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Impacts of ozone on biodiversity: mapping habitats at risk

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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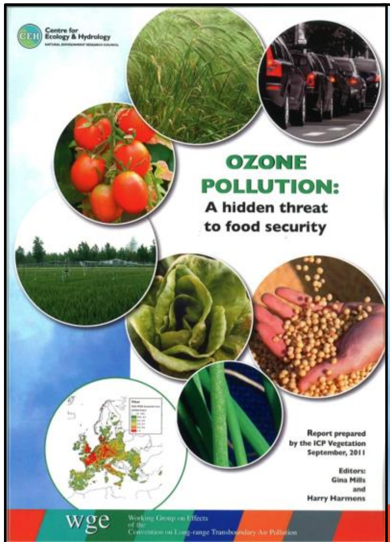
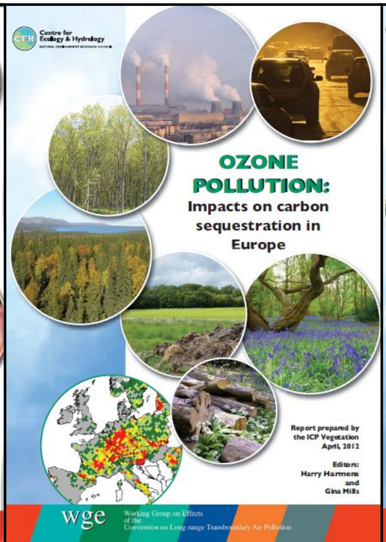
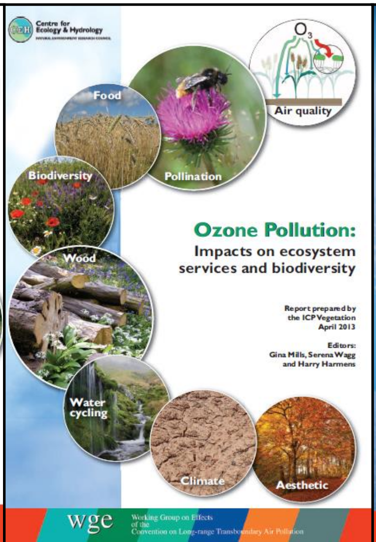
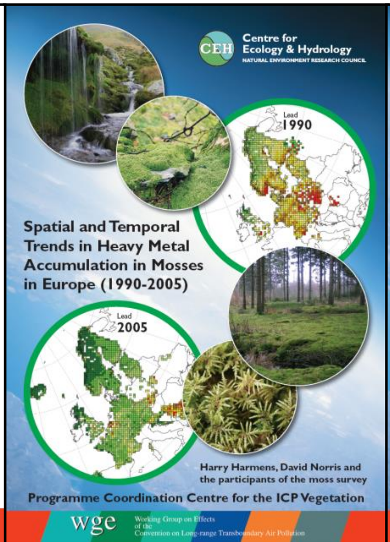
ICP Vegetation (http://icpvegetation.ceh.ac.uk)

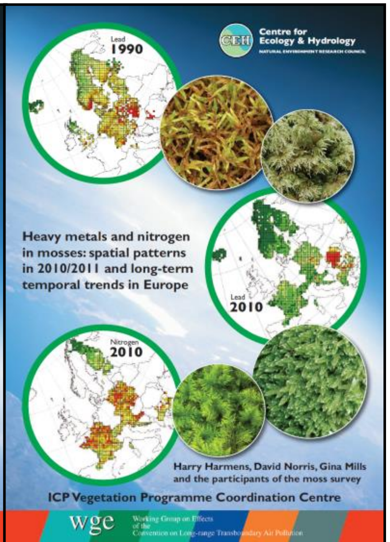
- International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops
- Reports to the Working Group on Effects, together with EMEP forming the two scientific bodies of the Convention on Long-range Transboundary Air Pollution
- Policy body: Working Group on Strategies and Review (e.g. TF on Reactive N)
- Ozone: - Field-based evidence of impacts
  - Setting ozone critical levels for vegetation
  - Impact on biodiversity, interactions with N and climate change
- Biomonitoring pollutant deposition using mosses (every 5 years):
  - Heavy metals (since 1990), N (since 2005), POPs (pilot study in 2010)











