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A decision framework to attribute atmospheric nitrogen deposition as a threat to or cause of unfavourable habitat condition on protected sites

Laurence Jones[1], Jane Hall[1], Ian Strachan[2], Chris Field[3], Ed Rowe[1], Carly Stevens[4], Simon Caporn[3], Ruth Mitchell[5], Andrea Britton[5], Ron Smith[6], Bill Bealey[6], Dario Masante[1], Richard Hewison[5], Kevin Hicks[7], Clare Whitfield[8] & Ed Mountford[8].

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Developing a decision framework to attribute atmospheric nitrogen deposition as a threat to or cause of unfavourable habitat condition on protected sites

Annex 2: Strength of site-based evidence - Work Package 2 report

Jones, L., Field, C., Stevens, C., Strachan, I., Mitchell, R., Caporn, S. & Rowe, E.

Contents

1 Introduction 1

2 Aims and objectives of this Work Package 1

3 Overview of approach 1

4 WP2.1 Identification of potential indicators in CSM 2

4.1 Aim 2

4.2 Description of approach 3

4.3 Overview of target scoring across CSM habitats 9

4.4 Assessing Habitat Feature outcome by Pass/Failure of its constituent CSM targets 13

4.5 Recommendations for developing CSM targets to assess N deposition 14

5 WP2.2 Using other site-based evidence 17

5.1 Aim 17

5.2 Existing evidence sources 17

5.3 Information source considerations 18

5.3.1 Type of data 18

5.3.2 Information format 18

5.3.3 Purpose of study 18

5.3.4 Quality 18

5.3.5 Data accessibility 19

5.3.6 Age 19

5.4 Evidence sources 19

5.4.1 Data confirming evidence of N deposition impact 19

5.4.2 Evidence about confounding factors 20

5.4.3 Not N-targeted data 20

5.5 Collection of additional field data 20

5.6 Guidelines on how to interpret other sources of site-based evidence 21

6 References 24

Appendix A. Guidance on using the Factor 2 (WP2.1) spreadsheets 26

1 Introduction

Work undertaken by the Statutory Nature Conservation Bodies (SNCBs) has shown that it is extremely hard to attribute, with confidence, nitrogen (N) deposition as a cause of unfavourable condition based on CSM assessments (Whitfield & Mountford 2014). Amongst the reasons for this are that CSM guidance does not include definitive and specific indicators of N deposition impacts; the CSM process was not designed to detect or attribute N deposition impacts; and to attribute N deposition as a cause of unfavourable condition with high confidence requires more detailed and structured monitoring methods, which are not consistent with the rapid assessment approach of CSM (see also Emmett *et al* 2011; Stevens *et al* 2009).

However, in many cases, CSM guidance will contain targets of attributes which would be expected to respond negatively in response to excess nutrient loads. Although failure of such targets in CSM assessments may be confounded by other pressures, such as grazing, this would nevertheless indicate a response consistent with eutrophication. The principle of the approach adopted in this project is that this, together with the theoretical evidence (brought together in the Exceedance Score (Factor 1), should serve as a mechanism to point to action being required to reduce N deposition impacts (e.g. to reduce deposition loads at a site, and to mitigate impacts), should N deposition be identified as the likely cause of unfavourable condition.

2 Aims and objectives of this Work Package

This Annex is a report of Work Package (WP) 2 which aimed to identify and evaluate the contribution of site-based information in determining the overall strength of evidence that the condition of a Habitat Feature[1] is, or is not, being adversely impacted by N deposition.

The approach taken was based mainly around identifying potential indicators of N deposition among the existing targets described in CSM guidance (section 4, WP2.1). These can then be used to assess the likelihood that N deposition is leading to the failure of particular targets, and the habitat feature as a whole, given the potential influence of confounding factors[2].

In addition, other possible sources of site-based information were considered, with a view to assessing their potential contribution in assessing N deposition impacts (section 5, WP2.2).

3 Overview of approach

Evidence from CSM or other sources was combined to form eight realistic levels of evidence in terms of interpreting N deposition impacts in the context of other potentially confounding factors (Table 1). The highest level is “strong” site-based evidence that N deposition is causing adverse impacts. This can only arise through specific evidence from sources other than CSM assessments (see WP2.2), as CSM assessments are not able to provide this strength of evidence. Subsequent levels of evidence can be arrived at through CSM assessments (see section 4) in combination with additional site-based information (see section 5).

[1] This refers to a specific type of habitat which is an interest feature within a protected site, such as an area of alpine flush, fixed dune grassland or lowland dry heath

[2] Confounding factors are defined here as: “Those factors producing ecological responses which could be confused with N deposition impacts”.

Table 1. Framework to summarise the strength of site-based evidence that N deposition is the cause of adverse impacts on the condition of a habitat.
The categories reflect: (i) the quality and how widely the interpretation of evidence is agreed upon (evidence strength); (ii) the likelihood that habitat condition is unfavourable due to N deposition impacts, rather than due to confounding factors. The categories are designed so that site-based evidence from either CSM assessments (WP2.1, section 4) or additional sources (W2.2, section 5) can be incorporated into the final assessment matrix (WP3.1, see Annex 3 section 1).

Category	Description
Strong	Site-based evidence of adverse N deposition impacts is strong – impacts clearly due to N deposition rather than confounding factors – very likely that habitat condition is unfavourable due to N deposition impacts
Moderately strong	Site-based evidence of adverse N deposition impacts is moderately strong – some strong indicators of possible N deposition impacts which are weakly confounded – likely that habitat condition is unfavourable due to N deposition impacts
Moderate	Site-based evidence of adverse N deposition impacts is moderate – some strong indicators of possible N deposition impacts which are strongly confounded – moderately likely that habitat condition is unfavourable due to N deposition impacts
Weak	Site-based evidence of adverse N deposition impacts is weak – some weak indicators of possible N deposition impacts which are weakly confounded – it is possible that habitat condition is unfavourable due to N deposition impacts but evidence is weak
Very weak	Site-based evidence of adverse N deposition impacts is very weak – some weak indicators of possible N deposition impacts that are strongly confounded – unlikely that habitat condition is unfavourable due to N deposition impacts
No evidence	No site-based evidence of N deposition impacts – no possible influence on the assessment of site condition
Weak evidence for no N impact	Site based evidence for NO adverse N deposition impacts is weak – some weak indicators of possible N deposition impacts, but these show no adverse impacts – quite unlikely that habitat condition is being impacted by N deposition impacts
Moderate evidence for no N impact	Site based evidence for NO adverse N deposition impacts is moderately strong – some strong indicators of possible N deposition impacts, but these show no adverse impacts – unlikely that habitat condition is being impacted by N deposition impacts

4 WP2.1 Identification of potential indicators in CSM

4.1 Aim

The aim of WP2.1 was to identify which targets shown in the CSM guidance are “potential indicators” of N deposition impacts, i.e. where current evidence shows the target is likely to respond negatively to enrichment from N deposition.

