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Working Group on Effects

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Item 4 of the provisional agenda
Recent results and updating of scientific and technical knowledge

Empirical critical loads and dose-response relationships

Prepared by the Coordination Centre for Effects of the International Cooperative Programme on Modelling and Mapping Critical Levels and Loads and Air Pollution Effects, Risks and Trends

I. Introduction

1. The workshop on the review and revision of empirical critical loads and dose-response relationships was held from 23 to 25 June 2010 in Noordwijkerhout, the Netherlands, in accordance with item 3.7 (d) of the 2010 workplan for the implementation of the Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/99/Add.2), adopted by the Executive Body at its twenty-seventh session in December 2009. The Working Group on Effects, at its twenty-seventh session in September 2009, adopted the decision to organize the workshop, following the recommendation of the eighteenth workshop of the Coordination Centre for Effects (CCE), and as confirmed by the twenty-fourth meeting of the Task Force of the International Cooperative Programme (ICP) on Modelling and Mapping Critical Levels and Loads and Air Pollution Effects, Risks and Trends (ICP Modelling and Mapping), held from 21 to 23 and on 24 and 25 April 2008, respectively, in Berne, Switzerland.

A. Attendance

2. Fifty-one experts attended the workshop. The following Parties to the Convention were represented: the Czech Republic, France, Germany, Ireland, the Netherlands, Norway, Portugal, Romania, Spain, Sweden Switzerland, the United Kingdom of Great Britain and Northern Ireland and the United States of America. Also present were representatives of the ICP on Assessment and Monitoring of the Effects of Air Pollution on Rivers and Lakes

(ICP Waters), the ICP on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) and the ICP on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP Modelling and Mapping). The secretariat to the Convention was not represented.

B. Organization of work

3. The workshop was organized by CCE of ICP Modelling and Mapping and supported by the Dutch Ministry of Housing, Spatial Planning and the Environment (VROM), the Swiss Federal Office for the Environment and the German Federal Environment Agency.

4. The Director of the Climate and Air Quality Directorate of VROM opened the meeting.

II. Objectives and structure of the workshop

5. The objectives of the workshop were to:

(a) Review and revise the empirical critical loads of nitrogen (N) for natural and semi-natural ecosystems, which had been set in an expert workshop on empirical critical loads for nitrogen deposition on (semi-)natural ecosystems, held from 11 to 13 November 2002 in Berne, Switzerland, and its report.[1] The basis for amendments was the additional scientific information available for the period 2002–2010, as presented in a new and updated background document;

(b) Provide guidance on how to use the table with site-specific modifying factors to improve the national application of the empirical approach;

(c) Review relationships between exceedance of the empirical critical N loads and species diversity on a European scale together with possible regional applications.

6. The EUropean Nature Information System (EUNIS) classes include three levels of aggregation to allow specification of ecosystem types in required detail. The following classes were addressed: marine habitats (EUNIS class A); coastal habitats (B); inland surface waters (C); mires, bogs and fens (D); grassland and land dominated by forbs, mosses or lichens (E); heathland, scrubland and tundra (F); and woodland, forest and other wooded land (G) without effects on tree growth.

7. An international team of scientists had prepared the background documentation for each EUNIS class. Another team reviewed the information during the workshop.

8. In addition, three working groups deliberated on the background documentation, empirical critical loads, modifying factors and further work according to specifically designed outlines. The groups were:

(a) A working group on marine habitats, coastal habitats, inland surface waters and grassland habitats;

(b) A working group on mire, bog and fen habitats and heathland, scrub and tundra habitats;

(c) A working group on forest and woodland habitats.

[1] Achermann B. and Bobbink R., eds., *Empirical critical loads for nitrogen* (2003). Proceedings of the Expert Workshop, Berne 11–13 November 2002, Swiss Agency for the Environment, Forests and Landscape (SAEFL), Environmental Documentation No.164, 327 pp.

9. The working groups exchanged their progress in short plenary sessions. Results, conclusions and recommendations were discussed and summarized in a final plenary session.

