their habitat requirements or impacts do not coincide with a high quality habitat from a floristic perspective. This emerged as a potential issue across all three habitats. Examples include golden plover (which require bare peat in wetlands), red deer (which can negatively impact on vegetation through herbivory and trampling), some butterflies (e.g. those that require scrub in grasslands) and potentially some lizards (which require bare ground on heaths). Such tensions were thought to be greater at small sites, where there is less opportunity to vary management across the site for multiple purposes. However, in general it was considered that the differences in management needs of other taxa and the vegetation could be accommodated, particularly over larger sites, as explained below:

"... it's odd because some of the birds that are prized from the conservation viewpoint are actually associated with degraded sites. So golden plover is the best example, it seems to like very ultra-short vegetation and patches of bare peat, because it can spot predators coming….There is that ability in the Common Standards Monitoring to add certain indicators of local distinctness, and I think you'd have to come to some intelligent decision on a big upland peat massif, along the lines of well 5% for golden plover of trashed bog is a good thing, rather than 100% favourable condition floristically, because that would reduce the golden plover." I6 Wetlands [Wales]

"And managing for marsh fritillary, you're managing for the habitat conservation. So usually the two are compatible but occasionally you do get conflicts. On some of the small sites particularly." I8 Grasslands [Wales]

T4 c) Barriers to using other taxa

There are evidently several barriers to using other taxa for assessing habitat quality, which to some extent may contribute to the focus on vegetation in habitat quality assessments. A key barrier, applicable to all habitat and countries, are the limitations in resources, time, and skill of the local officers:

"We don't use other groups, because we don't have the manpower. With plants the Area Officers can be taught to go out and identify the main species, but with invertebrates you couldn't do that, apart from the obvious groups like butterflies. They are not good as practical indicators in the field. So you can't even use fungi, for example, they remain a specialist study." I1 Grasslands [Scotland]

Furthermore, there is also the potential problem of consistency when using other taxa, as most fauna are not reliably visible – for example sighting butterflies in poor weather conditions, or nesting birds:

"...they make their nest in the moss, and are very well camouflaged. So if you've got dotterel nesting up there then you might think that it's better quality. But the chances of seeing them are fairly low." I7 Heaths [Wales]

"...the species might not be obvious or it might not be the right time of year" I4 Heaths, Wetlands, Grassland [Scotland]

In addition to these practical barriers, it was also argued that lack of understanding of the autecology of other taxa makes them less useful in habitat quality assessment:

"... what isn't quite known is whether there is enough information on the species' relationship to vegetation … and whether they really indicate quality or not... I think whether the inverts add any further quality assessment value over and above the floristics, I don't know. I don't know anybody that does it actually." I6 Wetlands [Wales]

T4 d) Proxy indicators of suitability for other taxa

Given the barriers to using other taxa in habitat quality assessments, other taxa are (or could be) assessed using vegetation composition or habitat structure as a proxy for monitoring their populations. There are limitations with this approach:

"To a certain extent, assessment for other groups has tended to rely on surrogate measures to a certain extent, hasn't it? But the problem is, if you just took my plant community condition assessment for grasslands, the problem with that is that it doesn't pick up some of the other structures that might be required for say invertebrates, does it?." I10 Grasslands [England]

Therefore, assessing aspects of habitat structure that are not directly related to vegetation composition may be more effective than using vegetation composition alone:

> *"... if you've got an invertebrate that depends on dead wood, and your site is important for that invertebrate, then you can either go and check if the invertebrate's there or you could go and check if there is dead wood." I4 Heaths, Wetlands, Grasslands [Scotland]*

> *"One of the things we've been doing... is actually looking at micro-niches in habitats, and looking at the suite of species that use those. And that's particularly important for heathlands. So, which of the species need bare ground, for example, which of the species needs tall heather, which need short heather..." I5 Heaths [Wales]*

Topic 5: Species-groups

T5 a) Pros and cons of using species-groups

Assessing cover of species-groups, sometimes in proportion to each other, has some potential benefits as a measure of habitat quality in all three habitats. Proportion cover can provide a useful guidance on the general condition of a habitat, from which management requirements can be inferred:

> *"It sets limits to say if you are growing too far in one direction, then perhaps you need to consider the habitat." I4 Heaths [Scotland]*

Using estimates of species group cover can also be useful for verifying the accuracy of estimations of individual species cover:

> *"Both on heaths and on bogs we would record dwarf shrub cover, grass cover, bryophyte cover, lichen cover, those sorts of broad headings. But we would also record the individual dwarf shrubs themselves... So it's actually quite a useful check that you've made your original estimation quite good" I9 Wetlands, Heaths [Northern Ireland]*

However, using species groups can depend on the interpretation of habitat quality, and may have more relevance when considering other ecosystem services, rather than specifically biodiversity, as explained below:

> *"If you're wanting the bog to capture carbon, or to moderate water flows, or provide grazing for sheep, deer, then the actual individual species don't matter too much. … It does make a difference if you're looking at it from a biodiversity perspective – do you still have your cranberries, sundews, etc. It depends what services you want your bog to provide." I3 Wetlands [Scotland]*

Furthermore, in some cases – such as for the more scarce sub-communities – assessment at the species level is more useful than assessing species-groups, as species-groups do not provide the level of detail necessary to gauge habitat quality:

> *"...there's certain groups like dwarf shrubs that are useful for most examples. But if there are specific sub-types of habitats, which are often ones that are more scarce, then we do need to determine at the deeper, species level." I4 Heaths [Scotland]*

A species-group level of assessment may also not provide sufficient information about environmental conditions, as individual species within a group may respond differently to different environmental factors, and some species within a group may not be considered a positive indicator in the same way as the others:

> *"It's more on the ecology of the* Sphagna *so if some of the* Sphagna *indicate something damaging on the site like water movement where you wouldn't expect water movement or enrichment where you wouldn't expect enrichment then they wouldn't count. So something like* S. squarrosum *on a bog is something that you wouldn't want to see on a bog. You'd see it around the edges of a bog but you wouldn't want to see it on the main surface, on the intact surface of the bog. Something like that we'd record, well we wouldn't record it as a negative but … we wouldn't include it as part of the suite of* Sphagnum *that we're trying to estimate cover for." I9 Wetlands [Northern Ireland]*

T5 b) Identifying useful species-groups

The percentage cover of forbs or herbs, which may typically be considered positive indicators, can be useful for assessing the quality of some types of grasslands, particularly for cases that are borderline fail:

> *"Well percent forb cover is one of the main attributes – in other words the feature could pass or fail on the basis of that whereas the structural attributes don't affect a pass or fail, so it is important. It's only used for neutral and calcareous grassland because it is just too difficult to assess forb cover where there are lots of bushes. So yes I think it is important, but it tends to just back up what you've already discovered, which is fair enough – if you've already spotted lots of important indicators, you might not rely on forb cover. It's important if you think you've got a borderline case, if you are not sure whether to call it favourable or unfavourable, it does help with that." I1 Grasslands [Scotland]*

> *"It's not quite so important for grassland apart the herb cover I think. The herb cover is important for most grassland. That would certainly affect your conservation assessment. But beyond that… I don't think about groups of species in particular."I8 Grasslands [Wales]*

The cover proportion of negative indicator species-groups can also be used as an indicator. For instance, in many grasslands a high proportion of grasses is seen as indicating lower habitat quality:

> *"...looking at it from the negative side, we use grasses, proportion of grass cover I think quite successfully in the Common Standards, because it does seem to give a fairly good signature of nutrient status. So, if your total grass component is increasing, then the chances are that there is something going wrong in terms of the nutrient loading on the site. ... it didn't work well with*

acid grasslands, because they are pretty grass-dominated by native species. So it didn't work very well for those. But it works well for neutral grasslands, it works well for calcareous grasslands, for instance." I10 Grasslands [England]

High cover of graminoids (grasses, sedges, rushes and other narrow-leaved monocotyledonous species) is sometimes referred to as a negative condition indicator. The distinction between 'grasses' and 'graminioids' was explored in some interviews. The predominant view was that non-grass graminoids, particularly sedges, should not be generally included as negative indicators:

*"…when you're thinking about desirable species, we tend to include them [*Carex *species]. Whether you call them actually forbs I don't know. But I don't think you would. But they are kind of desirable, usually."I8 Grasslands [Wales]*

"I don't think I've ever come across Carex *as being negative." I13 Heaths [England]*

The percentage cover of dwarf shrubs appears to be a useful assessment tool for heathlands in all four countries, either as a measurement by themselves, or in proportion to other groups such as graminoids:

"So on a heathland site we would look at overall dwarf shrub cover." I9 Heaths [Northern Ireland]

"…one of the species compositions that should be looked at should be the cover dwarf shrubs and cover of graminoids. There's quite a broad range for both of these, but … I suppose the ideal, if there is such a thing, would be about half of it covered by dwarf shrubs and half it covered with graminoids. It's bit of an abstraction that, but within that – the targets within CSM for that – is that neither dwarf shrubs nor graminoids should be more than 75%, so it gives you quite a wide range and it encompasses lots of different examples of the habitat.*" I4 Heaths [Scotland]*

Additionally, lichen and moss groups may be useful for habitat quality assessment in heathlands, for instance by providing information about habitat structure:

" The lichens are important, I think, mosses are important, and tells us a lot about the structure as well, so that's important." I5 Heaths [Wales]