ICP Vegetation participation

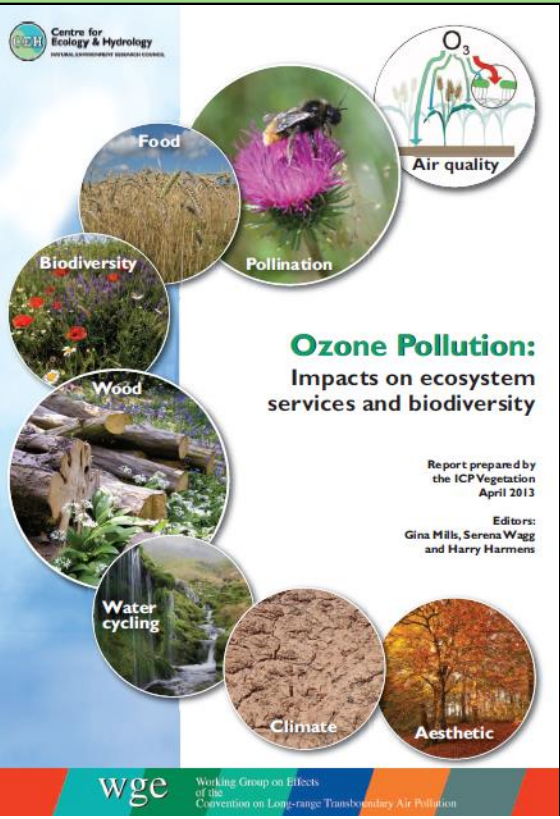
Outside UNECE:

- China
- Cuba
- Egypt
- Guatemala
- India
- Japan
- Mongolia
- Pakistan
- South Africa
- South Korea
- Thailand
- Vietnam

Ca. 90 experts from 33 countries

at 29th ICP Vegetation TFM, Dubna, Russia

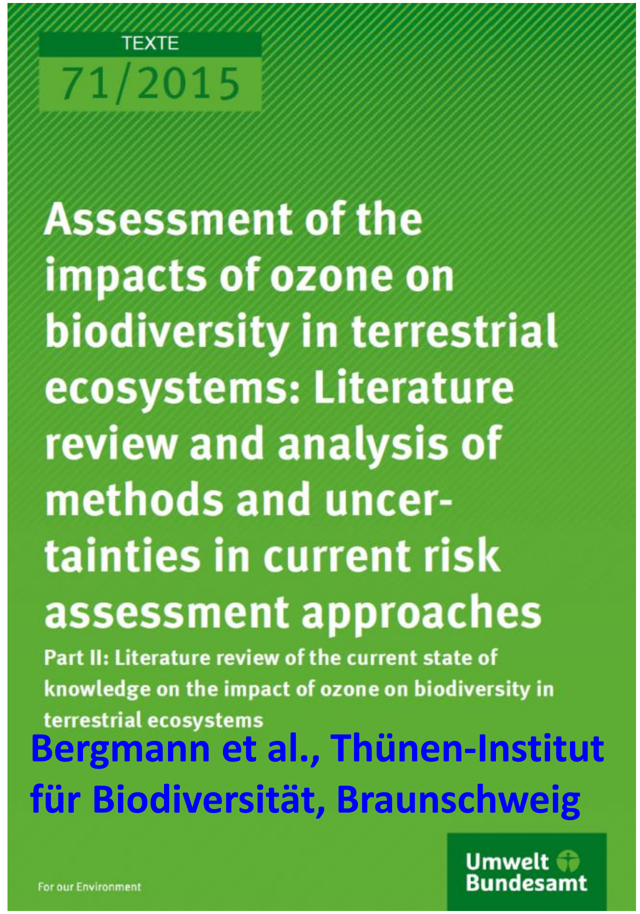
Ozone impacts on biodiversity: recent reviews



Chapter 4: Impact of ozone on biodiversity, including case studies
http://icpvegetation.ceh.ac.uk

