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TRANSBOUNDARY AIR POLLUTION**

Working Group on Effects

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RECENT RESULTS AND UPDATING OF SCIENTIFIC AND TECHNICAL KNOWLEDGE

WORKSHOP ON EFFECTS OF LOW-LEVEL NITROGEN DEPOSITION

Report by the workshop organizers*

INTRODUCTION

1. The workshop on the nitrogen critical loads for terrestrial ecosystems in low deposition areas, in particular nitrogen (N) critical loads for terrestrial ecosystems in low deposition areas, was held March 2007 in Stockholm as agreed by the Working Group on Effects (ECE/EB.AIR/WG.1/2006/2, para. 52) and endorsed by the Executive Body at its twenty-third session. It was organized by the Swedish University of Agricultural Sciences (SLU) and Swedish

* By tradition, the Convention has used the term "organizers" to indicate the nationally appointed rapporteurs who report workshop results.

Environmental Research Institute (IVL). The Swedish Environmental Protection Agency supported the meeting.

2. Twenty-seven experts attended the workshop. The following Parties to the Convention were represented: Finland, the Netherlands, Norway, Sweden, Switzerland and the United States of America. Also present were representatives of the Coordination Centre for Effects (CCE) of the International Cooperative Programme (ICP) on Modelling and Mapping. A member of the secretariat also attended.
3. Ms. A. Nordin (Sweden) and Ms. S. Hellsten (Sweden) chaired the meeting.

I. AIMS OF THE WORKSHOP

4. The objectives of the workshop were to:
 - (a) Increase knowledge and promote scientific discussion on effects of low levels of N deposition to north-latitude ecosystems;
 - (b) Focus on N effects on species composition and interactions of boreal and arctic ecosystems;
 - (c) Prepare guidelines for revised empirical critical loads for N in terrestrial ecosystems in low-deposition regions;
 - (d) Assess current scientific status of N-induced effects on vegetation in terrestrial ecosystems in low-deposition regions;
 - (e) Assess currently available modelling tools and recommendations for further research.
5. The following issues were addressed:
 - (a) Specification of critical loads of N for biodiversity in low N deposition regions;
 - (b) Assessment of current scientific status of N-induced effects on vegetation in terrestrial ecosystems in low N deposition regions;
 - (c) Different approaches to monitor N effects on vegetation;
 - (d) Current modelling tools and their further development;
 - (e) A network for future communication.
6. Mr. H. Staaf welcomed the participants on behalf of the Swedish Environmental Protection Agency.

II. CONCLUSIONS AND RECOMMENDATIONS

A. International research and policy context

7. The workshop noted that the understanding of the N and its effects had increased during recent years. It was deemed important to provide conclusions that were based on scientific

understanding and relevant for policymaking. The levels and criteria for critical loads, whether modelled with static mass balance or dynamic modelling methods or based on empirical studies, needed further assessment. The critical load concept would continue to be useful as Europe-wide environmental targets.

8. The workshop noted that there has been a general shift of focus in experimental work on N studies: the emphasis had changed from N leaching in N-saturated ecosystems to N-induced vegetation changes. N deposition was of central importance for biodiversity when compared to other environmental drivers. The links between experimental work, monitoring and modelling needed strengthening.

B. Recent major research results

1. Boreal forests

9. Mr. J. Strengbom (Sweden) presented fertilization experiments in low background deposition areas, where the abundance of graminoids increased when fertilizing with $6 \text{ kg N ha}^{-1} \text{ year}^{-1}$. The workshop took note that dwarf shrub abundance declined as N deposition gradient across Sweden exceeded $6 \text{ kg N ha}^{-1} \text{ year}^{-1}$.

10. Mr. P. A. Aarrestad (Norway) presented an experimental outline for derivation of updated empirical critical loads in Norway. The workshop noted the usefulness of the EUNIS (European Nature Information System) classification.

11. Ms. K. Mustajärvi (Finland) presented results from studies on N throughfall deposition at ICP Forests level II sites in the period 1998–2004. Canopy interactions with precipitation resulted in qualitative changes of N deposition. Canopies retained inorganic N in deposition and leached dissolved organic N. Canopy leaching increased with increasing bulk N deposition.

12. Mr. E. Kubin (Finland) presented the use of bryophytes as bioindicators for N deposition in an N deposition gradient over Finland. The workshop took note that average N concentrations in common bryophyte species correlated well with N deposition levels.

13. Ms. M. Salemaa (Finland) presented the study on differences in the growth response to N of three bryophyte species. The workshop noted that responses to N deposition could differ between bryophyte species, which should be taken into account when changes due to N deposition.

2. Boreal wetlands

14. Mr. U. Gunnarsson (Sweden) presented N effects when adding 15 and $30 \text{ kg N ha}^{-1} \text{ year}^{-1}$ to boreal mire. Vegetation changes were observed first after an initial lag-phase of five years. Thereafter, the continuous *Sphagnum* cover collapsed and vascular species increased in

abundance. In fens, N deposition caused reduced species richness, as a few highly competitive plant species became dominant and outcompeted less competitive species.

