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EXPERT WORKSHOP ON EMPIRICAL CRITICAL LOADS FOR NITROGEN DEPOSITION ON (SEMI-)NATURAL ECOSYSTEMS

Summary report prepared by the organizers

I. INTRODUCTION

1. The expert workshop on empirical critical loads for nitrogen deposition on (semi-)natural ecosystems took place in Bern on 11-13 November 2002. It was organized by the Swiss Agency for the Environment, Forests and Landscape (SAEFL).

2. The workshop was attended by 53 experts from the following Parties to the Convention: Austria, Denmark, Estonia, France, Germany, Netherlands, Norway, Sweden, Switzerland and the United Kingdom. The International Cooperative Programme (ICP) Forests, ICP Waters, ICP Integrated Monitoring, ICP Modelling and Mapping, the Coordination Center for Effects (CCE) and the secretariat to the Convention were represented.

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3. Empirical critical loads for nitrogen had already been set at previous workshops under the Convention (Skokloster, (Sweden), 1988, Lökeberg, (Sweden) 1992, Geneva, 1995). A workshop on chemical criteria and critical limits held in March 2001 in York, United Kingdom (EB.AIR/WG.1/2001/13) came to the conclusion that, on the basis of the availability of new scientific evidence for many nitrogen-sensitive ecosystems, an update of empirical nutrient nitrogen critical loads was needed and should be evaluated and discussed at an expert workshop. In addition, more guidance should be given regarding the classification and mapping of nitrogen-sensitive ecosystems and their corresponding empirical critical loads of nitrogen. The workshop in Bern aimed at implementing these proposals.

II. AIMS AND ORGANIZATION OF THE WORKSHOP

4. The aims of the workshop were to:

(a) Evaluate, update or revise the empirical critical loads for nitrogen for (semi-) natural ecosystems set in the 1996 Manual on Mapping Critical Levels/Loads on the basis of the additional scientific information available for the period 1996-2002;

(b) Address the following broad classes of nitrogen-sensitive ecosystems:

- (i) Forest habitats;
- (ii) Heathlands, scrub and tundra habitats;
- (iii) Grasslands and tall forb habitats;
- (iv) Mires, bogs, fens and inland surface water habitats;
- (v) Coastal and marine habitats;

(c) Evaluate appropriate criteria and ecological indicators for nitrogen effects to strengthen the scientific background for establishing cause-effect relationships and critical loads and to improve the assessment of ecosystem effects due to critical loads exceedances;

(d) Give guidance regarding the use of a harmonized classification of nitrogen-sensitive ecosystems as a prerequisite for their uniform mapping in the UNECE region.

5. An international team of scientists (R. Bobbink, M. Ashmore, S. Braun, W. Flückiger, J. Hall, I. Van den Wyngaert) prepared detailed background information on the update of empirical critical loads for nitrogen and on the harmonized European Nature Information System (EUNIS) classification. This information was reviewed by another team of scientists (U. Falkengren-Grerup, M. Hornung, J.G.M. Roelofs, M. Strandberg, S. Woodin) and made available to all participants one month before the workshop.

6. The workshop was opened by Mr. G. Leutert (Swiss Agency for the Environment, Forests and Landscape), who welcomed the participants on behalf of the host country and the organizers. Mr. R. Chrast from the secretariat to the Convention informed the participants of relevant ongoing activities under the Convention.

7. The contents of the background documents on empirical critical loads for nitrogen and on the EUNIS ecosystem classification were presented by the authors in an extended plenary session, chaired by Mr. J.-P. Hettelingh. In addition, information on nitrogen-specific results from ICP

Forests and ICP Integrated Monitoring and on the possibilities of multi-species models for the calculation of nitrogen critical loads was given during the plenary.

8. Detailed discussions of the background documents and the proposed empirical critical loads for nitrogen were carried out in three working groups:

(a) Working group on forest habitats (Chairpersons: U. Falkengren-Grerup/M. Hornung; Rapporteur: J. Strengbom);

(b) Working group on grasslands, fens and mires, inland surface waters, coastal and marine habitats (Chairman: A. Davison; Rapporteur: M. Strandberg);

(c) Working group on heathlands, scrub and tundra habitats, and bogs (Chairman: J.G.M. Roelofs; Rapporteur: S. Woodin).

9. The outcome of their discussions was considered in several short plenary sessions. The results, conclusions and recommendations were discussed and summed up in a final plenary session, chaired by Mr. R. Bobbink.

II. RESULTS, CONCLUSIONS AND RECOMMENDATIONS

10. Based on observed changes in the structure and function of ecosystems, reported in European publications, empirical nitrogen critical loads were evaluated for specific receptor groups of natural and semi-natural ecosystems. Results from field addition experiments and mesocosm studies, from correlative or retrospective field studies and, in a few cases, dynamic ecosystem modelling were relevant in this respect.