4.2 Description of approach

The list of CSM targets for each habitat type was evaluated for their potential to indicate N deposition impacts, and to understand the strength of evidence that exists to determine if N deposition may be a contributing factor to CSM target failure at a site.

The evidence used built on previous work by the SNCB Habitat Specialists (see Whitfield & Mountford 2014) and work funded by the SNCBs and Defra (e.g. Stevens *et al* 2009; Emmett *et al* 2011). We also used work undertaken for Natural England to examine at a site level the evidence for N impacts (e.g. Hall *et al* 2012), a broad range of N effects literature including UK N-manipulation experiments (e.g. Phoenix *et al* 2012), UK field surveys (e.g. Stevens *et al* 2004; Field *et al* 2014) and European evidence (e.g. Bobbink & Hettelingh 2010).

CSM target failure can also be caused by other factors acting either separately, or in conjunction with N. Habitat management practices, for example grazing, burning, or some form of hydrological management are considered to be frequent confounding factors (see examples in Table 2). For each habitat, confounding factors were identified by reference to the existing work by SNCB Habitat Specialists, the habitat management/N interaction knowledge of the project team including known literature (e.g. Alonso *et al* 2001; Barker *et al* 2004), and best-practice habitat management information (e.g. Averis *et al* 2004).

Factors such as agricultural fertiliser application or influence of groundwater-derived nutrients were scored as confounding factors, although their effects are often indistinguishable from atmospheric N deposition impacts.

Note that some targets are non-mandatory so may not be assessed at all sites.

Table 2. Examples of possible confounding factors with N responses for two dune habitat types (based in previous work by the SNCB Habitat Specialists)

Habitat	**Potential confounding factors identified by Habitat Specialists**
Fixed dune grassland	agricultural improvement
	alteration by golf course management
	changes in grazing intensity
	removal of grazing
	planting
	artificial stabilisation
	stock feeding
	fertiliser inputs
Humid dune slacks	hydrological changes
	drainage
	water quality
	other management
	scrub growth
	direct disturbance
	drier conditions

For every CSM habitat, assessments were carried out in separate Excel spreadsheets, one for each habitat. Each of the targets listed against the set of attributes was assessed using the following steps:

1. The confounding factors that could be confused with N deposition impacts were identified.

2. The two most important were identified in separate columns. All other confounding factors were grouped under ‘Any other factors’, but each was separately described and scored, where it was considered important. All factors were worded specifically to allow interpretation of how Pass/Fail of a target should be interpreted, e.g. ‘Lack of grazing’. Other less-frequently occurring confounding factors, e.g. ‘over-grazing’, were incorporated into the ‘Any other factors’ column. An example of the four columns for dune slack habitat is shown below, including the primary column for scoring the target as an indicator for N deposition impact:
    - N deposition
    - Management (lack of grazing)
    - Hydrological change (Drier hydrological conditions)
    - Any other factors (includes overgrazing, disturbance, etc.)

3. For each habitat, a brief description of the main responses to N was summarised, in a paragraph located at the top of each assessment spreadsheet, with supporting references.

4. Each target was then scored according to its utility as an indicator of N deposition and for confounding factors. This included a description of how the target responds to N or to the confounding factor, together with supporting references. Scoring used the scale 0, 1 or 2, and supporting explanations were preceded with the following wording (for more information and definitions for the criteria applied see Table 3 and Table 4).

    - Score 2 (strong indicator/confounding factor): ... **N is likely to** ... + *provide reasoning*
    - Score 1 (weak indicator/confounding factor): ... **N may** ... + *provide reasoning*
    - Score 0 (Unsuitable indicator/confounding factor): Wording here varies, but includes the following options:
        - “Current wording of the target does not allow its use to evaluate N impact.” *(describe N impact on the attribute, but show reasoning in the notes column O why the target can’t be used)*
        - “No evidence to suggest N affects this attribute.” + *provide reasoning if necessary*
        - “Equivocal evidence to suggest N affects this attribute.” + *provide reasoning*

5. Confounding factors were not scored when N had no effect on the target i.e. N score = 0, because they were not used in assessing the outcome even if such targets failed (see section 4.3).

6. The potential to adapt the CSM target to better capture N deposition impacts was also recorded in the column P. These took the form of short suggestions rather than detailed descriptions. It should be noted that detailed development of alternative / additional targets is outside the scope of this project.

7. Finally, as part of the Evidence Quality Assurance measures for the project, each completed spreadsheet was then ‘quality checked’ by (i) another member of the project team with experience of the particular habitat type; and (ii) the project lead who had an oversight of all the CSM assessment spreadsheets. Issues requiring follow-up (e.g. inconsistent scoring of evidence) were identified and followed up by email or telecon.

Table 3. Criteria for scoring CSM targets as N deposition indicators. The examples given are taken from the CSM coastal habitats guidance. Note, the assessment and the scoring are interpreted as follows: "If the target fails, could that be a result of N deposition"

