Ozone impacts on biodiversity

Felicity Hayes and colleagues
UK Centre for Ecology & Hydrology

fhay@ceh.ac.uk

UK Centre for
Ecology & Hydrology

Overview

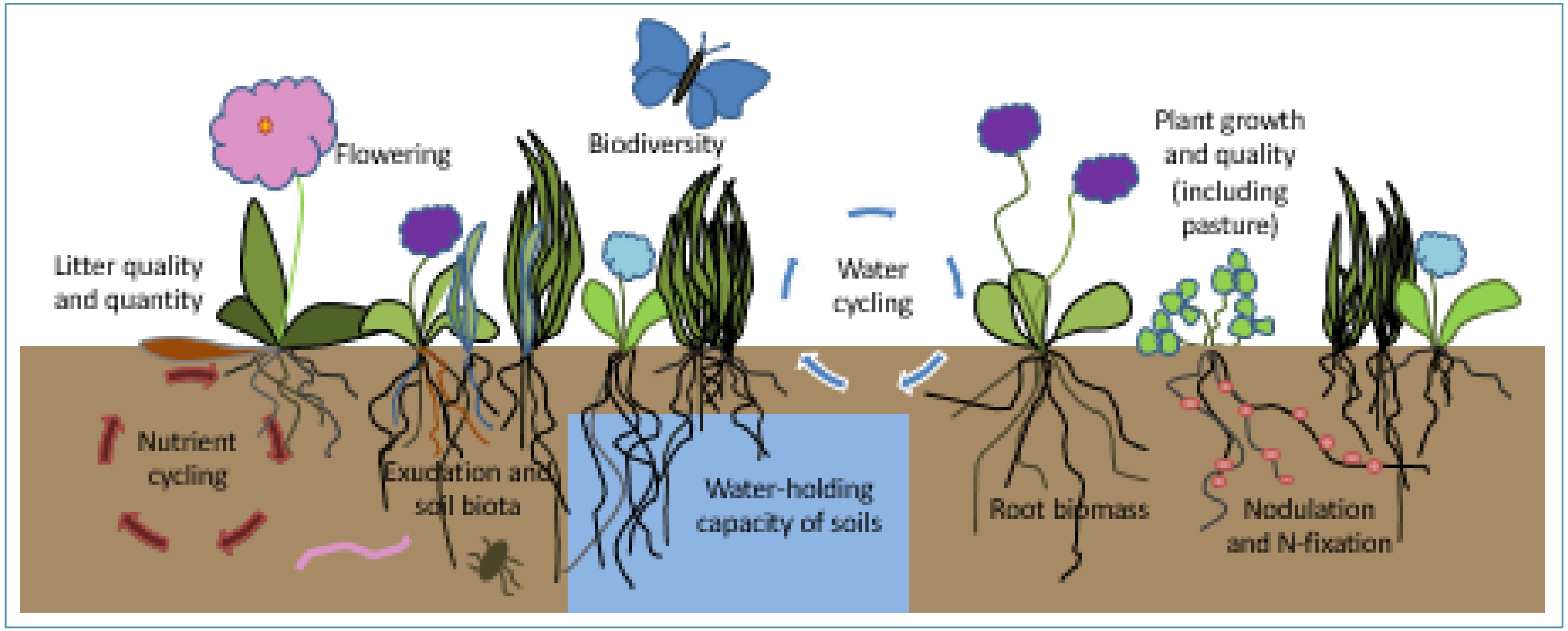
Impacts on plants

- Direct impacts
- Indirect impacts

Impacts on insects

- Direct impacts
- Indirect impacts

Impacts on other species



Ozone impacts on growth of 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%.

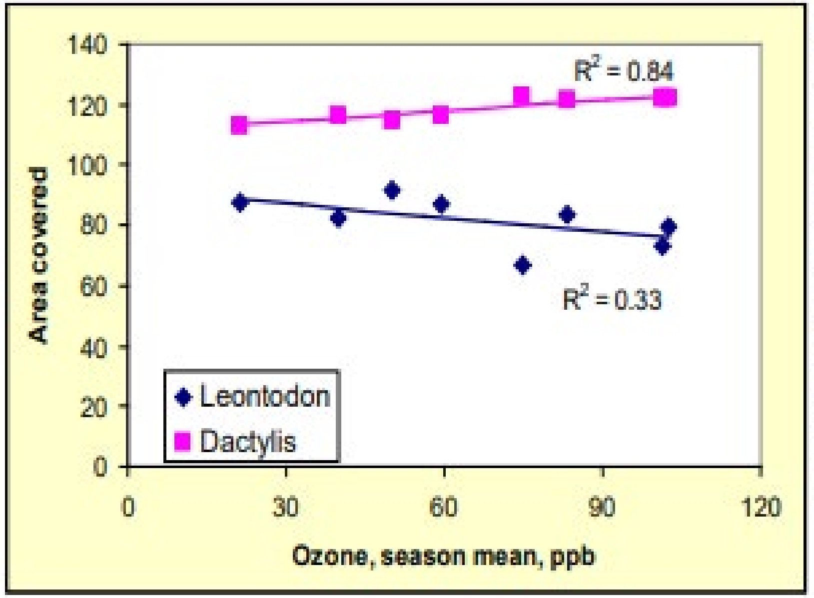
Bergmann et al. (2015):

