Centre for
Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Air Pollution and Vegetation

ICP Vegetation[*] Annual Report 2006/2007

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[*] The International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops.

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Executive Summary

Background

The ICP Vegetation[1] has studied the impacts of air pollutants on crops and (semi-)natural vegetation in the UNECE[2] region for two decades. The programme has focussed on two air pollution problems of particular importance: quantifying the risks to vegetation posed by ozone pollution and the atmospheric deposition of heavy metals to vegetation. Further pollution problems considered by the programme are: plant responses to pollutant mixtures (i.e. ozone and nitrogen interactions) and the impacts of nitrogen pollutants on vegetation. In addition, the ICP Vegetation is taking into consideration consequences for biodiversity and the modifying influence of climate change on the impacts of air pollutants. The results of studies conducted by the ICP Vegetation are reported to the Working Group on Effects (WGE) of the Convention on Long-Range Transboundary Air Pollution (LRTAP), where they are used in assessments of the current, and predictions of the future, state of the environment. Currently, the work of the ICP Vegetation is providing information for the review of the Gothenburg Protocol (1999) designed to address the problems of acidification, nutrient nitrogen and ground-level ozone, and the Aarhus Protocol (1998) designed to reduce emissions of heavy metals. Thirty five countries participate in the programme and the 20th Task Force meeting of the Programme was held in Dubna, Russian Federation, 5 – 8 March 2007, and was attended by 69 participants from 24 countries.

Biomonitoring of ozone impacts on vegetation

The ICP Vegetation collates information on the effects of ambient ozone on crops and (semi-) natural vegetation by conducting biomonitoring experiments, and by assessing information in the scientific literature. Since 1996, participants in the ICP Vegetation have detected effects of ambient ozone at sites across Europe and in the USA by growing ozone-sensitive and ozone-resistant biotypes of white clover. Several new sites and countries (e.g. Latvia and Portugal) participated in 2006. In 2006, the three-month AOT40[3] ranged from 2.2 (Latvia-Rucava) to 12.3 ppm h (Italy-Naples) and the critical level for agricultural crops for yield reduction (a three month AOT40 of 3 ppm h) was exceeded at over 60% of the sites. Visible leaf injury was observed at all but one site in Latvia, including sites which received less than the concentration-based critical level of ozone for yield reduction.

During 2005, ozone-sensitive and resistent biotypes of *Centaurea jacea* were produced using micropropagation as a contribution in kind from Switzerland. These were then supplied to participants from seven countries for a field trial across Europe in 2006. In general, resistant plants grew bigger, but plant weight differed strongly between sites, which was primarily due to the fact that at some sites plants did not produce flower stems. Across the sites with sufficient exposure time, the degree of visible leaf injury in the sensitive clone was related to the maximum hourly ozone concentration. However, results have to be interpreted with care as some participants had difficulties in separating ozone-specific and non-specific visible symptoms. Intercalibration and training (as well as a firm commitment of participants to follow the protocol) would be necessary to improve the data quality of the leaf injury assessments on *Centaurea jacea*.

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[1] The International Cooperative programme on Effects of Air Pollution on Natural Vegetation and Crops.

[2] The United Nations Economic Commission for Europe.

[3] The sum of the differences between the hourly mean ozone concentration (in ppb) and 40 ppb for each hour when the concentration exceeds 40 ppb, accumulated during daylight hours.

Field-based evidence for the impacts of ozone on vegetation

To coincide with the review of the Gothenburg Protocol, the ICP Vegetation is collating evidence of adverse effects on vegetation in Europe caused by ambient ozone concentrations for the period 1990 – 2006. The overall aim is to quantify the link between field observations and ozone critical level exceedances. Three main types of data exist in published papers and reports: records of ozone injury reported during field surveys, effects detected during biomonitoring exercises such as the ICP Vegetation clover network and effects detected experimentally by comparing responses of plants grown in ambient air with those exposed to air with reduced ozone concentration. Over 130 species of crops and (semi-)natural vegetation have been found to respond to ozone pollution at the concentrations currently experienced within the ECE region. Ozone injury is widespread across Europe and countries that have low ozone concentrations but high ozone stomatal fluxes (e.g. Sweden, Belgium, UK) have frequent records of visible injury attributed to ozone. Between 1998 and 2006, ozone induced leaf injury on white clover has been detected at almost every site in every year. Injury scores were generally highest for the Mediterranean, in particular Western Mediterranean and lowest in Northern Europe and Atlantic Central Europe. Trends in leaf injury scores reflect the spatial and temporal variation in ozone concentration, with no marked decline or increase evident. The final report on the impacts of ambient ozone on vegetation will be published by December 2007.

Ozone-sensitive communities of (semi-)natural vegetation

In recent years, existing datasets in the literature were collated into a database (OZOVEG: **Ozo**ne effects on **veg**etation) to allow identification of ozone-sensitive species and analysis of relationships between ozone sensitivity and plant characteristics. Currently, the OZOVEG database contains dose-response functions for relative biomass for 89 species of (semi-) natural vegetation. Previously, a model was developed that uses Ellenberg Indicator values for a species to predict its response to ozone and this approach was then applied to whole plant communities to predict their sensitivity to ozone. The OZOVEG database has been updated with individual plant species and community height data. This will allow a better prediction of the ozone-sensitivity of individual species grown under field conditions within plant communities. Information on the responses of species to ozone when grown in a competitive environment has also been added to the database. Despite the northern and central European bias of the database, preliminary analysis has indicated that ozone sensitivity of Mediterranean plant communities can be calculated based on the predicted response to ozone of sufficient component species for which Ellenberg numbers have been assigned.

Mapping areas at risk from adverse effects of ozone on vegetation

In 2006/2007, the Mapping Manual of the LRTAP Convention was updated with recommendations made at the workshop on ‘Critical levels of ozone: further applying and developing the flux-based concept’ (Obergurgl, Austria, November 2005) and at subsequent Task Force Meetings of the ICP Vegetation. A simplified stomatal flux-modelling method has been recommended for generic crop and forest tree species, only to be used for relative risk assessments in support of international policy making. The EMEP chemical transport model was used to map the risk of adverse affects of ozone across Europe for a generic crop and two generic tree species (Deciduous and Mediterranean evergreen). The spatial patterns of the simplified flux-based method are quite different from those of the concentration-based method, i.e. the gradients from northern to southern Europe are much greater for the concentration-based indices. Nevertheless, southern and central European countries were still identified as being at highest risk of adverse effects of ozone on crops and Deciduous forests.

The calculated ozone fluxes to the generic Mediterannean evergreen forest are substantially lower than those calculated for the generic crop species or deciduous forest. This is primarily due to the new phenology functions for the generic Mediterranean evergreen species, which severely limit ozone uptake during the summer months.

Critical levels of ammonia for vegetation

The ammonia critical levels for vegetation were revised at the LRTAP Convention workshop on 'Atmospheric ammonia: detecting emission changes and environmental impacts' (4–6 December 2006, Edinburgh, UK) and adopted by the ICP Vegetation Task Force. The new critical levels are: i) a long-term critical level for lichens and bryophytes of 1 µg m^{-3} (annual average); ii) a long-term critical level for higher plants of 3 µg m^{-3} (annual average) with an uncertainty range of 2 – 4 µg m^{-3}. The monthly critical level of 23 µg m^{-3} was retained for higher plants only as a provisional value to deal with the possibility of high peak emissions.

Heavy metal and nitrogen deposition to mosses

The European heavy metals in mosses survey is conducted every five years and provides data on concentrations of ten heavy metals (arsenic, cadmium, copper, chromium, iron, lead, mercury, nickel, vanadium and zinc) in naturally growing mosses. Currently, the ICP Vegetation Coordination Centre is processing and analysing the data of the 2005/2006 moss survey, which was conducted in 32 countries across Europe. Eighteen countries also determined the nitrogen concentration in mosses for the first time at the European scale. Between 1990 and 2000 the metal concentration in mosses generally declined with time for all metals. However, only the decreases for arsenic, cadmium, copper, lead vanadium and zinc were statistically significant and country-specific temporal trends were observed. Between 1990 and 2000 total emissions and modelled total heavy metal deposition in Europe also declined across for selected heavy metals studied by EMEP/MSC-East.

Future developments

The ICP Vegetation will continue to monitor the extent of ozone damage to vegetation by conducting standardized experiments and field surveys. However, it will focus more on collating information for the further development and local parameterisation of stomatal ozone flux models for crops. The biomonitoring experiments with ozone-sensitive species of crops (white clover) and (semi-)natural vegetation (*Centaurea jacea*) will be scaled down. The ICP Vegetation will further analyse the data on field-based evidence for the effects of current ground-level ozone concentrations on vegetation across Europe and will publish the report by the end of 2007. The ICP Vegetation will continue the fruitful collaboration with ICP Forests and EMEP/MSC-West regarding the further development of flux-effect models and the development of flux-based maps of risk of ozone damage to crops and tree species using local parameterisations. In addition, it will report on flux-based risk assessment of damage to managed pastures and develop flux-based methods for (semi-)natural vegetation. The Ellenberg modelling approach will be further developed and applied with the aim to quantify the risk of ozone effects on communities of (semi-)natural vegetation across Europe, including the modifying influence of nitrogen and mapping communities at risk using the EUNIS classification system. The ICP Vegetation will continue to review information on the impacts of ozone on vegetation in a changing climate and the potential feedbacks to climate change. The Coordination Centre will map the spatial distribution of the heavy metal and nitrogen concentrations in mosses for 2005/2006 at the EMEP 50 km x 50 km grid scale. Reports of the 2005/2006 moss survey will be published in the summer of 2008. Subsequently, further temporal trend analyses of the heavy metal concentrations in mosses across Europe will be conducted for the period 1990 to 2005.

Contents

1. Introduction

1.1. The ICP Vegetation

The ICP Vegetation is an international programme that reports to the Working Group on Effects (WGE) of the Convention on Long-range Transboundary Air Pollution (LRTAP) on the effects of air pollutants on (semi-)natural vegetation and crops. The WGE considers the effects of air pollutants on waters, materials, forests, vegetation, ecosystems, and health in Europe and North-America (Working Group on Effects, 2004). The ICP Vegetation has focussed on two air pollution problems of particular importance: quantifying the risks to vegetation posed by ozone pollution and the atmospheric deposition of heavy metals to vegetation. Two further pollution problems investigated by the programme are plant responses to pollutant mixtures (e.g. ozone and nitrogen interactions) and the deposition of nitrogen pollutants to vegetation. In addition, the ICP Vegetation is taking into consideration consequences for biodiversity and the modifying influence of climate change on the impacts of air pollutants. The work of the ICP Vegetation currently aims to provide information for the review of the Gothenburg Protocol (1999) designed to address the problems of acidification, nutrient nitrogen and ground-level ozone, and the Aarhus Protocol (1998) designed to reduce emissions of heavy metals (Working Group on Effects, 2004). Over 180 scientists from 35 countries of Europe and North-America contribute to the programme. The ICP Vegetation is chaired by Mr Harry Harmens at the Coordination Centre at the Centre for Ecology and Hydrology, Bangor, UK, and the coordination is supported by the UK Department for Environment, Food and Rural Affairs.

