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Introduction

In response to the "CCE Call for Data 2015-2017" the UK NFC has:

i. The UK critical loads database for sixteen EUNIS terrestrial and freshwater habitat classes was re-submitted to the CCE in the new database format required. The UK database additionally includes empirical nutrient nitrogen critical loads applied to the designated feature habitats of Natura 2000 sites as described in the CCE 2015 Status Report (Hall et al., 2015b). Further details on the methods and data used to derive the national database can be found in Hall et al. (2015a).

ii. Submitted the results of applying the MADOC-MultiMove model to calculate biodiversity-based critical loads based on a habitat quality metric, for 87% (i.e. 16,423) of the UK 1x1 km squares that contain bog habitat (D1 Raised and blanket bogs), and subsets of other acid-sensitive habitats. Methods are summarised below. More detail is provided in recent CCE reports (Hall et al., 2015b; Hall et al., 2014) and in publications describing the models and metrics used (Henrys et al., 2015; Rowe et al., 2016a; Rowe et al., 2014).

Calculating biodiversity-based critical loads

To take account of the combined effects of N and S pollution over time, including delays in recovery, dynamic modelling approaches have been developed that link soil processes to the responses of plant species (De Vries et al., 2010). The UK NFC has applied the MADOC-MultiMOVE model (Rowe et al., 2015) to predict changes to an index of habitat quality, *HQI*: the mean habitat-suitability for locally-occurring positive indicator species for the habitat. A threshold value for this index was obtained by running the model forward with N deposition set to the empirical critical load for nitrogen ($CL_{emp}N$) for the habitat, and used to calculate the combinations of N and S deposition that are likely to cause a decline in *HQI* below this critical threshold. These combinations are then summarised into a simple biodiversity-based critical load (CL_{bdiv}) function (Figure UK-1).

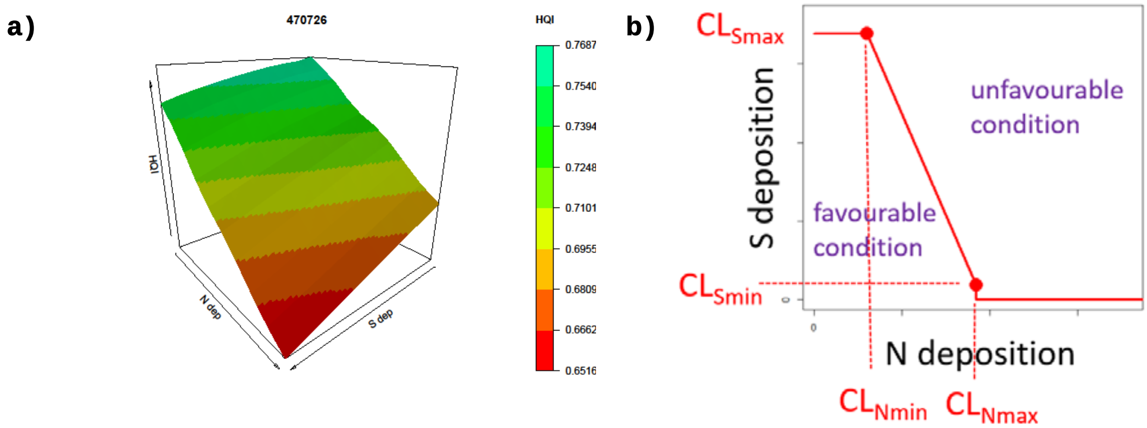
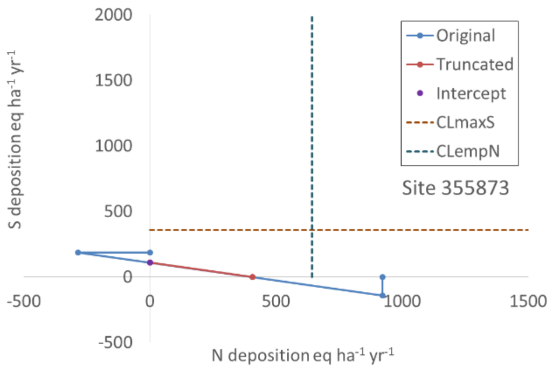


Figure UK-1. a) Response of a habitat quality index, HQI, to variation in nitrogen and sulphur deposition at a bog site in the Scottish Borders, showing high HQI with low values of S and N, a decline in HQI with more S, and a steeper decline with more N. The contour on the left-hand plot that corresponds to a critical threshold for HQI (calculated to be 72.8 % at this site) is approximated (b) using a simple two-node function which describes the biodiversity-based critical load.

