Global change in the desert: Effects of increased nitrogen on diverse annual plant communities

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Background & Research Question

Urban areas are expanding, with high projected growth in arid regions[1]. In addition to direct land transformation, cities have indirect effects on surrounding environments, such as increased air pollution, nitrogen (N) deposition, and nighttime temperatures[2]. In grasslands and forests, increased nutrient availability reduces diversity and alters species composition[3,4,5], but the response of desert plant communities to long-term nutrient enrichment combined with other indirect urban influences is not well understood. Sequential limitation of water and then nutrients[6,7] and the presence of shrubs as islands of fertility[8] may result in important differences between the response of plant communities to increased nutrient availability in desert compared to mesic communities. We conducted a long-term nutrient enrichment experiment to test the response of urban-influenced desert plant communities to multiple stressors.

How do water and nutrient availability interact to alter winter annual plant diversity in urban-influenced desert preserves?

H1: Primary limitation by water negates the impact of nitrogen fertilization in dry years.

H2: Annual plant diversity is reduced in urban desert remnants relative to native desert primarily due to high urban N deposition.

H3: Shrubs have net facilitative effects on annuals that reduce limitation by water and concentrate the effects of N.

H4: Abundant water and nutrient availability reduces limitations on annual plant growth, resulting in increased cover of dominant species, increased light competition, and loss of rare species.