Strength as indicator of N deposition	**Criteria**	**Example targets *(from CSM habitat)***	**Explanation**
Strong indicator (score = 2)	Where a target refers to a species, group of species, or other aspect (e.g. vegetation height, flowering) that is known to be clearly sensitive to N deposition.	No more than one other negative indicator species more than frequent or singly or together the cover of negative indicator species no more than 5%. *(Humid dune slacks).*	N deposition is likely to increase abundance of most of these negative indicator species. Over 2/3 of the species have Ellenberg N score >=6. Nitrophiles are likely to increase at high N deposition, e.g. close to point sources (Pitcairn et al. 1998; Pitcairn *et al* 2002; Jones *et al* 2013).
Weak indicator (score = 1)	Where a target refers a species that is part of a group (e.g. grasses or a wider species list), amongst which only some are known or likely to be sensitive to N deposition.	For calcareous fixed dune grasslands (SD7, SD8, SD9, SD19), at least eight typical species (see list at end of table) present at more than occasional level. *(Fixed dune grassland).*	No assessment has been carried out as to whether N deposition at UK loads is likely to cause failure of this target. However, the list of 34 typical species contains at least 6 species (not including *Arrhenatherum*) which are moderate nitrophiles (Ellenberg N score >= 6) (Hill *et al* 1999), or are graminoids which might respond positively to N deposition. In addition, N deposition is likely to reduce forb diversity (Jones *et al* 2004; Field *et al* 2014) and to increase graminoid cover (van den Berg *et al* 2005; Remke *et al* 2009).
	Where a target could in principle be useful for identifying N deposition impacts, based on expert judgement, but there is no clear	No net decrease in extent from the established baseline, subject to natural change. *(Fixed dune grassland).*	N deposition may result in conversion of some older fixed dune grassland to other communities, such as mesotrophic grassland (Rodwell 2000), and therefore loss of extent.

Strength as indicator of N deposition	**Criteria**	**Example targets *(from CSM habitat)***	**Explanation**
	literature supporting this.		
Unsuitable as, or not, an indicator of N (score = 0)	Where the wording of a target is not suitable for the purposes of assessing N deposition impacts.	30-70% of sward to comprise species-rich short turf, 2-10 cm tall. *(Fixed dune grassland).*	Current wording of the target does not allow its use to evaluate N deposition impact. Failure can occur at two different endpoints. Failure of target at <30% could be due to N deposition, but failure at >70% would probably not be.
	Where a target shows potential for mixed responses to N deposition (e.g. group of species with differing sensitivity).	Bryophytes always at least occasional. *(Machair).*	Equivocal evidence to suggest N deposition affects this attribute. Bryophytes have a range of nutrient requirements.
	Where the N sensitivity of a target is not known, or a target is not sensitive to N deposition.	Cliff habitat free of artificial sea defences. *(Soft cliff and slopes).*	Target is not sensitive to N deposition.

Table 4. Criteria for scoring CSM targets for confounding factors. The examples given are taken from the CSM coastal habitats guidance. Note, the assessment and the scoring are interpreted as follows: "If the target fails, could that be a result of lack of grazing, *etc*."

Strength of confounding factor	**Criteria**	**Example targets *(from CSM habitat)***	**Explanation**
Strong confounding factor (score = 2)	Where a target refers to a species or other aspect (e.g. vegetation height, flowering) that is known to be clearly sensitive to a confounding factor.	Vegetation composition: characteristic species. Mid-upper marsh: At least one listed species abundant and three frequent. *(Saltmarsh).*	Lack of grazing is likely to lead to dominance of a few species.
Weak confounding factor (score = 1)	Where a target refers to a specific species whose sensitivity to a confounding factor is not known, but where the sensitivity of other similar species is known.	Vegetation composition: negative indicator species. No more than one other negative indicator species more than frequent, or singly or together the cover of negative indicator species no more than 5%. *(Dunes with Salix repens).*	Drier conditions may favour some of these negative indicator species, based on interpretation of their Ellenberg Moisture values (Hill *et al* 1999).
Unsuitable as or not a confounding factor (score = 0)	Where the wording of target is not suitable for assessing a confounding factor, or sensitivity to a confounding factor is not known.	30-70% of sward to comprise species-rich short turf, 2-10 cm tall. *(Fixed dune grassland).*	Current wording of the target does not allow its use to evaluate impact of lack of grazing. Failure can occur at two different endpoints. Failure of target at <30% could be due to lack of grazing, but failure at >70% would probably not be.

4.3 Overview of target scoring across CSM habitats

An overview of the strong/weak target scoring across CSM habitats is shown in Table 5**Error! Reference source not found.**. This shows that:

- A majority of the habitats contained some targets for which N deposition may be either a strong or a weak contributor to failure; however, in all but a few cases there was an equivalent or stronger confounding factor.
- Less than a third of habitats had at least one strong N indicator target; and of these only six had more than two strong N indicators (Humid dune slacks, Dunes with *Salix repens*, Lowland meadows & upland hay meadows, Lowland dry heath, Acid grassland (upland), Calaminarian grassland (upland) and Calcareous scree).
- There were only two habitats (shaded **dark green** in Table 5) with a strong N indicator which was weakly confounded; these were Dunes with *Salix repens* and Lowland dry heath.
- The remaining habitats with strong indicators also had a strong confounding factor score (shaded **pale green** in Table 5**Error! Reference source not found.**).
- The strong N indicators were usually aligned to specific species or groups of species with known N responses, and throughout the assessments, it is these indicators that offer the most potential.
- Many more habitats had one or more weak N indicators (shaded **yellow** in Table 5).
- Eleven habitats had no N indicators (shaded **orange** in Table 5); two Coastal types, one Lowland Wetland, seven Upland types, and Woodland. The main reason for this is that the targets were not related to attributes which might be expected to respond to N, or were in habitats where little is known about species responses and few analogues in other habitats existed. However, in some cases, the target might respond to N, but the target was structured or worded in such a way that it could not be used to indicate N deposition impact. There appears to be scope to define N-focused targets for the majority of these habitats (see section 4.5).

Table 5. Summary of strong/weak scoring of CSM habitat targets as N indicators and for confounding factors (CF). For each habitat the number of targets in one of four strong/weak scoring combinations is shown. The coloured shading picks out rows referred to in the bullet list in section 4.3 above. Note, some targets have alternative wordings which may be scored separately. Therefore there may be two or more alternative scores for the same target. In practice, only the wording with best fit to the site target would be used.