11. Empirical nitrogen critical loads were agreed for a range of deposition values for each ecosystem class, because of: (i) real intra-ecosystem variation between different regions where an ecosystem had been investigated; (ii) the finite intervals between additions of nitrogen in experiments; and (iii) uncertainties in estimated total atmospheric deposition values, although these had been checked by local specialists on atmospheric nitrogen deposition. For every group of ecosystems, the empirical nitrogen critical loads were set with an indication of their reliability and of the effects to be expected in the event of exceedances.

12. The reliability of the nitrogen critical loads figures presented was indicated as follows:

(a) Reliable ##: when a number of published papers of various studies showed comparable results;

(b) Quite reliable #: when the results of some studies were comparable;

(c) Expert judgement (#): when no empirical data were available for this type of ecosystem. For this, the nitrogen critical load was based upon expert judgement and knowledge of ecosystems which were likely to be comparable with this ecosystem.

13. To facilitate and harmonize the mapping procedure, the receptor groups of natural and semi-natural ecosystems were classified and ordered according to the EUNIS habitat classification for Europe (http://mrw.wallonie.be/dgrne/sibw/EUNIS). In general, the ecosystems were classified

down to level 2 or 3 of the EUNIS hierarchy. The following habitat groups (with EUNIS level 1 code in parenthesis) were treated:

(a) Woodland and forests habitats (G);
(b) Heathland, scrub and tundra habitats (F);
(c) Grassland and tall forb habitats (E);
(d) Mire, bog and fen habitats (D);
(e) Inland surface water habitats (C);
(f) Coastal habitats (B);
(g) Marine habitats (A).

14. A limitation in using the many subcategories of the EUNIS classification was a lack of research and data on nitrogen impacts for those habitats. For forest ecosystems, it was at this moment only possible to set values for three broad EUNIS classes (G1, G3 and G4) with, however, some separation for grouping forest types, such as coniferous from deciduous and boreal from temperate.

15. The summarized updated empirical critical loads for nitrogen (table 1) were agreed by consensus at the workshop. To facilitate the shift between ecosystem classifications, table 2 shows a comparison of the ecosystem classification used in the 1996 Manual on Mapping Critical Levels/Loads with the proposed 2002 classification according to EUNIS.

16. Fine resolution maps of sensitive ecosystems of high conservation value are needed for each country to map nitrogen critical loads for these systems. It was recommended to use both the mass balance and empirically derived nitrogen critical loads for forest ecosystems and for other ecosystems for which the data were available. If the two approaches yielded different critical load values, the one with the lowest value should be used until the reasons for the difference had been clarified.

17. Some additional information was given on how to interpret the proposed ranges of critical load values for an ecosystem in a specific situation. In the case of insufficient national data for a specific (semi-)natural ecosystem, it was suggested to use the lower, middle or upper part of the proposed ranges of the nitrogen critical loads according to the general relationships between abiotic factors and critical loads for nitrogen as given in table 3.

III. GAPS IN KNOWLEDGE

18. Although considerable progress has been made since 1996 in the understanding of nitrogen impacts on several habitat groups, the following gaps in knowledge were recognized as the most important:

(a) Research/data collection was required to establish a critical load for the following ecosystems: steppe grasslands, all Mediterranean vegetation types, wet-swamp forests, many mires and fens, several coastal habitats and high-altitude systems;

(b) More research was needed for all EUNIS habitats with critical loads based on expert judgement or on little research;

(c) Impacts of nitrogen enrichment in (sensitive) freshwater and shallow marine ecosystems needed further research and were sometimes overlooked;

(d) Additional effort was needed to allocate observed nitrogen effects to the appropriate EUNIS forest subtypes (levels 2 and 3);

(e) The EUNIS classification needed clarification/adjustment with respect to some grassland groups, Nordic bogs and mires and surface water habitats;

(f) The possible effects of the different deposited nitrogen species (NO_y or NH_x) were insufficiently known to allow differentiation between these nitrogen species when setting critical loads;

(g) In order to refine current critical loads, long-term (> 3 – 5 years) nitrogen addition experiments with high resolution of treatments between 5 and 50 kg N ha^{-1} yr^{-1} in regions with low background depositions or in mesocosms were needed.

19. In conclusion, it was crucial to understand the long-term effects of increased nitrogen deposition on ecosystem processes in a representative range of ecosystems. It was thus very important to quantify the effects of nitrogen loads by manipulation of nitrogen inputs in long-term ecosystem studies in unaffected and affected areas. Such data were essential to validate the set critical loads and to develop robust dynamic ecosystem models and/or multiple correlative species models, which were reliable enough to calculate critical loads for nitrogen deposition in (semi-) natural ecosystems and to predict (natural) recovery rates for nitrogen-affected systems.

