Upland vegetation and ground-level ozone

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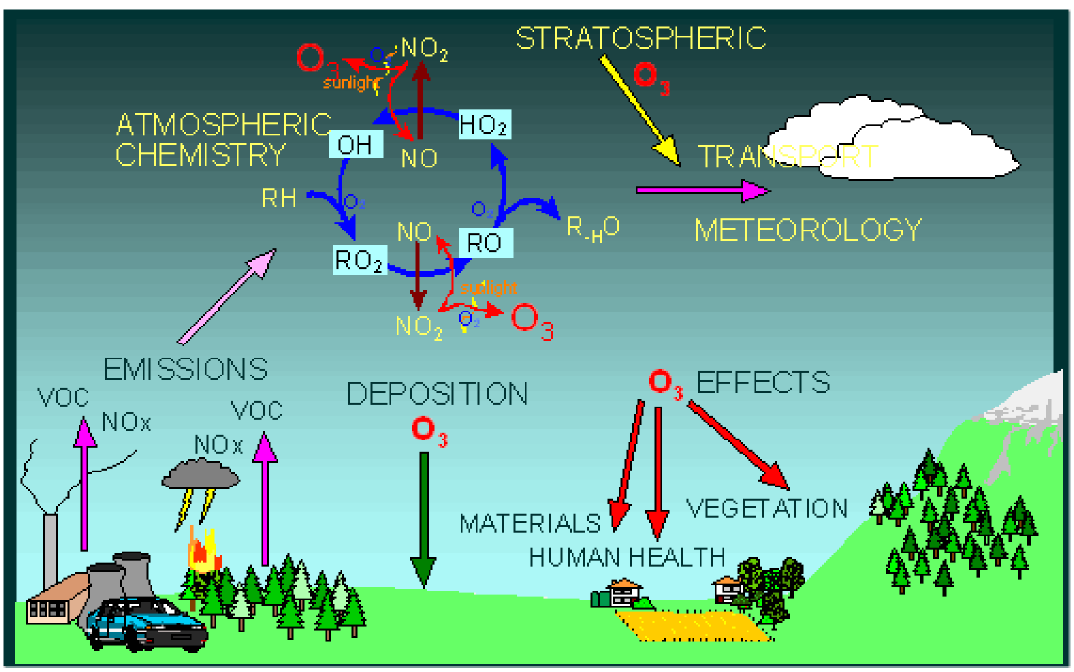
Introduction

Tropospheric ozone is a secondary pollutant as it is produced via photochemical reactions of nitrogen oxides (NOx), carbon monoxide and non-methane volatile organic compounds (VOCs) (Figure 1). Although it is a natural constituent of the troposphere, man-made emissions of NOx and VOCs have led to an increase in concentrations, mainly in the northern hemisphere (Oltmans *et al.* 2006; Vingarzan 2004). Average concentrations across much of N. America, Europe and Asia are now large enough to cause damage to many types of vegetation, including commercial crops (Krupa 2003) and in some regions peaks in concentration occur than can affect human health (Vautard *et al.* 2005; Syri *et al.* 2001).