"… if you used, certainly for the lichens, if you used... the Cladonia *species, and split them into the* Cladina*, the bushy ones like* Cladonia arbuscula *and all that lot, and use those, plus* Cetraria *species, I think they are good indicators of good quality, and most of the rest of that you get up there are indicators that something else is going on, like those that are more tolerant of higher N-deposition." I7 Heaths [Wales]*

Mosses, particularly the *Sphagnum* genus, are also useful for assessing the quality of wetland habitats. However, there is wide variation in the habitat requirements (e.g. on the oligotrophic-eutrophic axis) among mosses, and even among *Sphagna*. Observations of individual species may be necessary for gaining information regarding environmental conditions and habitat structure:

"Well in bogs, we're tending to use Sphagna as a group, but again, there's a lot of variation in Sphagna *from wet, sitting in ditches, and others from dry hummocks that are quite dry. So again, as a group we're using that as a proxy measure for water content, and also consistency of water content." I2 Wetlands [Scotland]*

Topic 6: Reference communities

T6 a) Defining a reference community

Although there was recognition of the appeal of a reference community, there was a very strong consensus amongst the habitat specialists, irrespective of habitat specialisation or country, that it was a difficult and potentially risky task to attempt to define a reference community to compare a site against. This is due to the fact that habitats are naturally variable, both spatially and temporally, and a single reference point would not reflect the variation in high quality habitat, as illustrated below:

"So I can see the attractiveness in all of this but it is quite difficult to define, and it's almost saying, setting habitats in stone, saying 'this is what it has to be'." I4 Heaths, Wetlands, Grasslands [Scotland]

"Whether you could find a site that was representative of the range of variation… you would struggle... I would be concerned that it wouldn't be representative of the range of variation that exists." I3 Wetlands [Scotland]

"...you can't define a best heathland – it's a broad habitat and the composition, the species composition, changes with altitude and latitude." I13 Heaths [England]

Using an NVC community type as a reference community appeared to be a particularly problematic concept. Whilst the NVC is a useful tool for classifying habitats, it is considered to be too specific to act as a reference community, and wouldn't capture the variation in habitats:

"...the NVC is only a coat hanger on which to hang your vegetation, it doesn't mean to say that just because you find something that is atypical it's somehow of less intrinsic interest. In fact, you could argue in some cases it's more interesting, so I think you have to be quite careful, that while the NVC is a useful tool for conservation assessment and communication between ecologists, it shouldn't be viewed in that very rigid kind of way, and the recognition that it's a continuum basically." I10 Grassland [England]

"... it's really difficult to say that, even recreating a habitat in a particular area it is difficult to say, well I'm aiming for this NVC class. I don't think you can do it really, I think it's very useful for us to classify vegetation, but it may not be useful for all the things." I13 Heaths [England]

The spatial scale of any reference community was also considered to be important, as explained in relation to heathlands:

"I'm also not sure how you define a perfect heathland spatially, because heathland isn't uniform, it's patchy. So, I know one of the things we had

issues with, I think Common Standards say there must be two species of ericoids. And, is that two species of ericoids within your sample, or is that two species of ericoids across the site? So if you are going to define it, you're going to have to define it spatially as well – what you mean by ideal habitat. It's not one patch." I5 Heaths [Wales]

The possibility of using a reference community based on predictions of future climates was considered risky due to limitations in climate model predictions:

"… although I appreciate that climate change is happening, I don't think our understanding is anywhere near the mark to start doing that. I think we could end up the creek without the paddle." I2 Wetlands [Scotland]

T6 b) Potential reference community definitions

Although a reference community was generally not a popular concept among the specialists, there was some consideration of how such a community might be chosen. For example, NVC communities may be an appropriate starting point, as long as flexibility was incorporated:

"I think any kind of referencing needs a certain amount of flexibility to account for change within the communities as well. ... I think the NVC is probably the closest you're going to get to have something that we all agree on that is relatively close to that single reference point, but around it there needs to be that grey area of a little bit of flexibility as well..." I2 Wetlands [Scotland]

However, one reference community per habitat is also not likely to be sufficient, as indicated below:

"So, I think you'd need more than one, you'd need a range or type-locations or type-states, that you could easily capture the geographical variation." I6 Wetlands [Wales]

CSM could be used as a starting point to devise a reference community. Such an approach has been attempted, but the outcome was not judged to be satisfactory:

"It [a reference community] is something that we've sort of played around with a bit previously, because of the way CCW did the Common Standards Monitoring, we actually almost did it in that way. We had an idea of what a perfect piece of heathland should look like, and your quadrat should fit into that perfect piece of heathland. But I've not been convinced about it. I think there's too much dissimilarity between different types of heathland. So... you can get a heathland that is very good, which doesn't match up to your perfect heathland." I5 Heaths [Wales]

Using previous records of a site was considered to be a possible approach to defining a reference community, but such a reference would likely be very site-specific. Such records also seldom exist:

"If you actually had old records for the site and could go back and compare, that would be very useful. I can't think of any instances where you are likely to have good enough old records that you would compare with. That would be useful but impractical." I1 Grasslands [Scotland]

"I don't know whether our data really would be in a state where you could say well this site had these, and now they've gone. So looking back I'm pretty sure we couldn't do it historically in the last 10 years." I11b Wetlands [England]

"The one thing with wetlands is our recording has been very slow...we've got rough species lists, and that's about as far as we've actually got." I2 Wetlands

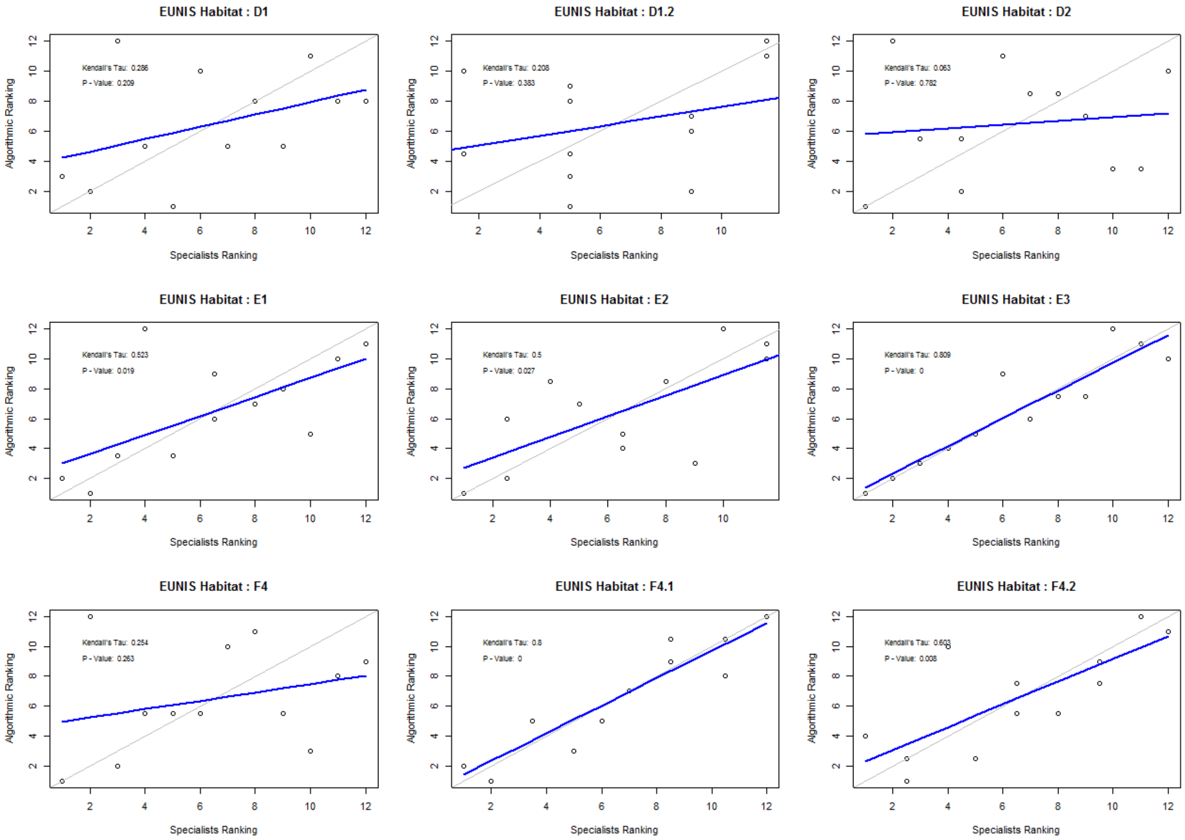
Another specialist noted that for some habitats, extensive quadrat data have been gathered. Such data could potentially be used to help define a reference community:

"We've got quite a big database of sites, so we've got hundreds of quadrats on MG5 for example, and we've got constancy values that give you the typical MG5 constancy for the whole of Wales, so that would be a starting point for this is what MG5 looks like in Wales, as a typical state." I8 Grasslands [Wales]