2013

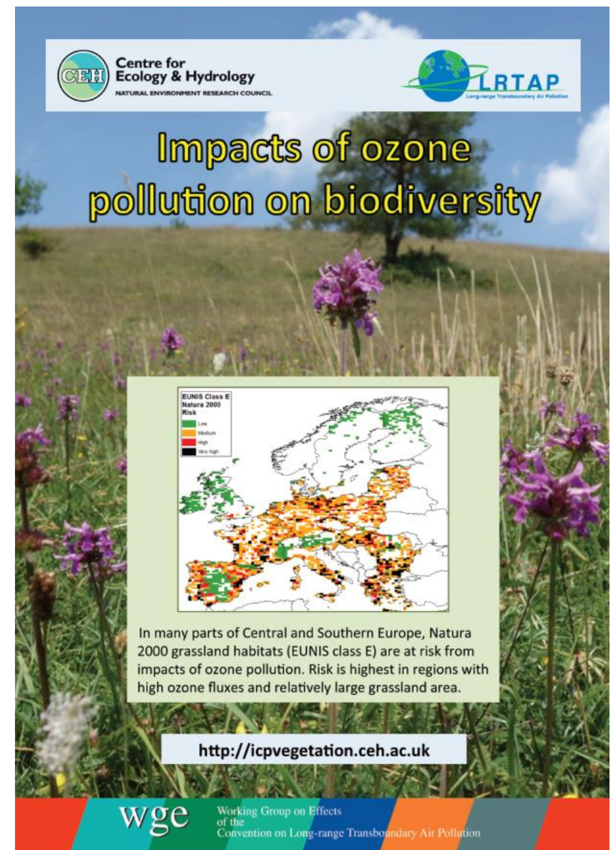
2015



Bergmann et al., Thünen-Institut für Biodiversität, Braunschweig

http://www.umweltbundesamt.de/en/publikationen/

2016



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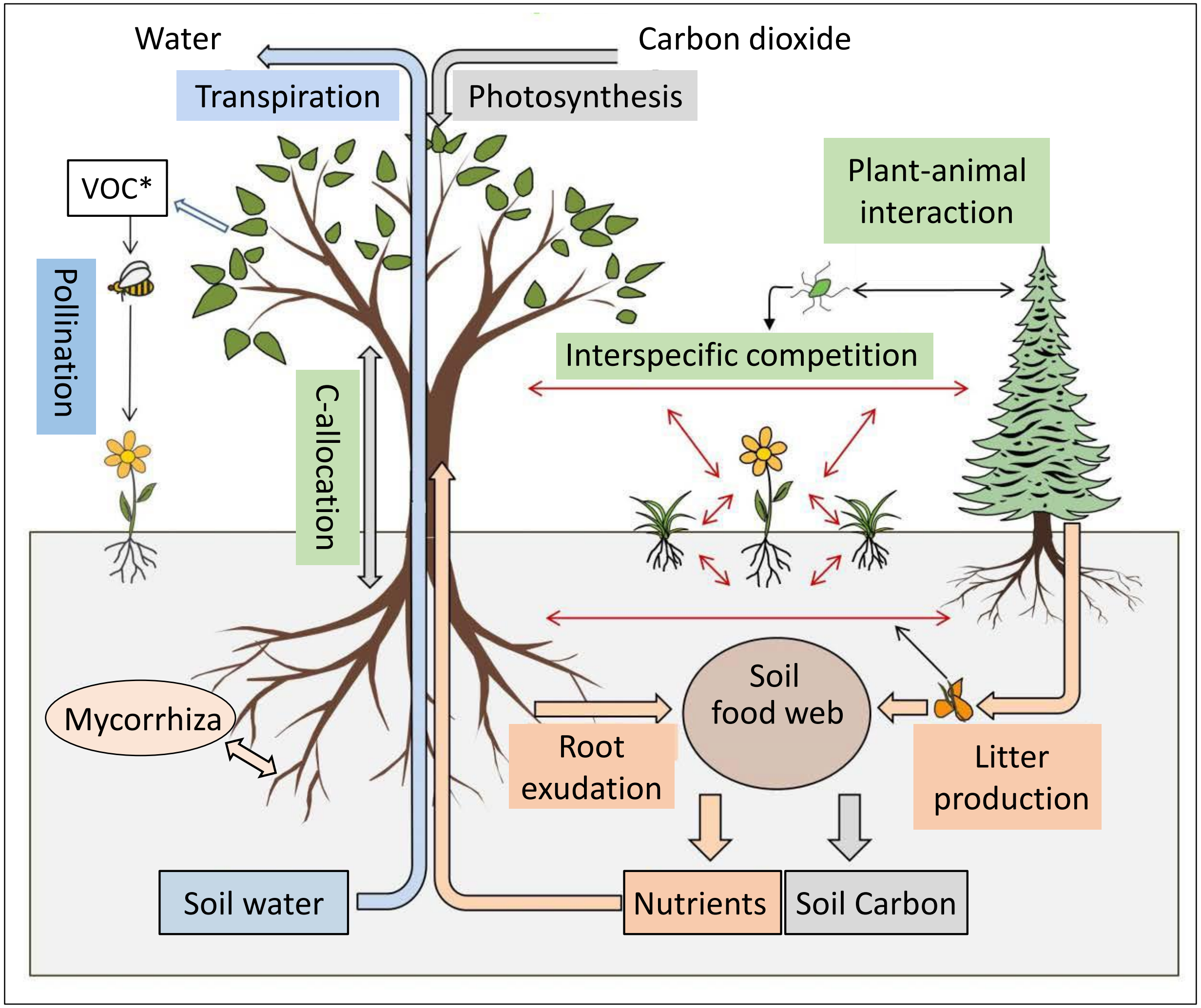
Ozone impacts on ecosystem processes



Modified from Bergmann et al., 2015.
http://www.umweltbundesamt.de

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Ozone impacts on growth individual species

Number of species with ozone effects on growth			
Plant group	Reduction	Stimulation	No effect
Forbs	85 (68)*	13 (11)	79
Grasses	27 (20)	6 (3)	42
(Bi)annuals	31 (23)	3 (2)	21
Perennials	75 (60)	16 (12)	103
Trees	70 (55)	2 (0)	37
Deciduous	40 (32)	2 (0)	19
Evergreen	34 (28)	0	23
Conifers	19 (16)	0	17
Broadleaved	56 (45)	2 (0)	25

* Values within brackets indicate a response of more than 15%.