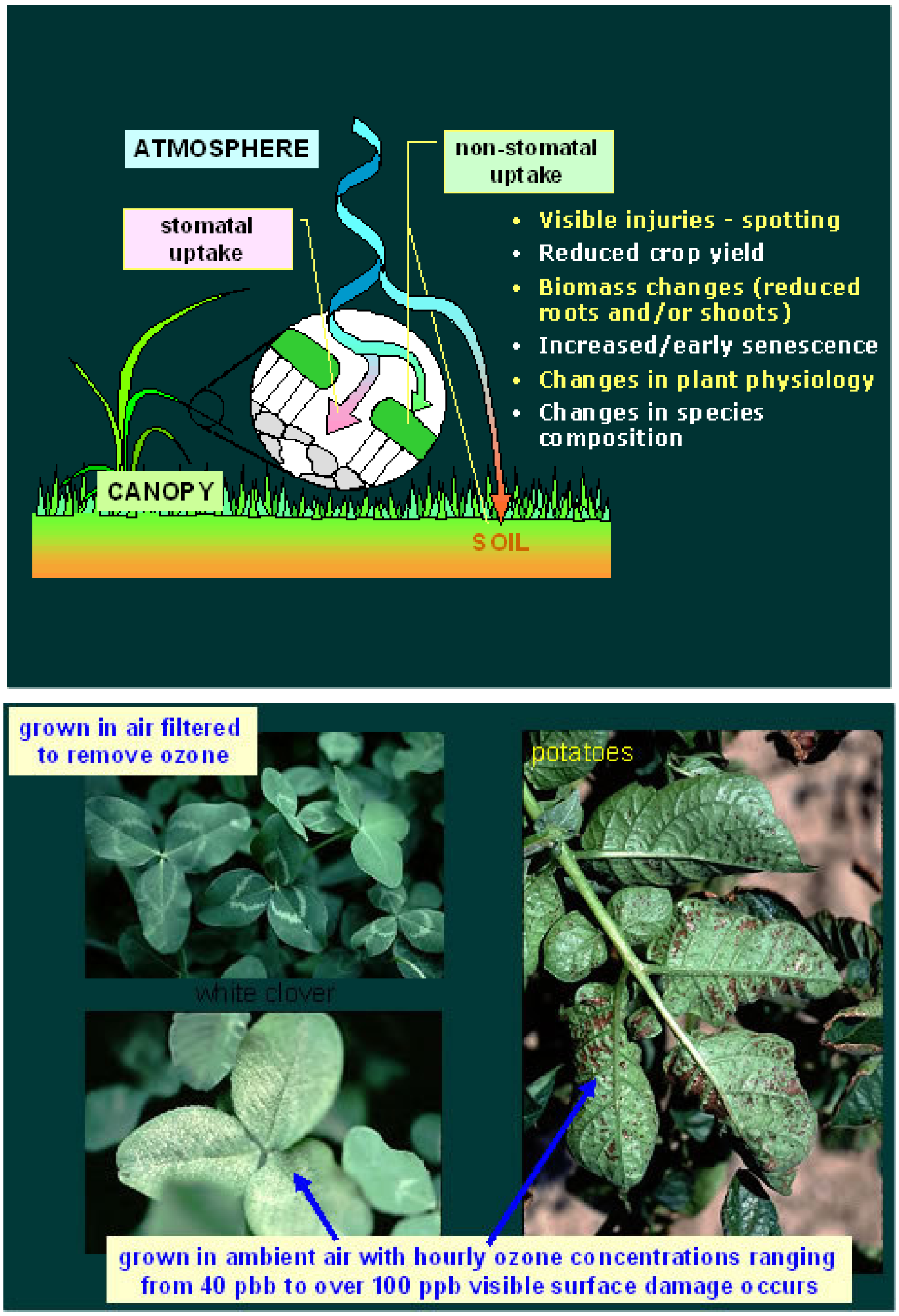
Figure 1. Tropospheric ozone



There have been many studies of the effects of ozone on vegetation although these mainly focussed on commercial crop species or trees (Ashmore *et al.* 2006; NEGTAP 2001). For many years the absolute concentration of ozone in the vicinity of the plant was considered as the influencing factor, although it was known that it was probably the ozone taken in by the plants through their stomata that caused the damage. Depending on the concentration levels used and the stomatal conductance of the plants, effects range from subtle physiological changes to large changes in biomass, root: shoot ratios, leaf morphology and visible injuries

(Figure 2). More recently the UNECE has recommended ozone flux and stomatal uptake based indices for assessing effects on vegetation (ICP, 2004), although at present critical levels have only been defined for wheat and potatoes, several studies across Europe are gathering data to define levels for other species and communities such as semi-natural grasslands, beech and Scots pine. The results of one such study into the effects of ozone on semi-natural upland species in the UK, funded by Defra, are summarised here.

Figure 2 The stomatal uptake of ozone and its effects on vegetation



Ozone trends

Although emission control measures have reduced peak ozone concentrations in the UK and Europe, the northern hemisphere background ozone concentration is increasing, bringing average levels close to or above thresholds for effects on vegetation (Figure 3). Predictions of future global ozone show this trend continuing (Figure 4). Maps of the concentration-based effects-threshold for crops and semi-natural vegetation (AOT40), show that it is currently exceeded over much of Scotland and by 2050 the area is likely to greatly increase (Figure 5).