- 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; Jones et al., 2007)

Reduced plant growth and increased senescence

Although *Dactylis glomerata* showed some response to ozone for shoots, there had been a large reduction in below-ground allocation

Reduced plant growth = altered species composition



Some species are more sensitive than others.

Changes in species composition can occur over time

(in this example, more grass and fewer forbs with flowers)

Risk of ozone impacts to biodiversity (based on responses of individual species)

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 O_3-responsive species*
D2	Valley and transition mires	25.0	20.0	3.0	60.0
I1	Arable and market gardens	57.3	23.8	7.5	56.4
I2	Cultivated gardens, parks	31.0	29.0	5.0	55.6
E5	Woodland fringes	58.9	22.8	6.8	51.1
E4	(Sub)alpine grasslands	70.0	21.4	7.0	46.7
E3	Seasonally wet grasslands	63.0	25.1	6.6	43.4
B1	Coastal dunes, sandy shores	49.0	25.5	5.0	42.8
E1	Dry grasslands	86.9	26.5	10.1	41.9
E2	Mesic grasslands	71.7	35.9	10.3	41.4
B3	Rock cliffs and shores	47.3	25.7	5.0	40.1
F3	Montane scrub	61.5	23.9	6.0	38.7
D5	Sedge and reed beds	40.0	22.5	3.0	33.3
F4	Temperate shrub heathland	65.0	22.1	4.0	27.2

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

Using data for individual species exposed to ozone in experimental conditions.

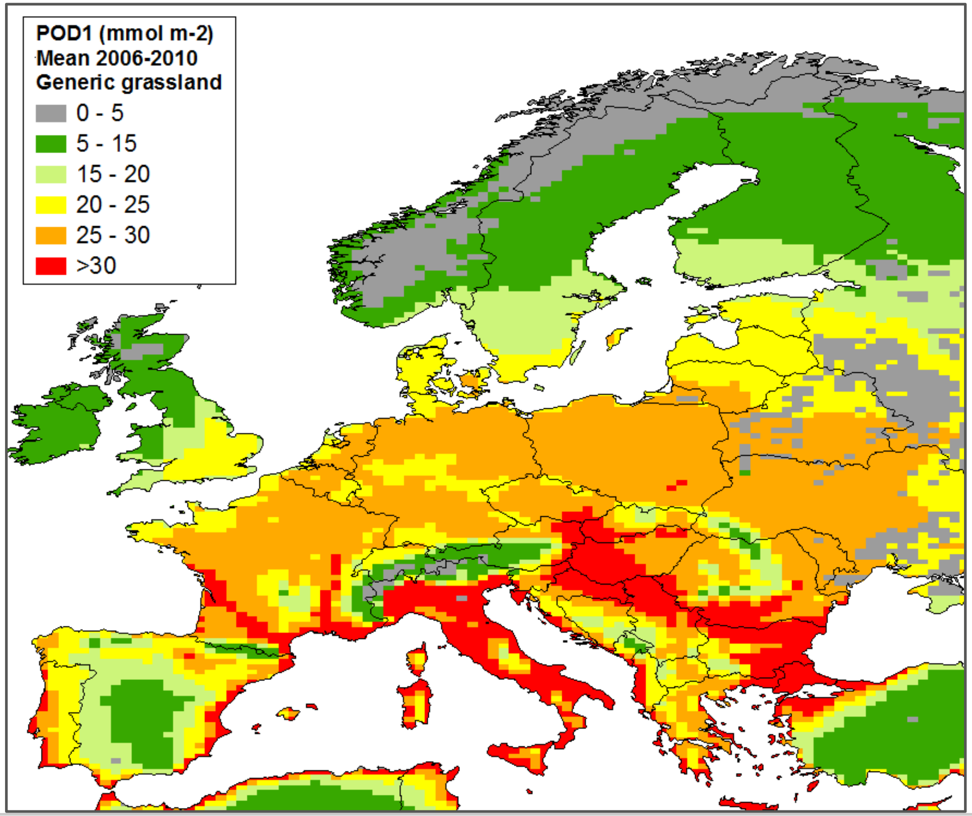
Following approach Mills et al., 2007, EUNIS habitats most sensitive to ozone were identified. However, now based on response individual species to 24hr mean ozone.