WP1 Habitat code	Name broad group	Name individual habitat type	N strong, CF weak	N strong, CF strong	N weak, CF weak	N weak, CF strong
1	**Coastal**	Hard maritime cliff and slope	0	0	**2**	0
2		Soft maritime cliff and slope	0	0	0	0
3		Saltmarsh	0	0	0	**1**
4		Strandline, embryo and mobile dunes	0	**1**	0	**1**
5		Fixed dune grassland	0	0	**2**	**4**
6		Humid dune slacks	0	**2**	**2**	**1**
7		Dunes with *Salix repens*	**1**	**1**	**1**	**1**
8		Machair	0	0	**1**	**3**
9		Shingle	0	0	0	0
10	**Lowland grassland**	Lowland dry acid grasslands	0	**1**	**3**	**15**
11		Lowland calcareous grasslands	0	0	**3**	**13**
12		Lowland meadows and upland hay meadows	0	**3**	0	**13**
13		Lowland purple moor grass and rush pastures	0	0	0	**12**
14		Lowland calaminarian grasslands	0	0	0	**5**
15	**Lowland heathland**	Lowland dry heath	**1**	**1**	**3**	**2**
16		Lowland wet heath	**0**	0	**5**	**2**
17	**Lowland wetland**	Lowland fens (see breakdown below)				
17a		*Lowland fens (base-*	0	0	***4***	0

WP1 Habitat code	Name broad group	Name individual habitat type	N strong, CF weak	N strong, CF strong	N weak, CF weak	N weak, CF strong
		poor/transitional)				
17b		*Lowland fens (base-rich)*	0	0	***4***	0
17c		*Lowland Filipendula mire*	0	0	**1**	**1**
17d		*Lowland swamps*	0	0	0	0
18	**Lowland wetland**	Lowland raised bog and lowland blanket bog	**0**	0	**5**	0
19	**Upland**	Acid grassland (upland)	0	**2**	0	**3**
20		Alkaline fen (upland, excluding alpine flushes)	0	0	**2**	0
21		Alpine dwarf-shrub heath	0	0	**4**	**1**
22		Alpine flush	0	0	0	0
23		Alpine summit communities of moss, sedge and three-leaved rush	0	0	0	0
24		Blanket bog and valley bog (upland)	**0**	0	**4**	0
25		Calaminarian grassland and serpentine heath (upland)	0	**2**	0	**1**
26		Calcareous grassland (upland)	0	**1**	0	**6**
27		Calcareous rocky slope	0	0	0	**1**
28		Calcareous scree	0	**2**	**1**	**1**
29		Fellfield	0	0	0	0
30		Fern-dominated snow-bed	0	0	0	0
31		Juniper heath and scrub (upland)	0	0	**2**	0
32		Limestone pavement	0	**1**	0	0
33		Mire grasslands and rush pastures (upland)	0	0	0	**12**
34		Montane willow scrub	0	0	0	0
35		Moss, dwarf-herb, and grass-	0	0	0	0

WP1 Habitat code	Name broad group	Name individual habitat type	N strong, CF weak	N strong, CF strong	N weak, CF weak	N weak, CF strong
		dominated snow-bed				
36		Short sedge acidic fen (upland)	0	0	0	**1**
37		Siliceous rocky slope	0	0	0	0
38		Siliceous scree	0	**1**	0	**1**
39		Soakway and sump (upland)	0	0	**1**	**1**
40		Spring-head, rill and flush (upland)	0	0	**1**	0
41		Subalpine dry dwarf-shrub heath	0	0	0	**2**
42		Tall herbs (upland)	0	0	**1**	**3**
43		Transition mire, ladder fen and quaking bog (upland)	0	0	**1**	0
44		Upland habitat assemblage/mosaic of habitats or vegetation types	**n/a**	**n/a**	**n/a**	**n/a**
45		Wet heath (upland)	0	0	**1**	**1**
46		Yellow saxifrage bank	0	0	0	**2**
47	**Woodland**	Woodland, Broadleaved, mixed and yew woodland, Coniferous woodland	0	0	0	0

4.4 Assessing Habitat Feature outcome by Pass/Failure of its constituent CSM targets

The overall outcome was based ONLY on those targets where the N indicator score was 1 or 2 and takes into account whether those targets failed or passed. On a target-by-target basis, the assessment process summarised the likelihood that N was the cause of that target failing, taking into account the confounding factors.

The assessment process then summarised the weight of evidence across all the relevant targets to calculate an outcome for the Habitat Feature based on the weight of evidence for N deposition or for confounding factors, as shown in Table 6. In this part of the assessment, greater weight of evidence was given to targets which had strong N indicators, so if any strong N indicator failed, that was considered a greater weight of evidence than failure of multiple weak N indicators. Guidance for conducting this part of the assessment is provided in Appendix A. Note that it is not currently possible to achieve a 'strong' category outcome from the CSM assessments because there are no targets which could indicate strong evidence for N impact with no confounding factors. Under subsequent revisions of the framework, this option may become available, if appropriate new targets can be developed.

Table 6. Outcome categories for the assessment of the scoring values assigned to CSM habitat targets as potential indicators of N deposition impacts and confounding factors (WP2.1). The categories are assigned to individual CSM site condition assessments. The codes and descriptions reflect particular combinations of: (i) scoring values (2 = strong indicator, 1 = weak indicator) given to failing N indicator targets; unless (ii) no N indicator targets fail; or (iii) there are no N indicators for a particular habitat type. The final column matches the categories with those used in the final assessment matrix to summarise the overall strength of site-based evidence of N deposition impacts (see Main report, section 4) before additional site based evidence is taken into account (if available).

Outcome category code *(target scoring values)*	**Description** *(shorthand summary)*	**Corresponding category in final assessment matrix**
Strong	*(This category not possible to achieve by scoring data from a CSM assessment in its current form)*	
N strong-CF weak *(2-1)*	Amongst the failing targets for a CSM assessment there is at least one strong N indicator target; the highest confounding factor score for this (or any other failing strong N indicator) target is only weak *(for failing targets, N score = 2_{max}, confounding factor score = 1_{max})*	Moderately strong
N strong-CF strong *(2-2)*	Amongst the failing targets for a CSM assessment there is at least one strong N indicator target; the highest confounding factor score for this (or any other failing strong N indicator) target is strong *(for failing targets, N score = 2_{max}, confounding factor score = 2_{max})*	Moderate
N weak-CF weak *(1-1)*	Amongst the failing targets for a CSM assessment there is at least one weak N indicator target (but none strong); the highest confounding factor score for this (or any other failing weak N indicator) target is also weak *(for failing targets, N score = 1_{max}, confounding factor score = 1_{max})*	Weak