Bergmann et al. (2015):

- Forbs and deciduous trees tend to be more responsive to ozone than grasses and coniferous trees.
- Although several ozone-sensitive plant families were identified, in general no significant relationship between plant traits and ozone-sensitivity was found. However, in some individual studies included in the review, such relationships have been reported (Hayes et al., 2007. Env. Poll. 146: 754-762; Jones et al., 2007. Env. Poll. 146: 744-753).

Ozone responsiveness of individual species

- Typical ozone effects: visible injury, premature and enhance senescence, changes in biomass (negative, but also positive), resource allocation and/or seed production

- Prediction response of ecosystems primarily based on known responses of individual species, either grown alone or in competition with other species in experimental studies (open top chambers, solardomes, field exposure systems)

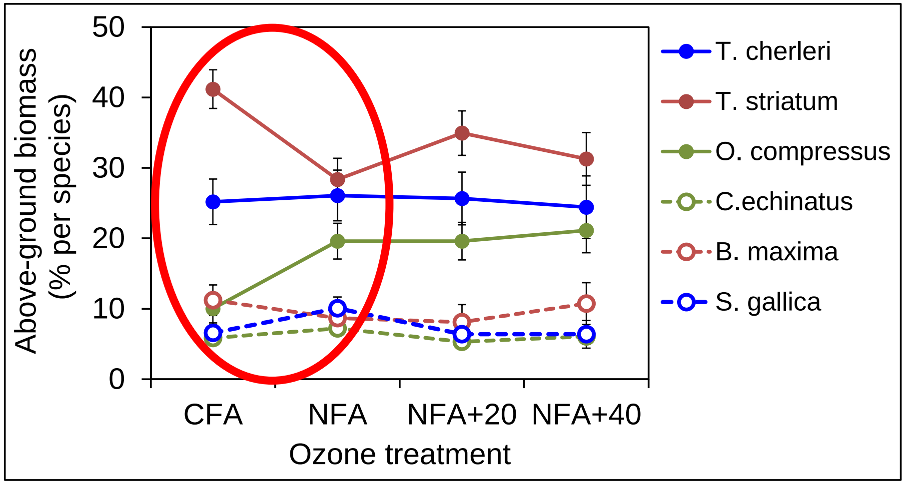
- Based on ICP Vegetation database (Hayes et al., 2007; Jones et al., 2007):
  - Thereophytic life form & Fabaceae family quite sensitive
  - No correlation with leaf longevity, flowering season, stomatal density, maximum altitude or Grime's CSR strategy
  - Relative ozone sensitivity can be predicted using Ellenberg values for light, moisture and salinity, but not for nutrient, 'reaction' (pH) or temperature

- Bassin et al. (2007. Env. Poll. 146: 678-691): three plant traits are main determinants for ozone sensitivity, i.e.

  high stomatal conductance, high specific leaf area and low defence capacity.

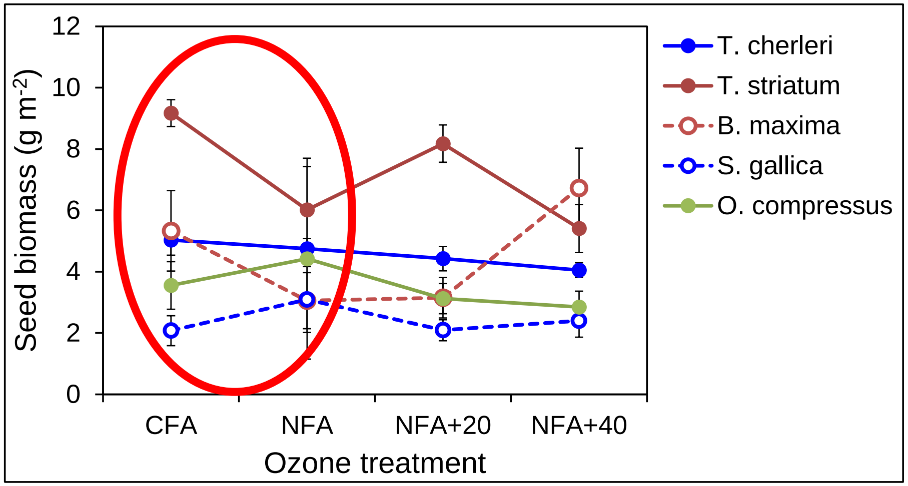
  Fast growing species more ozone sensitive (low response Alpine meadows?)