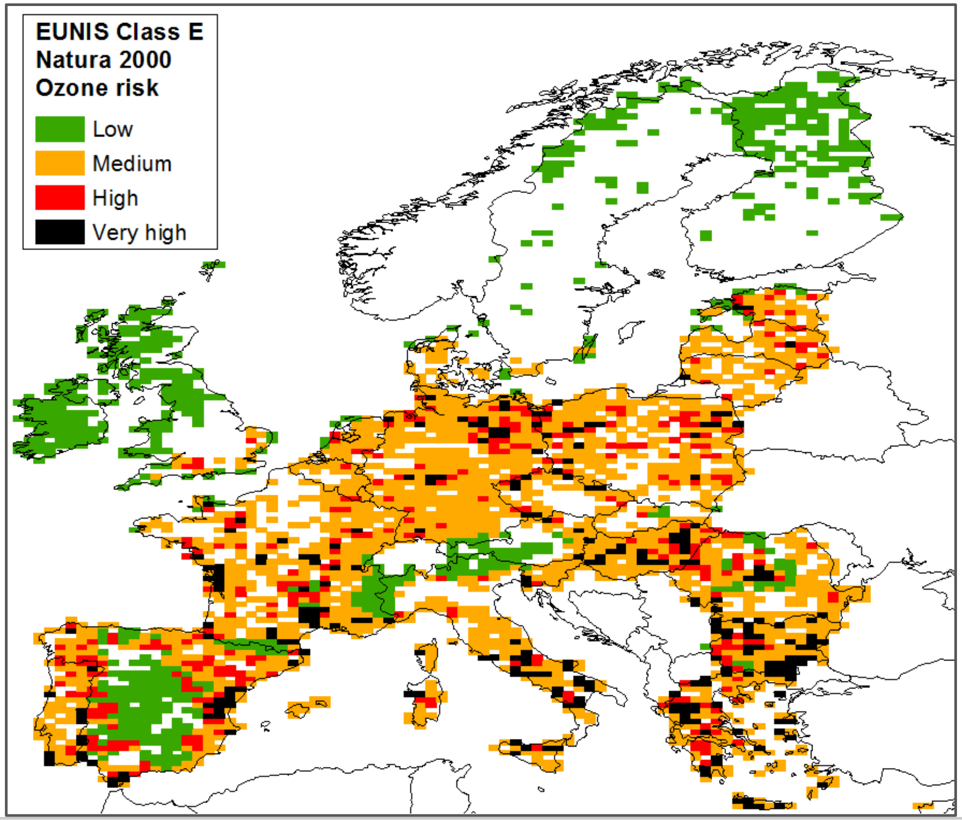
Drawback: Northern European bias

Risk of ozone impacts to biodiversity (based on abundance and exposure)

Grassland area in grid cell (%)	Mires, bogs, fen 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**	**1**	**2**	**3**	**4**	**5**	**6**
5 - 10	1-5	**2**	**2**	**4**	**6**	**8**	**10**	**12**
>10	>5	**3**	**3**	**6**	**9**	**12**	**15**	**18**

Natura 2000 grassland at highest risk from ozone, where phytotoxic ozone doses are medium to high and habitat area is high.