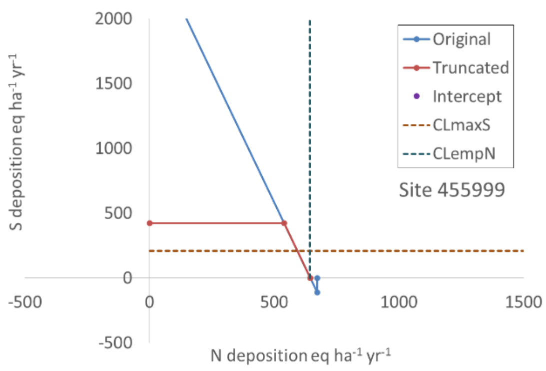
The UK NFC made an interim submission to the CCE in May 2016 of CL_{bdiv} functions calculated for acid-sensitive habitats within selected Natura2000 sites. Work in the last year has focused on parallelising the implementation of MADOC-MultiMOVE to make it feasible to calculate CL_{bdiv} functions for the UK at 1x1 km scale. These functions were calculated for the EUNIS class D1 (raised and blanket bogs) for the majority (87 %) of UK 1 km^2 grid-cells which contain this habitat. Results for other habitats were affected by the inclusion of some dominant species as positive indicators, giving a positive response of the habitat quality metric to increasing N deposition. We excluded these dominant species, recalculated the critical load functions, and submitted data for subsets (*ca*. 1000 randomly-selected sites per habitat) of the UK 1x1 km squares containing E1.7 (Closed non-Mediterranean dry acid and neutral grassland), F4.11 (Northern wet heaths) and F4.2 (Dry heaths). Responses remained problematic for E3.52 (Heath *Juncus* meadows and humid *Nardus stricta* swards) and data were not submitted for this habitat.

The procedure for summarising the critical threshold function (corresponding to a 'contour' in Figure UK-1a) into a simple two-node CL_{bdiv} function (Figure UK-1b) resulted in many cases in the nodes being placed outside the ranges of N and S deposition over which sensitivity was assessed, often giving negative values for CLN_{min} and/or CLS_{min} or extreme values for CLN_{max} and/or CLS_{max}. In such cases, the function was truncated to ensure that CLS_{min} and CLS_{max} are in the range (0 to 2 x $CL_{max}S$) and that CLN_{min} and CLN_{max} are in the range (0 to 2 x $CL_{emp}N$). Examples are illustrated in Figure UK-2.

a)



b)



FigureUK-2. Examples of sites where the values originally fitted for CLSmax, CLSmin, CLNmax and/or CLNmin were outside a reasonable range, which we defined as between zero and 2 x CLmaxS for S, or between zero and 2 x CLempN for N. Where the original function lay within these ranges, its shape was retained. Values less than zero were increased to zero, as in example a). Where original values were greater than 2 x CLmaxS for S, or greater than 2 x CLempN for N, they were decreased to these maximum reasonable values, as shown for CLSmax in example b). The UK data submission consisted of these truncated values.