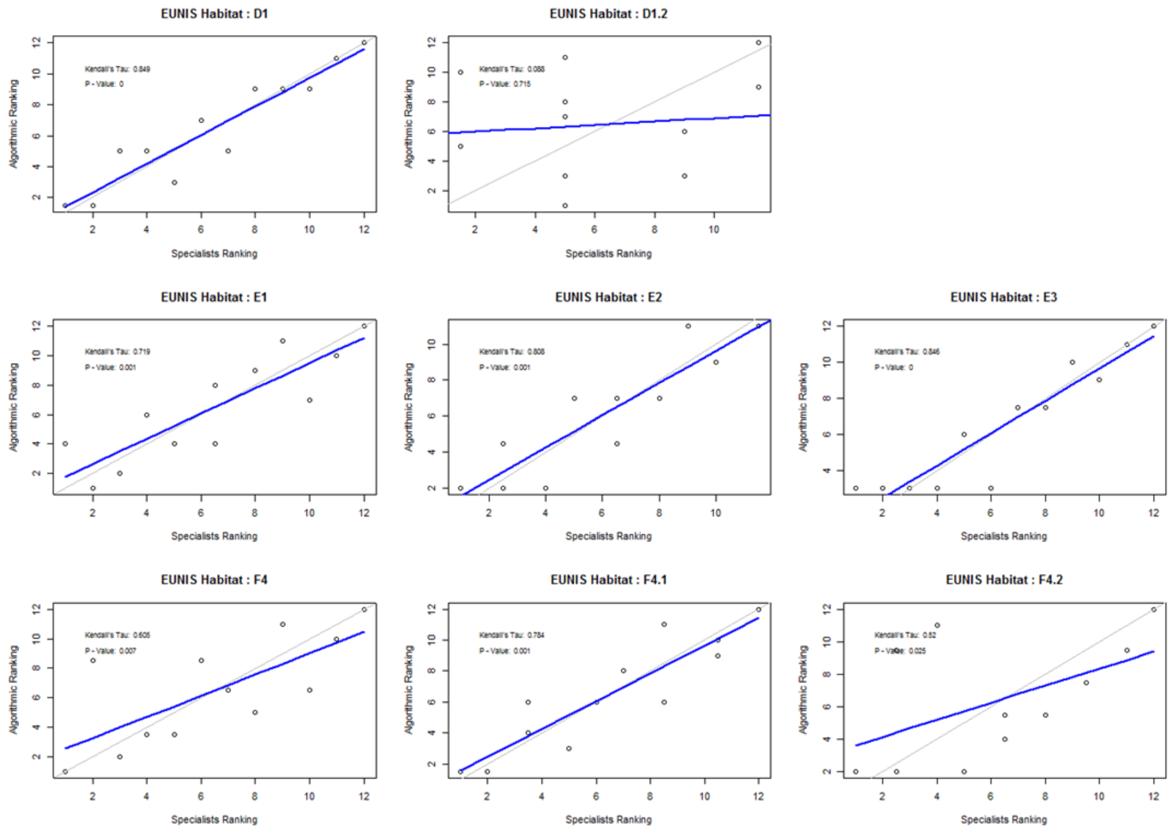
Appendix 2 Correlations between specialists' rankings and rankings according to different metrics

Habitat specialists of the Statutory Nature Conservation Bodies (SNCBs) were given 12 habitat examples, consisting of species-lists with cover-score (DOMIN) values. The examples in each set were all from a single EUNIS vegetation type, either at level 2 (e.g. D1 Raised and blanket bogs) or level 3 (e.g. D1.2 Blanket bogs). Each specialist was allowed to choose one or more sets of examples. In all, nine sets of examples were ranked by one or more habitat specialists. In this appendix, plots are presented to illustrate the degree of correlation between the mean ranks assigned by specialists, and the ranks of the same set of example according to different methods of calculating metrics of habitat quality.

