Desert herbaceous composition impacted by co-occurring pollutants in urban ecological airshed

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Central Arizona-Phoenix Long-Term Ecological Research CAP LTER

Urban air quality can be a *resource* or *stressor* in 'ecological airshed'

Cities occupy a small area of Earth's land, but urban-generated compounds, such as **carbon dioxide (CO_2), ozone (O_3)** and **reactive nitrogen (N)**, impact air quality at local to global scales.

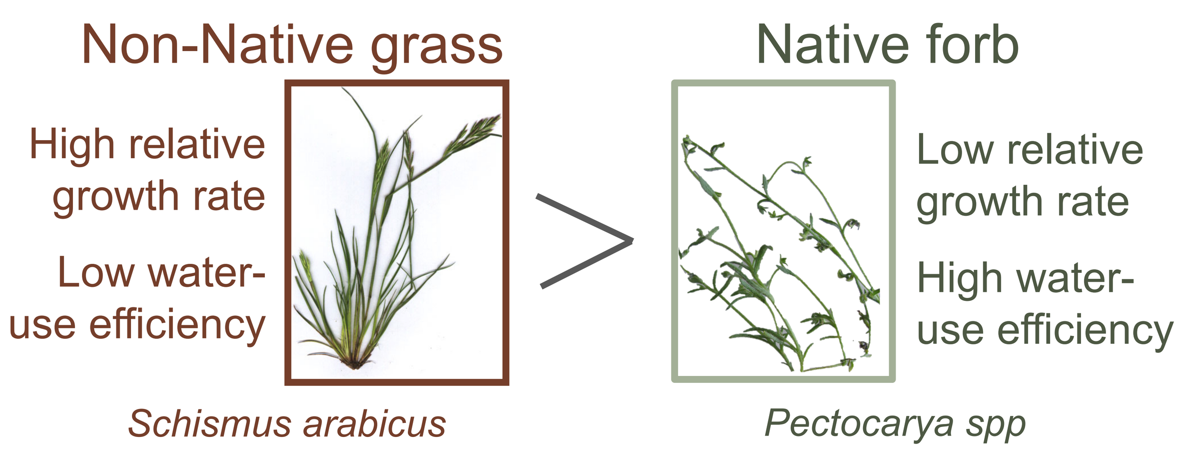
Despite their ecological relevance as a *resource* or *stressor* to primary producers (**Table 1**) the net co-occurring and long-term impacts of elevated CO_2, O_3 and N in protected ecosystems is unknown.

Table 1: Urban atmospheric compounds act *individually* as either a *resource* or *stressor* affecting primary production. Their net ecological impact is unknown.