IV. PROCEEDINGS OF THE WORKSHOP

20. The proceedings of the workshop, containing an executive summary, the working group reports, the background documents, summary papers of further plenary and working group presentations, the workshop agenda and the list of participants, were being made available in a full workshop report published by the Swiss Agency for the Environment, Forests and Landscape (B. Achermann & R. Bobbink (Eds.), SAEFL Environmental Documentation No. 164).

Table 1. Overview of empirical critical loads for nitrogen deposition (kg N ha^{-1} yr^{-1}) to natural and semi-natural ecosystems. Classification of habitats according to EUNIS (except for forests).
reliable; # quite reliable; and (#) expert judgement.

Ecosystem type	EUNIS code	kg N ha^{-1} yr^{-1}	Reliability	Indication of exceedance
Forest habitats (G)				
Soil processes				
Deciduous and coniferous	-	10-15	#	Increased N mineralization, nitrification
Coniferous forests	-	10-15	##	Increased nitrate leaching
Deciduous forests	-	10-15	(#)	Increased nitrate leaching
Trees				
Deciduous and coniferous	-	15-20	#	Changed N/macro nutrients ratios, decreased P, K, Mg and increased N concentrations in foliar tissue
Temperate forests	-	15-20	(#)	Increased susceptibility to pathogens and pests, change in fungistatic phenolics
Mycorrhiza				
Temperate and boreal forests	-	10-20	(#)	Reduced sporocarp production, changed/reduced below-ground species composition
Ground vegetation				
Temperate and boreal forests	-	10-15	#	Changed species composition, increase of nitrophilous species, increased susceptibility to parasites
Lichens and algae				
Temperate and boreal forests	-	10-15	(#)	Increase of algae, decrease of lichens
Overall				
Temperate forests	-	10-20	#	Changes in soil processes, ground vegetation, mycorrhiza, increased risk of nutrient imbalances and susceptibility to parasites
Boreal forests	-	10-20	#	Changes in soil processes, ground vegetation, mycorrhiza, increased risk of nutrient imbalances and susceptibility to parasites
Heathland, scrub and tundra habitats (F)				
Tundra	F1	5-10[a]	#	Changes in biomass, physiological effects, changes in species composition in moss layer, decrease in lichens
Arctic, alpine and subalpine scrub habitats	F2	5-15[a]	(#)	Decline in lichens, mosses and evergreen shrubs
Northern wet heath	F4.11			
• ‘U’ *Calluna*-dominated wet heath (upland moorland)	F4.11	10-20[a]	(#)	Decreased heather dominance, decline in lichens and mosses
• ‘L’ *Erica tetralix*-dominated wet heath	F4.11	10-25[a,b]	(#)	Transition heather to grass
Dry heaths	F4.2	10-20[a,b]	##	Transition heather to grass, decline in lichens

Table 1 (continued)

Ecosystem type	EUNIS-code	kg N ha^{-1} yr^{-1}	Reliability	Indication of exceedance
Grasslands and tall forb habitats (E)				
Sub-Atlantic semi-dry calcareous grassland	E1.26	15-25	##	Increase tall grasses, decline in diversity, increased mineralization, N leaching
Non-Mediterranean dry acid and neutral closed grassland	E1.7	10-20	#	Increase in graminoids, decline typical species
Inland dune pioneer grasslands	E1.94	10-20	(#)	Decrease in lichens, increase biomass
Inland dune siliceous grasslands	E1.95	10-20	(#)	Decrease in lichens, increase biomass, increased succession
Low-and medium-altitude hay meadows	E2.2	20-30	(#)	Increase in tall grasses, decrease in diversity
Mountain hay meadows	E2.3	10-20	(#)	Increase in nitrophilous graminoids, changes in diversity
Moist and wet oligotrophic grasslands	E3.5			
• *Molinia caerulea* meadows	E3.51	15-25	(#)	Increase in tall graminoids, decreased diversity, decrease of bryophytes
• Heath (*Juncus*) meadows and humid (*Nardus stricta*) swards	E3.52	10-20	#	Increase in tall graminoids, decreased diversity, decrease of bryophytes
Alpine and subalpine grasslands	E4.3 and E4.4	10-15	(#)	Increase in nitrophilous graminoids, biodiversity change
Moss-and lichen-dominated mountain summits	E4.2	5-10	#	Effects upon bryophytes or lichens
Mire, bog and fen habitats (D)				
Raised and blanket bogs	D1	5-10[a,c]	##	Change in species composition, N saturation of *Sphagnum*
Poor fens	D2.2 [d]	10-20	#	Increase sedges and vascular plants, negative effects on peat mosses
Rich fens	D4.1[e]	15-35	(#)	Increase tall graminoids, decrease diversity, decrease of characteristic mosses
Mountain rich fens	D4.2	15-25	(#)	Increase vascular plants, decrease bryophytes
Inland surface water habitats (C)				
Permanent oligotrophic waters	C1.1			
• Softwater lakes	C1.1	5-10	##	Isoetid species negatively affected
• Dune slack pools	C1.16	10-20	(#)	Increased biomass and rate of succession
Coastal habitat (B)				
Shifting coastal dunes	B1.3	10-20	(#)	Biomass increase, increase N leaching
Coastal stable dune grasslands	B1.4	10-20	#	Increase tall grasses, decrease prostrate plants, increased N leaching
Coastal dune heaths	B1.5	10-20	(#)	Increase plant production, increase N leaching, accelerated succession
Moist to wet dune slacks	B1.8	10-25	(#)	Increased biomass tall graminoids
Marine habitats (A)				
Pioneer and low-mid salt marshes	A2.64 and A2.65	30-40	(#)	Increase late-successional species, increase productivity