The ICP Vegetation:

- Conducts coordinated experiments to determine the effects of ozone pollution on crops and (semi-)natural vegetation and collates information on field-based evidence of the impacts of ozone on vegetation;
- Develops models to quantify and interpret the influence of climatic conditions and environmental stresses on the responses of plants to ozone, and uses the models to establish critical levels for effects of ozone;
- Develops maps showing where vegetation is at risk from ozone pollution within the UNECE region, including areas where critical levels are exceeded;
- Collates and reviews information on the effects of ozone on plant biodiversity;
- Collates and reviews information on the effects of ozone in a changing climate;
- Collates and reviews monitoring data on the atmospheric deposition of heavy metals, and subsequent accumulation by mosses and higher plants;
- Considers the evidence for effects of nitrogen deposition on communities of (semi-) natural vegetation in Europe, including its modifying effect on the impacts of ozone.

The medium-term workplan of the ICP Vegetation is presented in Annex 1.

1.2. Participation in the ICP Vegetation

In recent years, the participation in the ICP Vegetation has increased to 35 Parties to the Convention (Table 1.1). The contact details of the participants are included in Annex 2. It should be noted that in many countries, several other scientists (too numerous to mention individually) also contribute to the biomonitoring programmes, analysis and modelling procedures that comprise the work of the ICP Vegetation.

Table 1.1 Countries participating in the ICP Vegetation.

Austria	Germany	Serbia
Belarus	Greece	Slovakia
Belgium	Hungary	Slovenia
Bosnia and Herzegovina	Iceland	Spain
Bulgaria	Italy	Sweden
Croatia	Latvia	Switzerland
Czech Republic	Lithuania	Turkey
Denmark	Norway	Ukraine
Estonia	Poland	United Kingdom
Finland	Portugal	USA
France	Romania	Uzbekistan
FYR of Macedonia	Russian Federation	

1.3. Impacts of ozone on crops and (semi-)natural vegetation

As part of the work programme for the ICP Vegetation, information is collated on the effects of ambient ozone episodes on crops and species of (semi-)natural vegetation by conducting biomonitoring experiments and by assessing information in the scientific literature. Ozone episodes can cause short-term responses in plants such as the development of visible injury (fine bronze or pale yellow specks on the upper surface of leaves) or reductions in photosynthesis. If episodes are frequent, longer-term responses such as reductions in growth and yield and early scenescence can occur. Documentation of the extent of visible injury due to ozone, both in field surveys and in biomonitoring studies, provides important evidence for the significance of ozone as a phytotoxic pollutant across Europe.

To coincide with the review of the Gothenburg Protocol, the ICP Vegetation is collating evidence of adverse effects on vegetation in Europe caused by ambient ozone pollution for the period 1990 – 2006. The overall aim is to quantify the link between field observations and ozone critical level exceedances. Three main types of data exist in published papers and reports: records of ozone injury reported during field surveys, effects detected during biomonitoring exercises such as the ICP Vegetation clover network and effects detected experimentally by comparing responses of plants grown in ambient air with those exposed to air with reduced ozone concentration. For the clover biomonitoring experiment, ozone-sensitive (NC-S) and ozone-resistant (NC-R) biotypes of white clover (*Trifolium repens* cv Regal) have been grown at each of the ICP Vegetation sites according to a standardised experimental protocol since 1996. Effects of ozone were recorded as a score for visible injury, and as the ratio of the weight of the dried clippings (biomass) of the NC-S to the NC-R biotype. Literature reviews and monitoring programmes conducted by the ICP Vegetation so far have shown that over 130 species of (semi-)natural vegetation and crops are responding to ozone pollution at the concentrations currently experienced within the ECE region. The final report will be published by the end of 2007.

The negotiations concerning ozone for the Gothenburg Protocol (1999) were based on exceedance of a concentration-based long-term critical level of ozone for crops and (semi-)

natural vegetation. This value, an AOT40[1] of 3 ppm h accumulated over three months was set at the Kuopio Workshop in 1996 (Kärenlampi and Skärby, 1996) and is still considered to be the lowest AOT40 at which significant yield loss due to ozone can be detected for agricultural crops and (semi-)natural vegetation dominated by annuals, according to current knowledge (LRTAP Convention, 2006). However, several important limitations and uncertainties have been recognised for using the concentration-based approach. The real impacts of ozone depend on the amount of ozone reaching the sites of damage within the leaf, whereas AOTX-based critical levels only consider the ozone concentration at the top of the canopy. The Gerzensee Workshop in 1999 (Fuhrer and Achermann, 1999) recognised the importance of developing an alternative critical level approach based on the flux of ozone from the exterior of the leaf through the stomatal pores to the sites of damage (stomatal flux). This flux-based method provides an indication of the degree of risk for adverse effects of ozone on vegetation with a stronger biological basis than the concentration-based method. The flux-based approach required the development of mathematical models to estimate stomatal flux, primarily from knowledge of stomatal responses to environmental factors.

Lisa Emberson and colleagues developed a multiplicative model of stomatal conductance of ozone (Emberson *et al.*, 2000a) with the aim to model ozone deposition and stomatal uptake across Europe (Emberson *et al.*, 2000b). This model includes functions for the effects of phenology, light, temperature, vapour pressure deficit (VPD) and soil water potential on the stomatal conductance. At the Gothenburg Workshop in 2002 (Karlsson *et al.*, 2003), it was concluded that for the time being it was only possible to derive flux-based ozone critical levels for the crops of wheat and potato. Also included were provisional flux-based critical levels for the tree species birch and beech (LRTAP Convention, 2006). In November 2005, further application and development of the flux-based approach was reviewed and discussed at the ‘Ozone critical levels Workshop’ in Obergurgl, Austria (Wieser and Tausz, 2006). In Obergurgl, a simplified flux-modelling approach for crops and forest trees was recommended for large-scale and integrated assessment modelling, to be used only for relative risk assessments in support of international policy making.

In recent years, interest in the effects of ozone on (semi-)natural vegetation has increased considerably. Setting critical levels for this type of vegetation is far more complicated than for crops because of the diversity of species and ecosystems within the UNECE region. In contrast to crops and trees, only limited experimental data are available for a small proportion of the vast range of species. For (semi-)natural vegetation the current concentration-based critical level was defined as an AOT40 of 3 ppm h, based on a growth period of 3 months, for plant communities dominated by annual species and an AOT40 of 5 ppm h, based on a growth period of 6 months, for plant communities dominated by perennial species (LRTAP Convention, 2006). Further study of factors influencing the stomatal uptake of ozone is required before a flux-based critical level for ozone can be established for (semi-)natural vegetation. Data from the ICP Vegetation database were used to identify species at risk from ozone damage and the communities they represent (Hayes *et al.*, 2007; Jones *et al.*, 2007; Mills *et al.*, 2007) and mapping procedures were developed indicating where such communities might be at risk from ozone (Mills *et al.*, 2007). As a contribution in kind from the group led by Mr Jürg Fuhrer (FAL, Switzerland), the *Centaurea jacea* biomonitoring system for ozone was improved in 2005 and in 2006, ICP Vegetation has tested the improved biomonitoring system at the field scale across Europe (chapter 2).

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[1] The sum of the differences between the hourly mean ozone concentration (in ppb) and 40 ppb for each hour when the concentration exceeds 40 ppb, accumulated during daylight hours.

1.4. Heavy metal deposition to vegetation

Concern over the accumulation of heavy metals in ecosystems, and their impacts on the environment and human health, increased during the 1980s and 1990s. The LRTAP Convention responded to this concern by establishing a Task Force on Heavy Metals (and persistent organic pollutants) under the Working Group on Abatement Techniques. In 1998, the first Protocol for the control of emissions of heavy metals was adopted. Cadmium, lead and mercury emissions were targeted by the Protocol. The ICP Vegetation is addressing a short-fall of data on heavy metal deposition to vegetation by coordinating a well-established programme that monitors the deposition of heavy metals to mosses. The programme, originally established in 1980 as a Swedish initiative, involves the collection of mosses and determination of their heavy metal concentration at five-year intervals. Over 7,000 moss samples were taken in 32 countries in the 2005/2006 European survey. Trends in the concentrations of heavy metals in mosses across Europe were determined recently by Harmens *et al.* (in press a,b) and are described in detail in chapter 2.

1.5. Impacts of nitrogen deposition on (semi-)natural vegetation

The ICP Vegetation agreed at its 14th Task Force Meeting (January 2001) to include consideration of the impacts of atmospheric nitrogen deposition on (semi-)natural vegetation within its programme of work. This stemmed from concern over the impact of nitrogen on low nutrient ecosystems such as heathlands, moorlands, blanket bogs and (semi-)natural grassland (Achermann and Bobbink, 2003). Plant communities most likely at risk from both enhanced nitrogen and ozone pollution across Europe were identified (Harmens *et al.*, 2006). A pilot study has shown that mosses can be used as biomonitors of atmospheric nitrogen deposition in Scandinavian countries (Harmens *et al.*, 2005). Therefore, 18 countries participating in the European heavy metals in moss survey 2005/2006 have also determined the total nitrogen concentration in mosses (ca. 3,200 samples) to assess the application of mosses as biomonitors of nitrogen deposition at the European scale.

1.6. Web site

The ICP Vegetation web site can be found at http://icpvegetation.ceh.ac.uk and is regularly updated.

1.7. Aim of this report

This report provides an overview of the main activities and achievements of the ICP Vegetation in 2006/2007 (chapter 2). Conclusions and future developments are described in chapter 3.

2. Overview of activities in 2006/2007

2.1. Biomonitoring of ozone impacts on white clover

The ICP Vegetation collates information on the effects of ambient ozone episodes on crops and (semi-)natural vegetation by conducting biomonitoring experiments, and by assessing information in the scientific literature. Since 1996, participants in the ICP Vegetation have detected effects of ambient ozone at sites across Europe and in the USA by growing ozone-sensitive (NC-S) and ozone-resistant (NC-R) biotypes of white clover (*Trifolium repens* cv Regal; Heagle *et al.*, 1995). The initial aims were to determine the effect of ambient ozone on the biomass relationship between the NC-S and NC-R clover and to determine a dose-response relationship for use in derivation of a critical level for this species. More recently, there has been an increased focus on conditions required to induce visible injury symptoms on the NC-S biotype, with many sites assessing plants on a weekly basis. The aim was to quantify the frequency of ozone episodes that were sufficiently high and sustained as to cause ozone injury on sensitive vegetation. The response of white clover at individual sites is compared with pollutant and climatic conditions during the experiment.