III. Conclusions

10. The workshop agreed that statistically and biologically significant outcomes of field addition experiments and mesocosm studies were the basis for the assessment of empirical N critical loads. Only studies which had independent N treatments and realistic N loads and durations (below 100 kg N ha^{-1} $year^{1}$ with duration of more than one year) were used for the updating and refinement of critical load values. In cases where no appropriate N addition studies were available, gradient and retrospective studies were given a higher weight.

11. Studies with high N additions or short experimental periods had only been interpreted with respect to the understanding of effects mechanisms, possible N limitation or sensitivity of the system. The methods used in those studies had been carefully scrutinized to identify factors related to the experimental design or data analysis, which might constrain their use in assessing critical loads. That included evaluation of the precision of the estimated values of background deposition at experimental sites.

12. The workshop agreed on empirical critical loads for a range of deposition values for levels 2 and 3 for all EUNIS classes, including for forest and woodland habitats (EUNIS class G). New results regarding N effects in surface waters could be included on the basis of activities presented by ICP Waters. Novel findings for some Mediterranean species were adopted as well.

13. The workshop agreed on empirical critical N loads resulting from the reviewing and revising procedure and summarized the results in a table (see below). For comparison, the table also included the range and reliability of the empirical critical loads reported in 2003. The reliability had been qualitatively established to distinguish between “reliable”, “quite reliable” and “expert judgement”; those levels were symbolized with ##, # and (#) notations, respectively

14. Additional qualitative information had been assigned to a number of modifying factors, in comparison to recommendations reported in 2003 on interpreting the agreed critical load ranges in specific situations and ecosystems. The workshop had not reached full agreement on how to quantify modifying factors for assessments on broad regional scales. Therefore, the workshop decided to use the minimum value of the empirical critical load ranges of every EUNIS class to calculate exceedance of deposition assuming different emission abatement scenarios.

15. To assess effects of exceedance, the workshop agreed that specific relationships between the nitrogen load and relevant indicators could be considered. The results would be presented only in relative terms to compare environmental risks of different emission reduction scenarios in integrated assessment modelling studies.

IV. Recommendations

16. The workshop noted that more well-designed experiments with a wide range of N additions were urgently needed. Those would be at sites with low background deposition for several EUNIS classes, which were potentially sensitive, or in regions with many ecosystems that had not yet been studied. The workshop considered that crucial if any

significant progress were to be made in defining and improving empirical critical loads in future.

17. An increasing number of gradient (survey) studies with respect to atmospheric N deposition had been reported or recently initiated. It was agreed that more rigorous guidelines should be identified for evaluation of those studies. They should cover the estimation of deposition rates, the quantification of confounding factors and the application of methods for statistical analysis. The workshop recommended the organization of a meeting dedicated to that topic in the coming years.

Table

Overview of empirical critical loads for N deposition to natural and semi-natural ecosystems

(Overview of empirical critical loads for nitrogen deposition (kg N ha^{-1} $year^{-1}$) to natural and semi-natural ecosystems (column 1), arranged according to EUNIS class and level (column 2), as originally established in 2002 and reported in 2003 (column 3) and as revised in 2010 (column 4). The reliability is expressed in qualitative terms: ## reliable; # quite reliable; and (#) expert judgement (column 5). Column 6 provides a selection of effects that can occur when critical load are exceeded. Changes with respect to values of 2003 are indicated in bold.)

Ecosystem type	*EUNIS code*	*2003 kg N ha^{-1} $year^{-1}$ and reliability*	*2010 kg N ha^{-1} $year^{-1}$*	*2010 reliability*	*Indication of exceedance*
Marine habitats (A)					
Mid-upper salt-marshes	A2.53		20–30	(#)	Increase in dominance of graminoids
Pioneer and low-mid salt-marshes	A2.54 and A2.55	30–40 (#)	20–30	(#)	Increase in late-successional species, increase in productivity
Coastal habitat (B)					
Shifting coastal dunes	B1.3	10–20 (#)	10–20	(#)	Biomass increase, increase N leaching
Coastal stable dune grasslands (grey dunes)	B1.4[a]	10–20 #	8–15	#	Increase in tall graminoids, decrease in prostrate plants, increased N leaching, soil acidification, loss of typical lichen species
Coastal dune heaths	B1.5	10–20 (#)	10–20	(#)	Increase in plant production, increase in N leaching, accelerated succession
Moist-to-wet dune slacks	B1.8[b]	10–25 (#)	10–20	(#)	Increased biomass and tall graminoids