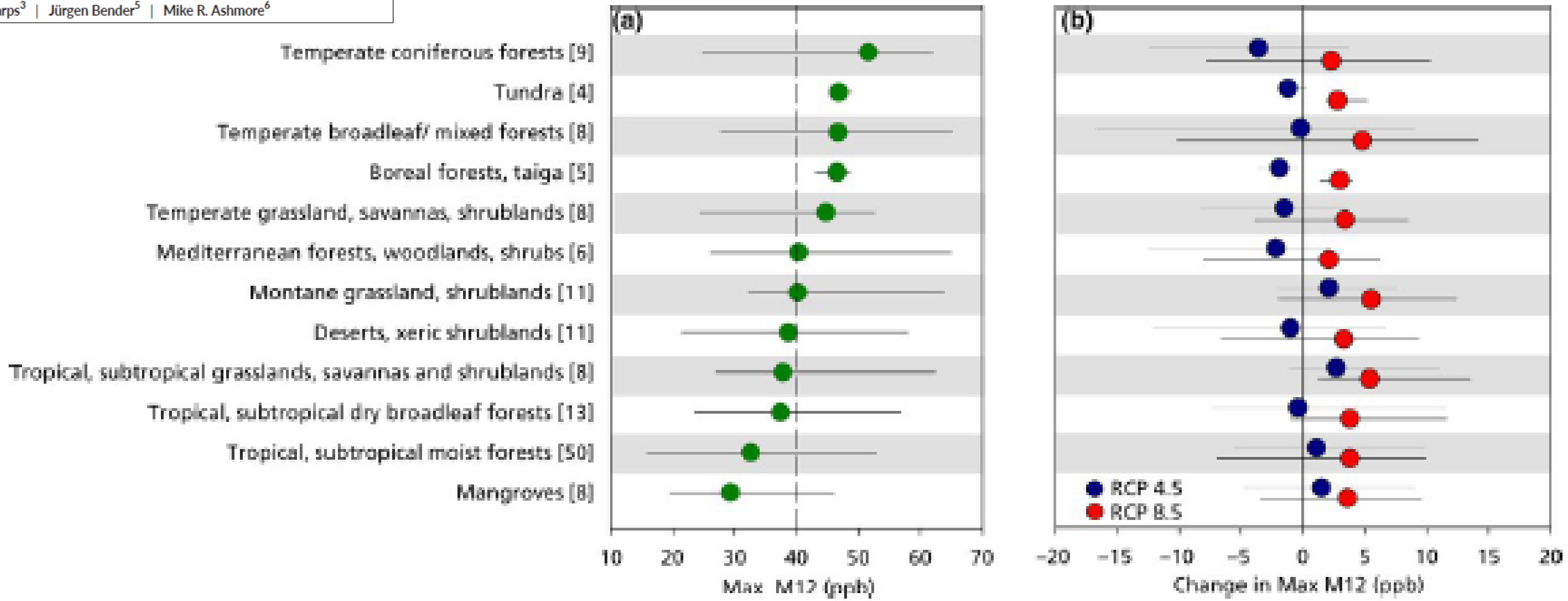
Global risk of ozone impacts to biodiversity (based on exposure)

REVIEW

WILEY Ecology and Evolution

Current and future ozone risks to global terrestrial biodiversity and ecosystem processes

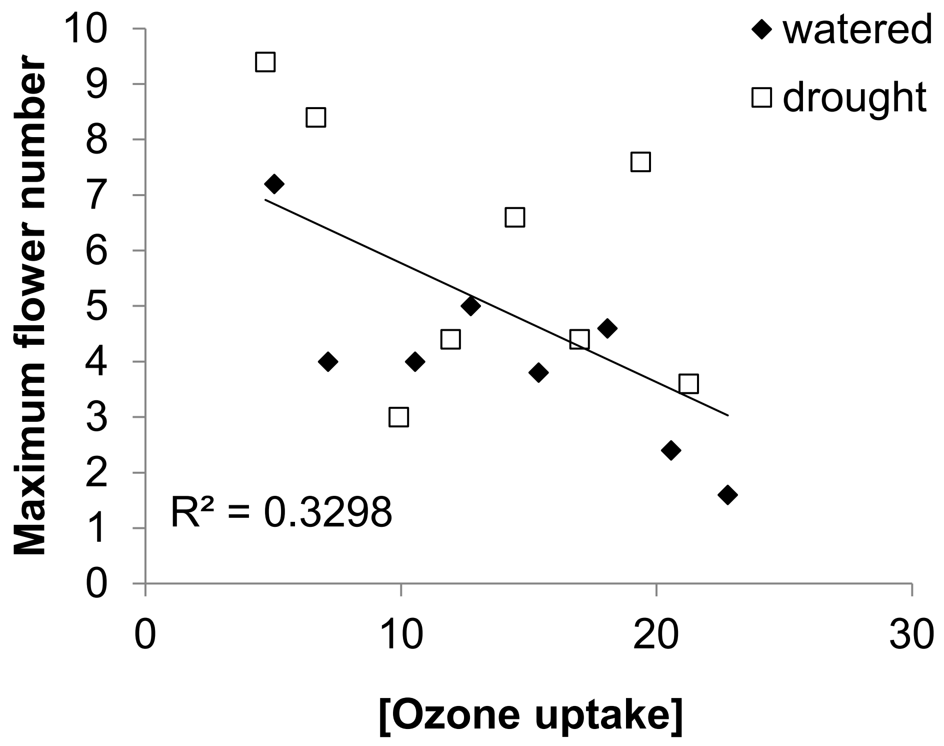
Jürg Fuhrer[1] | Maria Val Martin[2] | Gina Mills[3] | Colette L. Heald[4] | Harry Harmens[3] | Felicity Hayes[3] | Katrina Sharps[3] | Jürgen Bender[5] | Mike R. Ashmore[6]



Simulated O_3 exposure (Max M12) in 2000 grouped by biome (left) and changes in simulated ozone exposure (2000-2050) under RCP4.5 and RCP 8.5 (right)