In 2006, cuttings of ozone-sensitive (NC-S) and ozone-resistant (NC-R) biotypes of white clover (*Trifolium repens* cv Regal) were distributed by the Coordination Centre to participants of the programme. A standard protocol developed at the Coordination Centre was followed for establishment and subsequent exposure of the plants (Hayes *et al.*, 2006). Individual plants were placed in individual 30 litre pots, which had an integral wick system for watering, and maintained at a field site away from local pollution sources and major roads. Plants were generally inspected ones a week for ozone injury on leaves. At 28 day intervals the foliage was cut down to 7 cm above the soil surface. The plants were allowed to re-grow before a further harvest 28 days later. The period between the first and fourth harvest at each site equated to the three-month time period for calculation of AOT40 and other three-month based parameters. At many of the sites a second batch of NC-S clover was grown, using an identical protocol but 14 days later than the first batch. This ensured that there was always a full canopy of leaves on some clover plants at each site and allowed a more complete assessment of the development of visible injury at each site.

A wide range of climatic and pollution conditions are found over the network of biomonitoring sites in the ICP Vegetation. The range of sites in Europe extends from Sweden to Portugal and covers both urban and rural locations. The data from each experimental site were sent to the Coordination Centre for analysis. Data comprised measurements of biomass from four to five 28-day harvests, assessments of plant health and weekly assessments of visible injury. Hourly means of climatic and pollution data including temperature, humidity, solar radiation, windspeed and ozone were also sent to the Coordination Centre for analysis.

In 2006, the critical level for agricultural crops for yield reduction (a three month AOT40 of 3 ppm h) was exceeded at over 60% of the sites where ozone was continuously monitored (Table 2.1). The three-month AOT40 ranged from 2.2 (Latvia-Rucava) to 12.3 ppm h (Italy-Naples). As new sites participated in Latvia, Portugal, Slovenia and the UK and some previously established sites did not participate in 2006, it is difficult to compare the ozone pollution and climatic conditions at the clover biomonitoring sites in 2006 with those in previous years.

Table 2.1 Climatic and pollution conditions over a three-months experimental period at selected ICP Vegetation biomonitoring sites in 2006; - = data unavailable or insufficient.

	Ozone			**Temperature (°C)**		**Rainfall**	**VPD (kPa)**	
Site	Mean daily max (ppb)	Daylight mean (ppb)	3 month AOT40 (ppm h)[1]	Mean	Daylight mean	Total (mm)	Mean	Daylight mean
Belgium:								
- Tervuren	58.7	37.0	10.8	20.7	24.3	137	-	-
Italy:								
- Naples	65.7	36.7	12.3	23.6	-	130	1.00	1.81
Latvia:								
- Rucava	41.9	23.7	2.2	19.0	20.9	142	0.71	0.96
- Zoseni	-	-	-	16.4	18.3	104	0.62	0.82
Portugal:								
- M. Velho	50.8	43.6	4.6	19.6	22.2	92	0.42	0.65
Slovenia:								
- Ljubljana	56.7	31.5	10.7	20.5	22.4	341	1.00	1.32
Sweden:								
- Östad	46.5	29.3	4.3	17.0	19.9	-	0.47	0.79
UK:								
- Ascot	52.0	31.0	6.4	-	-	131	-	-
- Bangor	-	29.1	2.4	-	-	-	-	-
- Lullington	50.6	35.5	6.5	17.3	-	118	-	-

[1] UK-Bangor: May – July; Latvia, Sweden and UK-Lullington: July – September; other sites: June – August.

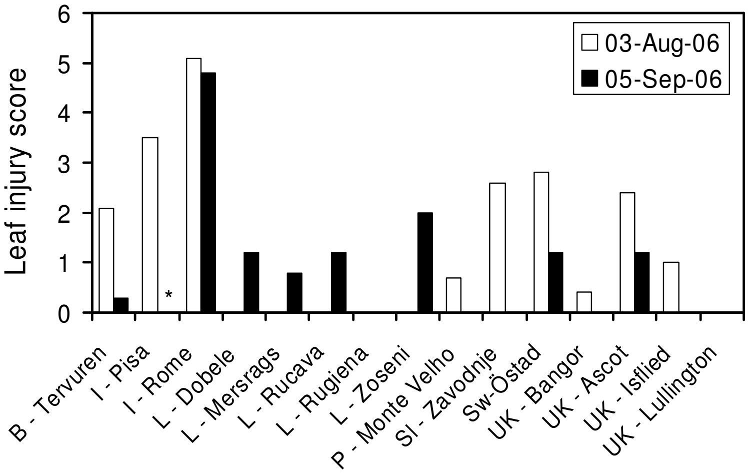

Figure 2.1 The extent of visible injury due to ozone on the sensitive biotype of *Trifolium repens* during two weeks in 2006 at sites across Europe. Leaf injury scores: 1 = <1%, 2 = 1%-5%, 3 = 5%-25%, 4 = 25%-50%, 5 = 50%-90%, 6 = 90%-100% of leaves affected. * = no leaf injury score determined, otherwise a score of zero indicates no leaf injury.

At 15 sites in 11 countries weekly assessments were conducted to score ozone-induced leaf injury on white clover. Generally no more than 25% of the leaves showed ozone injury symptoms at any of the sites (apart from Pisa and Rome in Italy) in 2006 (Figure 2.1). However, visible injury was still observed at all sites except one site in Latvia, including sites which received less than the concentration-based critical level of ozone for yield reduction (e.g. Sweden-Östad and UK-Bangor). The highest scores were recorded in Naples (Italy), where 50 – 90% of leaves were regularly injured by ambient ozone episodes.

2.2. Biomonitoring of ozone impacts on *Centaurea jacea*

Whilst there is considerable evidence for effects of ozone on a wide variety of crop plants, including clover, relatively few native plant species have been investigated. Existing evidence suggests that many species characteristic of (semi-)natural plant communities are at least as sensitive to ozone as the major crop plants. *Centaurea jacea* (brown knapweed) has been identified as one of several native species which is relatively sensitive to ozone, exhibiting characteristic symptoms of ozone injury following exposure (Buse *et al.*, 2003a). Since 2002, ozone biomonitoring experiments have been conducted at ICP Vegetation sites using seeds from an ozone-sensitive and resistant population of *Centaurea jacea* collected in Switzerland. In 2005, the *Centaurea jacea* biomonitoring system was further improved in Switzerland as a contribution in kind by Mr Jürg Fuhrer and colleagues. Two clones of brown knapweed (sensitive and resistant) were produced by micropropagation to reduce genetic variation among individuals. The original material consisted of plants differing in visual ozone sensitivity at field sites in Switzerland. The clones were previously tested for differences in ozone sensitivity (foliar injury) by exposures in climate-controlled chambers and an initial field trial was conducted at Cadenazzo (Switzerland) in 2005.

Table 2.2 Countries and sites participating in the *Centaurea jacea* biomonitoring experiment in 2006.

Country	Site
Austria	Seibersdorf
Greece	Naoussa
Italy	Curno, Napoli, Rome
Slovenia	Ljubljana, Velenje
Spain	La Peira
Switzerland	Cadenazzo, Zürich
United Kingdom	Ascot, Bangor*, Hurstwood, Isfield, Lullington

* Plants were grown in solardomes rather than ambient air.

In 2006, a field trial was conducted with the two clones across Europe. The aim of the experiment was to test the difference in ozone sensitivity between the clones by field exposure at a range of sites across Europe. Seedlings of clonal material were produced and shipped in two batches from the central Swiss laboratory to 15 sites in seven countries (Table 2.2). For plant cultivation and injury assessments during the field exposure period, a common protocol was developed, and observational data were collected using a standard datasheet (Hayes *et al.*, 2006). The presence of leaf injury was recorded weekly with the aim to develop a short-term critical level for visible leaf injury for a species of (semi-)natural vegetation. Meteorological and ozone data were also collected.

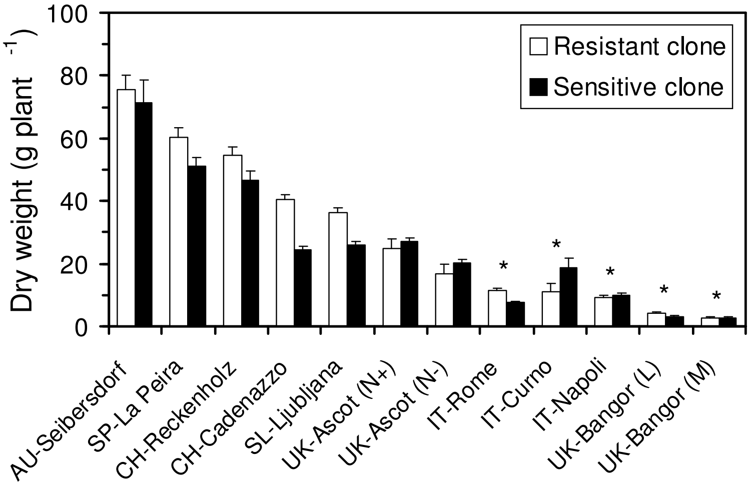

Figure 2.2 Dry weights of ozone-resistant and sensitive clones of *Centaurea jacea* exposed to ambient ozone concentrations at sites across Europe. Values are mean + one standard error. For UK-Ascot: N+ and N- = with and without addition of nitrogen; plants at UK-Bangor were exposed to low (L) or medium (M) ozone concentrations in solardomes. * = no flower stems present.

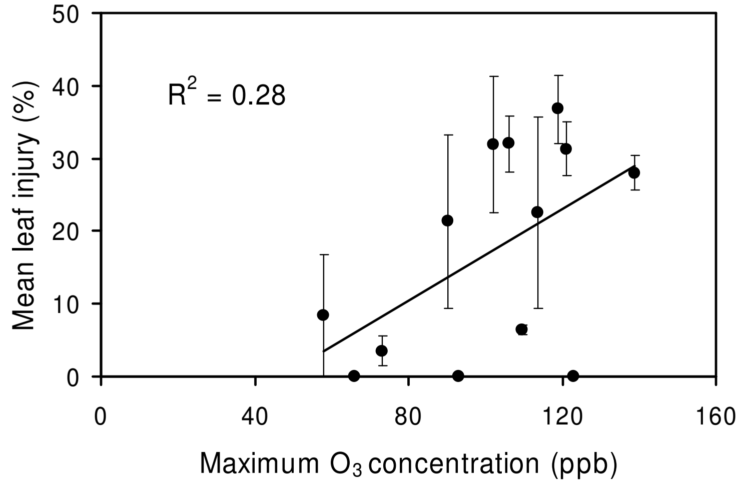

Figure 2.3 Mean injury (+/- one standard error) of rosette leaves of the sensitive clone of *Centaurea jacea* plotted versus maximum ozone concentration at sites across Europe.

In general, resistant plants grew bigger, but plant weight differed strongly between sites (Figure 2.2). This was primarily due to the fact that at some sites plants did not produce flower stems. Rosette leaves were available for injury assessment at all but one site (Greece-Naoussa). At several sites, clear differences in the degree of injury between clones were observed, with injury clearly more expressed in the sensitive clone at the majority of sites.