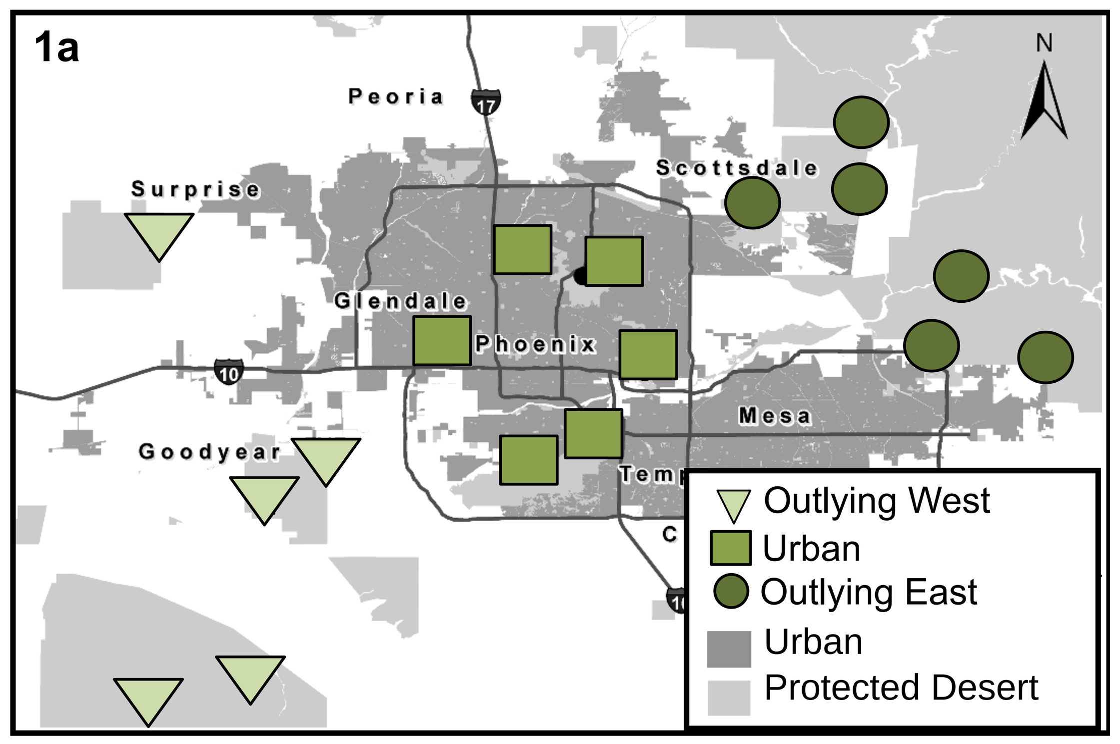
Atmospheric compounds		*Ecological relevance*
Carbon Dioxide (CO_2)	↑	Increase water-use and nitrogen-use efficiency; ***stimulate primary production***
Ozone (O_3)	↓	Foliar cell damage; ***inhibit photosynthesis*** and stomatal conductance; early senescence
Reactive Nitrogen (NO_x, NH_3, HNO_3)	↑	Alleviate nutrient limitation; ***stimulate primary production;*** alter species composition

How does the 'ecological airshed' impact native and non-native herbaceous community?

In multi-factor **field** and **chamber** experiments, we examined single and combined net effects of the urban ecological airshed (current and elevated O_3, CO_2, and N) on dominant Sonoran Desert winter herbaceous species.



Long-term multi-factor field experiment



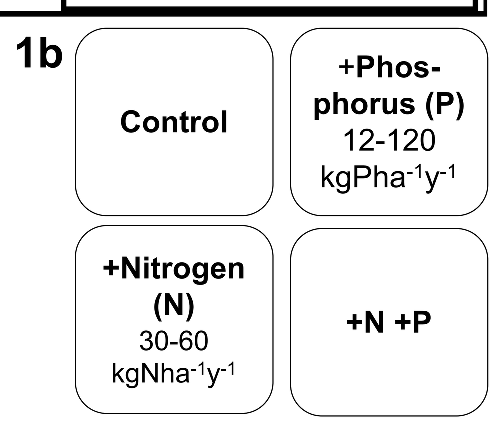


Figure 1a: Annual percent cover of dominant herbaceous species (collected in 1m² quadrats) was monitored at 15 protected desert preserves in Phoenix metro region over 7 years (2008-2017). **1b:** Multi-factor nutrient enrichment treatment within each site to reflect potential urban stressors and atmospheric inputs.

Rising winter O_3 concentrations and shifting native and non-native herbaceous composition