Ecosystem type	*EUNIS code*	*2003 kg N ha^{-1} $year^{-1}$ and reliability*	*2010 kg N ha^{-1} $year^{-1}$*	*2010 reliability*	*Indication of exceedance*
Inland surface water habitats (C)					
Soft-water lakes (permanent oligotrophic waters)	C1.1[c]	5–10 ##	3–10	##	Change in the species composition of macrophyte communities, increased algal productivity and a shift in nutrient limitation of phytoplankton from N to phosphorous (P)
Dune slack pools (permanent oligotrophic waters)	C1.16	10–20 (#)	10–20	(#)	Increased biomass and rate of succession
Permanent dystrophic lakes, ponds and pools	C1.4[d]		3–10	(#)	Increased algal productivity and a shift in nutrient limitation of phytoplankton from N to P
Mire, bog and fen habitats (D)					
Raised and blanket bogs	D1[e]	5–10 ##	5–10	##	Increase in vascular plants, altered growth and species composition of bryophytes, increased N in peat and peat water
Valley mires, poor fens and transition mires	D2[f]	10–20 #	10–15	#	Increase in sedges and vascular plants, negative effects on bryophytes
Rich fens	D4.1[g]	15–35 (#)	15–30	(#)	Increase in tall graminoids, decrease in bryophytes
Montane rich fens	D4.2[g]	15–25 (#)	15–25	(#)	Increase in vascular plants, decrease in bryophytes
Grasslands and tall forb habitats (E)					
Subatlantic semi-dry calcareous grassland	E1.26	15–25 ##	15–25	##	Increase in tall grasses, decline in diversity, increased mineralization, N leaching; surface acidification
Mediterranean xeric grasslands	E1.3		15–25	(#)	Increased production, dominance by graminoids
Non-Mediterranean dry acid and neutral closed grassland	E1.7[b]	10–20 #	10–15	##	Increase in graminoids, decline of typical species, decrease in total species richness

Ecosystem type	*EUNIS code*	*2003 kg N ha^{-1} year^{-1} and reliability*	*2010 kg N ha^{-1} year^{-1}*	*2010 reliability*	*Indication of exceedance*
Inland dune pioneer grasslands	E1.94[b]	10–20 (#)	8–15	(#)	Decrease in lichens, increase in biomass
Inland dune siliceous grasslands	E1.95[b]	10–20 (#)	8–15	(#)	Decrease in lichens, increase in biomass, increased succession
Low and medium altitude hay meadows	E2.2	20–30 (#)	20–30	(#)	Increase in tall grasses, decrease in diversity
Mountain hay meadows	E2.3	10–20 (#)	10–20	(#)	Increase in nitrophilous graminoids, changes in diversity
Moist and wet oligotrophic grasslands					
• Molinia caerulea meadows	E3.51	15–25 (#)	15–25	(#)	Increase in tall graminoids, decreased diversity, decrease of bryophytes
• Heath (Juncus) meadows and humid (Nardus stricta) swards	E3.52	10–20 #	10–20	#	Increase in tall graminoids, decreased diversity, decrease of bryophytes
Moss- and lichen-dominated mountain summits	E4.2	5–10 #	5–10	#	Effects upon bryophytes or lichens
Alpine and subalpine acid grasslands	E4.3		5–10	#	Changes in species composition; increase in plant production
Alpine and subalpine calcareous grasslands	E4.4		5–10	#	Changes in species composition; increase in plant production
Heathland, scrub and tundra habitats (F)					
Tundra	F1	5–10 #	3–5	#	Changes in biomass, physiological effects, changes in species composition in bryophyte layer, decrease in lichens
Arctic, alpine and subalpine scrub habitats	F2	5–15 (#)	5–15	#	Decline in lichens, bryophytes and evergreen shrubs