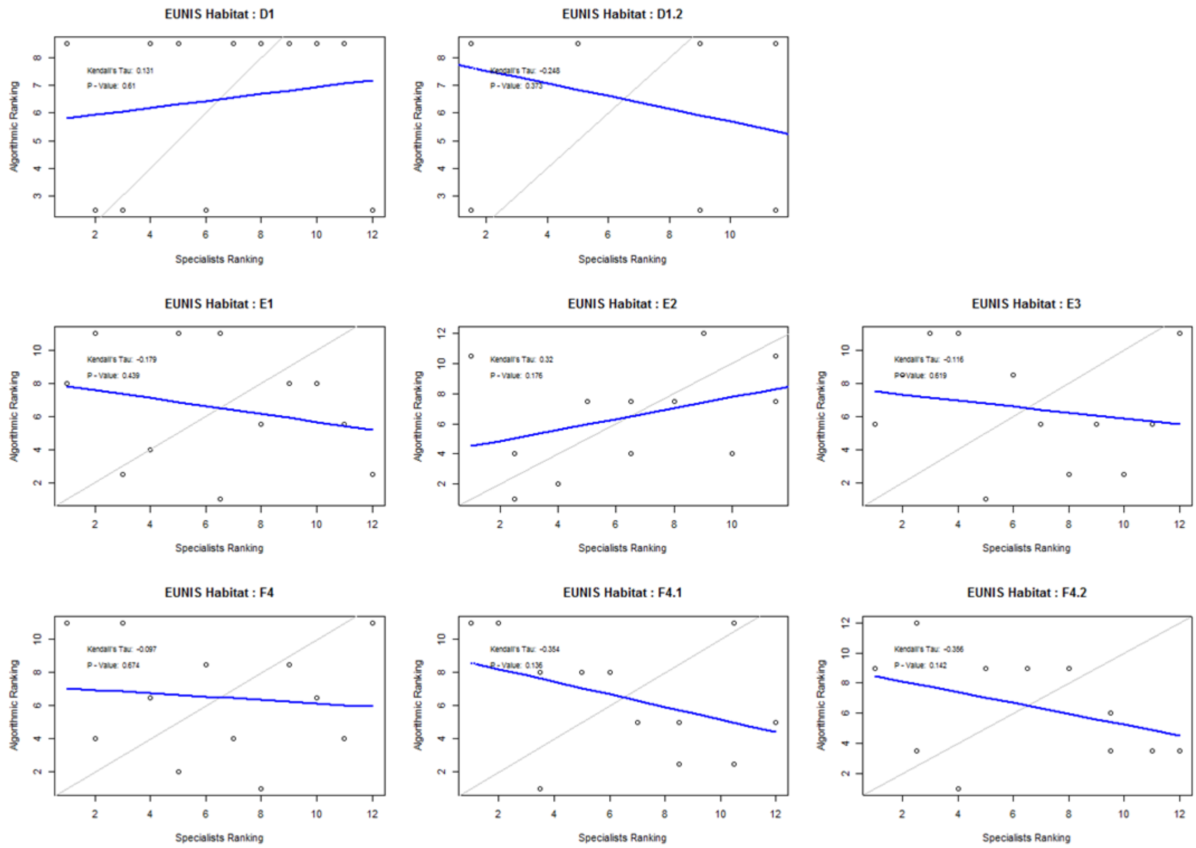
Species richness



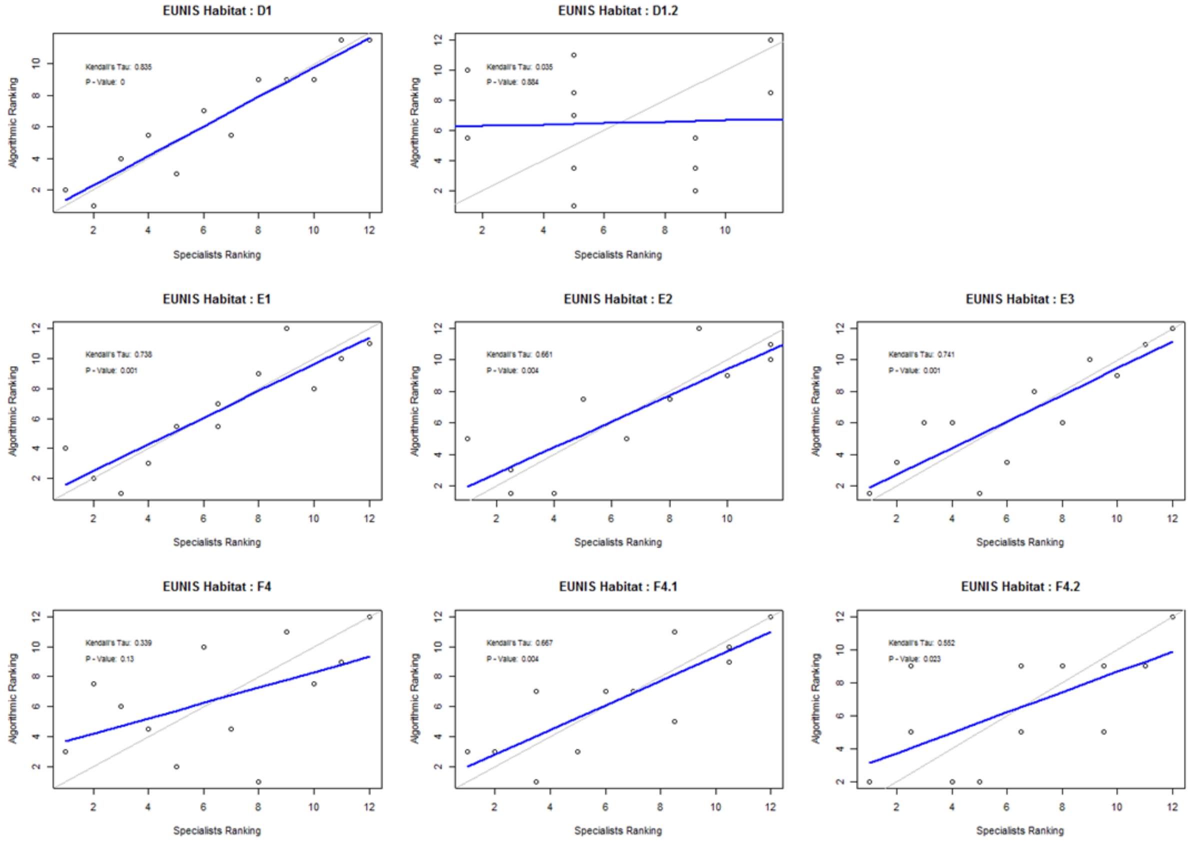
Number of CSM positive indicators



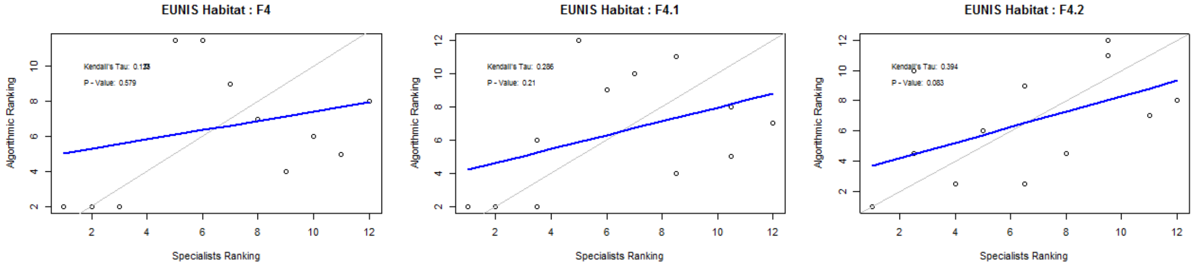
Number of CSM negative indicators



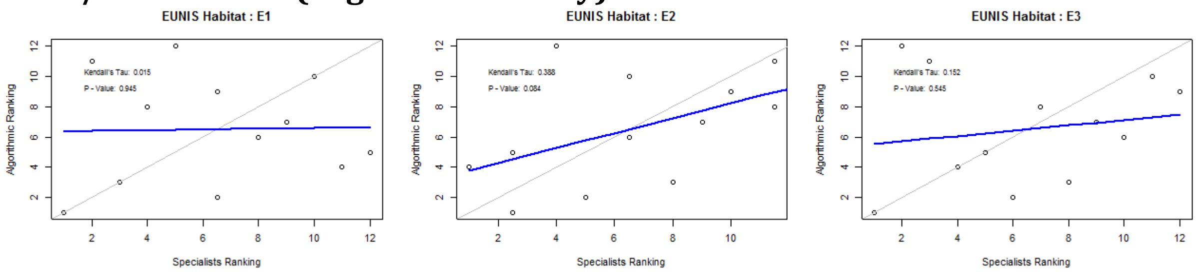
Number of CSM positive indicators minus negative indicators



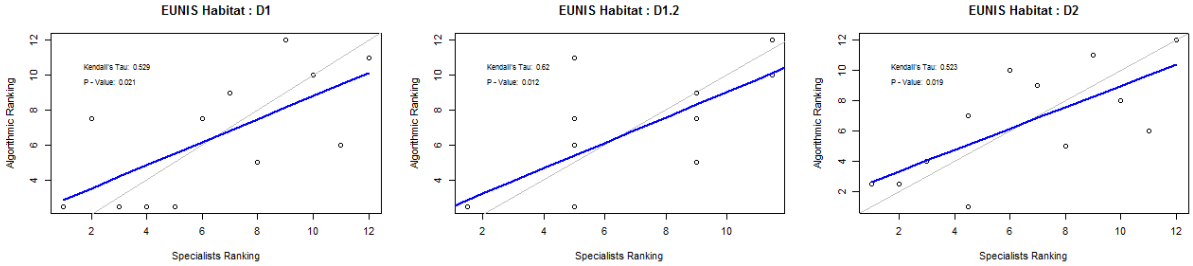
Subshrub cover (F: heathlands only)



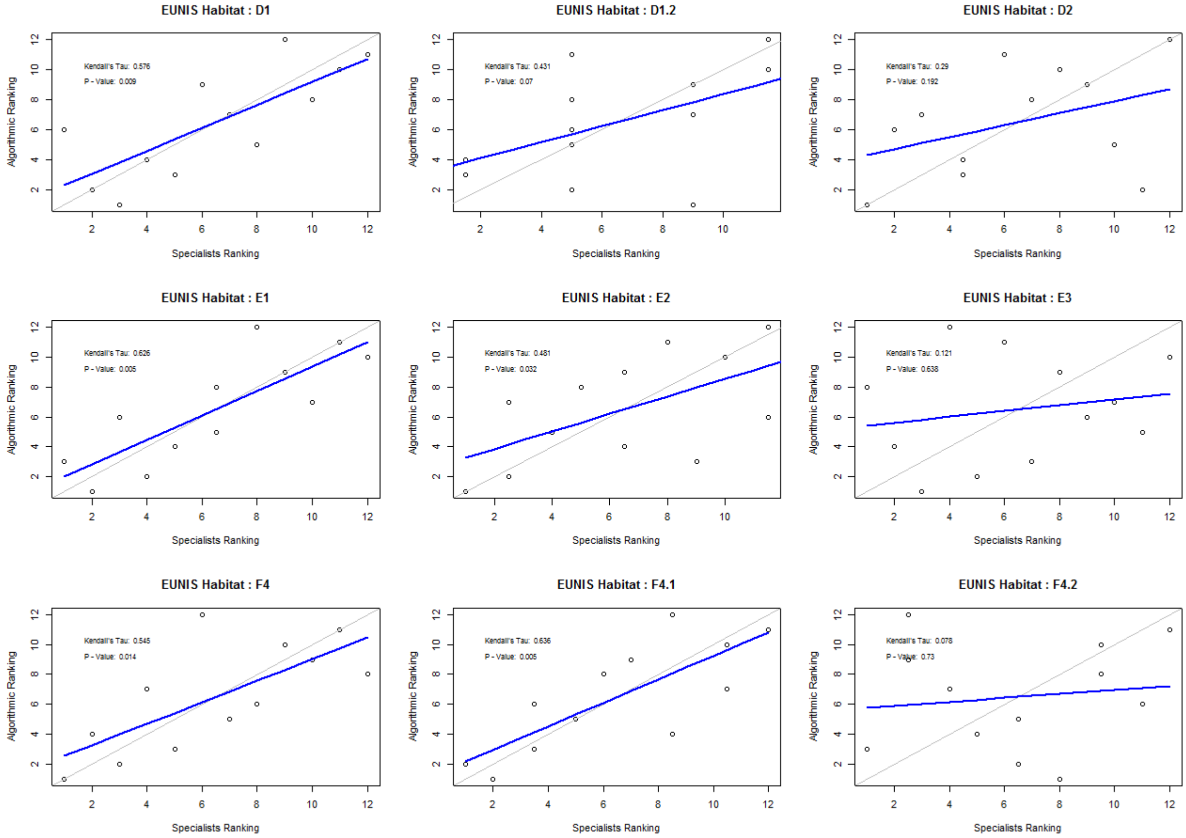
Forb / Total cover (E: grasslands only)



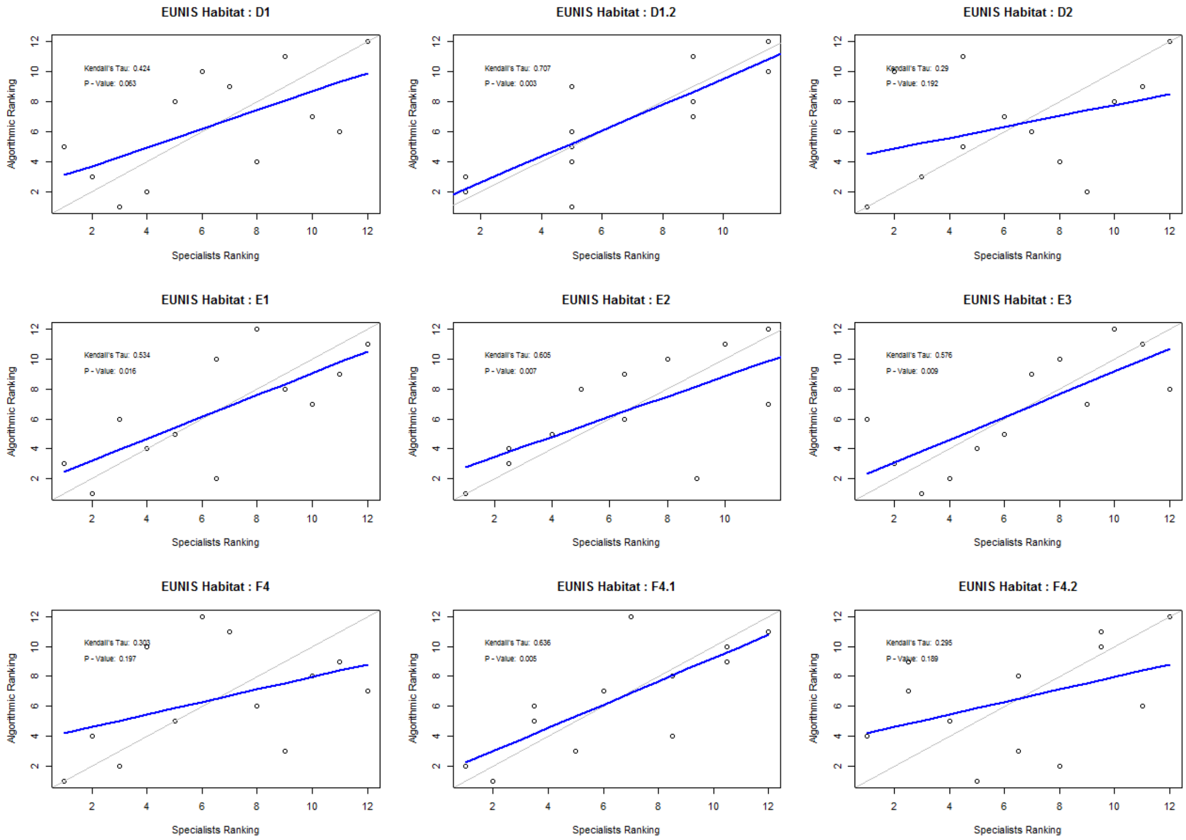
Sphagnum cover (D: bogs only)