However, at some sites injury occurred equally in both clones, and at a few sites (e.g. Italy-Curno and Slovenia-Ljubljana), no injury was observed in the presence of relatively high ozone. In the case of Curno, this likely occurred because the observation period was too short. At the site in Spain, the order of injury in the two clones was reversed, which could be due to interactions with climate, but the reason is not known. Across the sites with sufficient exposure time, the degree of injury in the sensitive clone was related to the maximum hourly ozone concentration (Figure 2.3).

The field-trial revealed some important problems. Most importantly, some participants had a difficulty in separating ozone-specific symptoms (bronzing) from general, non-specific reddening of leaves. The two types of symptoms can occur together, but reddening was more pronounced in the resistant clone. This can confuse the assessment, and thus the results must be viewed with caution, for instance those for the Rome site. Intercalibration and training would be necessary to improve the data quality of the leaf injury assessments. Although the developed protocol worked quite well, it could be improved. However, the protocol was not followed strictly by all participants, thus making comparisons between sites difficult. In spite of these difficulties, the results are encouraging but additional steps to improve the system and to define the boundaries of conditions within which the system could potentially be used would be necessary.

2.3. Field-based evidence for the impacts of ozone on vegetation

The ICP Vegetation is collating evidence of damage to vegetation in Europe caused by ambient ozone pollution over the time-scale 1990 – 2006. The ovearall aim is to quantify the link between field observations and critical level exceedances. Three main types of data exist in published papers and reports:

- effects detected during biomonitoring exercises such as the ICP Vegetation clover network;
- records of ozone injury observed during field surveys;
- effects detected experimentally by comparing responses of plants grown in ambient air with those exposed to air with reduced ozone concentration.

So far, the database contains over 500 records of ozone injury from 17 countries.

As part of the study, trends in the clover biomonitoring experiment (see section 2.1) have been analysed in more detail for the period 1996 – 2006. During the early years the clover biomonitoring experiment focussed on the impacts of ambient ozone on the biomass ratio between the ozone-sensitive and resistant clover clones. The dose-response relationship shown in Figure 2.4 includes all the data points collated in the last decade. Unfortunately, hardly any data are available from highly ozone polluted sites with an AOT40 above 20 ppm h.

There is scored injury data available from a total of 45 sites, representing 16 countries across Europe from 1998 to 2006, although each individual site did not necessarily perform the biomonitoring study every year. Ozone injury has been detected at almost every site in every year, with the extent of injury reflecting the fluctuating ozone climate. The injury scores at the monthly cut-backs have been averaged across five geographical regions to investigate trends (Figure 2.5). The component countries of each region were as defined in chapter 3 of the Mapping Manual (LRTAP Convention, 2006). Injury scores were generally highest for the Mediterranean, in particular Western Mediterranean (WM), were lowest in Northern

Europe (NE) and Atlantic Central Europe (ACE) and were generally intermediate for Central Continental Europe (CCE). There was high year-to-year variation in the mean injury scores in every month, however, there was no consistency between the regions. Trends in leaf injury scores reflect the spatial and temporal variation in ozone concentration, with no marked decline or increase evident. Visible leaf injury was frequently recorded in regions that have low ozone concentrations but high ozone stomatal fluxes, e.g. in Altantic Central Europe and Northern Europe.

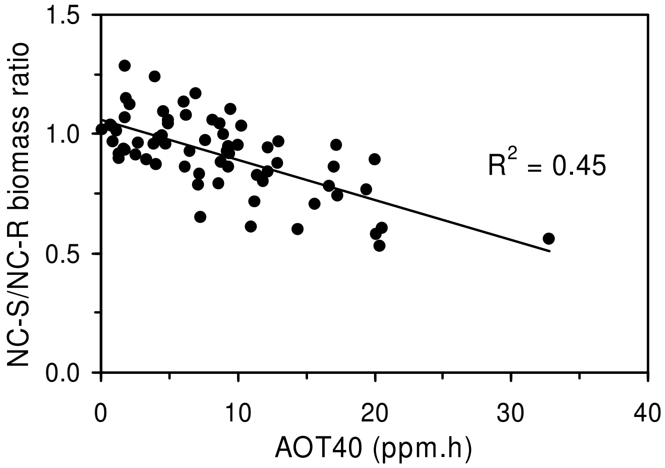

Figure 2.4 Response of the NC-S/NC-R biomass ratio of white clover to AOT40 over three months.

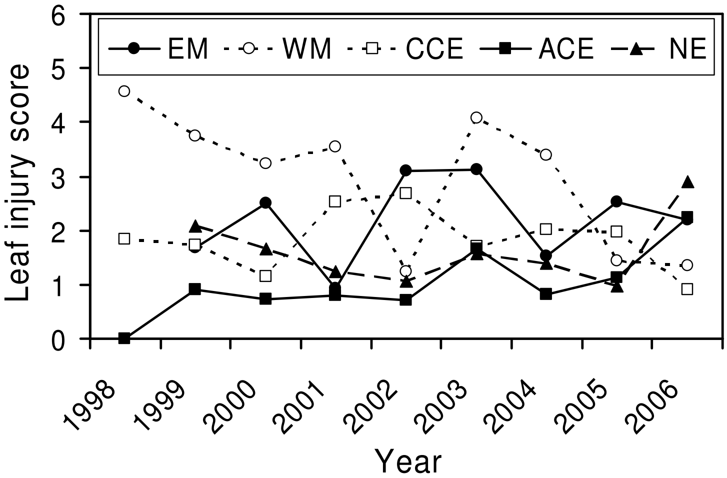

Figure 2.5 The mean visible leaf injury due to ozone on the sensitive biotype of *Trifolium repens* per region in Europe. Leaf injury scores: 1 = <1%, 2 = 1%-5%, 3 = 5%-25%, 4 = 25%-50%, 5 = 50%-90%, 6 = 90%-100% of leaves affected. EM = Eastern Mediterranean, WM = Western Mediterranean, CCE = Continental Central Europe, ACE = Atlantic Central Europe, NE = Northern Europe.

Regarding ozone injury observed during field surveys, literature searches have been carried out, and requests for records of visible injury (since 1990) have been sent to ICP Vegetation participants and selected other researchers who investigate the effects of ozone pollution on vegetation. Visible injury symptoms, attributed to ozone pollution, have been recorded on a wide range of crop, forb and shrub species across the length and breadth of Europe (Figure 2.6) Each record includes the country, grid reference, year of observation, species and species type. Data obtained to date indicates that ozone injury on (semi-)natural vegetation species is widespread across Europe and that countries that have low ozone concentrations but high ozone stomatal fluxes (e.g. Sweden, Belgium, UK) have frequent records of visible injury attributed to ozone.

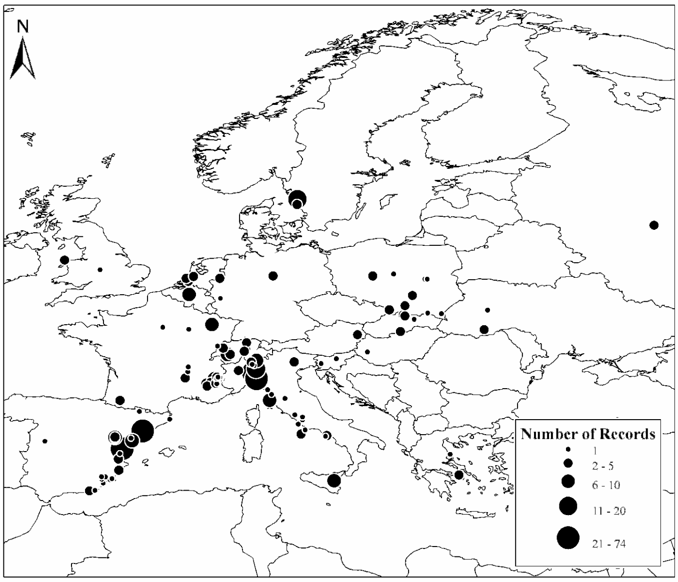

Figure 2.6 Number of records of ozone-induced visible leaf injury on crops and (semi-) natural vegetation at sites across Europe between 1990 and 2006.

Data have been collated also from experiments where there has been both a charcoal filtered air treatment and a non-filtered/ambient air treatment. This allows the effect of ambient air to be investigated. The database currently comprises over 100 datapoints from eight countries, from a wide range of crop, grass and forb species. A range of biological responses have been recorded and these include effects on yield, biomass, maximum rate of photosynthesis and relative growth rate. Some large effects have been recorded, for example above-ground biomass of *Trifolium cherleri* was reduced by 50% in non-filtered air compared to charcoal filtered air in Spain (Gimeno *et al.*, 2004a). In Germany the proportion of undeveloped pollen in *Lolium perenne* was increased from 18% to 24% in non-filtered air compared to charcoal filtered air (Schoene *et al.*, 2004). On the other hand, some species showed no measured responses, e.g. *Avena sterilis* in Spain (Gimeno *et al.*, 2004b).

Evidence collated so far indicates that over 130 species of crops and (semi-)natural vegetation are responding to ozone pollution at the concentrations currently experienced within the ECE region. Trends in impact reflect the spatial and temporal variation in ozone concentration, with no marked decline or increase evident. The final report on the impacts of ambient ozone on vegetation will be published by December 2007.

2.4. Ozone-sensitive communities of (semi-)natural vegetation

Existing datasets were collated from literature into a database named OZOVEG (**Ozo**ne effects on **veg**etation) to allow identification of ozone-sensitive species and analysis of relationships between ozone sensitivity and plant characteristics (Hayes *et al.*, 2007). A model was developed that uses Ellenberg Indicator values (Ellenberg *et al.*, 1991) for a species to predict its response to ozone and this approach was then applied to whole plant communities to predict their sensitivity to ozone (Jones *et al.*, 2007). A framework was developed to map the location of ozone-sensitive plant communities across Europe using the European Nature Information System (EUNIS) and to identify ozone-sensitive communities suitable for mapping exceedances of critical levels (Mills *et al.*, 2007). Currently, the OZOVEG database contains dose-response functions for relative biomass for 89 species of (semi-)natural vegetation. As ozone exposure of individual plants growing within communities generally reduces with decreasing plant height, the OZOVEG database has been updated with individual plant species and community height data. This will allow a better prediction of the ozone-sensitivity of individual species grown under field conditions within plant communities. Information on the responses of species to ozone when grown in a competitive environment has also been added to the database.