Ozone impacts on Dehesa pasture species



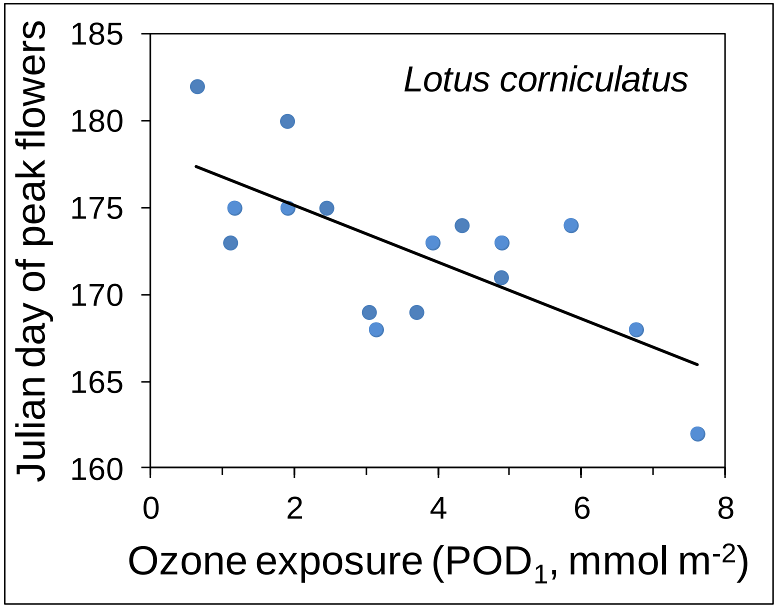
- Ozone induced changes in species composition of a mesocosm formed by six annual Dehesa pasture in open-top chambers: decline ozone-sensitive legume ***Trifolium striatum***, increase tolerant legume ***Ornithopus compressus*** (Calvete-Sogo et al., 2016, Oecologia).

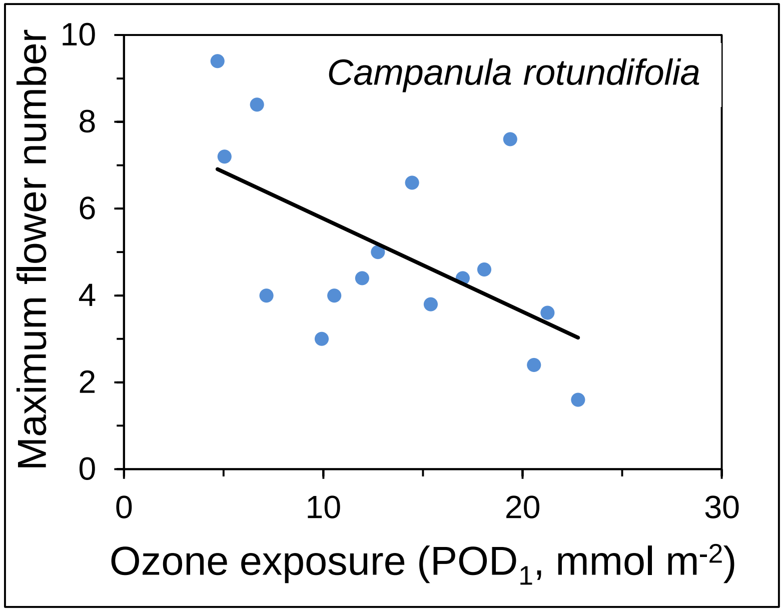
Dehesas are high biodiversity Mediterranean ecosystems protected under the EU Habitats Directive



- Ozone induced effects on seed production per species from a mesocosm study formed by six annual Dehesa pasture species in open-top chambers (Calvete-Sogo et al., in prep.).

Ozone impacts on flowering





- ❑ Ozone accelerates flowering of *Lotus corniculatus*, with potential implications for pollination and reproduction
- ❑ Ozone reduces maximum flower number in *Campanula rotundifolia*, with potential implications for reproduction

Hayes et al., 2012. Environmental Pollution 16: 40-47

EUNIS habitats at risk of ozone damage (1)

- Field-based evidence of ozone impacts on biodiversity is scarce. Mainly data for individual species exposed to ozone in experimental conditions.
- Following approach Mills et al. (2007. Env. Poll. 146: 736-743), EUNIS habitats most sensitive to ozone were identified, with some modifications.
- Ozone dose-response relationships for above-ground biomass were based on reported 24 hr mean ozone concentrations rather than AOT40.
- Species with negative or positive slope were considered ozone responsive if slope was lower or higher than median value of negative and positive slopes respectively. If not, species were considered non-responsive to ozone.
- Using the UK National Vegetation Classification (NVC; http://jncc.defra.gov.uk/page-1425), communities for which at least 20% of the species were tested for ozone sensitivity, were converted into EUNIS (European Nature Information System) habitat 4 code (http://eunis.eea.europa.eu/habitats.jsp).
- For level 3, 2 and 1 codes, data were averaged for the relevant level 4 codes.
- **Drawback: Northern European bias in database and by using UK NVC communities**.