Figure 3. Top: decreases in the annual maximum ozone concentration observed across the UK. Bottom: increases in the annual mean.

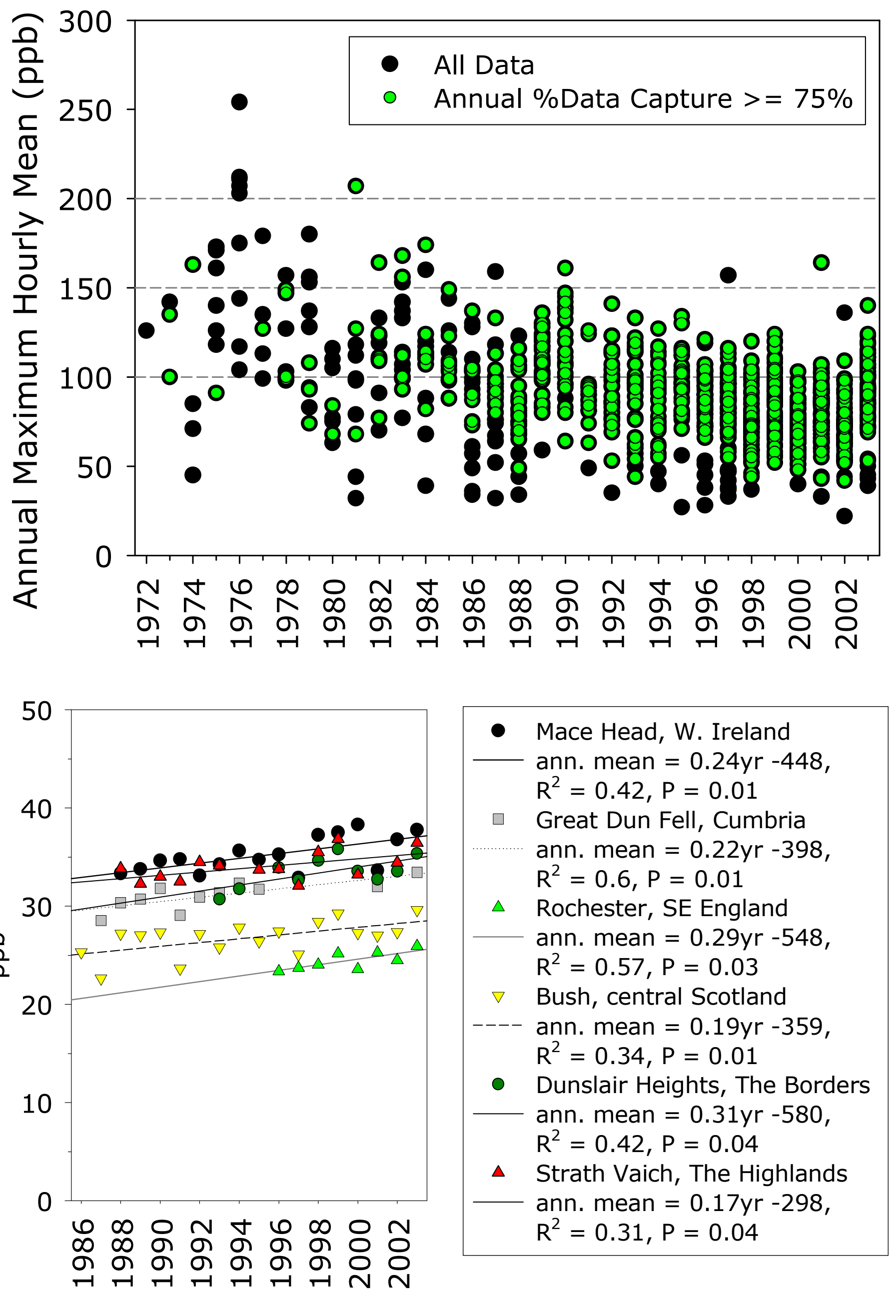


Figure 4. Predicted increases in global ozone by 2100 using a “business as usual” emissions scenario.