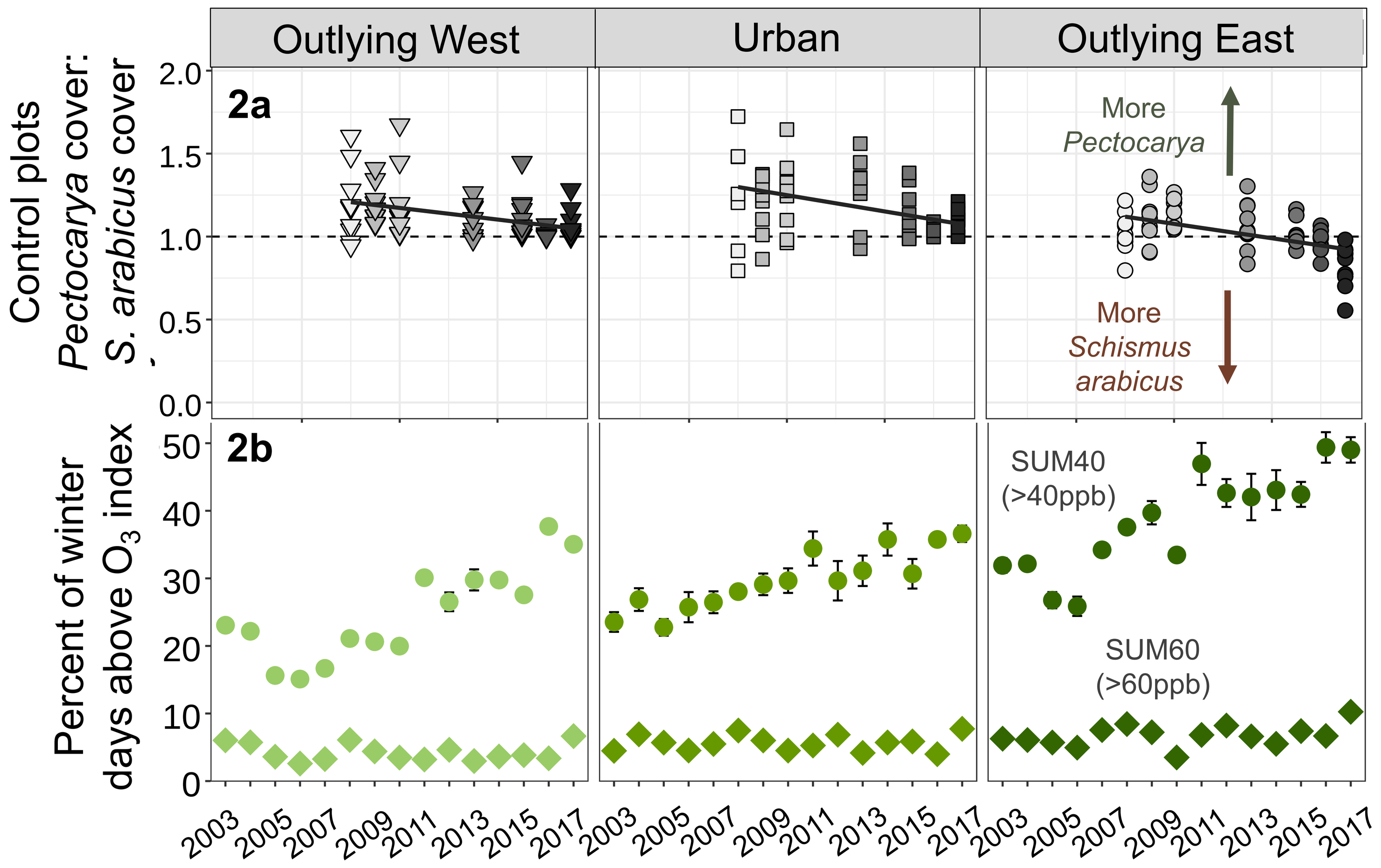


Figure 2a: Decreasing ratio of native to non-native cover during long-term monitoring in Control plots (2008-2010; 2013, 2015-2017). No significant difference in under plant, inter-plant composition (not shown).

Figure 2b: Average winter O_3 concentrations (+/- 1SE)—during the desert herbaceous growing season—are increasing over time, particularly in outlying east locations (Long-term O_3 concentrations interpolated from Maricopa and Pinal County Air Quality Department monitoring locations).