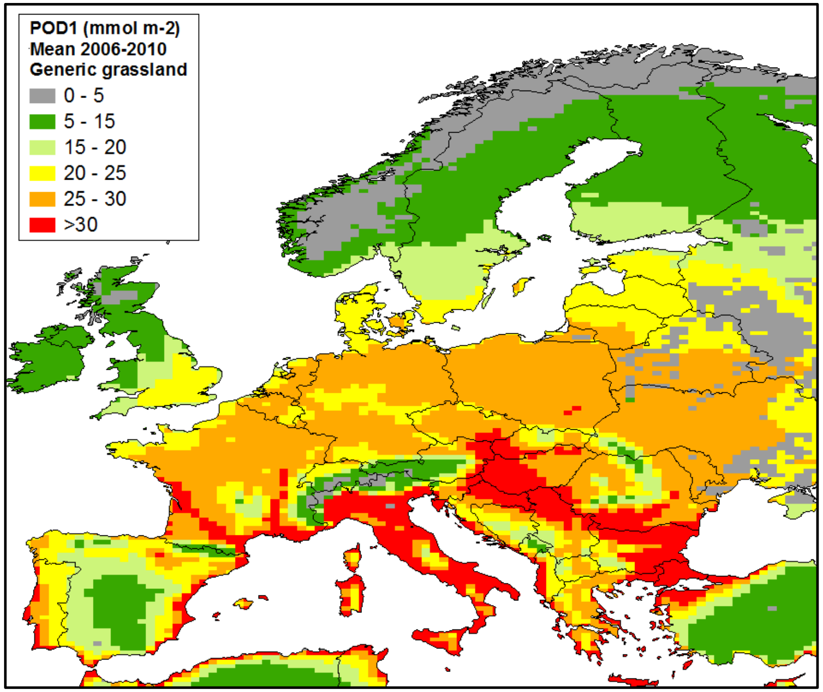
EUNIS habitats at risk of ozone damage (2)

EUNIS habitat	Abbreviated name	Mean no. of spp. in habitat	Mean % of species tested for O_3 sensitivity	No. of O_3-responsive species*	% of tested species affected by O_3*	No. of NVC communi-ties included
B1	Coastal dunes, sandy shores	49.0	25.5	5.0	42.8	8
B3	Rock cliffs and shores	47.3	25.7	5.0	40.1	6
D2	Valley and transition mires	25.0	20.0	3.0	60.0	1
D5	Sedge and reed beds	40.0	22.5	3.0	33.3	1
E1	Dry grasslands	86.9	26.5	10.1	41.9	9
E2	Mesic grasslands	71.7	35.9	10.3	41.4	6
E3	Seasonally wet grasslands	63.0	25.1	6.6	43.4	7
E4	(Sub)alpine grasslands	70.0	21.4	7.0	46.7	1
E5	Woodland fringes	58.9	22.8	6.8	51.1	9
F3	Montane scrub	61.5	23.9	6.0	38.7	2
F4	Temperate shrub heathland	65.0	22.1	4.0	27.2	2
I1	Arable and market gardens	57.3	23.8	7.5	56.4	6
I2	Cultivated gardens, parks	31.0	29.0	5.0	55.6	1

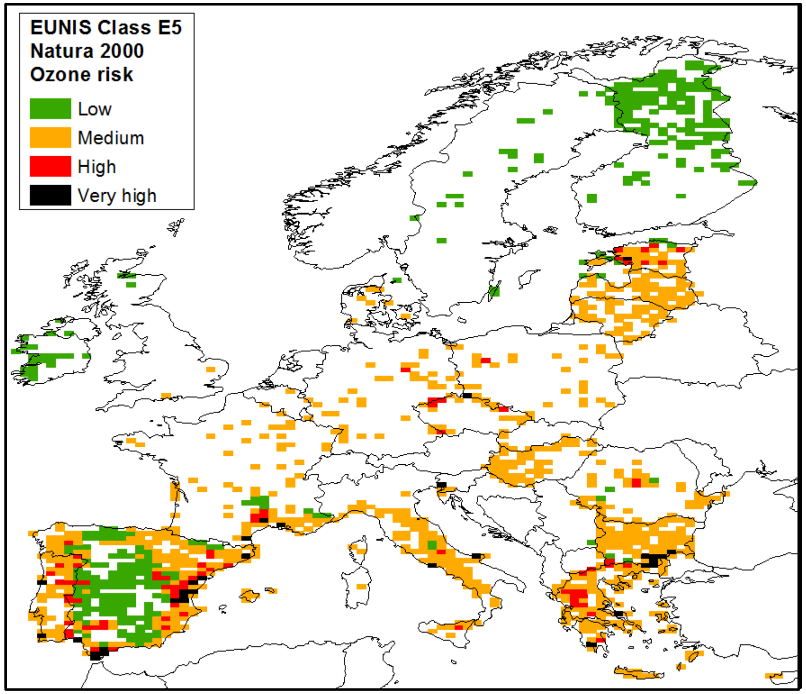
** Species for which above-ground biomass was either reduced or stimulated.*