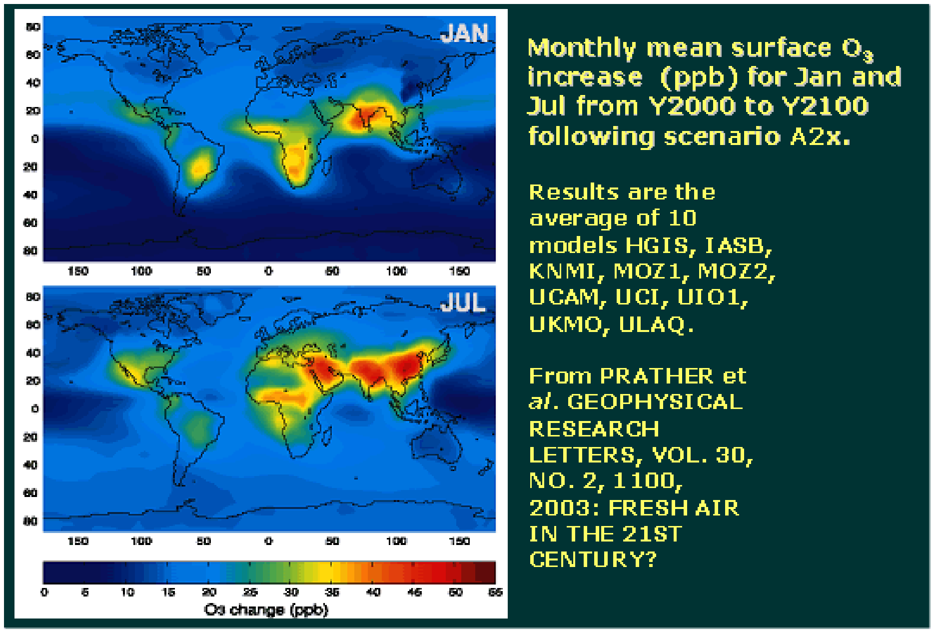
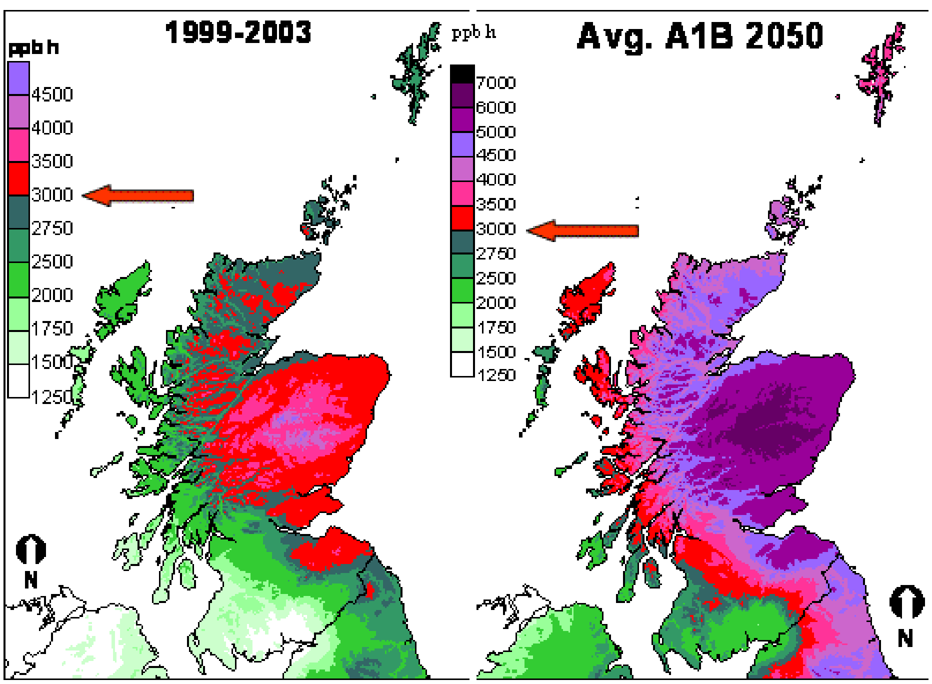


Figure 5. AOT40 for crops and semi-natural vegetation, present day 1999 to 2003 average and future prediction using a balanced emission control/development scenario. The arrows indicate the effects-threshold level of 3000 ppb.h.