UK Centre for Ecology & Hydrology

Reduced flower numbers



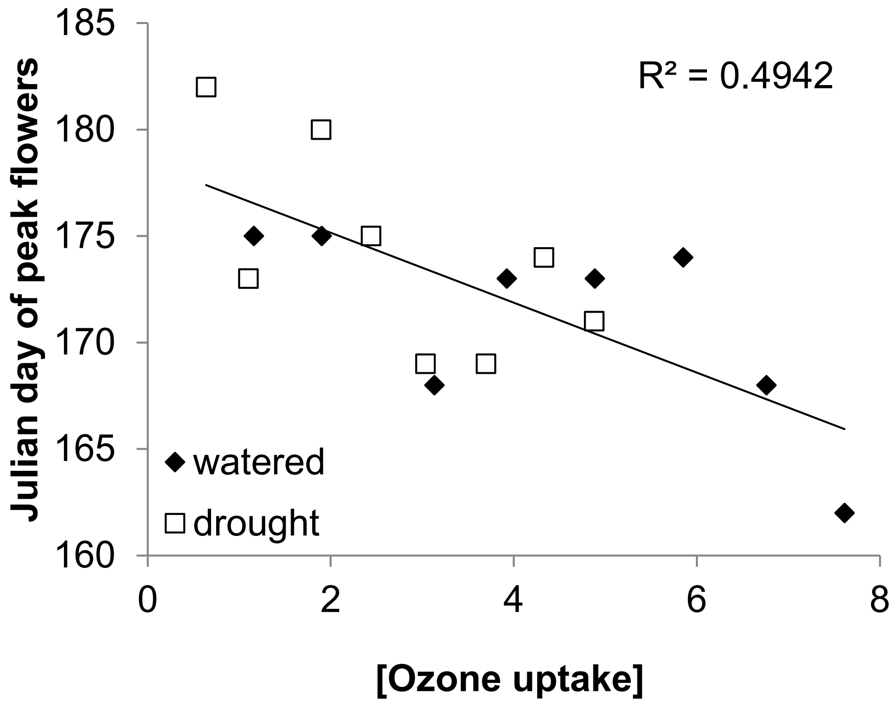
- Harebells in grassland communities
- The number of flowers was reduced with increased ozone
- Reduced watering did not protect plants from ozone

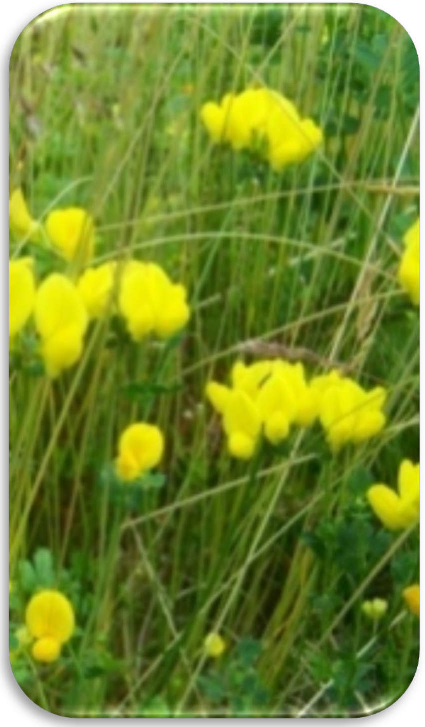
Hayes et al. 2012. Environmental Pollution 16:40-47