15. Mr. M. Nilsson (Sweden) presented N effects on flux of methane (CH₄) and carbon dioxide (CO₂) from boreal mire. Although previous research had pointed out that N addition may increase gas emissions from wetlands, new results demonstrate that N addition in fact can cause decreased emissions. This is due to decreased plant carbon allocation to roots supporting CH₄ and CO₂ producing microbes.

3. Modelling

16. Mr. S. Belyazid (Sweden) presented the ForSAFE-VEG model results on ground vegetation changes. The workshop noted that the model had been validated at 16 Swedish forest sites under different N deposition levels. The results showed a high risk for long-term changes in the composition of the ground vegetation, with forestry operations as the main driving force, but also due to changes in N deposition.

C. Critical loads for nutrient N

1. Empirical critical loads for boreal ecosystems

17. The workshop believed current empirical critical loads for nutrient N for boreal and arctic ecosystems were set too high. Several presentations indicated effects at lower deposition levels than currently recommended. Thus it was deemed necessary to introduce modifications to these.

18. Data were available from Swedish experiments on changes in vegetation in low deposition areas. Significant changes were observed at depositions of 8 kg N ha⁻¹ year⁻¹ for mires and 6 kg N ha⁻¹ year⁻¹ for forests. The shapes of the dose-response functions remained unknown.

19. The workshop recommended that the critical load for boreal forest should be 5–10 kg N ha⁻¹ year⁻¹ compared to current recommendation of 10–20 kg N ha⁻¹ year⁻¹ for both boreal and temperate forest. During the workshop no data was presented concerning N effects on temperate forest. Critical loads for bogs and poor minerotrophic mires would be below 8 kg N ha⁻¹ year⁻¹. No data were available to evaluate mesotrophic and rich minerotrophic mires. Critical loads for fens would remain as earlier (5–20 kg N ha⁻¹ year⁻¹).

20. N accumulation in the ecosystem has to be taken into account as well as the rate of yearly additions. According to the methodology of critical loads, the dynamic processes in vegetation communities would be treated as an average over a long-term period.

21. The workshop took note of the following future tasks:

- (a) A separation of effects of climate and forestry from effects from N deposition was needed;
- (b) Modellers should use all available experimental data to support and validate calculated critical loads;
- (c) Long-term low N dose experiments, and also replicating ones, in low deposition regions were needed;
- (d) Recent experimental data should be presented for inclusion in Convention's documentation.

2. Data for revision

22. The workshop noted that there were enough indicative data to consider lower critical loads than currently, as a precautionary approach. Vegetation changes in boreal forest have been observed with average loads of $6 \text{ kg N ha}^{-1} \text{ year}^{-1}$. Major changes occurred after only five years with $12.5 \text{ kg N ha}^{-1} \text{ year}^{-1}$. Currently, there were too few experiments with loads less than $6 \text{ kg N ha}^{-1} \text{ year}^{-1}$, e.g. $3 \text{ kg N ha}^{-1} \text{ year}^{-1}$ for 3–4 years, to draw any general conclusions on N effects of such low deposition.

23. The workshop noted that vegetation changes in forest ecosystems due to N deposition could be substantial even if no effects on the trees, or only positive growth effects, had taken place. Effect indicators such as N leaching or tree damage would result in higher critical N loads than other biological indicators such as changes in the ground flora species composition (which may be mediated via N enhanced attacks on plants by natural enemies, i.e. pathogens and herbivores).

24. The workshop also suggested that not only plant species composition per se, but also an abundance of herbivores, pathogens and mycorrhiza on plants should be monitored to evaluate N effects on an ecosystem. This was because effects on plant species composition could often be traced to N-induced changes in interactions between plants and these organisms.

3. Bridging empirical and calculated critical loads

25. The workshop noted that calculated and empirical critical loads for boreal forests did not conflict. In fact, empirical critical loads introduced improved biological understanding in ecosystem modelling.

26. Although there was empirical evidence that N deposition promoted vegetation changes, the definition of an unwanted change was not always straightforward. The proper indicator species or species composition, the time period, and what constituted a significant change, should be first agreed on. Dynamic models, which simulate vegetation changes, could support such discussion.

D. Monitoring

1. Efficiency of monitoring

27. Monitoring of vegetation changes due to N deposition was carried out with various intensities in the Nordic countries. There seemed to be no activity coordinated over the countries targeting N effects on biodiversity.

28. The workshop recommended preparing a summary on current national and international monitoring of vegetation changes due to N deposition. These would include, inter alia, ICP Forests level II sites and ICP Integrated Monitoring. The monitoring schemes, in particular in Nordic countries, should be made available.

2. Additionally monitored parameters

29. The workshop recommended considering additionally parameters to monitor to target N effects on biodiversity. These included selected indicator species (for boreal forest, mainly *Vaccinium* species and the ratio of *Vaccinium* spp. to graminoid species), pathogen/herbivore incidence on dominant plant species, as well as mycorrhizal infection of dominant species.

30. The workshop suggested improving links between monitoring and experiments. Enhanced monitoring of permanent plots joined with long-term controlled experiments would help to identify major drivers of vegetation change and improve the quality of monitoring data. Only experiments would enable the disentanglement and isolation of the effects of N deposition, land use and climate change on biodiversity. Environmental monitoring could also be improved by examining closely the links between soil chemistry dynamics and vegetation change.