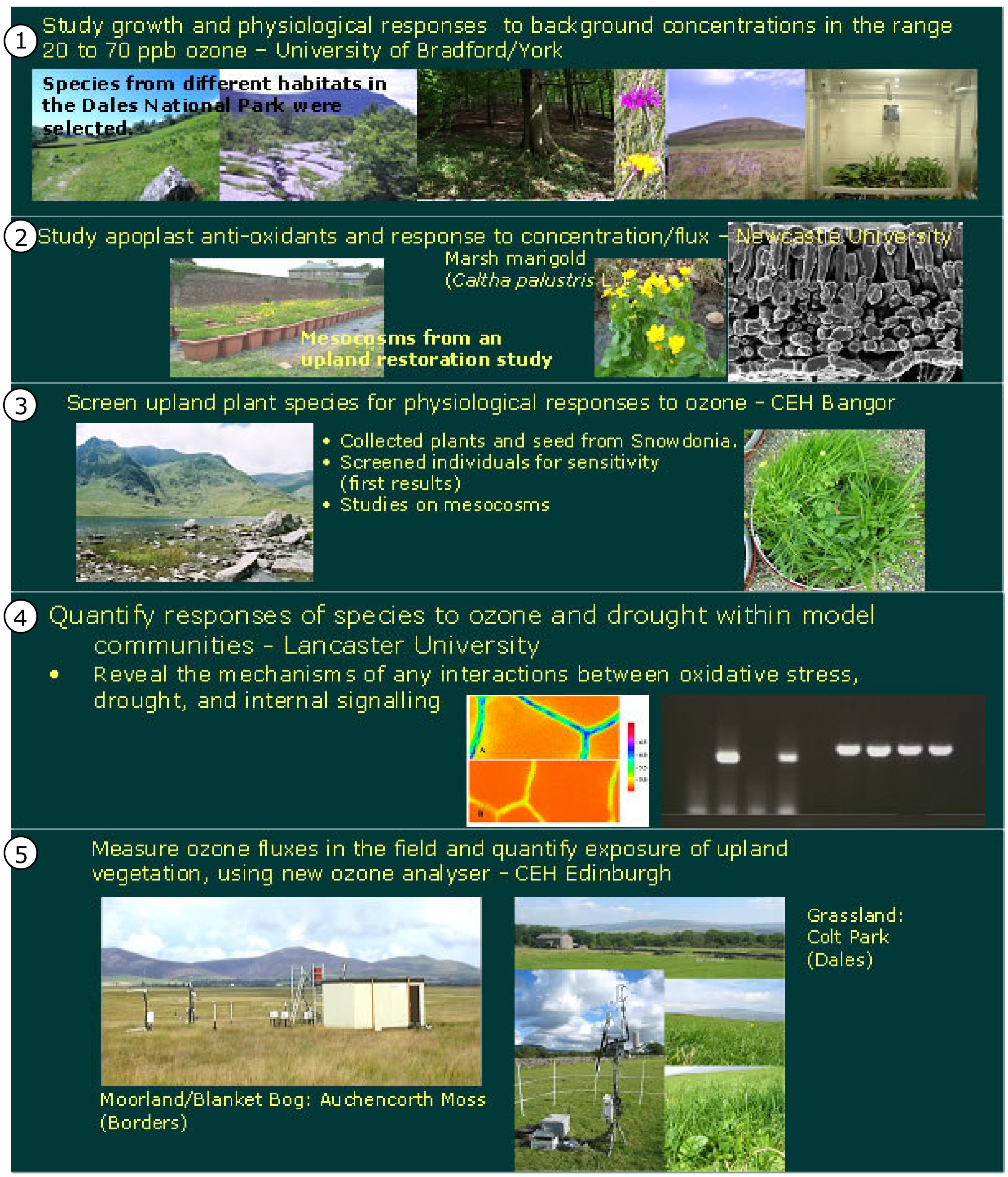
Research

Previous studies (Ashmore *et al* 2002; Coyle *et al* 2003) revealed that upland plant species may be at particular risk of damage caused by increasing background ozone concentrations. As a result of this, Defra funded a research program (1/3/201, Coyle*, et al.*, 2006) to assess the risks for upland and semi-natural vegetation in the UK. The work was undertaken by The

University of York (previously at Bradford), Lancaster University, University of Newcastle, Centre of Ecology and Hydrology Edinburgh and Bangor. There were five main areas of work:

- assess the effects of ozone on upland herbaceous species;
- screen for ozone sensitivity to identify species of high conservation value;
- measure physiological responses of vegetation to the absorbed ozone flux;
- measure ozone fluxes in field conditions;
- integrate the work to provide an assessment of the risk to upland vegetation of increasing background ozone concentrations.