N weak-CF strong *(1-2)*	Amongst the failing targets for a CSM assessment there is at least one weak N indicator target (but none strong); the highest confounding factor score for this (or any other failing weak N indicator) target is strong *(for failing targets, N score = 1 $_{max}$, confounding factor score = 2 $_{max}$)*	Very weak
No N indicators *(No N)*	Amongst the targets for a CSM assessment none are scored as strong or weak N indicators *(across all targets, N score = 0 $_{max}$)*	No evidence
N weak (none fail) *(1-no fail)*	Amongst the targets for a CSM assessment there is at least one weak N indicator target (but none strong); neither this nor any other weak N indicator targets fail *(across all targets, N score = 1 $_{max}$, none of these fail)*	Weak evidence for no N impact
N strong (none fail) *(2-no fail)*	Amongst the targets for a CSM assessment there is at least one strong N indicator target; neither this nor any other strong N indicator targets fail *(across all targets, N score = 2 $_{max}$, none of these fail)*	Moderate evidence for no N impact

4.5 Recommendations for developing CSM targets to assess N deposition

Since fewer than a third of habitats have a strong N indicator, this severely limits the ability of the framework to detect N impacts using CSM targets. There are opportunities to develop CSM targets with greater potential to indicate N deposition impacts. Either new targets or modified existing targets have the advantage of being defined specifically to indicate N impacts. Development of two strong N-focused indicators per habitat, with thresholds calibrated against existing survey data where possible, would more than double the number of strong N indicators currently available and would have the advantage of being linked to observed damage due to N. If these indicators were applied without the possibility for country-level or site-level modification, this would have the further advantage of consistency of assessment across the UK. New targets will not be able to definitively rule out confounding factors, but could considerably improve the assessment process from its current state.

They could take the form of new targets (which may be necessary in the case of habitats for which there are no targets currently suitable as N indicators), or modification of existing targets to better capture N deposition impacts. Table 7 summarises existing targets with the potential for modification and illustrates that for a number of habitat types, it would be necessary to design new targets rather than modify existing targets. This is particularly the case for many of the upland habitats and lowland wetlands. Where there is potential for existing targets to be modified, details of possible modifications are provided in the CSM habitat assessment spreadsheets. Some examples are discussed below. However, it may be preferable to design new N-focused targets in all habitats, but closely based on the guiding principles of the CSM process, and making use of existing indicators where relevant. In all instances, new or modified targets should be sensitive enough to record N impacts consistently across the UK, with appropriate thresholds to detect N damage.

Table 7. Number of targets that may offer potential for development as N-specific indicators, by habitat. Note that alternative wordings for some targets may be scored separately.

WP1 Habitat code	Name broad group	Name individual habitat type	No. of targets with N-indicator potential
1	**Coastal**	Hard maritime cliff and slope	0
2		Soft maritime cliff and slope	0
3		Saltmarsh	**2**
4		Strandline, embryo and mobile dunes	**2**
5		Fixed dune grassland	**3**
6		Humid dune slacks	**4**
7		Dunes with *Salix repens*	**3**
8		Machair	**4**
9		Shingle	**1**
10	**Lowland grassland**	Lowland dry acid grasslands	**5**
11		Lowland calcareous grasslands	**6**
12		Lowland meadows and upland hay meadows	**6**
13		Lowland purple moor grass and rush pastures	**3**
14		Lowland calaminarian grasslands	0
15	**Lowland heathland**	Lowland dry heath	**2**
16		Lowland wet heath	**1**
17	**Lowland wetland**	Lowland fens	
17a		*Lowland fens (base-poor/transitional)*	0
17b		*Lowland fens (base-rich)*	0
17c		*Lowland Filipendula mire*	***n/a***
17d		*Lowland swamps*	0
17x		*Inland salt meadows*	***n/a***
18	**Lowland wetland**	Lowland raised bog and lowland blanket bog	**3**
19	**Upland**	Acid grassland (upland)	**3**
20		Alkaline fen (upland, excluding alpine flushes)	
21		Alpine dwarf-shrub heath	**1**
22		Alpine flush	**1**
23		Alpine summit communities of moss, sedge and three-leaved rush	**2**
24		Blanket bog and valley bog (upland)	**3**
25		Calaminarian grassland and serpentine heath (upland)	**3**
26		Calcareous grassland (upland)	**3**
27		Calcareous rocky slope	**1**
28		Calcareous scree	**2**
29		Fellfield	0
30		Fern-dominated snow-bed	0
31		Juniper heath and scrub (upland)	0
32		Limestone pavement	**1**
33		Mire grasslands and rush pastures (upland)	0
34		Montane willow scrub	0
35		Moss, dwarf-herb, and grass-dominated snow-bed	**1**

WP1 Habitat code	Name broad group	Name individual habitat type	No. of targets with N-indicator potential
36		Short sedge acidic fen (upland)	0
37		Siliceous rocky slope	0
38		Siliceous scree	**1**
39		Soakway and sump (upland)	0
40		Spring-head, rill and flush (upland)	0
41		Subalpine dry dwarf-shrub heath	**1**
42		Tall herbs (upland)	0
43		Transition mire, ladder fen and quaking bog (upland)	0
44		Upland habitat assemblage/mosaic of habitats or vegetation types	**n/a**
45		Wet heath (upland)	**1**
46		Yellow saxifrage bank	0
47	**Woodland**	Woodland, Broadleaved, mixed and yew woodland, Coniferous woodland	**2**

In many cases, it may be possible to adapt the wording of existing targets for this purpose. For example, targets which include specific functional groups that are known to be sensitive to N (e.g. forbs, bryophytes or lichens), but are embedded in a table of less responsive species and covered under a broad % cover target, could be adapted. In Upland wet heath, the ‘Vegetation composition’ target includes ‘at least 50% cover of species from Table 1’; this target could be adapted to focus on N-sensitive species (e.g. *Drosera*, *Narthecium*, *Racomitrium*, or non-crustose lichens). Another example is Lowland wetlands where the ‘Vegetation composition’ target includes ‘>10% cover of *Sphagna*”. This target is not currently useful in assessing N deposition impacts as different *Sphagnum* species exhibit different preferences for nutrient conditions. However, if the target focused on N-sensitive sphagna such as *Sphagnum capillifolium*, which has been found to be sensitive to N (particularly ammonia), it would provide more robust indication of whether that Habitat Feature is in unfavourable condition.

In other cases there is the opportunity to make minor adjustments to the thresholds of targets, or how those thresholds are phrased. For example, in Lowland meadows and upland hay meadows the target “Sward composition grass:herb ratio” should fall within the range 40-90%. Therefore, N could theoretically contribute to both the initial failure and then subsequent pass of this target, depending on which end of the threshold the assessment falls. This would benefit from defining a single condition at which failure of the target due to N deposition would occur, and preferably after testing the threshold against existing survey and experimental data to directly link the threshold to observed impacts due to N.