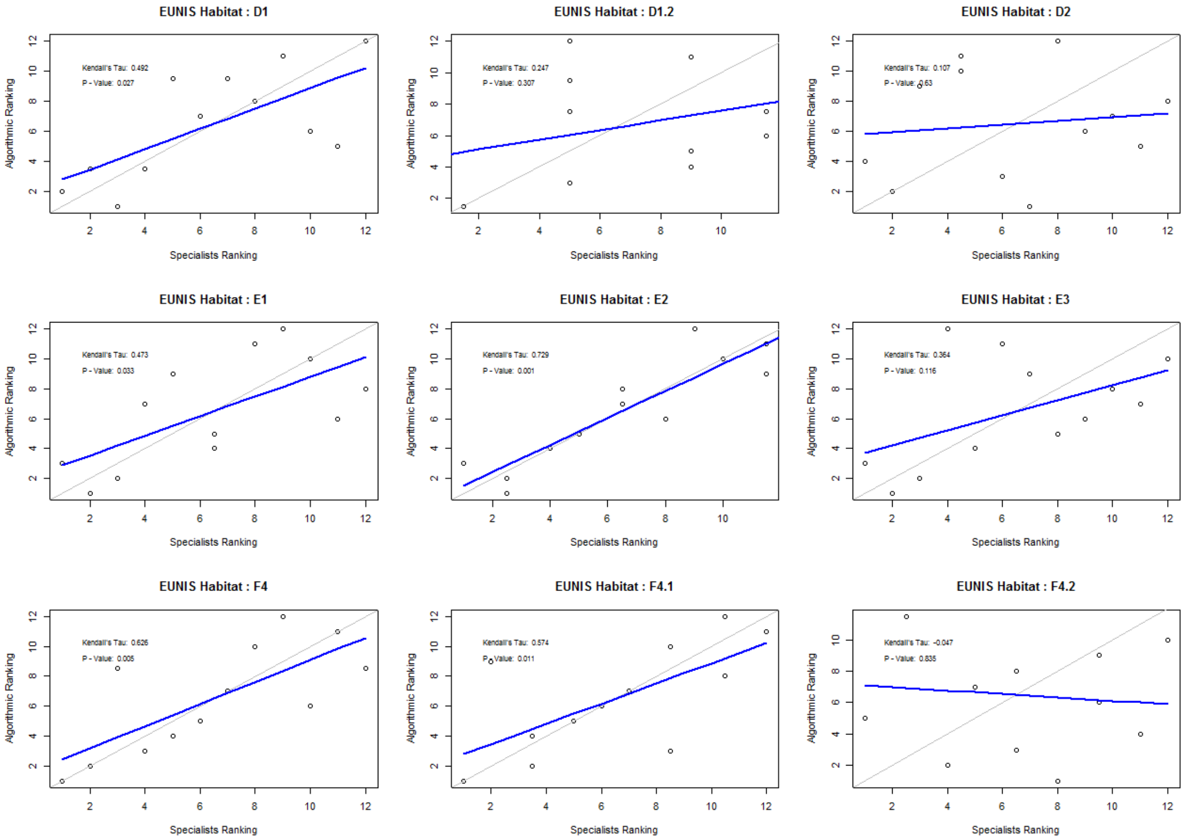
Similarity to reference community (maximum)



Similarity to reference community (mean)



Mean Ellenberg N



Appendix 3 Positive and negative indicator-species for different EUNIS classes.

The following species were collated from text descriptions and indicator-species lists in the summary tables contained in Common Standards Monitoring Guidance.

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Acer pseudoplatanus (c)	9205		N		N				N				N	N		
Aceras anthropophorum	9206		P	P	P				P	P	P	P	P	P		
Achillea ptarmica	9209				P								P	P		
Acinos arvensis	92012		P						P							
Agrimonia eupatoria	92022		P	P					P		P	P				
Agrostis canina	92035					N										N
Agrostis canina sens.lat.	92035					N										N
Agrostis capillaris	92040	N				N	N	N							N	N
Agrostis curtisii	92038		P			N				P						N
Agrostis gigantea	92036					N										N
Agrostis stolonifera	92039					N										N
Agrostis vinealis	92035.1					N										N
Aira caryophyllea	92041		P						P	P						
Aira praecox	92042		P			P			P	P						P
Alchemilla alpina	92048		P	P					P		P	P				
Alchemilla glabra	92051		P	P					P		P	P				
Alchemilla vulgaris agg.	92058		P	P					P		P	P				
Alnus glutinosa (c)	92077					N									N	
Ammophila arenaria	92097					N										N
Anacamptis pyramidalis	92098		P	P	P				P	P	P	P	P	P		
Anagallis tenella	920100				P	P							P	P	P	
Andromeda polifolia	920103	P				P	P	P							P	
Anenome nemorosa	920105		P	P						P	P	P				
Angelica sylvestris	920109		P		P				P				P	P		
Antennaria dioica	920116		P						P							
Anthriscus sylvestris	920125		N		N				N				N	N		
Anthyllis vulneraria	920126		P						P							
Aphanes arvensis	920131		P						P	P						
Apium nodiflorum	920137					N									N	
Arbutus unedo	920149		N						N							
Arctostaphylos alpinus	920156	P				P	P	P							P	P
Arctostaphylos uva-ursi	920155	P				P	P	P							P	P
Armeria maritima	920166		P			P			P							P
Arrhenatherum elatius	920169		N	N	N				N	N	N	N	N	N		
Asperula cynanchica	9205472		P						P							
Astragalus danicus	920207		P						P	P						
Bellis perennis	920231		N						N	N						
Berberis vulgaris	920232		N						N							
Berula erecta	920234			P							P	P				
Betula nana	920238	P				P	P	P							P	P
Betula pendula	920239	N				N	N	N							N	N
Betula pubescens	920240	N				N	N	N							N	N
Betula spp.	9204445	N				N	N	N							N	N
Brachypodium pinnatum	920249		N						N							
Briza media	920256		P						P							
Bromus erectus	920263		N						N							
Bromus hordeaceus	920269			N							N	N				

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Calluna vulgaris	920309	P	P		P	P	P	P		P			P	P	P	P
Caltha palustris	920310			P	P						P	P	P	P		
Campanula glomerata	920315		P						P							
Campanula rotundifolia	920322		P						P	P						
Campylopus subulatus	820147		N						N							
Carduus acanthoides	920335		N						N							
Carduus nutans	920337		N						N	N						
Carex atrata	920345		P			N			P						P	N
Carex atrofusca	920346		P			N			P						P	N
Carex bigelowii	920349	P	P			N	P	P	P						P	N
Carex binervis	920350		P			N			P						P	N
Carex buxbaumii	920352		P			N			P						P	N
Carex capillaris	920353		P			N			P						P	N
Carex caryophyllea	920355		P			N			P						P	N
Carex chordorrhiza	920356		P			N			P						P	N
Carex curta	920359		P			N			P						P	N
Carex depauperata	920362		P			N			P						P	N
Carex digitata	920364		P			N			P						P	N
Carex dioica	920365		P			N			P						P	N
Carex distans	920366		P			N			P						P	N
Carex disticha	920367		P			N			P						P	N
Carex divisa	920368		P			N			P						P	N
Carex echinata	920370		P			N			P						P	N
Carex ericetorum	920373		P			N			P						P	N
Carex filiformis	920375		P			N			P						P	N
Carex flacca	920376		P			N			P						P	N
Carex hostiana	920382		P			N			P						P	N
Carex humilis	920383		P			N			P						P	N
Carex lachenalii	920384		P			N			P						P	N
Carex limosa	920388		P			N			P						P	N
Carex magellanica	920403		P			N			P						P	N
Carex microglochin	920390		P			N			P						P	N
Carex nigra	920393		P			N			P						P	N
Carex ornithopoda	920395		P			N			P						P	N
Carex ovalis	920397		P			N			P						P	N
Carex panicea	920400		P			N			P							N
Carex pauciflora	920402		P			N			P						P	N
Carex pilulifera	920405		P			N			P						P	N
Carex pulicaris	920408		P			N			P							N
Carex punctata	920409		P			N			P						P	N
Carex rariflora	920410		P			N			P						P	N
Carex recta	920411		P			N			P						P	N
Carex rupestris	920415		P			N			P						P	N
Carex saxatilis	920417		P			N			P						P	N
Carex spicata	920357		P			N			P						P	N
Carex strigosa	920420		P			N			P						P	N
Carex sylvatica	920421		P			N			P						P	N
Carex trinervis	920422		P			N			P						P	N
Carex vaginata	920423		P			N			P						P	N
Carex vesicaria	920424		P			N			P						P	N
Carex viridula subsp.brachyrrhyncha	920387		P			N			P						P	N
Carex viridula subsp.oedocarpa	920361		P			N			P						P	N
Carex viridula subsp.viridula	9207118		P			N			P						P	N