Long-term changing community composition related to higher O_3 and aridity index

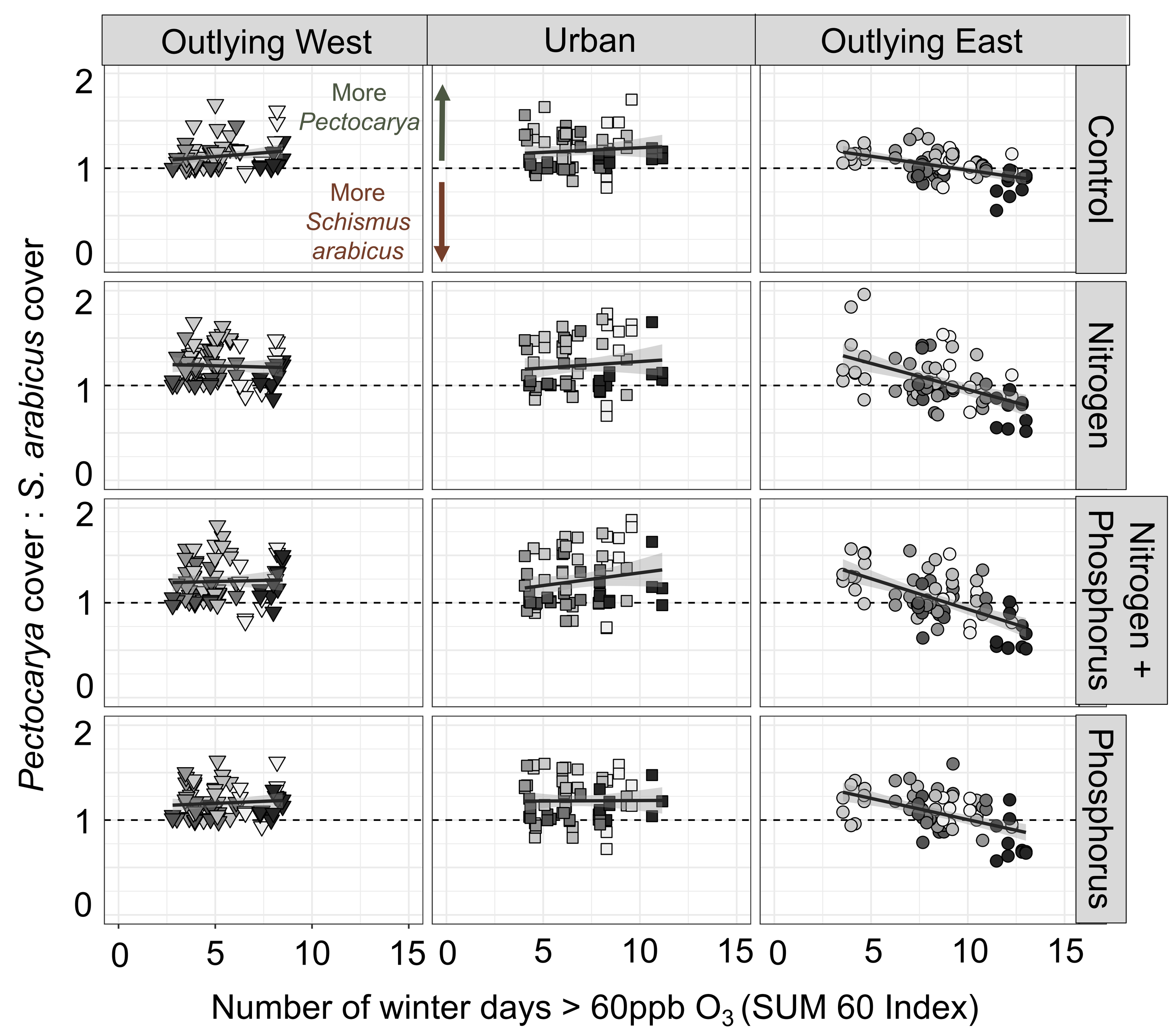


Figure 3: In Outlying East, changing herbaceous species cover (decreasing native *Pectocarya*, increasing non-native *S. arabicus*) significantly related to days with O_3 concentrations >60ppb, as well as Aridity Index (Aridity = Precipitation / PET, not shown). Nutrient treatment addition is not a significant fixed factor.