In addition, whilst the purpose of the work package is to consider where N deposition may be contributing to unfavourable condition, there may be many negative effects of N that overall, reduce the habitat quality, for example, a reduction in bryophyte diversity, but do not currently contribute to habitat CSM failure. Existing CSM targets could be reworded, or new targets designed, to reflect some of these wider shifts in biodiversity that are observed in N addition experiments and gradient surveys above the critical load. There may subsequently be an issue in mis-match of these targets and the site-specific targets defined.

Finally, in almost every case (climate change excepted), the confounding factors relate to site management. Yet, the assessment tool offers no flexibility to consider these factors at a site level. For example, one of the key effects of N deposition is an increased cover of graminoid species and a reduction in forbs and bryophytes (e.g. Stevens *et al* 2006; Field *et al* 2014), often by shading. If more information about on-site grazing was known, cover of grasses could be a useful indicator, by discounting the response if grazing levels were known to be appropriate (it is appreciated that in some habitats, excessive grazing may increase grass cover). Other examples are where it is known that a site may be impacted by hydrological change, or fertiliser application. With this additional knowledge on confounding factors, it is then possible to discount an apparent signal of excess N due to atmospheric deposition as being a less likely cause of unfavourable condition. The spreadsheet tool could be adapted to incorporate the input of high-level management information to help with this process.

5 WP2.2 Using other site-based evidence

5.1 Aim

The aim of WP2.2 was to identify, describe and provide guidance on how to interpret other sources of site-based evidence which could be used to increase the confidence that N deposition is, or is not, impacting on the condition of a Habitat Feature.

Such evidence could be used in the absence of information about N deposition from a CSM site condition assessment, or it could be combined with this to increase the evidence-base. It could include additional evidence from more technical, targeted surveys or site-based studies on aspects potentially relevant to N deposition impacts, or it could be based on rapid visual assessment approaches for the non-expert.

It is envisaged that this component of the evidence-base will only be available occasionally, and that it will be fed into the framework in an iterative way for selected sites which warrant further examination, i.e. any additional information that can inform the assessment, following the guidelines below, will be fed into the process in a second iteration and considered alongside the existing evidence. It is not expected that this will be routinely applied to all sites. Therefore, the framework can be applied flexibly and iteratively.

5.2 Existing evidence sources

Work package 2.1 (section 4) focused on evidence from site condition assessment based on CSM guidance, which is the most widespread approach to assessing the condition of protected sites. However, there are a number of other sources of site-based evidence that could potentially be included in the assessment of N deposition impacts. This includes a range of existing data sources, as well as the potential for collecting new evidence. Data sources with potential utility are outlined here together with an assessment of whether they provide additional evidence, and guidance produced on how this information can be fed into the assessment process. A list of example evidence sources is shown below:

- sites included in N-manipulation or N-gradient studies (usually peer-reviewed research)
- sites included in other peer-reviewed research
- targeted site surveys (e.g. pig and poultry surveys; Natural England work comparing site surveys and modelling (Hall *et al* 2012))
- lichen/bryophyte data
- Field Studies Council (FSC) lichen assessment field guide
- Quadrat data

- Site monitoring data from Environmental Change Network (ECN), the England Long-Term Monitoring Network (LTMN) or the Welsh Environmental Change Biodiversity Network (ECBN)

5.3 Information source considerations

5.3.1 Type of data

The type of data is likely to be very important in assessing its utility for providing additional evidence of N deposition impacts. Relevant data may include:

- botanical data of varying levels of detail, focusing on the community as whole, specific groups or habitats, the whole site or small parts of the site.
- Data on species known to be sensitive to N deposition.
- Biogeochemical data on soils or plant tissues and soil microbial process or community data.
- Other information in reports or from previous site visits which may provide useful contextual information.

Data may be from a single sampling period or repeated sampling over time. Both have the potential to be useful, but <u>data which provides a time series can be especially valuable</u>.

The most useful types of information are likely to be those which provide site specific information of a greater level of detail than CSM, or information not collected in CSM such as on specific target groups of organisms or biogeochemical data.

5.3.2 Information format

Information may come in a range of formats some of which are more readily accessible than others. Data may be provided as raw data, in tables or as text and summaries or as raw data. <u>Electronic data is likely to be more readily accessible</u> or utilised than paper reports with <u>raw data in tables the most useful and readily used format</u>.

5.3.3 Purpose of study

The purpose for which data is collected is closely related to the type of data collected and can be very important in determining its utility. Information could have been collected on a given site for a very wide range of reasons, such as management and conservation status assessments, as well as data collected specifically to assess N deposition impacts. <u>Data collected for assessing N deposition impacts has the greatest potential to be useful</u> but, depending on the data type, frequency of collection and other factors outlined here, <u>data collected for a range of other purposes could also be useful</u>.

In order to maximise the potential of data and ensure it can be used quickly and easily, it <u>needs to have either been analysed and interpreted in respect of N deposition or that this can be easily achieved</u>.

5.3.4 Quality

The quality of data is a very important factor in assessing its potential for incorporation into the assessment. <u>Data needs to be provided together with information on the methodology used</u> – if this information is absent it may lead to serious misinterpretation. Evidence of quality control procedures or peer review would also add to confidence in the evidence.

However, it is not always possible to fully assess the quality of the data and it should only be utilised if data quality appears to be good.

5.3.5 Data accessibility

Data can only be incorporated into the framework if it is accessible. If data is not readily accessible or access to it and accompanying information may take long periods of time or incur costs then it may not be suitable. Accessibility and data format may be issues with peer reviewed research data, as published reports or papers may not be readily available without journal subscriptions. In large-scale studies sites may not be specifically identified and only summary data may be available without making contact with the study author.

5.3.6 Age

The age of data (year in which it was collected) will vary. Data may be recent or rather older. This does not impact on its potential for use *per se,* but rather how it is used. Data that is less than approximately five-ten years old is likely to reflect current condition, as long as there have not been major changes since, such as a major flood. Older data may still be of relevance depending on the individual habitat and circumstances. It can provide evidence of past N deposition impacts and act as a baseline to show how conditions have changed over time and to inform on the conservation objectives and target setting.

5.4 Evidence sources

In this section we identify different evidence types and assess their potential for providing additional evidence to be applied where necessary.