The geographical coverage of the OZOVEG database reflects the sources of published data. It has a central and northern European bias since over 95% of the data is from experiments conducted in Sweden, Denmark, UK, Netherlands, Germany and Switzerland. To extend the Ellenberg modelling approach to the European scale, a full electronic list of the European Ellenberg numbers has been obtained. Plant community descriptions, together with characteristic species lists have been obtained for Natura 2000 habitats. These community descriptions are very broad, and approximate broadly to level 3 of the EUNIS classification. It would be preferable to use the EUNIS system which is a more robust phytosociological classification, however adequate species lists for each community are not yet available in EUNIS for the purposes of a broad assessment of the ozone sensitivity of many community types. The species lists for the Natura 2000 habitats vary in length from 2 species to 40+, and usually provide enough information to make preliminary assessments of ozone sensitivity using the method described in Jones *et al.* (2007), i.e. calculating ozone sensitivity from Ellenberg indicator scores. An assessment requires at least nine species to provide a reliable estimate of ozone sensitivity using this approach, although a less robust estimate which tends to under-estimate sensitivity can be obtained with fewer species.

Work is underway to assess whether the Ellenberg modelling approach can be extended to Mediterranean and other key European habitats for which the majority of species do not have Ellenberg indicator values assigned. A preliminary assessment of two Mediterranean grassland communities suggests that the overlap in species composition in some communities is sufficient to allow calculation of ozone sensitivity of the whole community based on the predicted response to ozone of the species for which Ellenberg numbers have been assigned. Work is also ongoing to collate experimental data and metadata from the five ozone exposure experiments in Europe that have been conducted on whole plant communities (Finland, Switzerland and three in the UK). These experiments range from artificially sown communities in open-top chambers to transplant and in-situ field exposures using free air ozone exposure technology. This data will be used to test the extended Ellenberg model.

2.5. Critical levels of ozone for vegetation

The critical levels of ozone for vegetation, including their scientific basis, are described in detail in the Mapping Manual and were updated in 2006 (LRTAP Convention, 2006), based on the recommendations of the LRTAP Convention workshop on ‘Critical levels of ozone: further applying and developing the flux-based concept’ in Obergurgl, Austria, 15-19 November 2005 (Wieser and Tausz, 2006; Working Group on Effects, 2006).

Table 2.3 Parameterisation for flux-based simplified method for integrated assessment modelling to estimate relative risk for adverse ozone effects on forests (see Mapping Manual for further details).

Parameter	Units	Deciduous species	Evergreen species for the Mediterranean area
Land use	Eunis class, area in km^2	All forested areas	Mediterranean evergreen forest species
g_{max}	mmol O_3 m^{-2} projected leaf area (PLA) s^{-1}	150	175
f_{min}	(fraction)	0.1	0.02
SGS [*]	year day	Latitude model	1 (1 Jan)
EGS [*]	year day	Latitude model	365 (31 Dec)
$f_{phen\_lim}1$ [*]	year day	= SGS	80 (21 Mar)
$f_{phen\_lim}2$ [*]	year day	= EGS	320 (16 Nov)
f_{phen_a} [*]	(fraction)	0.0	1.0
f_{phen_b} [*]	(fraction)	0.0	1.0
f_{phen_c} [*]	(fraction)	1.0	0.3
f_{phen_d} [*]	(fraction)	0.0	1.0
f_{phen_e} [*]	days	15	130
f_{phen_f} [*]	days	20	60
light_a	(co-efficient)	0.006	0.009
T_{min}	°C	0	2
T_{opt}	°C	21	23
T_{max}	°C	35	38
VPD_{max}	kPa	1.0	2.2
VPD_{min}	kPa	3.25	4.0
SWP_{max}	MPa	f_{SWP}=1 [**]	f_{SWP}=1 [**]
SWP_{min}	MPa	f_{SWP}=1 [**]	f_{SWP}=1 [**]
Y	nmol m^{-2} PLA s^{-1}	1.6	1.6
LAI_{min}	m^2 m^{-2}	0	5
LAI_{max}	m^2 m^{-2}	4	5
LAI_s	m^2 m^{-2}	15	-
LAI_e	m^2 m^{-2}	30	-
h	m	20	8
L	m	7	3.5

[*] It should be noted that the structure of the f_{phen} function has changed from that provided previously in the Mapping Manual (LRTAP Convention, 2006) to allow for the decrease in stomatal conductance that is commonly found in Mediterranean forests during the summer period, which is driven by soil moisture limitation and phenology.

[**] The value 1 would capture most sensitive ecosystem in a grid cell but not give information on variation due to this parameter within a grid cell.

Abbreviations: g_{max} = maximum stomatal conductance; SGS = start of growing season; EGS = end of growing season; f_{phen} = phenology function; T = temperature; VPD = vapour pressure deficit; SWP = soil water potential; Y = stomatal flux threshold; LAI = leaf area index; h = height; L = cross wind leaf dimension.

In Obergurgl, a simplified stomatal flux-modelling approach for generic crop and forest tree species was recommended for large-scale and integrated assessment modelling, to be used only for relative risk assessments in support of international policy making. Thus, no critical level is defined for the new flux metrics for the generic crop and forest trees. Details of the parameterisation of the generic stomatal flux model for crops were agreed in 2006 and for forest trees details of the parameterisation were discussed further within a sub-group formed at the Obergurgl Workshop. The parameterisation of two generic tree species (Deciduous and Mediterranean Evergreen) was agreed at a meeting of the forest sub-group in Antwerp, Belgium, June 2006 (Table 2.3) and adopted by the Task Forces of the ICP Vegetation, ICP Modelling and Mapping and ICP Forests at their annual meetings in 2007. In 2006, chapter 3 of the Mapping Manual was updated with Annex III to include the parameterisation for the generic crop species. In 2007, Annex III was further updated to include the parameterisation for the two generic tree species. Currently, the ICP Vegetation is streamlining the text of chapter 3 of the Mapping Manual to include all information of the annexes into the body of the main text.

2.6. Mapping areas at risk from adverse effects of ozone on vegetation

In collaboration with EMEP/MSC-West, the EMEP chemical transport model was used to map the risk of adverse affects of ozone across Europe for a generic crop and two generic tree species (Figure 2.7). The stomatal component of the DO_3SE (Deposition of Ozone and Stomatal Exchange) model was parameterised using the agreed parameterisations for generic crop and tree species.

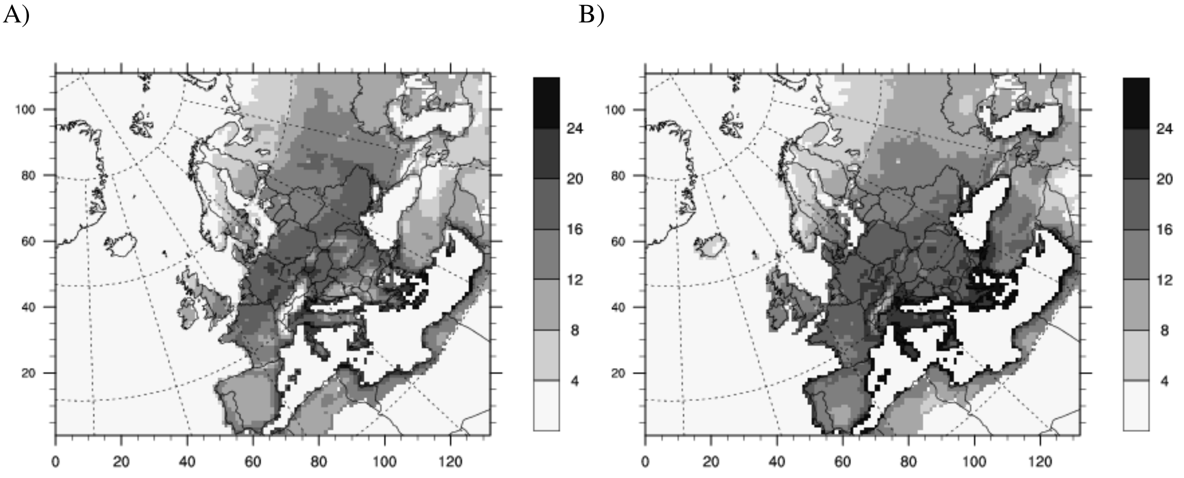

Figure 2.7 Modelled ozone fluxes to A) generic crops ($AF_{st}3_{gen}$, mmol m^{-2}) and B) generic deciduous forests ($AF_{st}1.6_{gen}$, mmol m^{-2}) for the year 2004. Note that calculations were carried out to all vegetated grid squares, in order to allow later mapping against the actual distribution of relevant species. Modified after Simpson and Emberson (2006).

The spatial patterns of the simplified flux-based approach are quite different from those of the concentration-based approach, but are similar to the spatial patterns reported for the exceedances of critical levels using the full flux-based method for wheat and beech (Simpson *et al.*, 2007). For example, the gradients from northern to southern Europe for the concentration-based indices are much greater than those for the flux-based indices (Simpson and Emberson, 2006; Simpson *et al.*, 2007). Nevertheless, both the concentration and flux-based indices identify vegetation in the Mediterannean and Central Europe at highest risk from ozone pollution. The calculated ozone fluxes to the generic Mediterannean evergreen forest are substantially lower than those calculated for the generic crop species or deciduous forest (Simpson and Emberson, 2006). The large difference is primarily caused by the new phenology functions for the generic Mediterranean evergreen species, which severely limit ozone uptake during the summer months. The absolute values for the accumulated stomatal flux for the generic crop and deciduous tree species (Simpson and Emberson, 2006) are significantly higher than those calculated for wheat and beech using the full stomatal flux model (Simpson *et al.*, 2007). These increases are due to a combination of new emission estimates, revised deposition parameters for the standard deciduous forest classes, and the sensitivity of the accumulated stomatal flux values for even small changes in calculated ozone values (Tuovinen *et al.*, 2007).

2.7. Critical levels of ammonia for vegetation

The LRTAP Convention workshop on ‘Atmospheric ammonia: detecting emission changes and environmental impacts’ was held on 4–6 December 2006 in Edinburgh (United Kingdom). Background documents and presentations are available at www.ammonia-ws.ceh.ac.uk/documents.html. One of the objectives of the workshop was to examine the case for setting new ammonia critical levels based on current scientific evidence of direct impacts of ammonia on different receptors. Data reviewed at the workshop showed that the then existing critical levels of ammonia for vegetation were not sufficiently precautionary. Therefore, the workshop recommended the following new critical levels for ammonia (Working Group on Strategy and Reviews, 2007):

- long-term critical level for lichens and bryophytes, including for ecosystems where lichens and bryophytes are a key part of the ecosystem integrity, of 1 µg m^{-3} (annual average);
- long-term critical level for higher plants, including heathland, grassland and forest ground flora and their habitats, of 3 µg m^{-3}, with an uncertainty range of 2 – 4 µg m^{-3} (annual average).

The workshop noted that these long-term critical level values could not be assumed to provide protection for longer than 20–30 years. The workshop recommended to retain the monthly critical level (23 µg m^{-3}) for higher plants only as a provisional value in order to deal with the possibility of high peak emissions during periods of manure application (e.g. in spring). Further research is required to improve the future estimation of ammonia critical levels, including addressing uncertainties relating to the shortage of observational data and long-term ammonia concentration measurements, particularly in southern and eastern Europe. Similarly, there is a need for a better understanding of the mechanisms whereby ammonia affects plants, especially over decadal timescales, so that predictive models can be constructed for extrapolation to other types of vegetation and land use in different climatic zones. The Task Forces of the ICP Vegetation and the ICP Modelling and Mapping adopted the new ammonia critical levels at their annual meetings in 2007 and the ICP Vegetatation Coordination Centre will revise chapter 3 of the Mapping Manual accordingly.