Results

Biodiversity-based critical load functions

The CL_{bdiv} functions calculated for D1 bogs are illustrated in Figure UK-3. Since the critical threshold for *HQI* is calculated on the basis of the $CL_{emp}N$, the value of CLN_{max} is usually close to the $CL_{emp}N$ (see Figure UK-1b). Variation in value of CLS_{max} is of more interest (Figure UK-3a). Many aspects of the response may be responsible for this variation, such as the selection of locally-occurring indicator species, pollution history, rainfall, and/or temperature. Rainfall has a relatively strong influence, as shown by the often greater values of $CL_{max}S$ in more westerly, wetter areas. The main effects of N and S (i.e. the mean response to N over all levels of S deposition, and the mean response to S over all levels of N deposition) were calculated from *HQI* response surfaces (e.g. Figure UK-1a) to more clearly illustrate the geographic variation in sensitivity. These maps show the decline in *HQI* likely at each site if rates of deposition of S (Figure UK-3b) and N (Figure UK-3c) were to increase. Relatively unpolluted sites were usually more sensitive to S, showing declines of more than 0.2 % *HQI* per kg S ha^{-1} yr^{-1} in areas such as SW England, South Wales W Scotland. By contrast, bog sites in chronically polluted areas such as the South Pennines were relatively insensitive to S. Sites were in general more sensitive to N than to S, with a mean decline of 0.41 % *HQI* per kg N ha^{-1} yr^{-1}, compared with 0.11 % *HQI* per kg S ha^{-1} yr^{-1}. The spatial pattern of sensitivity to N (Figure UK-3c) was similar to the pattern of sensitivity to S, with sites shown to be more sensitive to N in less-polluted areas towards the north and west. The step-changes in sensitivity to N along some 10 x 10 km grid boundaries, notably in the north of Scotland in Figure UK-3c, reflect the influence of particular indicator species, for which occurrence data are at 10 km scale.

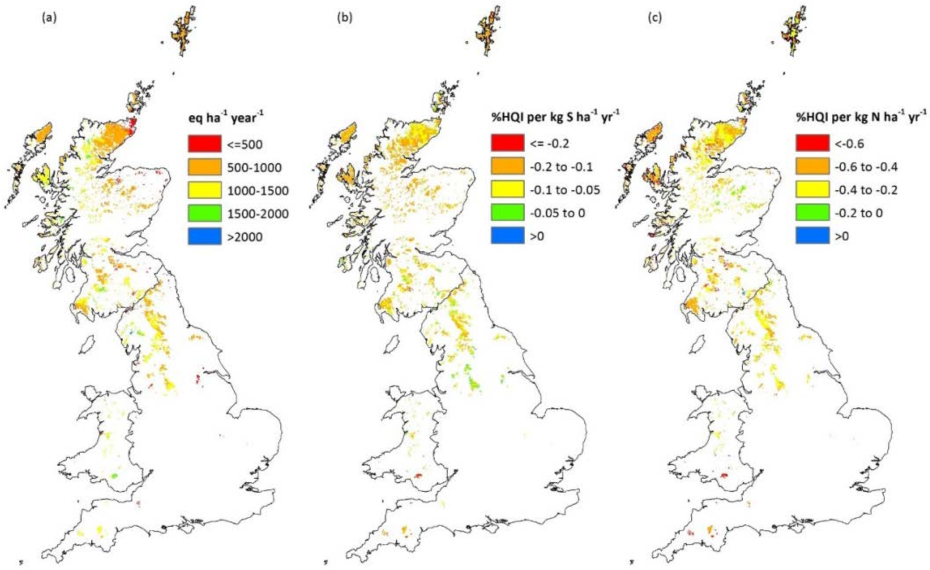


Figure UK-3. Geographical variation in biodiversity-based Critical Load functions for bogs: a) CLSmax; b) slope of main effect of sulphur deposition rate on a habitat quality index, HQI; c) slope of main effect of nitrogen deposition rate on HQI.

Results for other habitats

In the other habitats assessed, for some positive-indicator species there was a decline in habitat suitability with increasing plant productivity, but an overriding increase with greater vegetation height, resulting in increasing habitat-suitability with greater N deposition. We therefore excluded species that we considered likely to become dominant under conditions of N enrichment (even when these species are characteristic of the habitat, such as *Calluna vulgaris* in heathlands) from lists used to calculate *HQI* (Table UK-1). Species that responded positively to N at some sites but that we considered unlikely to become dominant were not excluded. The choice of species to exclude would be better made on the basis of survey evidence, and guidance is also needed from habitat specialists, so the results may be subject to revision.

Table UK-1. Species excluded from lists of positive indicator-species used to calculate a habitat quality metric, HQI, for three habitats.