Ecosystem type	*EUNIS code*	*2003 kg N ha^{-1} year^{-1} and reliability*	*2010 kg N ha^{-1} year^{-1}*	*2010 reliability*	*Indication of exceedance*
Northern wet heath	F4.11				
• "U" Calluna-dominated wet heath (upland moorland)	F4.11[e,h]	10–20 (#)	10–20	#	Decreased heather dominance, decline in lichens and mosses, increased N leaching
• "L" Erica tetralix-dominated wet heath (lowland)	F4.11[e,h]	10–25 (#)	10–20	(#)	Transition from heather to grass dominance
Dry heaths	F4.2[e,h]	10–20 ##	10–20	##	Transition from heather to grass dominance, decline in lichens, changes in plant biochemistry, increased sensitivity to abiotic stress
Mediterranean scrub	F5		20–30	(#)	Change in plant species richness and community composition
Forest habitats (G)					
Fagus woodland	G1.6		10–20	(#)	Changes in ground vegetation and mycorrhiza, nutrient imbalance, changes soil fauna
Acidophilous Quercus-dominated woodland	G1.8		10–15	(#)	Decrease in mycorrhiza, loss of epiphytic lichens and bryophytes, changes in ground vegetation
Meso- and eutrophic Quercus woodland	G1.A		15–20	(#)	Changes in ground vegetation
Mediterranean evergreen (Quercus) woodland	G2.1		3–7	(#)	Changes in epiphytic lichens
Abies and Picea woodland	G3.1		10–15	(#)	Decreased biomass of fine roots, nutrient imbalance, decrease in mycorrhiza, changed soil fauna
Pinus sylvestris woodland south of the taiga	G3.4		5–15	#	Changes in ground vegetation and mycorrhiza, nutrient imbalances, increased N_2O and NO emissions
Pinus nigra woodland	G3.5		15	(#)	Ammonium accumulation
Mediterranean Pinus woodland	G3.7		3–15	(#)	Reduction in fine root biomass, shift in lichen community

Ecosystem type	*EUNIS code*	*2003 kg N ha^{-1} year^{-1} and reliability*	*2010 kg N ha^{-1} year^{-1}*	*2010 reliability*	*Indication of exceedance*
Spruce taiga woodland	G3.A[i]	10–20 #	5–10	##	Changes in ground vegetation, decrease in mycorrhiza, increase in free algae
Pine taiga woodland	G3.B[i]	10–20 #	5–10	#	Changes in ground vegetation and in mycorrhiza, increase occurrence of free algae
Mixed taiga woodland with Betula	G4.2		5–8	(#)	Increased algal cover
Mixed Abies-Picea Fagus woodland	G4.[()]		10–20	(#)	
Overall					
Broadleaved deciduous woodland	G1[k,)]	10–20 #	10–20	##	Changes in soil processes, nutrient imbalance, altered composition mycorrhiza and ground vegetation
Coniferous woodland	G3[k,l]	10–20 #	5–15	##	Changes in soil processes, nutrient imbalance, altered composition mycorrhiza and ground vegetation

[a] For acid dunes, use the 8–10 kg N ha-1 year-1 range, for calcareous dunes use the 10–15 kg ha-1 year-1 range.

[b] Use the lower end of the range with low base cation availability. Use the higher end of the range with high base cation availability.

[c] This critical load should only be applied to oligotrophic waters with low alkalinity with no significant agricultural or other human inputs. Use the lower end of the range for boreal and alpine lakes, use the higher end of the range for Atlantic softwaters.

[d] This critical load should only be applied top waters with low alkalinity with no significant agricultural or other direct human inputs. Use the lower end of the range for boreal and alpine dystrophic lakes.

[e] Use the high end of the range with high precipitation and the low end of the range with low precipitation. Use the low end of the range for systems with a low water table, and the high end of the range for systems with a high water table. Note, that water table can be modified by management.

[f] For D2.1 (quaking fens and transition mires) use lower end of the range (#).

[g] For high latitude systems use lower end of the range.

[h] Use the high end of the range when sod cutting has been practiced; use the lower end of the range with low intensity management.

[i] In 2003 presented as overall value for boreal forests.

[j] Included in studies which were classified into G1.6 and G3.1.

[k] In 2003 presented as overall value for temperate forests.

[l] For application at broad geographical scales.