2.8. Temporal trends of heavy metal concentrations in mosses

The European heavy metals in mosses survey provides data on concentrations of ten heavy metals in naturally growing mosses and is repeated at five-year intervals (Harmens *et al.*, in press a,b). Over the years the heavy metals in mosses survey has expanded gradually from the Nordic and Baltic countries to the rest of Europe. Currently, the ICP Vegetation Coordination Centre is collating and processing the data of the 2005/2006 moss survey in which 32 countries participate and mosses were sampled from over 7,000 sites across Europe. The majority of countries (18) have also determined the nitrogen concentration in mosses (ca. 3,200 sites) for the first time. Sampling and analysis of the mosses was conducted according to a standard protocol (Harmens *et al.*, 2005) and certified reference moss samples were distributed amongst participants for quality assurance purposes (Steinnes *et al.*, 1997).

Table 2.4 Median values of arsenic (As), chromium (Cr) and copper (Cu) concentrations in mosses across Europe in 1990, 1995 and 2000; - = not determined.

	As ($\mu g\ g^{-1}$)			**Cr ($\mu g\ g^{-1}$)**			**Cu ($\mu g\ g^{-1}$)**		
Country	**1990**	**1995**	**2000**	**1990**	**1995**	**2000**	**1990**	**1995**	**2000**
Austria	0.56	0.13	0.10	1.85	0.70	0.73	5.85	5.35	6.13
Bulgaria	-	-	0.21	-	2.30	2.41	-	14.70	14.51
Czech Republic	1.70	0.50	0.29	1.90	1.37	1.88	8.40	7.15	6.52
Denmark	-	0.27	-	1.22	0.65	-	6.41	4.73	-
- Faroe Islands	-	-	0.15	-	0.68	0.68	-	5.47	6.84
Estonia	-	0.23	-	1.63	0.77	1.01	5.48	3.64	3.39
Finland	-	0.23	0.16	1.47	1.43	1.06	5.07	4.46	3.38
France	-	0.30	0.23	-	3.16	1.69	-	5.30	6.40
Germany	0.34	0.25	0.16	1.83	1.39	0.91	9.13	9.57	7.14
Hungary	-	-	-	-	3.61	6.40	-	5.77	7.65
Iceland	-	0.07	0.14	2.33	2.38	2.61	8.42	8.09	8.36
Italy	-	0.29	0.40	2.16	2.47	3.80	8.90	8.90	9.10
Latvia	-	-	0.06	1.46	1.13	0.95	6.03	3.79	5.10
Lithuania	-	0.40	0.32	1.17	1.31	1.27	6.55	5.87	6.45
Netherlands	0.39	0.41	-	2.45	4.23	-	13.21	23.96	-
Norway	0.27	0.21	0.13	0.90	1.05	0.69	5.22	5.21	4.26
Poland	-	-	-	2.34	1.50	0.89	9.30	7.60	8.03
Portugal	-	-	0.33	1.40	2.17	1.08	7.00	7.37	6.16
Romania	-	0.96	1.56	10.85	9.15	8.46	18.42	11.30	21.56
Russian Fed.	-	0.24	0.21	-	1.27	1.43	-	7.12	5.84
- St. Petersburg	-	-	0.17	-	1.99	1.42	4.90	4.58	5.19
Slovakia	-	-	0.71	3.55	13.21	6.45	18.60	16.35	8.76
Slovenia	-	0.38	0.33	-	4.29	2.59	-	8.40	-
Spain	-	0.19	0.21	4.89	2.71	5.73	7.78	6.07	4.24
Sweden	-	0.15	0.16	1.28	0.60	0.68	5.47	4.58	4.36
Switzerland	0.33	0.12	0.12	2.40	0.76	0.89	3.90	4.30	4.35
Ukraine	-	0.10	0.24	-	1.70	1.50	-	6.20	7.31
United Kingdom	-	0.37	0.16	0.60	1.40	1.47	6.10	5.43	4.32

Here we report on the temporal trends of the heavy metal concentrations in mosses between 1990 and 2000 for arsenic, chromium, copper, iron, nickel, vanadium and zinc (Harmens *et al.*, in press b). Temporal trends for the heavy metals targeted by the Aarhus Protocol (1998), i.e. cadmium, lead and mercury, were reported previously (Harmens *et al.*, 2006; Harmens *et* *al.*, in press a): the concentration of cadmium and lead in mosses declined significantly between 1990 and 2000 but the mercury concentration in mosses did not change between 1995 and 2000. For detailed information on the sources of heavy metals in each country we refer to the reports of the individual surveys (Rühling, 1994; Rühling and Steinnes, 1998; Buse *et al.*, 2003b). These reports also discuss in more detail the spatial trends observed across Europe, showing that there was a general trend of higher heavy metal concentrations in eastern regions compared with other regions of Europe.

Maps were produced of the metal concentration in mosses for 1990, 1995 and 2000, showing the mean concentration per metal per 50 km x 50 km EMEP grid square, according to the method described by Buse *et al.* (2003b). Metal- and country-specific temporal trends were observed (Table 2.4-2.6). Although the metal concentration in mosses generally declined with time between 1990 and 2000 across Europe for all metals, only the decreases for arsenic, copper, vanadium and zinc were statistically significant (Table 2.6).

Table 2.5 Median values of nickel (Ni), vanadium (V) and zinc (Zn) concentrations in mosses across Europe in 1990, 1995 and 2000; - = not determined.

	Ni (μg g^{-1})			**V (μg g^{-1})**			**Zn (μg g^{-1})**		
Country	**1990**	**1995**	**2000**	**1990**	**1995**	**2000**	**1990**	**1995**	**2000**
Austria	2.50	1.30	1.26	2.00	1.30	1.27	36.6	30.0	31.5
Bulgaria	-	3.06	3.33	-	4.90	4.95	-	30.5	32.6
Czech Republic	3.40	1.95	1.95	5.40	2.00	1.52	45.5	41.9	35.0
Denmark	1.32	1.38	-	2.66	2.51	-	36.0	41.8	-
- Faroe Islands	-	1.56	1.73	-	4.36	3.34	-	14.6	14.4
Estonia	2.07	1.21	1.01	2.88	3.90	1.72	30.8	32.8	31.5
Finland	1.70	1.65	1.38	3.36	2.18	1.24	35.9	37.5	27.6
France	-	1.94	2.30	-	2.46	2.89	-	32.4	40.4
Germany	2.38	1.64	1.13	2.87	1.71	1.06	50.2	54.0	41.0
Hungary	-	4.00	5.35	-	4.62	4.20	-	27.6	30.0
Iceland	2.59	2.96	3.32	12.15	11.30	11.95	18.2	17.2	27.7
Italy	1.47	2.28	3.80	-	3.10	5.89	31.3	45.0	48.3
Latvia	1.40	1.07	0.98	3.19	3.05	1.80	41.7	30.2	31.0
Lithuania	1.75	1.78	1.36	3.34	4.58	3.44	42.0	40.0	34.5
Netherlands	2.64	15.00	-	4.71	4.53	-	47.5	68.6	-
Norway	1.56	1.63	1.11	2.36	2.27	1.36	36.4	37.7	29.5
Poland	2.21	1.44	1.57	4.80	4.00	5.84	53.1	43.0	41.5
Portugal	1.80	10.75	1.21	-		2.72	29.0	40.4	28.1
Romania	8.41	2.19	3.35	12.53	6.40	7.99	69.1	43.9	79.6
Russian Fed.	-	4.98	2.01	-	3.03	2.79	-	38.0	35.3
- St. Petersburg	6.70	2.70	2.05	5.10	4.13	2.18	42.0	48.1	36.2
Slovakia	1.70	1.99	3.15	-	0.12	5.70	162.5	49.1	55.0
Slovenia	-	2.76	-	-	4.00	-	-	38.8	34.5
Spain	3.86	1.95	4.16	9.60	-	-	35.4	40.7	30.0
Sweden	1.50	1.11	1.41	2.36	2.19	1.31	43.7	40.0	38.8
Switzerland	3.00	1.25	1.22	2.03	1.40	0.88	29.8	30.8	29.7
Ukraine	-	2.69	2.06	-	1.80	1.29		31.0	29.3
United Kingdom	1.60	1.52	0.83	1.40	1.55	0.99	29.2	34.2	22.7

Table 2.6 Average geometric mean values of metal concentrations in mosses for countries (see Table 2.7) that determined these metals in all three surveys; n = the number of countries. The statistical significance (P-value) of country and year of the survey are also shown.

Metal	Average geometric mean (µg g^{-1})				P-value	
	1990	1995	2000	n	Country	Year
As[1]	0.66	0.26	0.17	5	0.205	0.026
Cr	2.47	2.63	2.36	18	0.000	0.180
Cu	8.04	7.25	7.29	19	0.000	0.026
Fe	1262	765	852	18	0.000	0.099
Ni	2.76	2.30	2.00	19	0.049	0.074
V	4.32	3.59	2.96	15	0.000	0.000
Zn	46.8	40.2	38.9	19	0.000	0.021

[1] For arsenic the values are based on data from 5 countries only (see Table 2.5). The geometric mean values of arsenic concentrations in mosses for countries (n = 17) that analysed arsenic both in 1995 and 2000 are 0.32 and 0.31 respectively; therefore, the arsenic concentrations in mosses did not change significantly (P = 0.30) between 1995 and 2000 for those countries.

Here we summarise the temporal trends per metal, for further details we refer to Harmens *et al.* (in press b). Only five countries determined the **arsenic** concentration in mosses in all three survey years. For these countries, the average geometric mean arsenic concentration declined significantly between 1990 and 2000 with the biggest decline between 1990 and 1995. However, 17 countries determined the As concentration in both 1995 and 2000 and for those countries the arsenic concentration did not change significantly between 1995 and 2000. In the central European countries the arsenic concentration in mosses generally decreased with time. As for arsenic, the **chromium** concentrations in mosses generally decreased with time in central European countries. However, the average median chromium concentration across Europe declined by only 8% between 1990 and 2000 (Table 2.7) and no significant trend was found in the average geometric mean values for countries that analysed chromium in all survey years (Table 2.6). The decline in the average median **copper** concentration across Europe was 16% between 1990 and 2000. However, in a number of countries (Austria, Italy, Romania and Switzerland) the median copper concentration in mosses increased between 1990 and 2000. The average geometric mean **iron** concentration in mosses decreased between 1990 and 1995, but increased again between 1995 and 2000, resulting in no significant change with time (Table 2.6). The decrease between 1990 and 1995 was particularly observed in most of central and eastern Europe. Overall, the decrease in the median iron concentration in mosses was 44% between 1990 and 2000 (Table 2.7). Despite a steady decline in the average geometric mean **nickel** concentration in mosses across Europe between 1990 and 2000, the decline was not significant. Although the overall decline in the median value was 30%, in a number of countries (Iceland, Italy, Slovakia and Spain) the median value increased between 1990 and 2000. The average geometric mean **vanadium** concentration in mosses declined steadily and significantly between 1990 and 2000, with an overall decline in the median value of 32%. Despite the steady decline with time across Europe, country-specific changes in the median values between 1990 and 1995 or 1995 and 2000 were observed. The average geometric mean **zinc** concentration in mosses declined significantly with time and the highest decline occurred between 1990 and 1995. The overall decline in the median value was 19% between 1990 and 2000.