The following studies were undertaken by the research groups.



Results

Conservative increases in ozone concentrations, as predicted for the UK over the next 30-50 years, resulted in significant shifts in the composition of a species-rich upland meadow community within a relatively short period (12-14 months to yield statistically discernible changes). Rare grasses of high conservation value (*Phleum* and *Briza*) were suppressed in favour of an opportunistic grass (*Alopercurus*) (Figure 6). For upland communities the results are summarised in Figure 7 and the work at Lancaster is summarised in Figure 8. The other main findings were:

- evidence of substantial night-time conductance in a significant fraction of the upland flora was found. This could be significant as ozone concentrations remain large at night in upland areas (Figure 9);

- exposure to ozone at night or at low temperature was shown to have a disproportionately adverse effect on plant growth, this may indicate a need to ‘weight’ ozone exposures (e.g., day/night and by season), when considering risk assessment approaches for upland vegetation;

- some species showed no effects during exposure experiments but did have carry-over effects on biomass the following spring, highlighting the importance of long-term studies.

Summary

Increasing background ozone concentrations are likely to lead to shifts in species composition, reductions in biomass and loss of key species in sensitive habitats.

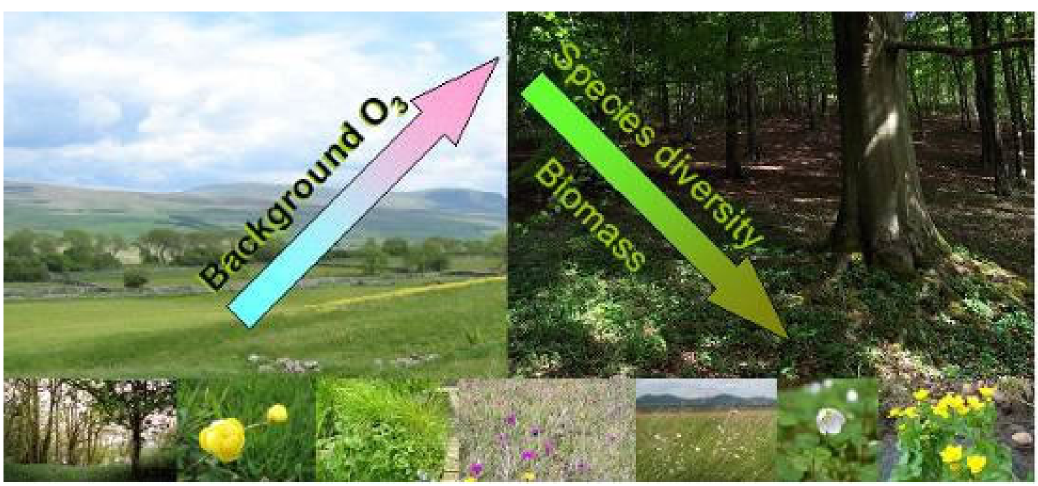


Figure 6. Shifts in species composition in an upland meadow.