Natura 2000 grassland habitats at risk (1)

Grassland area in grid cell (%)	POD_1 grass ($mmol\ m^{-2}$)*	<5	5 - 15	15 - 20	20 - 25	25 - 30	>30
	RISK	**1**	**2**	**3**	**4**	**5**	**6**
0.5 – 5	**1**	**1**	**2**	**3**	**4**	**5**	**6**
5 - 10	**2**	**2**	**4**	**6**	**8**	**10**	**12**
>10	**3**	**3**	**6**	**9**	**12**	**15**	**18**



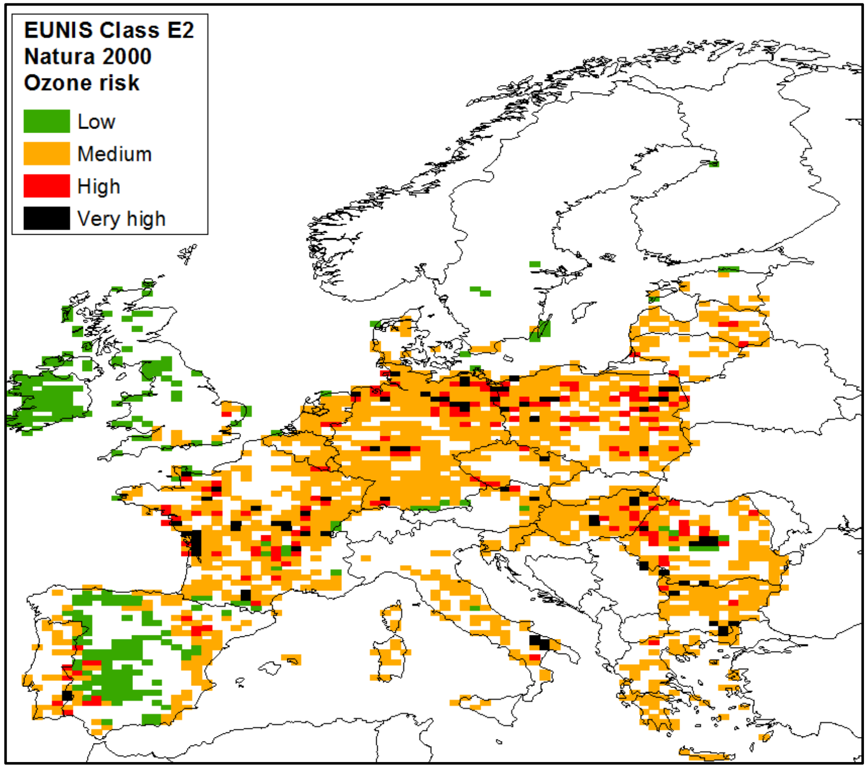
Ozone flux grassland (POD_1)
EMEP: Simpson et al., 2012



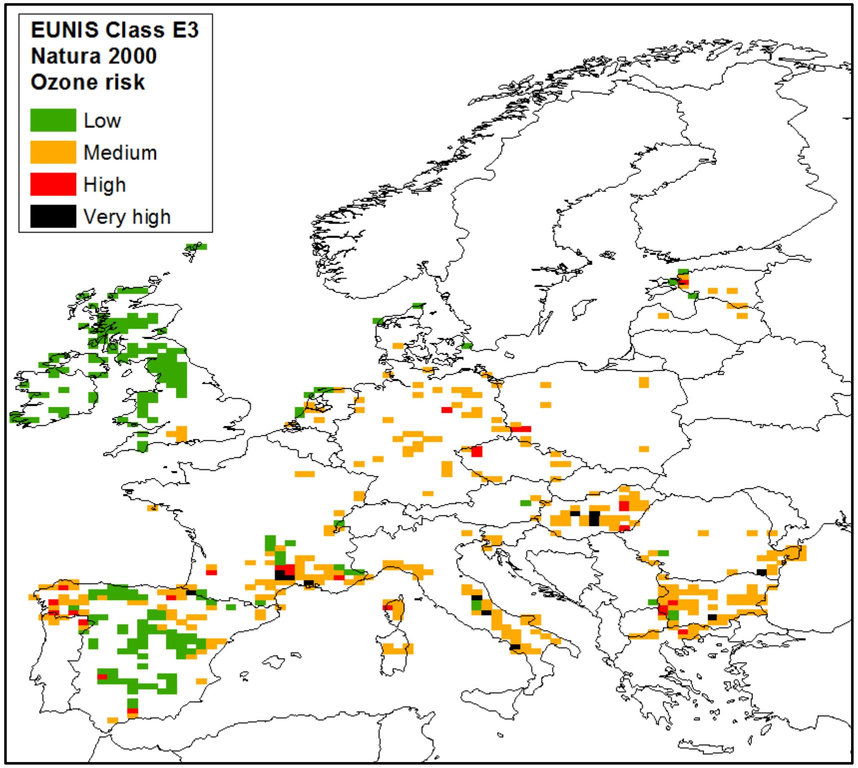
EUNIS class E5 – woodland fringes (CCE)
Natura 2000 area per grid (%)
at risk