Habitat	**Species excluded**	
E1.7 Closed non-Mediterranean dry acid and neutral grassland	*Calluna vulgaris*	*Erica cinerea*
F4.11 Northern wet heaths	*Calluna vulgaris* *Erica cinerea* *Ulex gallii*	*Ulex minor* *Vaccinium vitis-idaea*
F4.2 Dry heaths	*Agrostis stolonifera* *Molinia caerulea*	*Calluna vulgaris* *Erica cinerea*

Data were submitted on the basis of the revised indicator-species lists for subsets (*ca*. 1000 randomly-selected sites per habitat) of the UK 1x1 km squares that contain: E1.7 (Closed non-Mediterranean dry acid and neutral grassland), F4.11 (Northern wet heaths) and F4.2 (Dry heaths).

Variation in values of CLS_{max} for these habitats is shown in Figure UK-4. The responses remained problematic for E3.52 (Heath *Juncus* meadows and humid *Nardus stricta* swards) even after excluding dominant species, and data were not submitted for this habitat. The results (Figures UK-3a and UK-4) illustrate an overall decrease in acid-sensitivity from Dry acid grassland to Dry heath to Wet heath to Bog, reflecting greater numbers of rather acid-tolerant species in the latter habitats.

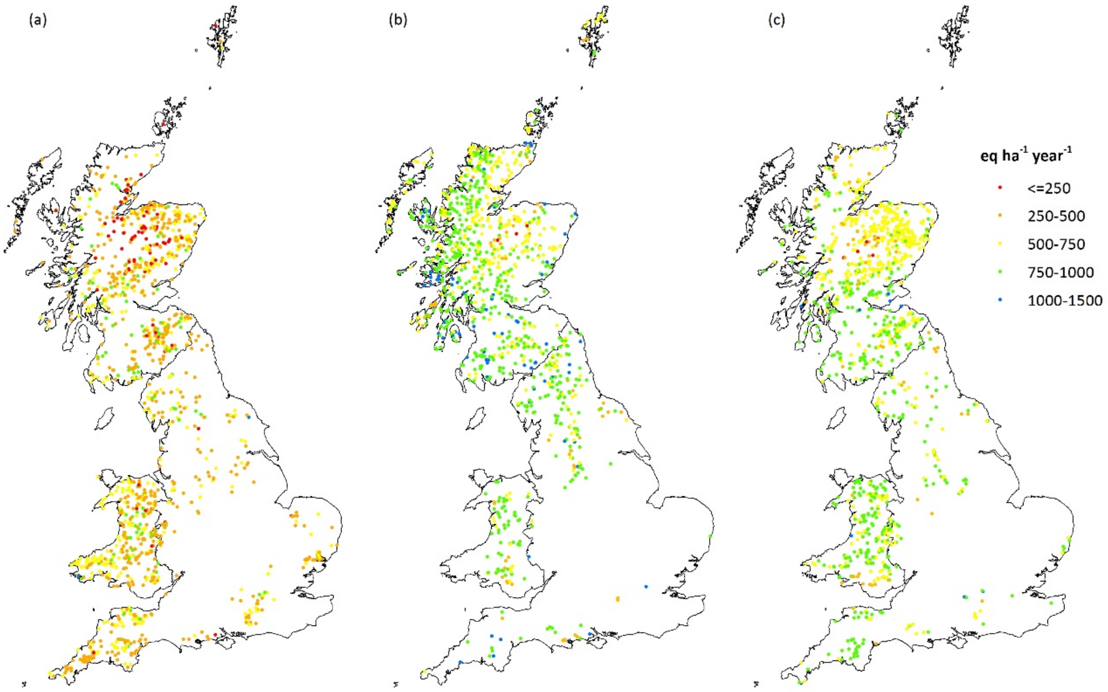


Figure UK-4. Geographical variation in CLSmax values from fitted biodiversity-based Critical Load functions, for: a) E1.7 Closed non-Mediterranean dry acid and neutral grassland; b) F4.11 Northern wet heaths; and c) F4.2 Dry heaths.