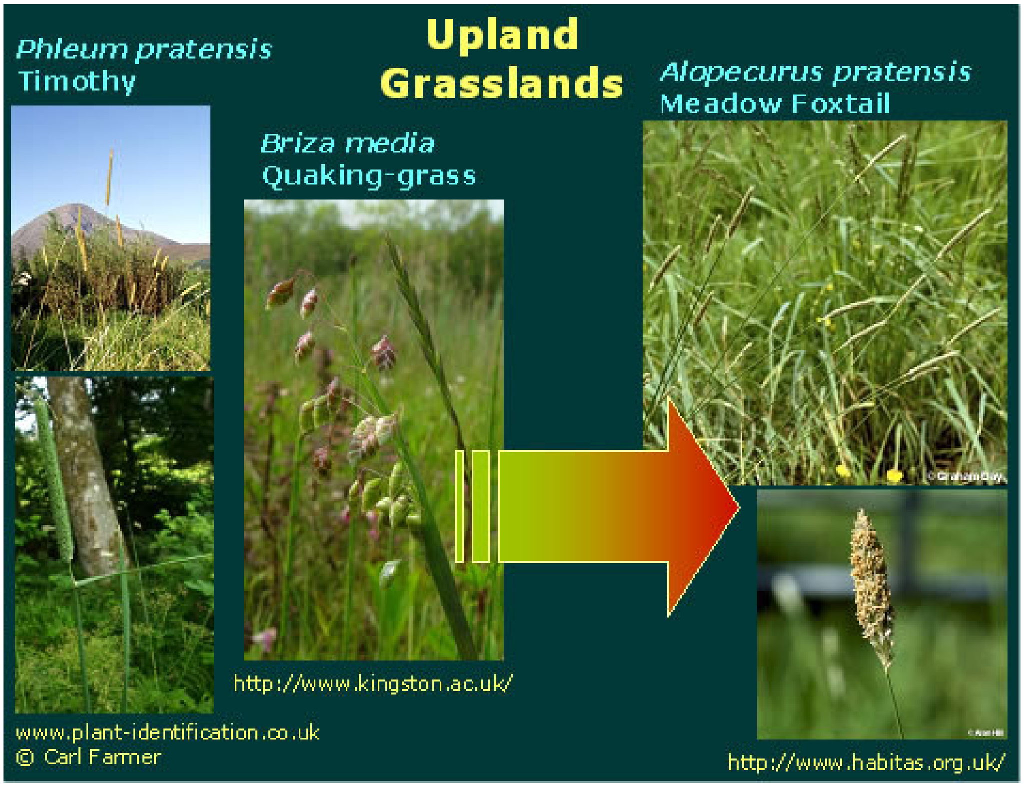


Figure 7. Summary of results for upland woodland species.

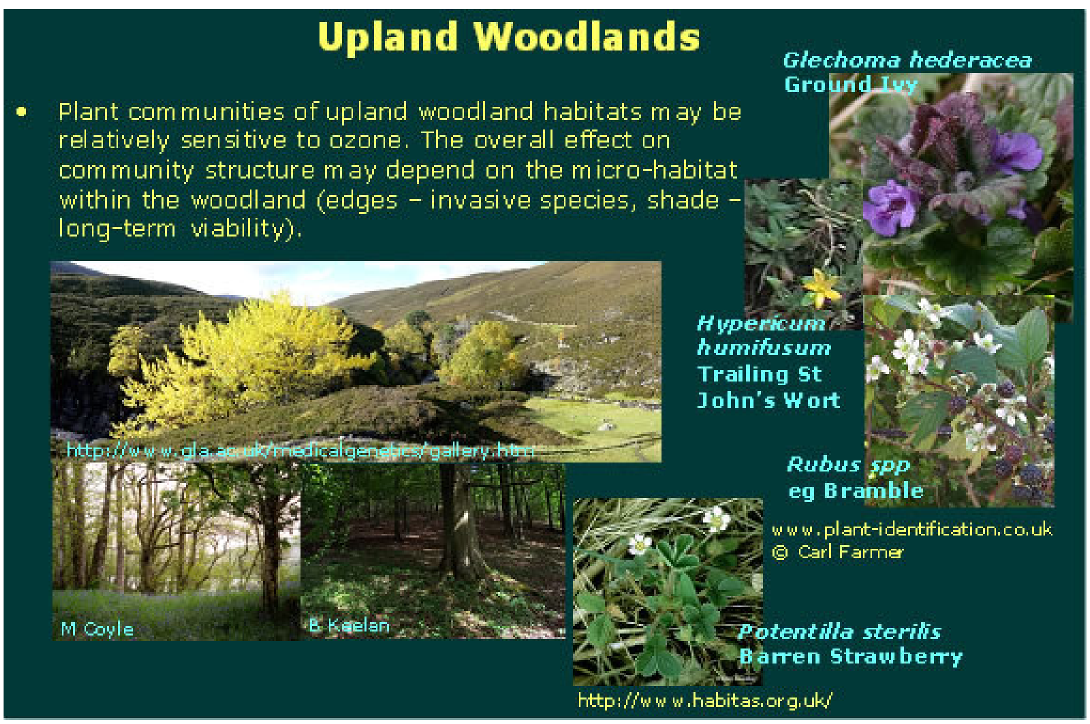


Figure 8. Summary of results from drought/stress interaction studies (Lancaster University).