Natura 2000 grassland habitats at risk (2)

Mesic grassland (E2)

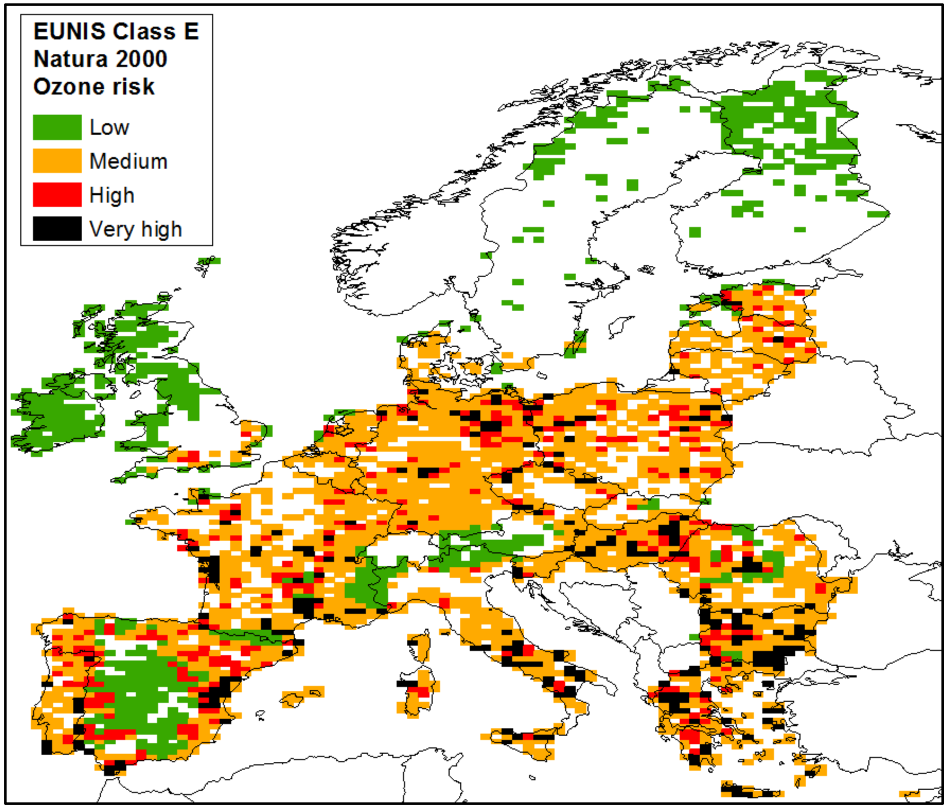


Wet grassland (E3)



Natura 2000 grassland at risk

Grassland (E)



- In many parts of central and southern Europe, Natura 2000 grassland habitats are at risk from impacts of ozone pollution. Risk is highest in regions with high ozone fluxes (Phytotoxic Ozone Dose) and relatively large grassland area.
- Payne et al. (2011. Env. Poll. 159: 2602-2608): ozone third strongest driver plant community composition change in calcifuge grasslands in UK, behind inorganic N deposition and annual evapotranspiration. However, ozone exposure not associated with reduction in species richness or diversity.

Summary

- In many parts of central and southern Europe, Natura 2000 grassland habitats are at risk from impacts of ozone pollution. Risk is highest in regions with high ozone fluxes (Phytotoxic Ozone Dose) and relatively large grassland area.

- There is evidence that current ambient ozone levels are sufficiently high enough to change plant community composition, flowering and seed production at the species level. Changes in plant community composition can potentially lead to changes in soil microbial communities and pools of carbon, nutrient and water (Mills et al., 2013). Such changes are slow, hence there is a requirement for long-term monitoring of terrestrial ecosystem responses to ozone.

- There is a lack of field-based evidence for the impacts of ozone on plant species diversity, especially in biodiversity hotspots such as the Mediterranean Basin. Results from European grassland field exposure experiments have been rather mixed regarding the impacts of ozone on plant growth and species composition (Mills et al., 2013). Whilst there is evidence that ozone might affect plant species composition, consequences for biodiversity require further study.

http://icpvegetation.ceh.ac.uk

- ❑ 30th ICP Vegetation Task Force meeting, 14 – 17 February 2017, Poznan, Poland

Thank you!

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