Different responses to co-occurring pollutants in multi-factor dose-response chamber experiment

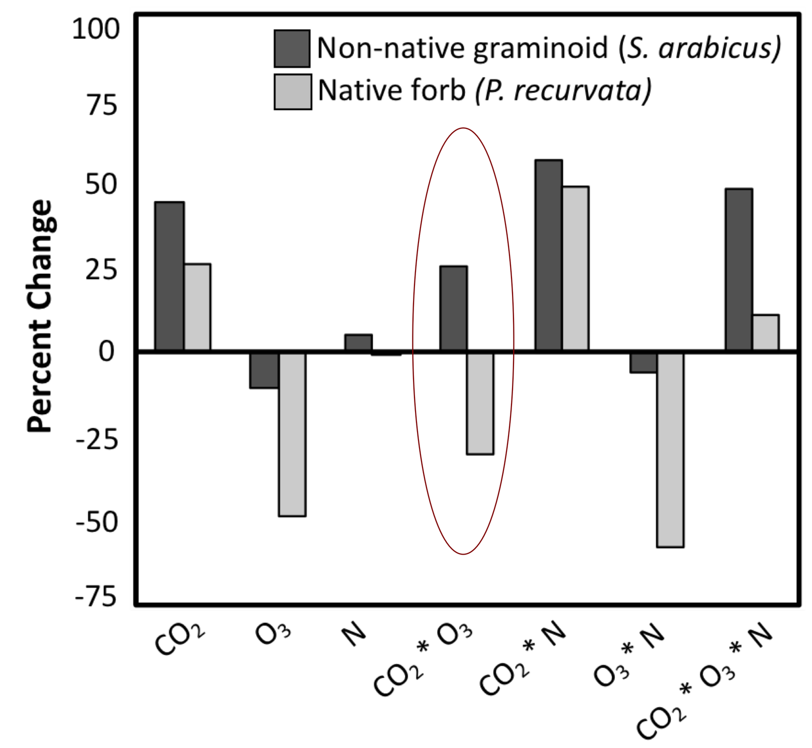


Figure 4: In 7-week multi-factor fumigation chamber experiment at ambient and expected future concentrations, observed percent change in growth rate relative to the control (ambient CO_2, O_3, and/or N) differed for non-native *S. arabicus* (dark grey) and native *Pectocarya* (light grey) in single and combined high CO_2 (700ppm), O_3 (100ppb), and N (8 kgN ha^{-1} yr^{-1}) treatments.

Non-native species has net positive growth when exposed co-occurring pollutants, despite negative O_3 impact on physiological response