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Carex vulpinoidea	920426		P			N			P						P	N
Carlina vulgaris	920427		P						P							
Carum verticillatum	920431				P								P	P		
Centaurea nigra	920444		P	P	P				P		P	P	P	P		
Centaurea scabiosa	920446		P						P							
Centaurium erythraea	9205486		P						P	P						
Centranthus ruber	920455		N						N							
Cephalanthera damasonium	920457		P	P	P				P	P	P	P	P	P		
Cephalanthera longifolia	920458		P	P	P				P	P	P	P	P	P		
Cephalanthera rubra	920459		P	P	P				P	P	P	P	P	P		
Cerastium fontanum	920467		N						P	N						
Cetraria chlorophylla	5502842		P							P						
Cetraria commixta	5502843		P							P						
Cetraria cucullata	5502844		P							P						
Cetraria glauca	5505299		P						P	P						
Cetraria hepatizon	5502847		P						P	P						
Cetraria islandica	5502848		P						P	P						
Cetraria nivalis	5502851		P						P	P						
Cetraria pinastri	5502852		P						P	P						
Cetraria sepincola	5502853		P						P	P						
Chamanerion angustifolium	920477		N			N			N	N						N
Cirsium acaule	920514		P						P							
Cirsium arvense	920515	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Cirsium dissectum	920516			P	P						P	P	P	P		
Cirsium heterophyllum	920518		P	P					P		P	P				
Cirsium vulgare	920522	N	N	N	N	N	N	N	N	N	N	N	N	N		N
Cladonia acuminata	5502858	P	P			P	P	P	P	P					P	
Cladonia alcicornis	5505226	P	P			P	P	P	P	P					P	
Cladonia alpestris	5505300	P	P			P	P	P	P	P					P	
Cladonia alpicola	5505324	P	P			P	P	P	P	P					P	
Cladonia amaurocraea	5502859	P	P			P	P	P	P	P					P	
Cladonia arbuscula	5502860	P	P			P	P	P	P	P					P	
Cladonia bacillaris	5502861	P	P			P	P	P	P	P					P	
Cladonia bellidiflora	5502862	P	P			P	P	P	P	P					P	
Cladonia caespiticia	5502864	P	P			P	P	P	P	P					P	
Cladonia cariosa	5502865	P	P			P	P	P	P	P					P	
Cladonia carneola	5502866	P	P			P	P	P	P	P					P	
Cladonia cenotea	5502867	P	P			P	P	P	P	P					P	
Cladonia cervicornis	5502868	P	P			P	P	P	P	P					P	
Cladonia cf.coccifera	5505338	P	P			P	P	P	P	P					P	
Cladonia cf.polydactyla	5505246	P	P			P	P	P	P	P					P	
Cladonia cf.subcervicornis	5505339	P	P			P	P	P	P	P					P	
Cladonia chlorophaea agg.	5505327	P	P			P	P	P	P	P					P	
Cladonia ciliata	5502871	P	P			P	P	P	P	P					P	
Cladonia coccifera	5502873	P	P			P	P	P	P	P					P	
Cladonia coniocraea	5502874	P	P			P	P	P	P	P					P	
Cladonia conista	5505301	P	P			P	P	P	P	P					P	
Cladonia convoluta	5502875	P	P			P	P	P	P	P					P	
Cladonia cornuta	5502876	P	P			P	P	P	P	P					P	
Cladonia crispata	5502877	P	P			P	P	P	P	P					P	
Cladonia cyathomorpha	5502880	P	P			P	P	P	P	P					P	
Cladonia deformis	5502881	P	P			P	P	P	P	P					P	
Cladonia degenerans	5505302	P	P			P	P	P	P	P					P	
Cladonia delessertii	5505349	P	P			P	P	P	P	P					P	

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Cladonia destricta	5505334	P	P			P	P	P	P	P					P	
Cladonia digitata	5502882	P	P			P	P	P	P	P					P	
Cladonia ecmocyna	5505340	P	P			P	P	P	P	P					P	
Cladonia fimbriata	5502883	P	P			P	P	P	P	P					P	
Cladonia floerkeana	5502885	P	P			P	P	P	P	P					P	
Cladonia foliacea	5502886	P	P			P	P	P	P	P					P	
Cladonia furcata	5502888	P	P			P	P	P	P	P					P	
Cladonia glauca	5502890	P	P			P	P	P	P	P					P	
Cladonia gonecha	5505303	P	P			P	P	P	P	P					P	
Cladonia gracilis	5502891	P	P			P	P	P	P	P					P	
Cladonia impexa	5505304	P	P			P	P	P	P	P					P	
Cladonia incrassata	5502894	P	P			P	P	P	P	P					P	
Cladonia leucophaea	5505305	P	P			P	P	P	P	P					P	
Cladonia luteoalba	5502895	P	P			P	P	P	P	P					P	
Cladonia macilenta	5502896	P	P			P	P	P	P	P					P	
Cladonia macrophylla	5502897	P	P			P	P	P	P	P					P	
Cladonia mitis	5502902	P	P			P	P	P	P	P					P	
Cladonia nylanderi	5505306	P	P			P	P	P	P	P					P	
Cladonia ochrochlora	5502903	P	P			P	P	P	P	P					P	
Cladonia papillaria	5505307	P	P			P	P	P	P	P					P	
Cladonia parasitica	5502904	P	P			P	P	P	P	P					P	
Cladonia pityrea	5505308	P	P			P	P	P	P	P					P	
Cladonia pocillum	5502908	P	P			P	P	P	P	P					P	
Cladonia polydactyla	5502909	P	P			P	P	P	P	P					P	
Cladonia portentosa	5502910	P	P			P	P	P	P	P					P	
Cladonia pyxidata	5502912	P	P			P	P	P	P	P					P	
Cladonia ramulosa	5502913	P	P			P	P	P	P	P					P	
Cladonia rangiferina	5502914	P	P			P	P	P	P	P					P	
Cladonia rangiformis	5502915	P	P			P	P	P	P	P					P	
Cladonia scabriuscula	5505309	P	P			P	P	P	P	P					P	
Cladonia squamosa	5502919	P	P			P	P	P	P	P					P	
Cladonia strepsilis	5502923	P	P			P	P	P	P	P					P	
Cladonia subcervicornis	5502925	P	P			P	P	P	P	P					P	
Cladonia subrangiformis	5505285	P	P			P	P	P	P	P					P	
Cladonia subsquamosa	5505286	P	P			P	P	P	P	P					P	
Cladonia subulata	5502926	P	P			P	P	P	P	P					P	
Cladonia tenuis	5505322	P	P			P	P	P	P	P					P	
Cladonia turgida	5502929	P	P			P	P	P	P	P					P	
Cladonia uncialis	5502931	P	P			P	P	P	P	P					P	
Cladonia verticillata	5505287	P	P			P	P	P	P	P					P	
Clinopodium vulgare	920530		P						P							
Cochlearia pyrenaica	9205422		P						P							
Coeloglossum viride	920537		P	P	P				P	P	P	P	P	P		
Conopodium majus	920541			P							P	P				
Corallorhiza trifida	920545		P	P	P				P	P	P	P	P	P		
Cornus suecica	920478	P					P	P								
Corynephorus canescens	920558					P										P
Cotoneaster spp.	9204526		N						N							
Crataegus monogyna (s)	920569		N		N				N				N	N		
Crepis paludosa	920576				P								P	P		
Cynosurus cristatus	920597		N						N	N						
Cypripedium calceolus	920601		P	P	P				P	P	P	P	P	P		
Cytisus scoparius	9201822					N										N
Dactylis glomerata	920607		N	N	N				N	N	N	N	N	N		