[a)] Use towards high end of range at phosphorus limitation, and towards lower end if phosphorus is not limiting.
[b)] Use towards high end of range when sod cutting has been practised, use towards lower end of range with low-intensity management.
[c)] Use towards high end of range with high precipitation and towards low end of range with low precipitation.
[d)] For D2.1 (quaking fens and transition mires): use lower end of range (#) and for D2.3 (valley mires): use higher end of range (#).
[e)] For high-latitude or N-limited systems: use lower end of range.

Table 2. Cross-comparison between the ecosystem classification used in the 2002 empirical N critical load setting (according to the EUNIS system) and the classification used previously (1996 Manual on Mapping Critical Levels/Loads); with n.d. = not distinguished.

Ecosystem classification 2002	EUNIS	Ecosystem classification 1996
Heathland, scrub and tundra habitats	**F**	**Heathlands**
Tundra	F1	n.d.
Arctic, alpine and subalpine scrub	F2	Arctic and alpine heaths
Northern wet heaths		
• 'U' *Calluna*-dominated wet heath	F4.11	Upland *Calluna* heath
• 'L' *Erica tetralix*-dominated wet heath	F4.11	Lowland wet heathlands
Dry heaths	F4.2	Lowland dry heathlands
Grasslands and tall forb habitats	**E**	**Species-rich grassland**
Sub-Atlantic semi-dry calcareous grasslands	E1.26	Calcareous grasslands
Non-Mediterranean dry acid and neutral closed grasslands	E1.7	Species-rich heaths and neutral acidic grasslands (partly)
Inland dune pioneer grasslands	E1.94	n.d.
Inland dune siliceous grasslands	E1.95	n.d.
Low-and medium-altitude hay meadows	E2.2	Neutral-acid grasslands (partly)
Mountain hay meadows	E2.3	Montane-subalpine grasslands
Moist and wet oligotrophic grasslands	E3.5	Neutral-acid grasslands (partly), Mesotrophic fens (partly)
• *Molinia caerulea* meadows	E3.51	n.d.
• Heath (*Juncus*) meadows and humid (*Nardus stricta*) swards	E3.52	n.d.
Alpine and subalpine grasslands	E4.3 and E4.4	Montane-subalpine grasslands (partly)
Moss-and lichen-dominated mountain summits	E4.2	n.d.
Mire, bog and fen habitats	**D**	**Wetlands**
Raised and blanket bogs	D1	Ombrotrophic bogs
Poor fens	D2.2	n.d.
Rich fens	D4.1	Mesotrophic fens
Montane rich fens	D4.2	n.d.
Inland surface water habitats	**C**	**Wetlands**
Permanent oligotrophic waters	C1.1	n.d
• Softwater lakes	C1.1	Shallow softwater bodies
• Dune slack pools	C1.16	n.d.
Coastal habitats	**B**	n.d
Shifting coastal dunes	B1.3	n.d.
Coastal stable dune grasslands	B1.4	Neutral-acid grasslands (partly)
Coastal dune heaths	B1.5	n.d.
Moist to wet dune slacks	B1.8	n.d
Marine habitats	**A**	n.d.
Pioneer and low-mid salt marshes	A2.64 and A2.65	n.d.

Table 3. Suggestions to use lower, middle or upper part of the set critical loads ranges for terrestrial ecosystems (excluding wetlands), if national data are insufficient.

	Temperature/ Frost period	**Soil wetness**	**Base cation availability**	**P limitation**	**Management intensity**
Action					
Move to lower part	COLD/LONG	DRY	LOW	N-LIMITED	LOW
Use middle part	INTERMED.	NORMAL	INTERMED.	UNKNOWN	USUAL
Move to higher part	HOT/NONE	WET	HIGH	P-LIMITED	HIGH