Changes in timing of flowering

4th July

9th June

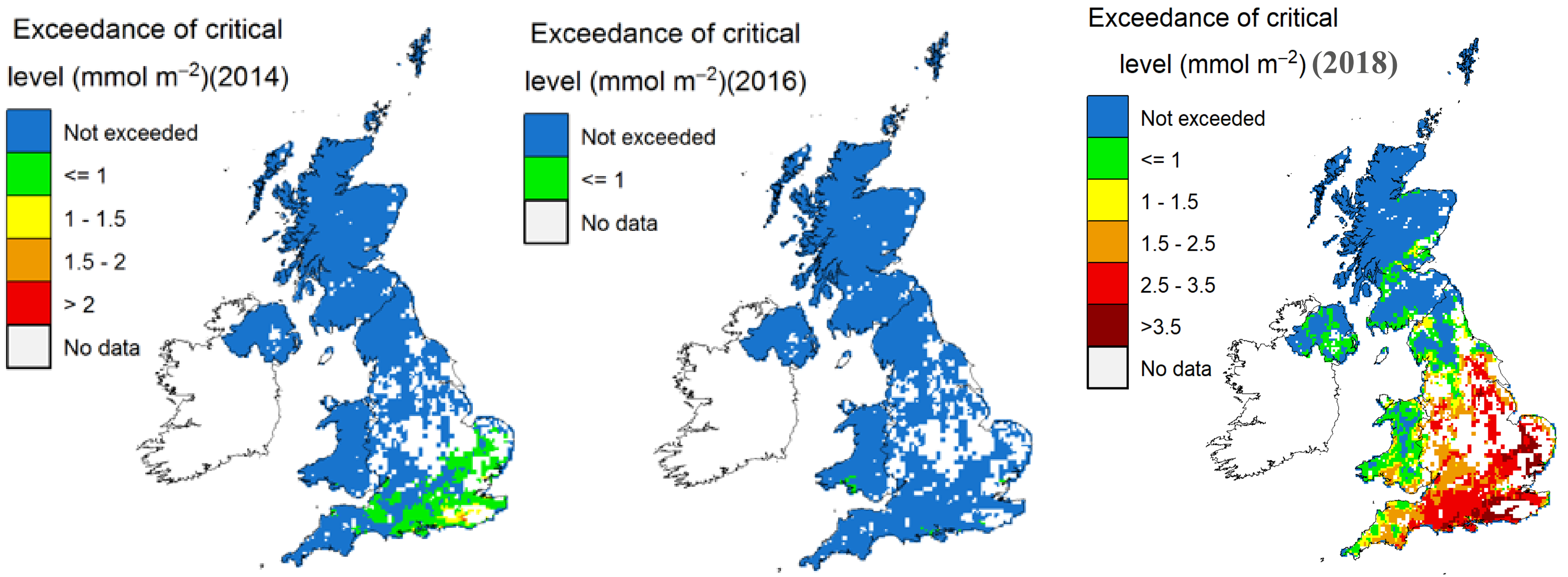




- *Lotus corniculatus* in grassland communities
- The date of maximum flowering was increasingly earlier with increased ozone
- Reduced watering did not protect plants from ozone
- Ecological consequences for bees/butterflies

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

Flower number - grasslands



- Critical level set at 10% loss of flower number

Country	2014		2016		2018	
	Area ex. (%)	Loss (%)	Area ex. (%)	Loss (%)	Area ex. (%)	Loss (%)
England	16.3	8.3	0.4	7.5	74.8	12.8
Wales	0	6.5	0.6	7.4	62.9	10.6
Scotland	0	3.2	0	4.0	4.5	6.9
NI	0	4.9	0	7.1	18.2	9.3
UK	**3.2**	**5.8**	**0.1**	**6.1**	**37.9**	**10**

Signalling using VOCs

The signal emitted by flowers is altered by ozone – altered bVOC quality and quantity. Examples from crops and native (grassland) species

The floral signal is degraded by ozone

More difficult to locate flowers, especially from a distance, which increases foraging times

Foraging time is significantly increased with ozone concentrations of 60 ppb (Fuentes et al., 2016)

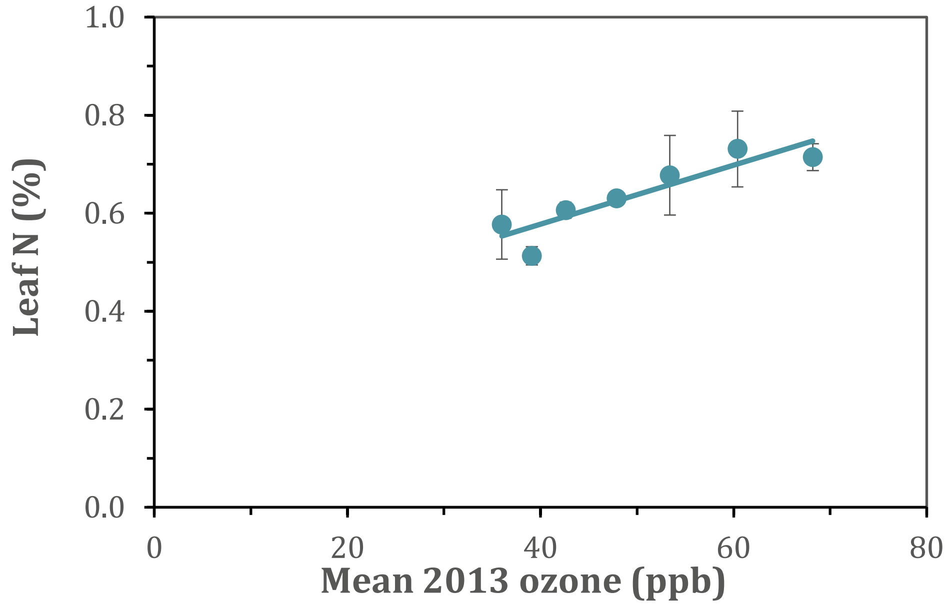
Direct effects on insects

Some evidence of direct toxicity at high ozone (100 ppb). At very, very high concentrations ozone can be used as an insecticide for grains.