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Dactylorhiza fuchsii	920608		P	P	P				P	P	P	P	P	P		
Dactylorhiza incarnata	920609		P	P	P				P	P	P	P	P	P		
Dactylorhiza lapponica	9202964		P	P	P				P	P	P	P	P	P		
Dactylorhiza maculata	920610		P	P	P				P	P	P	P	P	P		
Dactylorhiza majalis	920611		P	P	P				P	P	P	P	P	P		
Dactylorhiza praetermissa	920612		P	P	P				P	P	P	P	P	P		
Dactylorhiza purpurella	920613		P	P	P				P	P	P	P	P	P		
Dactylorhiza spp.	9204528			P							P	P				
Dactylorhiza traunsteineri	920614		P	P	P				P	P	P	P	P	P		
Danthonia decumbens	9201915		P			N			P							N
Deschampsia cespitosa	920627	N		N	N		N	N			N	N	N	N		
Deschampsia flexuosa	920628		N			N				N						N
Dianthus deltoides	920635		P						P							
Digitalis purpurea	920640					N									N	N
Draba incana	920651		P						P							
Drosera intermedia	920655	P				P	P	P							P	
Drosera longifolia	920654	P				P	P	P							P	
Drosera rotundifolia	920657	P				P	P	P							P	
Dryas octopetala	920658		P						P							
Eleocharis acicularis	920673					N									N	
Eleocharis austriaca	9202267					N									N	
Eleocharis multicaulis	920674					N									N	
Eleocharis palustris	920675					N									N	
Eleocharis quinqueflora	920677					N									N	
Eleocharis uniglumis	920678					N									N	
Empetrum nigrum	920684	P				P	P	P							P	P
Epilobium alsinifolium	920690					N									N	N
Epilobium anagallidifolium	920691					N									N	N
Epilobium brunnescens	920699					N									N	N
Epilobium ciliatum	920688					N									N	N
Epilobium hirsutum	920692	N				N	N	N							N	N
Epilobium lanceolatum	920694					N									N	N
Epilobium montanum	920695					N									N	N
Epilobium obscurum	920696					N									N	N
Epilobium parviflorum	920698					N									N	N
Epilobium roseum	920700					N									N	N
Epilobium tetragonum	9207292					N									N	N
Epipactis atrorubens	920702		P	P	P				P	P	P	P	P	P		
Epipactis helleborine	920705		P	P	P				P	P	P	P	P	P		
Epipactis leptochila	9205476		P	P	P				P	P	P	P	P	P		
Epipactis palustris	920708		P	P	P				P	P	P	P	P	P		
Epipactis phyllanthes	920709		P	P	P				P	P	P	P	P	P		
Epipactis purpurata	920710		P	P	P				P	P	P	P	P	P		
Epipactis youngiana	9202549		P	P	P				P	P	P	P	P	P		
Epipogium aphyllum	920711		P	P	P				P	P	P	P	P	P		
Equisetum arvense	910712			N							N	N				
Erica cilliaris	920725	P				P	P	P							P	P
Erica cinerea	920726	P	P			P	P	P		P					P	P
Erica tetralix	920731	P	P		P	P	P	P		P			P	P	P	P
Erica vagans	920732	P				P	P	P							P	P
Erigeron acer	920733		P						P							
Eriophorum angustifolium	920740	P				N	P	P							N	
Eriophorum vaginatum	920744	P					P	P								
Erodium cicutarium	920745		P			P			P	P						P

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Eupatorium cannabinum	920763			P	P						P	P	P	P		
Euphrasia officinalis agg.	9202243		P	P					P		P	P				
Fallopia japonica	9201528					N									N	N
Festuca altissima	920812					N										N
Festuca arenaria	920819					N										N
Festuca armoricana	9207359					N										N
Festuca arundinacea	920813					N										N
Festuca filiformis	920822.2					N										N
Festuca gigantea	920816					N										N
Festuca huonii	9207361					N										N
Festuca lemanii	9205430					N										N
Festuca longifolia	920817					N										N
Festuca ovina	920822					N										N
Festuca ovina agg.	920821					N										N
Festuca pratensis	920823					N										N
Festuca pratensis x Lolium perenne (x Festulolium loliaceum)	920815					N										N
Festuca rubra	920825					N										N
Festuca rubra agg.	920824					N										N
Festuca vivipara	920826					N										N
Filipendula ulmaria	920833		P	P	P				P		P	P	P	P		
Filipendula vulgaris	920834		P	P		P			P		P	P				P
Fragaria vesca	920838		P						P							
Fraxinus excelsior (c)	920841		N						N							
Galium aparine	920873		N	N					N		N	N				
Galium palustre	920882			P	P						P	P	P	P		
Galium saxatile	920878		P			P			P	P					P	P
Galium sterneri	920883.2		P						P							
Galium uliginosum	920887			P	P						P	P	P	P		
Galium verum	920888		P	P		P			P	P	P	P				P
Gaultheria shallon	920890					N										N
Genista anglica	920891					P									P	P
Genista pilosa	920892					P										P
Genista tinctoria	920893		P	P						P	P	P				
Gentiana verna	920896		P						P							
Gentianella amarella	920897		P						P							
Gentianella anglica	920899		P						P							
Gentianella campestris	920901		P						P							
Gentianella ciliata	9202629		P						P							
Gentianella germanica	920903		P						P							
Gentianella uliginosa	920905		P						P							
Geranium sanguineum	920920		P						P							
Geranium sylvaticum	920921		P	P					P		P	P				
Geum rivale	920924		P	P	P				P		P	P	P	P		
Glyceria fluitans	920933				N	N							N	N	N	
Glyceria maxima	920934	N		N	N		N	N			N	N	N	N		
Goodyera repens	920943		P	P	P				P	P	P	P	P	P		
Gymnadenia conopsea	920948		P	P	P				P	P	P	P	P	P		
Hammarbya paludosa	920951		P	P	P				P	P	P	P	P	P		
Helianthemum appeninum	920593		P						P							
Helianthemum canum	920954		P						P							
Helianthemum nummularium	920955		P			P			P							P
Helictotrichon pubescens	920962		N						N							
Herminium monorchis	920969		P	P	P				P	P	P	P	P	P		

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Himantoglossum hircinum	920978		P	P	P				P	P	P	P	P	P		
Hippocrepis comosa	920979		P						P							
Hippophaea rhamnoides	920980					N										N
Holcus lanatus	920983	N	N	N	N	N	N	N	N	N	N	N	N	N	N	
Hydrocotyle vulgaris	920999			P	P						P	P	P	P		
Hypericum hirsutum	9201010		P						P							
Hypericum humifusum	9201011		P						P							
Hypericum maculatum	9201006		P						P							
Hypericum montanum	9201013		P						P							
Hypericum perforatum	9201014		P						P							
Hypericum pulchrum	9201015		P						P							
Hypocheoris radicata	9201020					P										P
Juncus acutiflorus	9201050			N		N					N	N			N	
Juncus articulatus	9201054			N		N					N	N			N	
Juncus effusus	9201067	N	N	N		N	N	N		N	N	N			N	N
Juncus squarrosus	9201075		N	N		N				N	N	N			N	N
Knautia arvensis	9201084		P						P							
Kobresia simpliciuscula	9201085		P						P							
Koeleria macrantha	9201087		P						P							
Lathyrus linifolius	9201112		P	P					P	P	P	P				
Lathyrus pratensis	9201116			P							P	P				
Leontodon hispidus	9201130		P	P	P				P		P	P	P	P		
Leontodon saxatilis	9201131		P	P					P		P	P				
Leontodon taraxacoides	9201131		P							P						
Linum catharticum	9201169		P						P							
Liparis loeselii	9201171		P	P	P				P	P	P	P	P	P		
Listera cordata	9201172		P	P	P				P	P	P	P	P	P		
Listera ovata	9201173		P	P	P				P	P	P	P	P	P		
Logfia minima	920831					P										P
Lolium perenne	9201183		N	N	N				N	N	N	N	N	N		
Lotus corniculatus	9201191		P	P		P			P	P	P	P				P
Lotus uliginosus	9201194			P	P						P	P	P	P		
Luzula spicata	9201208		P						P							
Lychnis flos-cuculi	9201210			P	P						P	P	P	P		
Lythrum salicaria	9201227				P								P	P		
Mentha aquatica	9201272			P	P						P	P	P	P		
Menyanthes trifoliata	9201289	P					P	P								
Molinia caerulea	9201307					N									N	N
Myosotis alpestris	9201316		P						P							
Myrica gale	9201328	P				P	P	P							P	P
Nardus stricta	9201344					N										N
Narthecium ossifragum	9201345	P			P	P	P	P					P	P	P	
Neotinea maculata	9201351		P	P	P				P	P	P	P	P	P		
Neottia nidus-avis	9201352		P	P	P				P	P	P	P	P	P		
Oenanthe crocata	9201363					N									N	
Oenanthe silaifolia	9201368			P							P	P				
Ophrys apifera	9201382		P	P	P				P	P	P	P	P	P		
Ophrys fuciflora	9201383		P	P	P				P	P	P	P	P	P		
Ophrys insectifera	9201384		P	P	P				P	P	P	P	P	P		
Ophrys sphegodes	9201385		P	P	P				P	P	P	P	P	P		
Orchis laxiflora	9201386		P	P	P				P	P	P	P	P	P		
Orchis mascula	9201387		P	P	P				P	P	P	P	P	P		
Orchis militaris	9201388		P	P	P				P	P	P	P	P	P		
Orchis morio	9201389		P	P	P				P	P	P	P	P	P		