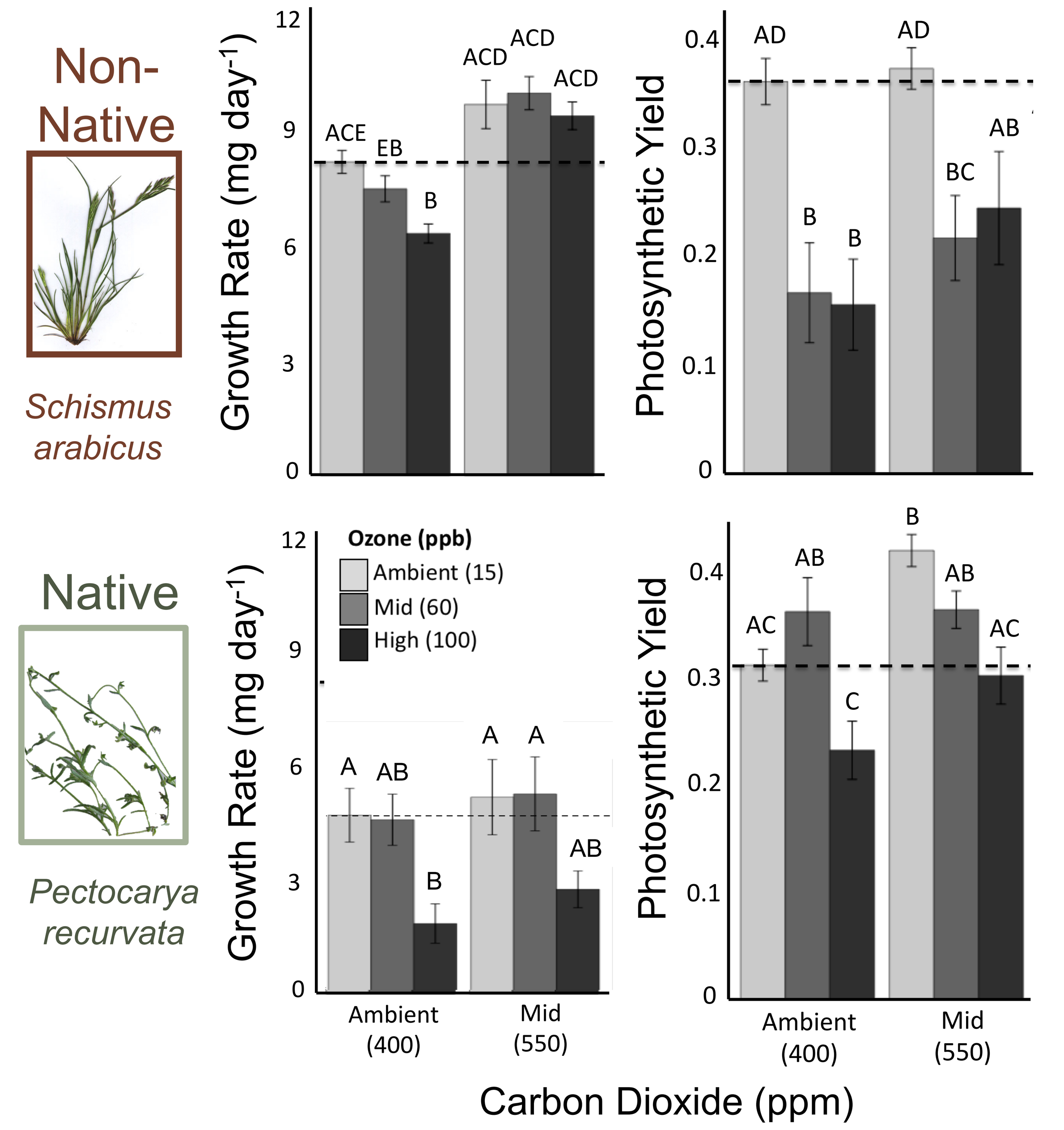


Figure 5: Average (+/-1SE) growth rate (mg day^{-1}) and photosynthetic yield in combined CO_2 and O_3.

Dashed line is average from control (grown in ambient CO_2 and O_3).

Different letters represent significantly different means from pairwise comparison with Bonferroni adjustment.

Next steps toward multi-pollutant critical load

Our findings highlight differences in herbaceous species responses to the urban 'ecological airshed'—particularly increasing O_3 even at moderate rates—and potential long-term shifts in community composition.

Next steps: Examine thresholds in species responses and consider a multi-pollutant critical load for realistic ecosystem exposure to co-occurring compounds, rather than the typical critical load for single pollutants.

Acknowledgements: We especially thank Ron Pope (AZ Air Quality Dept); Megan Wheeler (ASU); David Jones and Tait Rounsville (USFS, Riverside CA); Elizabeth Hessom, Darrel Jenerette, Lou Santiago (UC Riverside). This work is based upon work supported by the National Science Foundation under grant numbers DEB-1637590 and DEB-1832016.