Reduced insect abundance (17%) in Aspen-FACE elevated ozone plots compared to ambient. Generally, eO_3 had the strongest impact on parasitoids (negative) but also influenced some sucking herbivores (positive). (Hillstrom and Lindroth, 2008)

Changes to insect numbers could be mediated by changes in secondary compounds within plant (leaves), e.g. phenols, by changes in the numbers of host plants, or by changes in the habitat quality for predators

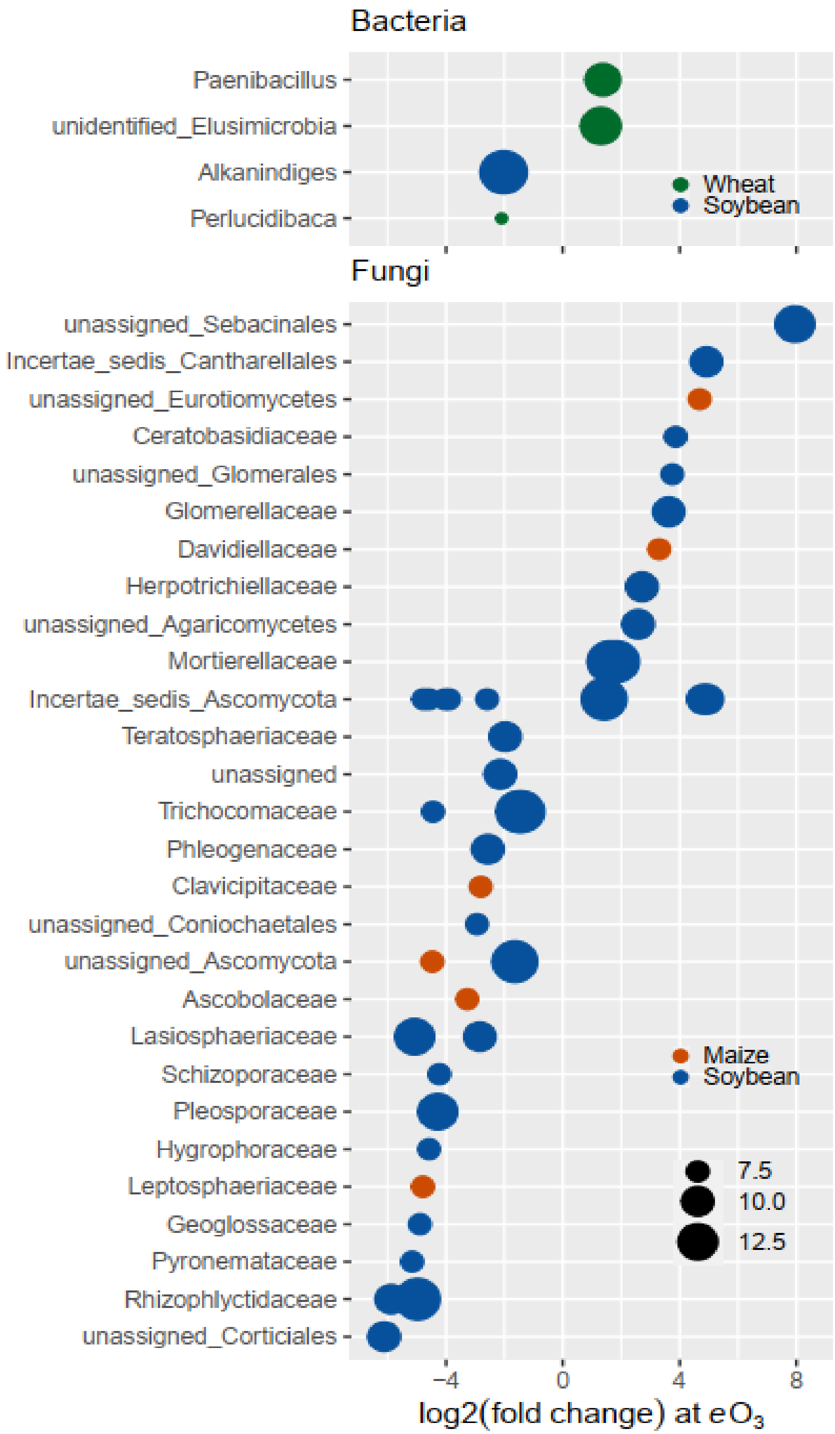
Ozone impacts on other ecosystem processes



In higher ozone, leaves are lost from trees before most N is re-absorbed.

Higher N content of leaf litter – potential effects on decomposers

Changes in N content and other factors can influence palatability for herbivores. Some (limited) evidence from choice-experiments



Soil bacteria and fungi

Some evidence of changes to fungal and bacterial diversity in the soil of plant communities exposed to ozone

The role / function of the bacteria/fungi in the ecosystem is not always known.

Sometimes many have similar function

Wang et al., 2022

Birds and mammals

Impacts on birds and mammals are predicted, with mechanisms similar to that for human health.