5.4.1 Data confirming evidence of N deposition impact

Site specific data which clearly confirms evidence of N deposition impact may take the form of reports on point source pollution impact, academic studies or reports on lichen flora. This data may or may not be concerned with the severity of an impact, which could make it difficult to interpret. Data that clearly confirms an impact on a given habitat feature will be very important in resolving inconsistencies and can be easily incorporated into the decision framework. This could include data from N manipulation studies, gradient studies, or specific N-focused assessments.

An increasing number of UK sites have now been included in either specific N-manipulation studies (see Phoenix *et al* 2012; RoTAP 2012), or in UK wide or point-source related N-gradient studies (see e.g. Field *et al* 2014; Stevens *et al* 2004; Pitcairn *et al* 2003; Jones *et al* 2013). These now cover a range of UK habitats including acid and calcareous grasslands, sand dune grasslands and dune slacks, montane, upland and lowland heaths, bogs and moss-heaths, and woodland. These sites provide the greatest potential for identifying subtle ecosystem changes due to N deposition, because they allow individual observations to be placed in context across a range of potential N deposition impacts in those habitats, in many cases carefully controlling for confounding factors such as temperature, rainfall, historical sulphur deposition, and underlying soil characteristics.

However, when using data confirming evidence of N deposition impact it is important to consider issues of data quality, especially how potential confounding factors are dealt with, and age in determining the suitability of such data. Such data is unlikely to be commonly available.

Overall assessment: Potential to provide additional evidence of N deposition impact and additional evidence helping to separate confounding factors.

5.4.2 Evidence about confounding factors

As has been identified in this report, there are a number of confounding factors leading to ecological responses which could be confused with atmospheric N deposition impacts and which therefore make it difficult to attribute N impacts to atmospheric deposition. These are detailed in the Factor 2 (WP2.1) spreadsheets for each habitat, but we briefly highlight some examples here for reference:

- inappropriate levels of grazing (either under-grazing or over-grazing)
- changes in hydrological regime, particularly drying out of wetland habitats
- other sources of nutrients (fertiliser or manure application, nutrients from flooding or groundwater)
- soil disturbance leading to increases in nitrophilic species

Evidence about such factors could be site specific data in reports or academic studies, management plans or monitoring data. This information will need careful interpretation by someone with expertise in both the habitat type and impacts of N deposition, and ideally with knowledge of the site, if it is to be useful to identify confounding factors as a possible cause of adverse condition, rather than N deposition. However, it has the potential to provide extremely useful information on the possible contribution of confounding factors. Data quality and age of data will again be important factors to consider in interpreting this data, as will the purpose for which data were collected or interpreted.

Overall assessment: No additional evidence of N deposition impact but provides evidence helping to confirm or to rule out confounding factors.

5.4.3 Not N-targeted data

Data collected on a site which was not concerned with assessing the impact of N deposition could cover a wide range of potential sources including surveys and monitoring data or various groups of organisms, reports and results from experimental manipulations and targeted surveys. Data not collected specifically to determine N deposition impact is likely to be of mixed utility in determining impact or eliminating confounding factors and will inevitably need some expert interpretation. This data could be useful in a number of contexts. For example, lichen populations may have been monitored at a site because they were considered an important conservation feature. By examining species composition and abundance over time it may be possible to attribute N deposition impacts, providing evidence that N sensitive lichen species have declined which could then be used to support assessment. Plant quadrat data could be interpreted for impacts on species richness or other plant community-based metrics relevant to N impact such as grass:forb ratio.

Overall assessment: Potential to provide additional evidence of N deposition impact and additional evidence helping to confirm or to rule out confounding factors but would need interpretation.

5.5 Collection of additional field data

Collection of additional data could potentially be very beneficial in ruling out confounding factors or making a more specific analysis of N deposition impacts. Hall et al. (2012) suggest some data which could be collected for this purpose. This is likely to be most useful in situations where existing information is inconsistent or inadequate and where data is collected and interpreted by someone with a suitable level of expertise. Additional data collection may be useful in situations where it gives rise to data types outlined above.

5.6 Guidelines on how to interpret other sources of site-based evidence

This assessment will feed into the framework to help identify the same outcomes as described in Table 1. It will generally be used in a second iteration of the assessment process primarily for sites where there is no CSM evidence, or where there is a discrepancy between the national/theoretical evidence provided by the N deposition and the site-based evidence outcomes from the CSM scoring. For example, if site-based evidence from CSM indicates that there is no apparent impact of N but the Exceedance Score is High or Very high. This situation could arise if there are no suitable N indicators in a habitat, or if targets which were strong N indicators were not failing as we might expect, perhaps due to intensive management to maintain some aspects of the vegetation community. In these cases the use of extra data may assist in resolving this discrepancy.

Evidence from additional data sources can be treated in a similar manner to data from CSM assessments giving rise to an evidence category. These categories are outlined in Table 8. Information from Table 8 can then be considered in the assessment in the same way as evidence from CSM is used as set out in Table 1.

Table 8. Outcome categories for the assessment of the scoring values assigned to additional site-based data sources of N deposition impacts and confounding factors (WP2.2).

Description *(shorthand summary)*	**Corresponding category in final assessment matrix**
Reliable and recent evidence confirms impacts of N deposition, and rules out confounding factors. *This data might take the form of a specific assessment of N impacts considering multiple forms of evidence which confirms impacts are due to N-deposition impacts rather than potential confounding factors e.g. Site-specific investigations such as that produced for Moninea Bog (Sutton* et al *2011).*	Strong
Reliable and recent evidence confirms impacts of N deposition, but there are possible confounding factors. *This data might take the form of a specific assessment of N impacts such as where a site has formed part of an experimental study e.g. Stevens* et al *(2010) used over acid grasslands from across the UK. Alternatively there may be a specific site assessment that uses only one source of evidence e.g. lichen assessment. There is also some (weaker) evidence that confounding factors may be responsible for apparent impacts.*	Moderately strong
Reliable and recent evidence suggests impacts of N deposition, but there is equal evidence that confounding factors are responsible. *This data might take the form of a specific assessment of N impacts such as a gradient study site, or a site assessment that uses only one source of evidence e.g. lichen assessment. Confounding factors*	Moderate