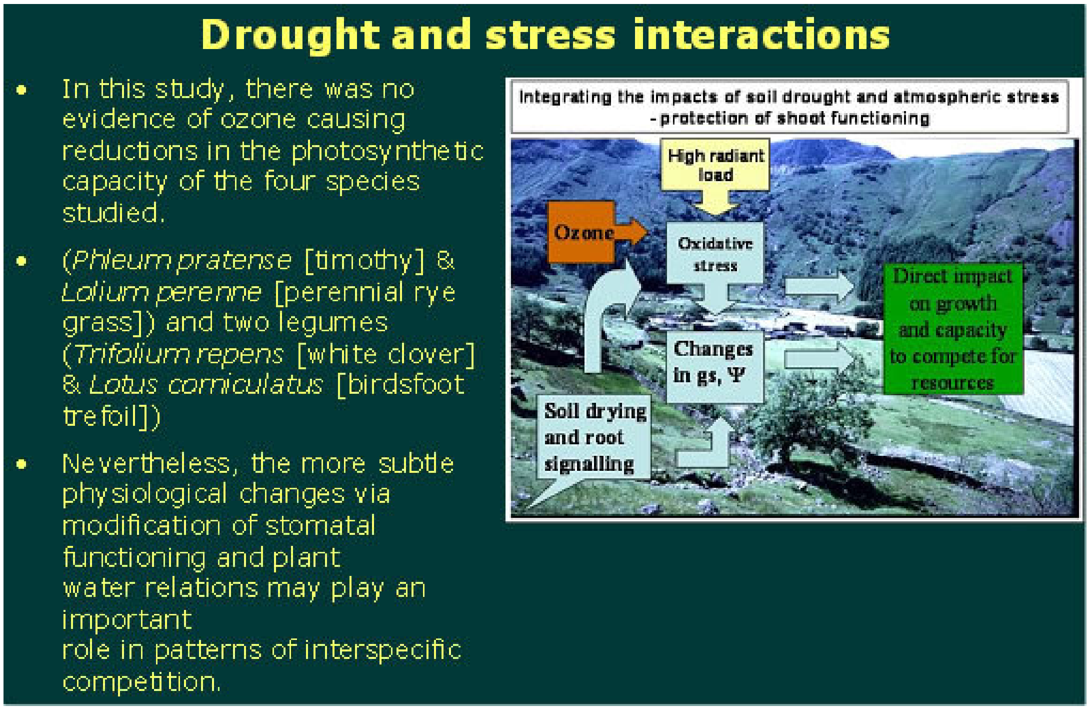
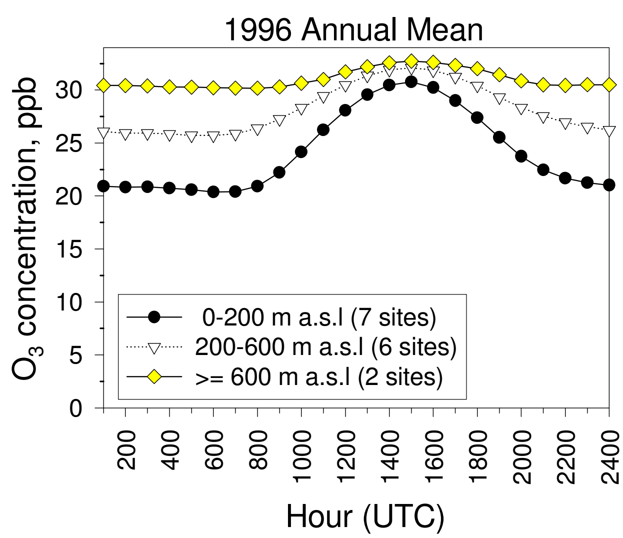


Figure 9. The daily variation in ozone concentration at different heights above sea-level across the UK (data from the national rural ozone monitoring network and CEH Edinburgh).



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