Conclusions

Calculating CL_{bdiv} functions for large sets of sites allows exploration of typical values and variation. Since the critical value for *HQI* is calculated using $CL_{emp}N$, the value of CLN_{max} is generally close to that of $CL_{emp}N$. Values of CLS_{max} calculated for bog sites were typically 50-100 % greater than values of $CL_{max}S$, which may indicate that it takes considerable quantities of S deposition to cause the same degree of damage to bog habitats as does deposition above the empirical CL for N. Results were strongly affected by the choice of positive indicator-species.

References

De Vries W., Wamelink W., Van Dobben H., Kros H., Reinds G.J., Mol-Dijkstra J., Smart S., Evans C., Rowe E., Belyazid S., Sverdrup H., Van Hinsberg A., Posch M., Hettelingh J.-P., Spranger T., Bobbink R., 2010. Use of dynamic soil-vegetation models to assess impacts of nitrogen deposition on plant species composition and to estimate critical loads: an overview. *Ecological Applications* 20, 60-79

Emmett B.A., Rowe E.C., Stevens C.J., Gowing D.J., Henrys P.A., Maskell L.C., Smart S.M., 2011. Interpretation of evidence of nitrogen impacts on vegetation in relation to UK biodiversity objectives. JNCC Report 449. JNCC, Peterborough, UK, 105 pp

Hall J., Curtis C., Dore T., Smith R., 2015a. Methods for the calculation of critical loads and their exceedances in the UK. CEH, Report to Defra under contract AQ0826

Hall J., Rowe E., Evans C., 2015b. United Kingdom National Focal Centre Report. In: Slootweg, J., Posch, M., Hettelingh, J.-P. (eds) Modelling and mapping the impacts of atmospheric deposition of nitrogen and sulphur: CCE Status Report 2015. Coordination Centre for Effects, Bilthoven, the Netherlands, pp. 157-174; www.wge-cce.org

Hall J., Rowe E.C., Evans C., 2014. United Kingdom National Focal Centre Report. In: Slootweg J., Posch M., Hettelingh J.-P., Mathijssen L. (eds) Modelling and mapping the impacts of atmospheric deposition on plant species diversity in Europe: CCE Status Report 2014. Coordination Centre for Effects, Bilthoven, the Netherlands, pp. 139-149; www.wge-cce.org

Henrys P.A., Smart S.M., Rowe E.C., Evans C.D., Emmett B.A., Butler A., Jarvis S.G., Fang Z., 2015. Niche models for British plants and lichens obtained using an ensemble approach. *New Journal of Botany* 5, 89-100

Rowe E.C., Tipping E., Posch M., Oulehle F., Cooper D.M., Jones T.G., Burden A., Monteith D.T., Hall J., Evans C.D., 2014. Predicting nitrogen and acidity effects on long-term dynamics of dissolved organic matter. *Environmental Pollution* 184, 271-282

Rowe E.C., Wamelink G.W.W., Smart S.M., Butler A., Henrys P.A., Van Dobben H., Reinds G.J., Evans C.D., Kros J., De Vries W., 2015. Field survey based models for exploring nitrogen and acidity effects on plant diversity and assessing long-term critical loads. In: De Vries W., Hettelingh J.-P., Posch M. (eds) *Critical Loads and Dynamic Risk Assessments: Nitrogen, Acidity and Metals in Terrestrial and Aquatic Ecosystems.* Springer, Dordrecht, the Netherlands, pp. 297-326

Rowe E.C., Ford A.E.S., Smart S.M., Henrys P.A., Ashmore M.R., 2016a. Using qualitative and quantitative methods to choose a habitat quality metric for air pollution policy evaluation. PLoS ONE 11(8): e0161085; DOI: 10.1371/journal.pone.0161085

Rowe E.C., Jones L., Dise N.B., Evans C.D., Mills G., Hall J., Stevens C.J., Mitchell R.J., Field C., Caporn S.J., Helliwell R.C., Britton A.J., Sutton M., Payne R.J., Vieno M., Dore A.J., Emmett B.A., 2016b. Metrics for evaluating the ecological benefits of decreased nitrogen deposition. *Biological Conservation*; DOI: 10.1016/j.biocon.2016.11.022