Sites & Methods

3 regions
15 sites

7 years sampled *(excluded very dry years w/little annual growth)*

4 nutrient treatments

2 positions *(under or between Larrea tridentata)*

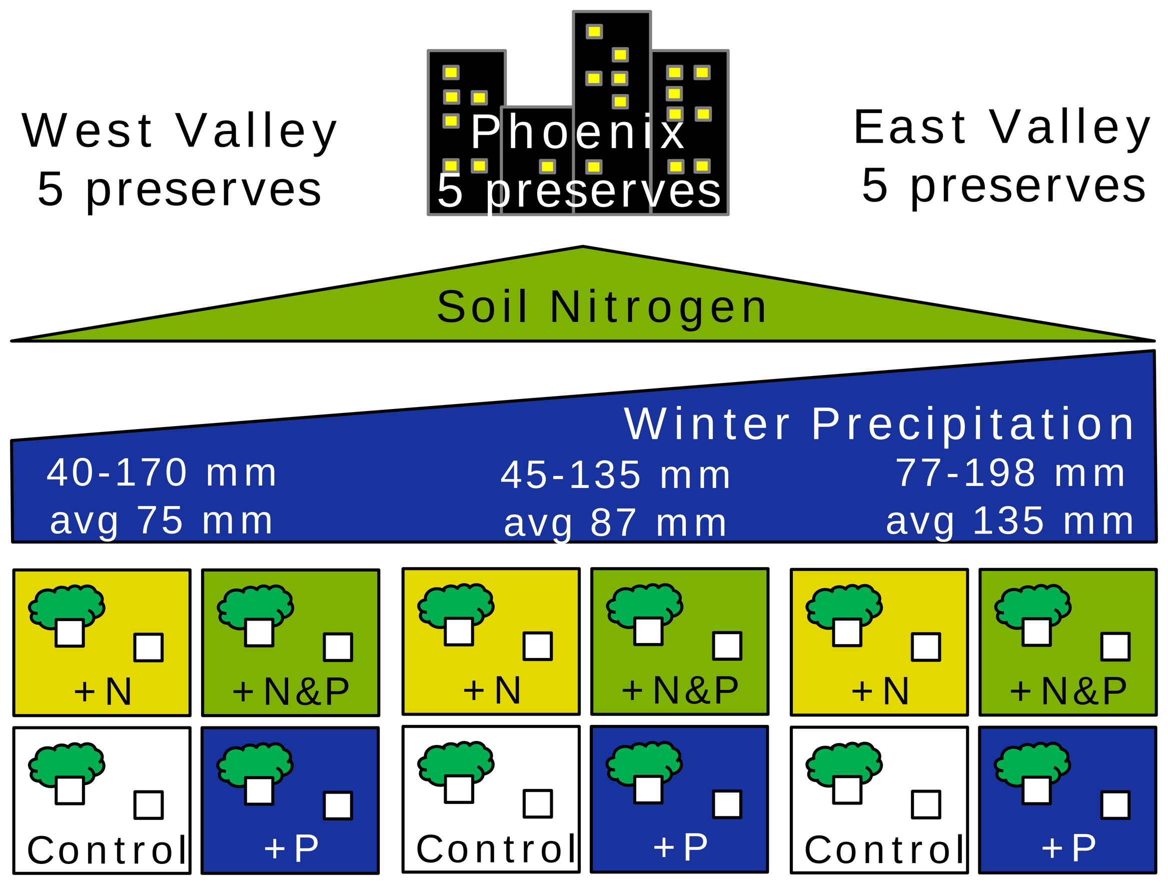

Figure 1. Annual plant composition under *L. tridentata*

- Nutrient addition treatments 2005 to present
  - 60 kg N ha^{-1} yr^{-1} (2005-2016)
  - 30 kg N ha^{-1} yr^{-1} (2017)
  - 120 kg P ha^{-1} yr^{-1} (2005-2009)
  - 12 kg P ha^{-1} yr^{-1} (2010-2017)
- Model of annual plant species richness
  - Averaged Poisson-distributed generalized linear mixed-effects models with weight >0.1 (21 models)
  - Random effects: site & year
  - Fixed effects: aridity index (growing season precipitation/PET)[9], N addition, P addition, location between or under shrub, region

Drivers of Species Richness

- Interaction between aridity and N is negligible (Reject H1). Both aridity and N addition are significant predictors, but the effect of N does not significantly vary with aridity as hypothesized.

Table 1. Averaged GLMM predicting annual plant species richness. Only predictors with relative importance greater than or equal to 0.5 are shown.

Predictor	Estimate	Std. Error	Importance
Aridity index	10	3	1
N addition	-0.40	0.08	1
East Valley	1.2	0.2	1
West Valley	0.6	0.2	1
Position under shrub	0.01	0.08	1
Aridity:East Valley	-14	3	1
Aridity:West Valley	-5	3	1
Aridity:N addition	2	2	0.84
Aridity:Position under shrub	2	2	0.68
P addition	-0.02	0.03	0.5

- Richness declines with N and is lowest in the urban core (Support for H2). Decreased richness in the urban core could be due to higher soil N.