Table 2.7 Average median values of metal concentrations in mosses for countries that determined the metals both in 1990 and 2000, and their decrease with time.

Metal	Countries	Median 1990 ($\mu g\ g^{-1}$)	Median 2000 ($\mu g\ g^{-1}$)	Decrease with time (%)
As[1]	AT, CH, CZ, DE, NO	0.64	0.16	75
Cr	AT, CH, CZ, DE, EE, ES, FI, GB, IS, IT, LV, LT, NO, PL, PT, RO, SE, SK	2.44	2.25	8
Cu	AT, CH, CZ, DE, EE, ES, FI, GB, IS, IT, LV, LT, NO, PL, PT, RO, RU[2], SE, SK	7.92	6.67	16
Fe	AT, CH, CZ, DE, EE, ES, FI, IS, IT, LV, LT, NO, PL, PT, RO, RU[2], SE, SK	1223	809	44
Ni	AT, CH, CZ, DE, EE, ES, FI, GB, IS, IT, LV, LT, NO, PL, PT, RO, RU[2], SE, SK	2.72	1.91	30
V	AT, CH, CZ, DE, EE, FI, GB, IS, LV, LT, NO, PL, RO, RU[2], SE	4.38	2.97	32
Zn	AT, CH, CZ, DE, EE, ES, FI, GB, IS, IT, LV, LT, NO, PL, PT, RO, RU[2], SE, SK	45.4	36.8	19

[1] For arsenic the values are based on data from 5 countries only. The median value of arsenic concentrations in mosses for countries (n = 17) that analysed arsenic both in 1995 and 2000 is 0.29 for both years, indicating that arsenic concentrations in mosses primarily decreased between 1990 and 1995.

[2] RU = St. Petersburg region in the Russian Federation.

For Europe as a whole total emission (including anthropogenic, natural and historical) and deposition trends should be of a similar magnitude. At a smaller scale (regions, country, provinces etc.) the trends can be different, depending on local emissions, depositions from long-range transport, meteorological peculiarities, site specific characteristics (e.g. Schröder *et al.*, in press) etc. Natural plus historical emissions contribute to a certain level of heavy metals in mosses which is not affected directly by current anthropogenic emission sources. Therefore, when comparing deposition trends or the heavy metal concentrations in mosses with the trends in anthropogenic emissions, the latter should be steeper as the annual natural plus historical emissions are almost the same from year to year according to EMEP parameterizations (Ilyin, pers. comm.). This was indeed the case when comparing the temporal trends in the concentrations in mosses with the temporal trends in the anthropogenic emissions reported by EMEP for arsenic (between 1995 and 2000), chromium and nickel. Decreases in the anthropogenic emission of metals according to official data combined with experts estimates were ca. 40, 25 and 55% for arsenic, chromium and nickel, respectively (Ilyin *et al.*, 2006). For plant essential trace elements such as copper and zinc the difference in temporal trends between the concentrations in mosses and anthropogenic emissions would be expected to be even bigger since mosses recycle these essential elements within the plant and therefore have an intrinsic background level for essential trace elements. However, no big difference were observed in temporal trends at the European scale in the current study: 16 – 19% decrease in the concentration in mosses compared to a 24 – 27% decrease in anthropogenic emissions for copper and zinc (Task Force on Heavy Metals, 2006).

When examining the results of the moss surveys it should be kept in mind that the heavy metal concentrations in mosses do not directly reflect the total deposition of heavy metals. There are differences in the accumulation rates for individual heavy metals in mosses, and the heavy metal concentrations in mosses are also affected by factors other than atmospheric pollution. These factors were discussed in more detail by Harmens *et al.* (in press a). However, the similarity in temporal trends reported for the data of the European moss survey and the modelled total depositions of cadmium, lead and mercury suggests that at the European scale the reported temporal trends for these metals were not affected by any potential confounding factors.

2.9. Task Force Meeting

Each year, the ICP Vegetation holds a Task Force Meeting in one of the participating countries to consider recent results and to plan the future work programme. The 20th Task Force Meeting of the ICP Vegetation was held in Dubna, Russian Federation, from 5 – 8 March 2007, and was hosted by the Joint Institute for Nuclear Research (JINR). The meeting was attended by 63 experts from 22 Parties to the Convention, the chairman and a vice-chairman of the Working Group on Effects (WGE), the UNECE secretariat for the LRTAP Convention, a representative from the ICP Modelling and Mapping and three guests from Uzbekistan and Vietnam. Attendance included 23 experts from four EECCA (Eastern Europe, Caucasus and Central Asia) countries. The minutes of the meeting, a book of abstracts and a selection of presentations are available on http://icpvegetation.ceh.ac.uk.

Poster sessions, presentations and discussions addressed the following main topics:

- effects-based approaches for review and possible revision of the Convention protocols, in particular the Gothenburg Protocol;
- field-based evidence on the impacts of ozone on vegetation, including biomonitoring of ozone pollution using crops and (semi-)natural vegetation;
- recent developments in modelling stomatal ozone fluxes and their application;
- biomonitoring of heavy metal and nitrogen pollution using mosses, including progress of the European moss survey 2005/2006.

Progress of the 2007 workplan was reviewed and the medium-term workplan of the ICP Vegetation was updated (see Annex 1).

2.10. Outputs

Papers

Harmens, H., Mills, G., Emberson, L., Ashmore, M. (2007). Implications of climate change for the stomatal flux of ozone: a case study for winter wheat. Environmental Pollution 146, 763-770.

Harmens, H., Norris, D.A., Koerber, G.R., Buse, A., Steinnes, E., Rühling, Å. (in press). Temporal trends (1990 – 2000) in the concentration of cadmium, lead and mercury in mosses across Europe. Environmental Pollution.

Harmens, H., Norris, D.A., Koerber, G.R., Buse, A., Steinnes, E., Rühling, Å. (in press). Temporal trends in the concentration of arsenic, chromium, copper, iron, nickel, vanadium and zinc in mosses across Europe between 1990 and 2000. Atmospheric Environment.

Hayes, F., Jones, M.L.M., Mills, G., Ashmore, M. (2007). Meta-analysis of the relative sensitivity of semi-natural vegetation to ozone. Environmental Pollution 146, 754-762.

Jones, M.L.M., Hayes, F., Mills, G., Sparks, T.H., Fuhrer, J. (2007). Predicting community sensitivity to ozone, using Ellenberg Indicator values. Environmental Pollution 146, 744-753.

Mills, G., Buse, A., Gimeno, B., Bermejo, V., Holland, M., Emberson, L., Pleijel, H. (2007). A synthesis of AOT40-based response functions and critical levels of ozone for agricultural and horticultural crops. Atmospheric Environment 41, 2630-2643.

Mills, G., Hayes, F., Jones, M.L.M., Cinderby, S. (2007). Identifying ozone-sensitive communities of (semi-) natural vegetation suitable for mapping exceedance of critical levels. Environmental Pollution 146, 736-743.

Pleijel, H., Danielsson, H., Emberson, L., Ashmore, M., Mills, G. (2007). Ozone risk assessment for agricultural crops in Europe: Further development of stomatal flux and flux-response relationships for European wheat and potato. Atmospheric Environment 41, 3022-3040.

Schröder, W., Pesch, R., Englert, C., Harmens, H., Suchara, I., Zechmeister, H.G., Thöni, L., Maňkovská, B., Jeran, Z., Grodzinska, K., Alber, R. (in press). Metal accumulation in mosses across national boundaries: uncovering and ranking causes of spatial variation. Environmental Pollution.

Reports

Harmens, H., Mills, G., Hayes, F., Jones, L., Norris, D., Fuhrer, J. and the participants of the ICP Vegetation (2007). Air Pollution and Vegetation: ICP Vegetation Annual Report 2006/2007. Centre for Ecology and Hydrology, Bangor, UK. ISBN 978 1 85531 233 3.

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Working Group on Effects (2007). Ellenberg modelling approach to identify (semi-)natural vegetation at risk from ozone. Technical Report prepared by the ICP Vegetation (EB.AIR/WG.1/2007/9).

Contributions were made to the following reports:

Working Group on Effects (2007). Joint Report of the International Cooperative Programmes and the Task Force on Health Apects of Air Pollution (ECE/EB.AIR/WG.1/2007/3).

Working Group on Effects (2007). Draft 2008 workplan for effects-oriented activities (ECE/EB.AIR/WG.1/2007/4).

Working Group on Effects (2007). Review of the 1999 Gothenburg Protocol. Review report of the Working Group on Effects. (EB.AIR/WG.1/2007/14).

Working Group on Effects (2007). Review of the 1999 Gothenburg Protocol (EB.AIR/WG.1/2007/17).

Book of abstracts

Harmens, H., Mills, G., Cooper, J., Sissakian, A., Frontasyeva, M., Donskova, T. (2007). 20th Task Force Meeting of the ICP Vegetation. Programme and abstracts, 5 – 9 March 2007, JINR, Dubna, Russian Federation. ISBN 5-9530-0140-1.

Web site

http://icpvegetation.ceh.ac.uk

3. Conclusions and future developments

In 2006/2007, the ICP Vegetation has conducted research on two air pollution problems of particular relevance for the review of the 1998 Aarhus Protocol and the 1999 Gothenburg Protocol of the LRTAP Convention (Working Group on Effects, 2004):

- Quantifying the risks to vegetation posed by ozone pollution;
- Quantifying the accumulation of heavy metals and nitrogen in mosses.

Over 180 scientists from 35 countries of Europe and North America contribute to the programme by conducting experiments, sampling and analysing vegetation or modelling pollutant deposition and effects. The 20th Task Force Meeting of the ICP Vegetation (Dubna, Russian Federation, March 2007) attracted 69 participants from 24 countries.

3.1. Biomonitoring of ozone impacts on vegetation

Monitoring of the impacts of ambient ozone on vegetation in Europe continued during 2006 using the NC-S (ozone-sensitive) and NC-R (ozone-resistant) biotypes of white clover. In 2006, the three-month AOT40 ranged from 2.2 ppm h in Rucava (Latvia) to 12.3 ppm h in Naples (Italy). The critical level for agricultural crops for yield reduction (a three-month AOT40 of 3 ppm h) was exceeded at more than 60% of the biomonitoring sites and visible leaf injury on white clover was widespread across Europe. In 2006, a field trial was conducted across Europe with an ozone-sensitive and resistant clone of *Centaurea jacea*. In general, resistant plants grew bigger, but plant weight and development differed strongly between sites. Across the sites with sufficient exposure time, the degree of injury in the sensitive clone was related to the maximum hourly ozone concentration. However, some participants had a difficulty in separating ozone-specific and non-specific injury symptoms on leaves. Continuation of the *Centaurea jacea* biomonitoring programme would depend on a firm commitment from all participants and on additional resources for training to ensure the quality of data and continuity in leaf injury assessment.