3. Monitoring data for critical loads

31. The workshop noted that long-term, high-quality monitoring data on ground vegetation could be extremely useful in developing critical loads. To this end, it would be important to coordinate ground vegetation monitoring between countries to ensure an overall high quality of available data. The workshop suggested that data from the Nordic countries be presented in a comparable and consistent form, to make the data more usable.

32. The workshop recommended using monitoring data in combination with experimental data to single out N effects on biodiversity from climatic and other environmental factors. Long-term time series of monitoring data could also be useful in ecosystem modelling, in addition to critical load calculations.

E. Modelling

1. New empirical knowledge for models

33. The workshop suggested focusing on ecosystem foundation species, divided into functional groups. Classification schemes with representative indicator species, also including species functional traits, should be created to support model development.
34. Biodiversity should be approached from different viewpoints, including abundance of trivial as well as rare species in a specified habitat. In addition, the provision of ecosystem services to human societies should be addressed.
35. The mechanistic link between soil N availability and plant biodiversity should be strengthened. Ecosystem specific response delays between N addition and vegetation response should be described in more detail. More data on vegetation effects from low N doses (below 6 kg N ha⁻¹ year⁻¹) were needed.
36. More data on plant phenology and ephemeral occurrences of plants might improve models. The ForSAFE-VEG model system currently includes within-year phenology for trees, but not for ground vegetation.

2. Variety of empirical research

37. Existing data on long-term data on changes in the ground vegetation should be made readily accessible to allow for testing and validation of models, e.g. data from the Convention's programmes and national databases. In particular, data from Finland on site geochemistry and vegetation could enable in-depth spatial and temporal testing of models.
38. The workshop noted that experiments showed different impacts from oxidized and reduced N. However, the processes behind these differences had not yet been properly modelled.
39. The workshop concluded that enhanced use of existing empirical data required close collaboration between modellers and experimentalists. Long-term data on site chemistry and vegetation, available from national databases and Convention's monitoring data, should be employed for model validation, exclusion of climatic and other confounding factors, and for quantification of the relative impact of N.

F. Future strategies

1. Land use strategies to diminish N deposition impacts

40. The workshop discussed possibilities to develop land use strategies in boreal and arctic ecosystems to diminish negative impacts on ecosystem biodiversity due to N deposition. The workshop noted many ways to remove large amounts of N from the ecosystem, in order to reset

the N status. These would include, inter alia, elimination of N fertilization of forest, a halt to wetland drainage, enhanced biomass removal via whole-tree harvesting and stump removal, prescribed burning of forests and refraining from fighting forest fires and barn grazing.

41. Land use changes might conflict with other environmental problems. Forest fertilization was used to increase tree growth, but it could degrade ground vegetation composition. Whole-tree harvesting could reduce N leaching risk, but might lead to depletion of other nutrients. Reducing N input to ecosystems might hamper carbon sequestration and accelerate climate change.

42. The workshop concluded that it was preferable to reduce N deposition rather than employ land use strategies in order to reduce negative impacts on ground vegetation.

2. Red-listed species and plant functional traits

43. The workshop noted that red-listed species were important and interesting receptors. They were deemed useful but not the only avenue for considering biological diversity aspects and indicators for specific communities. The reasons for a species to be red-listed were not necessarily related to N deposition, but more often to land management changes.

44. For most red-listed species, N deposition was not considered to be a major threat, although there could be indirect impacts through a cascade of N-induced effects. Red-listed species were normally very rare, which had made them impractical and difficult to use for critical load modelling and mapping. Environmental issues required a common scientific understanding, therefore all European Union directives, including the Habitats and Birds Directives, would need to be addressed in a harmonized way. No red-listed species were currently included in the ForSAFE-VEG and SMART models. The workshop concluded that red-listed species should be included, if possible, as risk indicators.

45. The workshop noted that biodiversity needed to be considered from different perspectives, including species richness and ecosystem services depending on specific traits of the assembled species. Species could be selected for protection according to their functional traits, and thus the aim would be to protect targeted traits.

46. The workshop recommended considering both species diversity and ecosystem functions, in particular species that were functionally important for ecosystem processes or species that other species depended on (e.g. as substrate or food). Foundation species, which were often dominant, were usually important for the function of ecosystems, and their health could indicate the entire ecosystem vitality. The workshop recommended using foundation species as indicators for ecosystem functions.

3. Further activities

47. The workshop considered it to be important for experimental N scientists to meet under the Convention. Such meetings should include experimental, monitoring and modelling researches. Currently modellers convene together, but effects-oriented experimentalists were in general not well represented in Convention bodies.

48. The workshop agreed to enhance the inclusion of experimental scientists in the Convention activities. Proposals included workplan items common to all bodies under the Working Group on Effects, meetings connected to the Task Force meetings of the International Cooperative Programmes, jointly prepared reports to the Working Group of Effects, thematic workshops, and linking national focal points and centres directly to their national habitat experts.