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Orchis purpurea	9201390		P	P	P				P	P	P	P	P	P		
Orchis simia	9201391		P	P	P				P	P	P	P	P	P		
Orchis ustulata	9201392		P	P	P				P	P	P	P	P	P		
Origanum vulgare	9201393		P						P							
Ornithopus perpusillus	9201397		P						P	P						
Parietaria judaica	9201435		N						N							
Parnassia palustris	9201437		P						P							
Pedicularis palustris	9201441				P								P	P		
Pedicularis sylvatica	9201442		P		P					P			P	P		
Periscaria vivipara	9201543		P						P							
Persicaria bistorta	9201525			P							P	P				
Phalaris arundinacea	9201454	N		N	N		N	N			N	N	N	N		
Phleum arenarium	9201459					P										P
Phleum pratense	9202247		N	N	N					N	N	N	N	N		
Phragmites australis	9201465	N			N	N	N	N					N	N	N	
Picea abies	9201470	N				N	N	N							N	N
Picea sitchensis	9202401	N				N	N	N							N	N
Pilosella officinarum	920976		P						P	P						
Pimpinella saxifraga	9201476		P	P					P	P	P	P				
Pinguicula lusitanica	9201480					P									P	
Pinguicula vulgaris	9201481		P			P			P						P	
Pinus sylvestris	9201484	N				N	N	N							N	N
Plantago coronopus	9201485		P						P	P						
Plantago lanceolata	9201487					P										P
Plantago major	9201488		N	N					N	N	N	N				
Plantago maritima	9201489		P			P			P							P
Plantago media	9201490		P						P							
Platanthera bifolia	9201492		P	P	P				P	P	P	P	P	P		
Platanthera chlorantha	9201493		P	P	P				P	P	P	P	P	P		
Poa trivialis	9201507				N								N	N		
Polygala amara	9201510		P	P					P	P	P	P				
Polygala calcarea	9201512		P	P					P	P	P	P				
Polygala serpylifolia	9201514		P	P		P			P	P	P	P			P	P
Polygala vulgaris	9201515		P	P					P	P	P	P				
Polytrichum alpinum	820481	N					N	N								
Polytrichum commune	820482	N					N	N								
Polytrichum formosum	820483	N					N	N								
Polytrichum juniperinum	820485	N					N	N								
Polytrichum longisetum	820484	N					N	N								
Polytrichum piliferum	820488	N					N	N								
Polytrichum sexangulare	820487	N					N	N								
Potentilla erecta	9201588		P	P	P	P			P	P	P	P	P	P	P	P
Potentilla palustris	9201592			P	P						P	P	P	P		
Primula farinosa	9201603		P						P							
Primula veris	9201605		P	P					P		P	P				
Prunus spinosa	9201617		N		N	N			N				N	N	N	N
Pseudorchis albida	920947		P	P	P				P	P	P	P	P	P		
Pteridium aquilinum	9101619	N	N		N	N	N	N		N			N	N	N	
Quercis robur	9201640				N	N							N	N	N	N
Quercus petraea	9201638				N	N							N	N	N	N
Racomitrium lanuginosum	820525	P				P	P	P							P	P
Ranunculus acris	9201642					N										N
Ranunculus flammula	9201651			P		N					P	P				N
Ranunculus repens	9201660	N	N		N	N	N	N		N			N	N	N	N

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Rhinanthus minor	9201678			P							P	P				
Rhododendron ponticum	9205194	N	N			N	N	N		N						N
Rhynchospora alba	9201691	P					P	P								
Rhynchospora fusca	9201692	P					P	P								
Rhytidiadelphus squarrosus	820533		N							N						
Rubus chamaemorus	9201727	P				P	P	P							P	
Rubus fruticosus agg.	9201728	N			N	N	N	N					N	N	N	N
Rubus idaeus	9201729					N									N	N
Rumex acetosella	9201735		P			P			P	P						P
Rumex crispus	9201742		N	N	N	N			N	N	N	N	N	N		N
Rumex obtusifolius	9201748		N	N	N	N			N	N	N	N	N	N	N	N
Salix alba	9201784	N			N	N	N	N					N	N	N	
Salix arbuscula	9201785	N			N	N	N	N					N	N	N	
Salix aurita	9201787	N			N	N	N	N					N	N	N	
Salix caprea	9201788	N			N	N	N	N					N	N	N	
Salix cinerea	9201789	N			N	N	N	N					N	N	N	
Salix fragilis	9201793	N			N	N	N	N					N	N	N	
Salix herbacea	9201794	N			N	N	N	N					N	N	N	
Salix lanata	9201795	N			N	N	N	N					N	N	N	
Salix lapponum	9201796	N			N	N	N	N					N	N	N	
Salix myrsinifolia	9201797	N			N	N	N	N					N	N	N	
Salix myrsinites	9201798	N			N	N	N	N					N	N	N	
Salix pentandra	9201799	N			N	N	N	N					N	N	N	
Salix phylicifolia	9201800	N			N	N	N	N					N	N	N	
Salix purpurea	9201801	N			N	N	N	N					N	N	N	
Salix repens	9201802				P	P							P	P	P	P
Salix reticulata	9201803	N	P		N	N	N	N	P				N	N	N	
Salix triandra	9201804	N			N	N	N	N					N	N	N	
Salix viminalis	9201805	N			N	N	N	N					N	N	N	
Sanguisorba minor	9205442		P	P		P			P		P	P				P
Sanguisorba officinalis	9201818		P	P	P					P	P	P	P	P		
Saxifraga aizoides	9201826		P						P							
Saxifraga hypnoides	9201835		P						P							
Saxifraga oppositifolia	9201837		P						P							
Scabiosa columbaria	9201846		P						P							
Schoenus nigricans	9201855					N									N	
Scilla verna	9201857		P			P			P							P
Sedum acre	9201875		P			P			P	P						P
Sedum album	9201876		N						N							
Sedum anglicum	9201877		P						P	P						
Senecio aquaticus	9201891					N										N
Senecio erucifolius	9201896					N										N
Senecio jacobaea	9201899		N	N		N			N	N	N	N			N	N
Senecio vulgaris	9201905					N										N
Serapias parviflora	9204243		P	P	P				P	P	P	P	P	P		
Serratula tinctoria	9201906		P	P	P	P			P	P	P	P	P	P	P	P
Sesleria caerulea	9201908		P						P							
Sibbaldia procumbens	9201913		P						P							
Silaum silaus	9201916			P							P	P				
Silene acaulis	9201917		P						P							
Sonchus arvensis	9201952		N						N							
Sonchus asper	9201953		N						N							
Sphagnum auriculatum	820578	P			P	P	P	P					P	P	P	
Sphagnum balticum	820552	P			P	P	P	P					P	P	P	

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Sphagnum capillifolium	820564	P			P	P	P	P					P	P	P	
Sphagnum compactum	820554	P			P	P	P	P					P	P	P	
Sphagnum contortum	820555	P			P	P	P	P					P	P	P	
Sphagnum cuspidatum	820556	P			P	P	P	P					P	P	P	
Sphagnum fimbriatum	820557	P			P	P	P	P					P	P	P	
Sphagnum fuscum	820558	P			P	P	P	P					P	P	P	
Sphagnum girgensohnii	820559	P			P	P	P	P					P	P	P	
Sphagnum imbricatum	820560	P			P	P	P	P					P	P	P	
Sphagnum lindbergii	820561	P			P	P	P	P					P	P	P	
Sphagnum magellanicum	820562	P			P	P	P	P					P	P	P	
Sphagnum molle	820563	P			P	P	P	P					P	P	P	
Sphagnum palustre	820566	P			P	P	P	P					P	P	P	
Sphagnum papillosum	820567	P			P	P	P	P					P	P	P	
Sphagnum platyphyllum	820555.2	P			P	P	P	P					P	P	P	
Sphagnum pulchrum	820569	P			P	P	P	P					P	P	P	
Sphagnum quinquefarium	820570	P			P	P	P	P					P	P	P	
Sphagnum recurvum	820571				P	P							P	P	P	
Sphagnum riparium	820572	P			P	P	P	P					P	P	P	
Sphagnum russowii	820574	P			P	P	P	P					P	P	P	
Sphagnum squarrosum	820575	P			P	P	P	P					P	P	P	
Sphagnum strictum	820576	P			P	P	P	P					P	P	P	
Sphagnum subnitens	820568	P			P	P	P	P					P	P	P	
Sphagnum tenellum	820579	P			P	P	P	P					P	P	P	
Sphagnum teres	820580	P			P	P	P	P					P	P	P	
Sphagnum warnstorfii	820581	P			P	P	P	P					P	P	P	
Spiranthes aestivalis	9201995		P	P	P				P	P	P	P	P	P		
Spiranthes romanzoffiana	9201996		P	P	P				P	P	P	P	P	P		
Spiranthes spiralis	9201997		P	P	P				P	P	P	P	P	P		
Stachys officinalis	920237		P	P					P	P	P	P				
Succisa pratensis	9202021		P	P	P	P			P	P	P	P	P	P	P	
Teesdalia nudicaulis	9202041		P						P							
Thalictrum alpinum	9202047		P						P							
Thalictrum flavum	9202048			P	P						P	P	P	P		
Thalictrum minus	9202049		P						P							
Thymus polytrichus	9202060		P			P			P	P						P
Thymus pulegioides	9202061		P						P	P						
Trichophorum cespitosum	9201858	P				N	P	P								N
Trifolium repens	9202092		N	N	N				N	N	N	N	N	N		
Trinia glauca	9202104		P						P							
Trisetum flavescens	9202105		N						N							
Trollius europaeaus	9202106			P	P						P	P	P	P		
Typha angustifolia	9202110					N									N	
Typha latifolia	9202111					N									N	
Ulex europaeus	9202112				N	N							N	N	N	N
Ulex gallii	9202113					P									P	P
Ulex minor	9202114					P									P	P
Urtica dioica	9202126	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Vaccinium myrtillus	9202136	P	P			P	P	P		P					P	P
Vaccinium oxycoccus	9201419	P				P	P	P							P	P
Vaccinium vitis-idaea	9202138	P				P	P	P							P	P
Valeriana dioica	9202139			P	P						P	P	P	P		
Valeriana officinalis	9202140				P								P	P		
Veronica officinalis	9202173		P						P	P						
Vicia orobus	9202196		P							P						

BRC_name	BRC_number	D1	E1	E2	E3	F4	D1.1	D1.2	E1.2	E1.7	E2.1	E2.2	E3.4	E3.5	F4.1	F4.2
Viola hirta	9202210		P						P	P						
Viola palustris	9202215		P	P	P					P	P	P	P	P		
Viola riviniana	9202218		P			P				P						P
Viola seedling/sp	9204565		P							P						