are also identified with an equal weight of evidence.	
There are data or reports which may indicate N deposition impacts, but equal evidence that confounding factors may be responsible. *This data might take the form of 'Not N-targeted studies' e.g. additional vegetation surveys or management information which requires specialist and careful interpretation, and cannot definitively identify either N or confounding factors as a cause of unfavourable condition.*	Weak
There are data or reports which may indicate N deposition impacts, but stronger evidence that confounding factors are responsible. *This data might take the form of 'Not N-targeted studies' e.g. additional vegetation surveys or management information that shows stronger evidence that confounding factors are the cause of unfavourable condition.*	Very weak
No additional data sources available.	No evidence
Reliable and recent evidence suggests one measure that indicates absence of N deposition impacts. *This data might take the form of a specific assessment of N impacts considering multiple forms of evidence or quadrat data that indicates the site is not impacted by N deposition, such as high species richness, low grass:forb ratios, healthy Calluna vulgaris, lichen surveys confirming no increase in nitrophiles or loss of N-sensitive species.*	Weak evidence for no N impact
Reliable and recent evidence suggests provides multiple measures indicating absence of N deposition impacts. *This data might take the form of a specific assessment of N impacts considering multiple forms of evidence and taking account of potential confounding factors. This could include confirmation from multiple evidence strands of no current N impact: e.g. high species richness, low grass:forb ratios, healthy Calluna vulgaris, lichen surveys confirming no increase in nitrophiles or loss of N-sensitive species.*	Moderate evidence for no N impact

It is not possible to provide a prescriptive method on how to combine evidence from other sources (Table 8) with that from CSM assessments (Table 6), because the forms of evidence and strength of evidence can vary considerably. However, some general guidance is provided below.

The combined evidence should be assessed within the framework outlined in Table 1. In most cases, site-based evidence should either confirm an outcome from the CSM assessments or, if the evidence is deemed strong enough, could be used to over-ride an outcome from CSM, by adding to the weight of evidence that N-deposition, or alternatively confounding factors are responsible for poor site condition. The simplest approach is to take the score resulting from the stronger evidence. However, in many cases it will be necessary to compare across all the forms of evidence available and come to an informed judgement within the framework outlined in Table 1 what the resulting outcome should be. In coming to this informed judgement, evidence should be assessed against each possible impact of N, and any relevant confounding factors <u>for that particular impact</u>.

For example, at Moninea Bog when running target pass/failure in the CSM report (Corbett 2009) through the WP2.1 habitat assessment spreadsheets it was not possible to directly match any of the targets with N-indicators, resulting in an outcome of 'No evidence'. After extraction of information and other data provided in the CSM report, one relevant target passed (positive indicator species; no single species > 50% cover), leading to an outcome of 'weak'. Additional site-based information in the form of a separate N-focused study (Sutton *et al* 2011) confirmed clear evidence of excess N at the site such as algae on trees, and evidence of damage to bryophytes and lichens on the open bog areas such as bleaching, visible injury and coverings of algal slime. Elevated byrophyte tissue N concentrations were also found within the site. Further evidence contained within the CSM report (Corbett 2009) shows a consistent trend of increasing graminoid cover over time, with a doubling of graminoid cover to 35% over eight years. There is a concurrent, although smaller, decline of dwarf shrubs. However, none of these changes trigger any target failure, and there is no obvious target which would capture such changes. There are also reports of excessive cattle grazing on the site, which can lead to graminoid dominance (Lake *et al* 2001), which would suggest some potential influence of confounding factors in addition to N deposition on graminoid dominance. However, the evidence for N impact is over-whelming in this case, and not likely to be solely due to the confounding factor of cattle grazing, although it may be compounding some damage. Therefore, in combination, these evidence sources would result in a 'Strong' category for site-based evidence.

Another example of how additional data could be used can be seen with the FSC lichen monitoring guide[3]. The lichen monitoring guide classifies lichens growing on tree trunks and twigs according to their tolerance to atmospheric concentrations of NH_3 and NO_x. Simple surveys can be conducted using a basic field guide and without the need for specialist knowledge or equipment. In this case there may be existing data from a site in the form of reports from the use of this method or lichen species composition data, or additional data could be collected at relatively low cost. This could provide data to confirm impacts of atmospheric N concentrations. However, it is worth noting that even specialist lichen surveys cannot always rule out confounding factors – see Woods (2009).

[3] http://www.apis.ac.uk/nitrogen-lichen-field-manual

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Appendix A. Guidance on using the Factor 2 (WP2.1) spreadsheets

N Decision Framework: Guidance Notes to Users – Factor 2 spreadsheets

Purpose: To obtain a Factor 2 score for the site-based evidence assessment. This guidance is aimed at the individual user looking up an individual site, but the process could be automated if issues such as matching targets can be resolved.

1. Open the relevant WP2 habitat spreadsheet for the habitat you are working on. They are mostly separated by broad habitat type, with multiple habitats within any one workbook. For example all lowland grasslands are within one workbook, all upland habitats are within one workbook. The habitats are numbered to match the codes given in the WP1 spreadsheet. Find the relevant worksheet for your CSM reporting feature.

2. Each habitat/reporting feature lists the generic CSM targets and any relevant notes (Columns B – E). It shows the scoring of N indicators (Columns G-H) and relevant confounding factors (Columns I-N) against each target. Column F is where you enter the outcome for each target from the CSM assessment.

3. Open or find the relevant CSM assessment for the habitat feature you are assessing.

4. For each target that has a N-indicator score of 1 or 2 you need to record in Column F, using the drop-down menu, whether:

   - **Pass** (Target Passes, or Target Met – note the terminology differs among country agencies)
   - **Fail** (Target Fails, or Target Not Met)
   - **Not Assessed** (Target not assessed)
   - **Could not match** (Wording of target used at the site does not match the generic target wording which has been scored as an indicator of N or of confounding factors).

5. When all targets that have been assessed, and that can be matched to the generic CSM targets, have been entered, read off the site-based code and outcome in Cell F7. This will populate as you enter the target information, and will be updated as you progress, so make sure you have entered information for all relevant targets before reading off the outcome. This provides the factor 2 score, use this together with the factor 1 score in the decision matrix (see Annex 3) to achieve a final assessment for the Habitat Feature.

6. If additional site-based information is to be used in a second iteration of the framework, the revised factor 2 score derived from the combination of evidence from the CSM assessment (WP2.1, Annex 2 section 4) and the additional site-based evidence (WP2.2, Annex 2 section 5) should be used instead. Annex 2 section 5.6 describes how this should be arrived at.