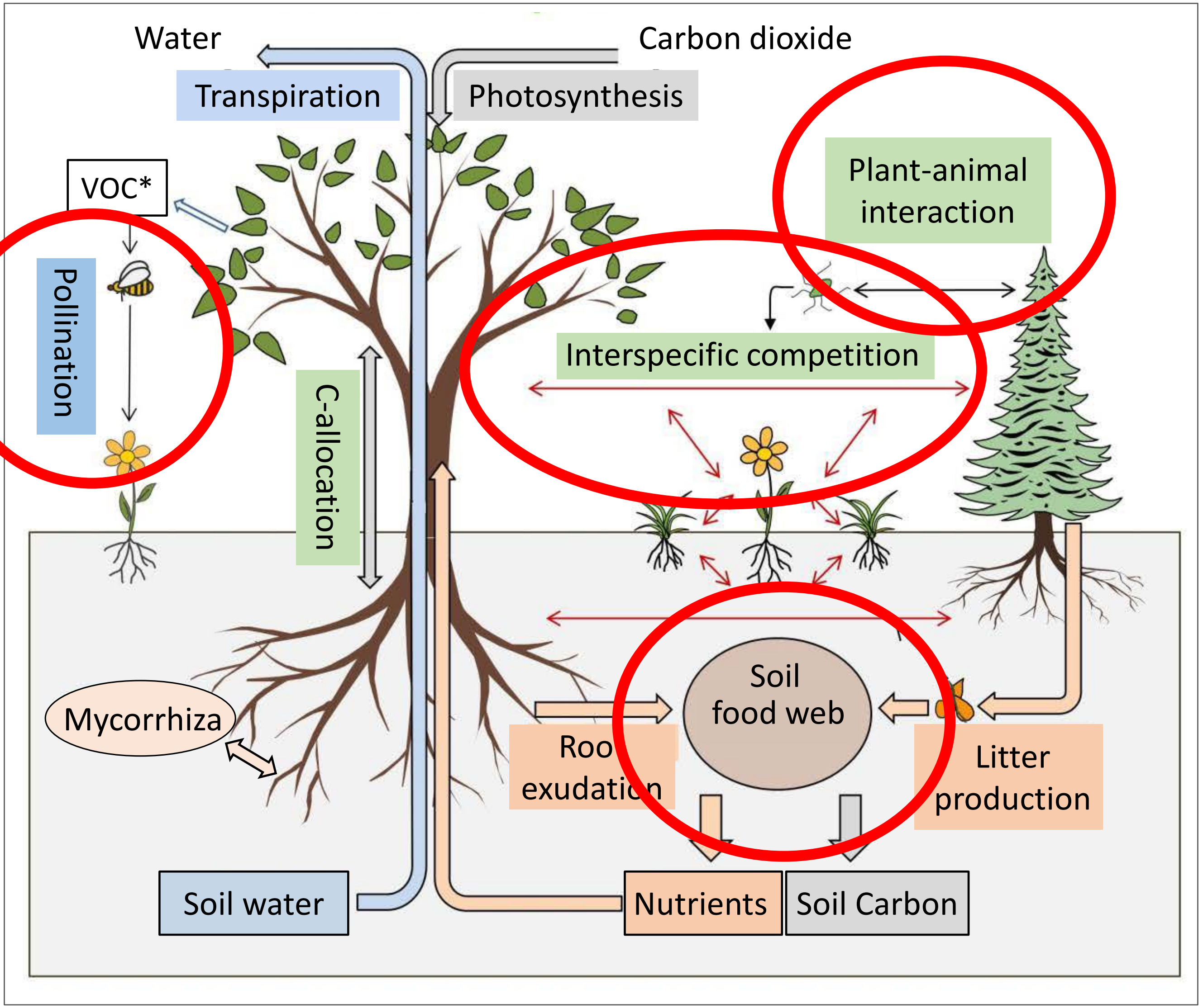
Bird and mammal populations are declining as a combined result of many stresses.

Evidence of impacts is largely from epidemiological studies – and often difficult to disentangle the different pollutants and other stresses.

Ozone has been identified as a contributing factor (Sanderfoot and Holloway, 2017)

Direct effects, but also indirect effects from changes to diet as species at lower trophic levels are impacted, and habitat degradation.

Ozone impacts on ecosystem processes



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

Summary

- There are many effects of ozone identified on plants, which can have direct relevance to biodiversity.
- ‘biodiversity’ is not always a good metric for impacts (change in species composition)
- Effects include ↓ growth including roots, ↓ nitrogen-fixation, altered decomposition/soil cycling, changes in flower number, timing, pollinator signalling.
- Effects are difficult and expensive to detect in natural systems
- <1% of plant species have been tested for ozone sensitivity
- There is increasing evidence of effects on insects that are mediated via effects on plants
- Evidence on species other than plants and (a few) insects is lacking







Thank you

Any questions?