3.2. Field-based evidence for the impacts of ozone on vegetation

Visible injury symptoms, attributed to ozone pollution, have been recorded on a wide range of crop, forb and shrub species across the length and breadth of Europe. Data obtained to date indicates that ozone injury on species of crops and (semi-)natural vegetation is widespread across Europe and that countries that have low ozone concentrations but high stomatal ozone fluxes (e.g. Sweden, Belgium, UK) have frequent records of visible injury attributed to ozone. For the clover biomonitoring experiment there was a high year-to-year variation in the mean injury scores for every month, with no consistency between regions. Trends in leaf injury scores reflect the spatial and temporal variation in ozone concentration, with no marked decline or increase evident. Evidence collated so far indicates that over 130 species of crops and (semi-)natural vegetation are responding to ozone pollution at the concentrations currently experienced within the ECE region.

3.3. Ozone-sensitive communities of (semi-)natural vegetation

Currently, the OZOVEG (**Ozo**ne effects on **veg**etation) database contains dose-response functions for relative biomass for 89 species of (semi-)natural vegetation. The OZOVEG database has been updated with individual plant species and community height data. This will allow a better prediction of the ozone-sensitivity of individual species grown under field conditions within plant communities, as ozone exposure of individual plants grown within communities generally reduces with decreasing plant height. Information on the responses of species to ozone when grown in a competitive environment has also been added to the database. Due to the availability of data in the literature, the OZOVEG database has a central and northern European bias. However, the ozone sensitivity of Mediterranean plant communities can be calculated based on the predicted response to ozone of sufficient component species for which Ellenberg numbers have been assigned.

3.4. Mapping areas at risk from adverse effects of ozone

In 2006 and 2007 the Mapping Manual (LRTAP Convention, 2006) was updated with a simplified stomatal flux-modelling method for generic crop and forest tree species, to be used only for relative risk assessments in support of international policy making. The EMEP chemical transport model was used to map the risk of adverse affects of ozone across Europe for a generic crop and two generic tree species. The spatial patterns of both the simplified flux-based approach for generic species and the detailed flux-based approach for wheat and beech are quite different from those of the concentration-based approach, i.e. the gradients from northern to southern Europe for the concentration-based indices are much greater than those for the flux-based indices. Nevertheless, southern and central European countries were still identified as being at highest risk of adverse effects of ozone on crops and deciduous forests. The calculated ozone fluxes to the generic Mediterannean evergreen forest are substantially lower than those calculated for the generic crop species or deciduous forest.

3.5. Critical levels of ammonia for vegetation

New ammonia critical levels for vegetation were recommended at the LRTAP Convention workshop on ‘Atmospheric ammonia: detecting emission changes and environmental impacts’ (4–6 December 2006, Edinburgh, UK):

- long-term critical level for lichens and bryophytes, including for ecosystems where lichens and bryophytes are a key part of the ecosystem integrity, of 1 $\mu g\ m^{-3}$ (annual average);
- long-term critical level for higher plants, including heathland, grassland and forest ground flora and their habitats, of 3 $\mu g\ m^{-3}$, with an uncertainty range of 2 – 4 $\mu g\ m^{-3}$ (annual average).

The monthly critical level of 23 $\mu g\ m^{-3}$ was retained for higher plants only. These new critical levels will be included in the revision of chapter 3 of the Mapping Manual.

3.6. Heavy metal deposition to mosses between 1990 and 2000

Although the metal concentration in mosses generally declined with time between 1990 and 2000 for all metals, only the decreases for arsenic, cadmium, copper, lead, vanadium and zinc were statistically significant. However, the temporal trends varied between countries for each metal. Country-specific temporal trends were also reported by EMEP/MSC-East for emissions and modelled total heavy metal deposition for selected heavy metals, but the emissions and modelled deposition declined for all investigated metals in Europe as a whole.

3.7. Future developments

The ICP Vegetation will continue to collate and review information on the impacts of air pollution on vegetation and report the outcome to the Working Group on Effects (WGE) of the Convention on Long-Range Transboundary Air Pollution (LRTAP). The work of the ICP Vegetation will provide information for a possible revision of the Gothenburg Protocol and the Aarhus Protocol in the future. The deliverables to the Working Group on Effects for 2008 and 2009 are listed in Annex 1. Future developments for each pollutant are described in more detail below.

Ozone

Experimental programme and field-based evidence

The ICP Vegetation will continue to monitor the extent of ozone damage to vegetation by conducting standardized experiments and field surveys. However, the ICP Vegetation will focus more on collating information for the further development and local parameterisation of stomatal ozone flux models for crops, in particular for wheat, potato and grasslands. The biomonitoring experiments with ozone-sensitive species of crops (white clover) and (semi-) natural vegetation (*Centaurea jacea*) will be scaled down. It will not be feasible to run the *Centaurea jacea* field experiments on a large-scale in 2007. If there is sufficient interest and commitment for a 2008 experiment, then it may be possible for colleagues in Switzerland to coordinate an extensive field experiment that year. The ICP Vegetation will further analyse data on field-based evidence for the effects of current ground-level ozone concentrations on vegetation across Europe and publish the report by the end of 2007. In 2008, the Coordination Centre will produce a glossy brochure and set up a web page for the general public and other interested parties on field-based evidence for the impacts of ozone on vegetation.

Flux-based risk assessments

The ICP Vegetation will continue the fruitful collaboration with ICP Forests and EMEP/MSC-West regarding the further development of flux-effect models and the development of flux-based maps of risk of ozone damage to crops and tree species using local parameterisations. In addition, it will report on flux-based risk assessment of damage to managed pastures and develop flux-based methods for (semi-)natural vegetation.

Communities of (semi-)natural vegetation at risk

The Ellenberg modelling approach will be further developed and applied with the aim to quantify the risk of ozone effects on communities of (semi-)natural vegetation in Europe, including the modifying influence of nitrogen. The European Ellenberg model will be applied to the EUNIS classification system to predict the relative sensitivity of plant communities to ozone and to determine and map the location of these communities.

Ozone impact on vegetation: consequences for climate change

A case study with winter wheat has shown that the stomatal flux of ozone might be reduced in a future climate (Harmens *et al.*, 2007), which could result in a reduction in ozone deposition to vegetation and a rise in ground-level ozone concentration. At the same time, ozone will affect carbon uptake and cycling in plants and subsequent carbon sequestration in soils. Changes in carbon fluxes into the soil are predicted to affect microbial processes, which could potentially lead to changes in the emission of greenhouse gases such as methane. It is important to understand the interactive impacts of ozone and climate change on vegetation as well as any feedback mechanisms affecting carbon sequestration in soils and greenhouse gas emissions in order to improve predictions of climate change models (Working Group on Effects, 2007). Therefore, the ICP Vegetation will continue to review information on the impacts of ozone on vegetation in a changing climate and the potential feedbacks to climate change.

Heavy metals and nitrogen

The ICP Vegetation Coordination Centre will further process and analyse the data of the 2005/2006 moss survey with the aim to map the spatial distribution of the heavy metal and nitrogen concentrations in mosses at the EMEP 50 km x 50 km grid scale. Reports of the 2005/2006 moss survey will be published in the summer of 2008. The data of the 2005/2006 survey will be included in further temporal trend analyses of the heavy metal concentrations in mosses across Europe. The ICP Vegetation will continue the fruitful collaboration with EMEP/MSC-East regarding the further application of the heavy metals in mosses database for modelling heavy metal deposition within the EMEP domain. In addition, the ICP Vegetation will consider field-based evidence on the impacts of heavy metals on vegetation.

The LRTAP Convention workshop on ‘Air pollution and its relations to climate change and sustainable development’ (12 – 14 March 2007, Gothenburg, Sweden) recommended to establish an expert group on nitrogen under the Convention to provide a framework on integrated nitrogen approaches and policy options (Working Group on Effects, 2007). The ICP Vegetation will actively contribute to such an integrated nitrogen approach.

3.8. Task Force Meeting 2008

The 21th Task Force Meeting of the ICP Vegetation will be held in Oulu, Finland, provisionally planned for the week of 25 – 29 February 2008.

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Annex 1. Medium-term workplan of the ICP Vegetation

Agreed at the 20th meeting of the Programme Task Force, Dubna, Russian Federation, 5 – 8 March 2007.

2008:

Workplan items common to bodies under the WGE (all ICPs and the Task Force on Health):

- Review of robustness of monitored and modelled air pollution impacts;
- Compilation of observed parameters, monitoring methodologies and intensities of effects-oriented activities;
- Summary of effects-oriented activities in countries of Eastern Europe, Caucasus and Central Asia (EECCA countries).

Workplan items specific to the ICP Vegetation:

- Annual report on experimental programme on responses of vegetation to ozone [O];
- Report on the evidence for effects of current ambient ozone on vegetation (1990 – 2006) [O];
- Flux-based maps of risk of ozone damage to crop and tree species using localised parameterisations (with ICP Forests and EMEP/MSC-W) [O];
- Report on progress with the development of flux-based methods for (semi-)natural vegetation [O];
- Report on the European heavy metals in mosses survey 2005/2006 [HM];
- Report on the nitrogen concentration in mosses in the 2005/2006 survey [N].

2009:

- Annual report on experimental programme on responses of vegetation to ozone [O];
- Report on the risk of damage to (semi-)natural vegetation communities in Europe [O];
- Report on flux-based assessment of risk of damage to managed pastures in Europe [O];
- A glossy brochure and associated web page for the general public and other interested parties on field-based evidence for the impacts of ozone on vegetation [O]*
- Interim report on modelling for combined effects of ozone and nitrogen on (semi-)natural vegetation [O, N];
- Report on the temporal trends in heavy metal concentrations in mosses between 1990 and 2005 [HM].

2010:

- To be decided after the LRTAP Convention workshop‘Saltsjobaden III’ (Air pollution and its relations to climate change and sustainable development – linking immediate needs with long-term challenges, 12 - 14 March 2007, Gothenburg, Sweden).

* Item not included in the official Convention’s workplan.

Acronyms: (EMEP/MSC-W): EMEP Meteorological Synthesizing Centre - West, [N]: Nutrient nitrogen, [O]: Ozone, [HM]: Heavy metals.

Annex 2. Participation in the ICP Vegetation

Those participants named in bold are members of the Steering Committee of the ICP Vegetation. In many countries, several other scientists (too numerous to include here) also contribute to the work programme of the ICP Vegetation.

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