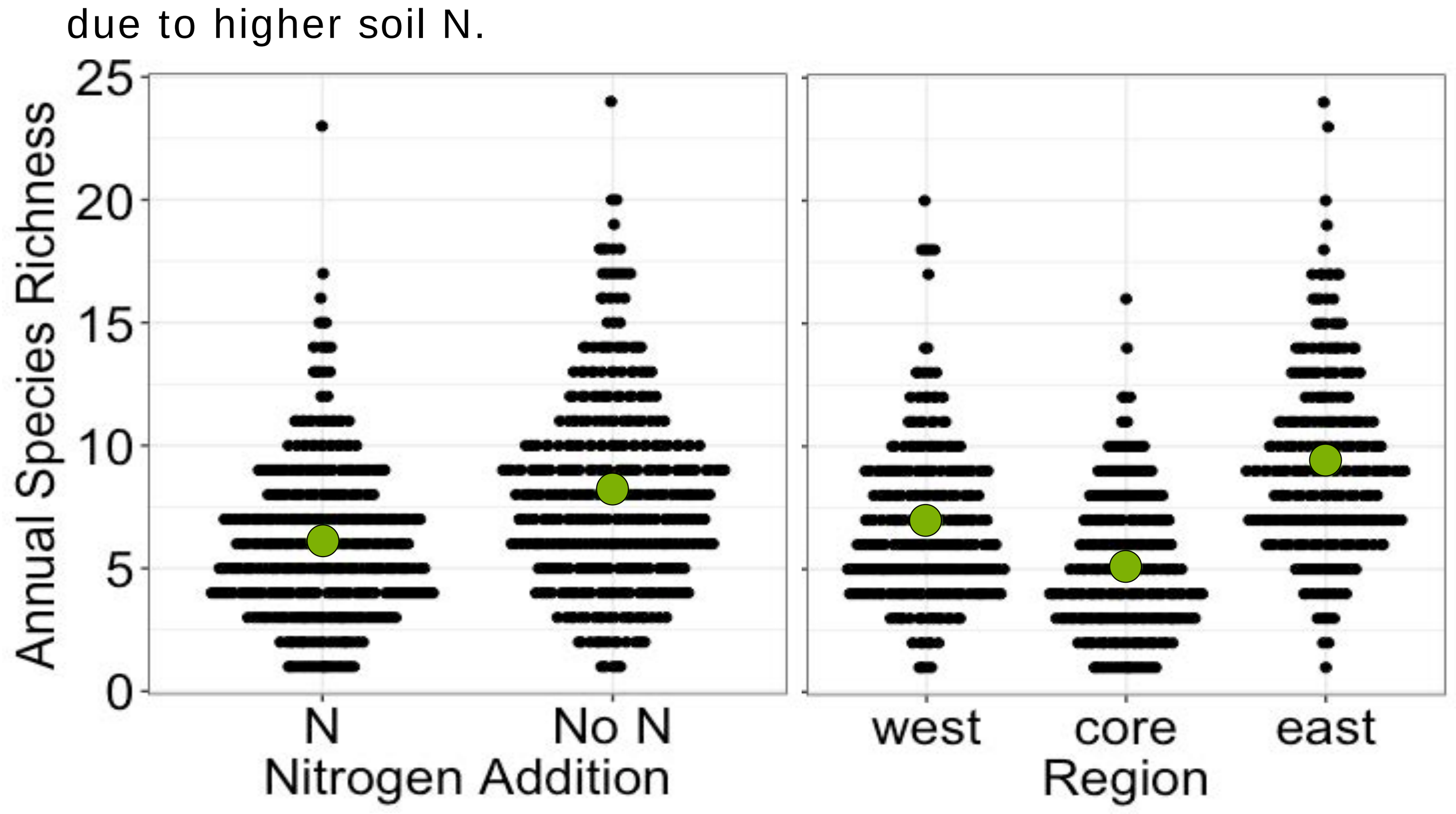

Figure 2. Annual diversity by region and N addition treatment. Black points represent richness at one sampling location, treatment, site, and year. Green points show averages for each N treatment and region.

- Effect of shrubs on annual species richness is negligible (Reject H3). Although the location relative to shrubs is included in the best models, its effect on annual diversity is very small.

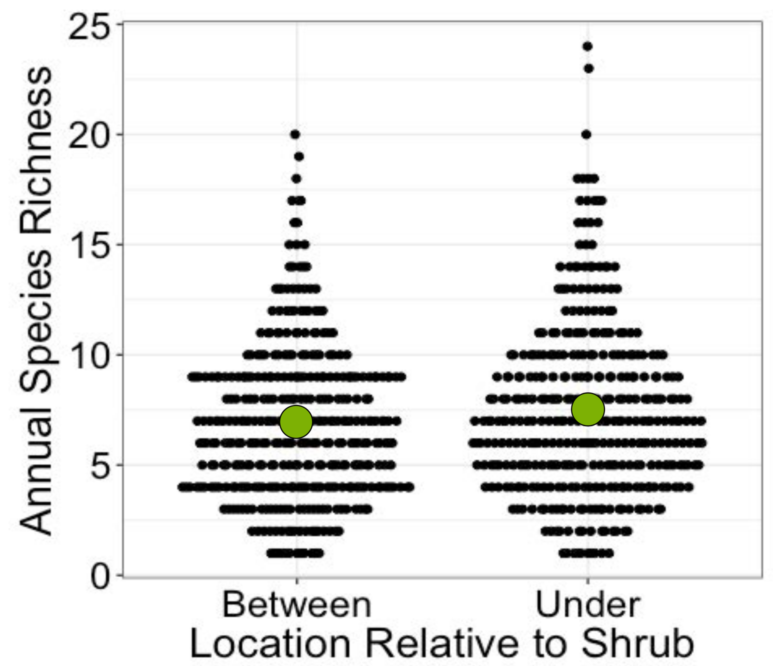

Figure 3. Annual diversity under and between shrubs. Black points represent richness at one sampling location, treatment, site, and year. Green points show averages for each position.

Community Composition

- N treatment decreased evenness and increased cover of the most common species (Support for H4). Effect is not limited to wet years, indicating greater importance of N over water.

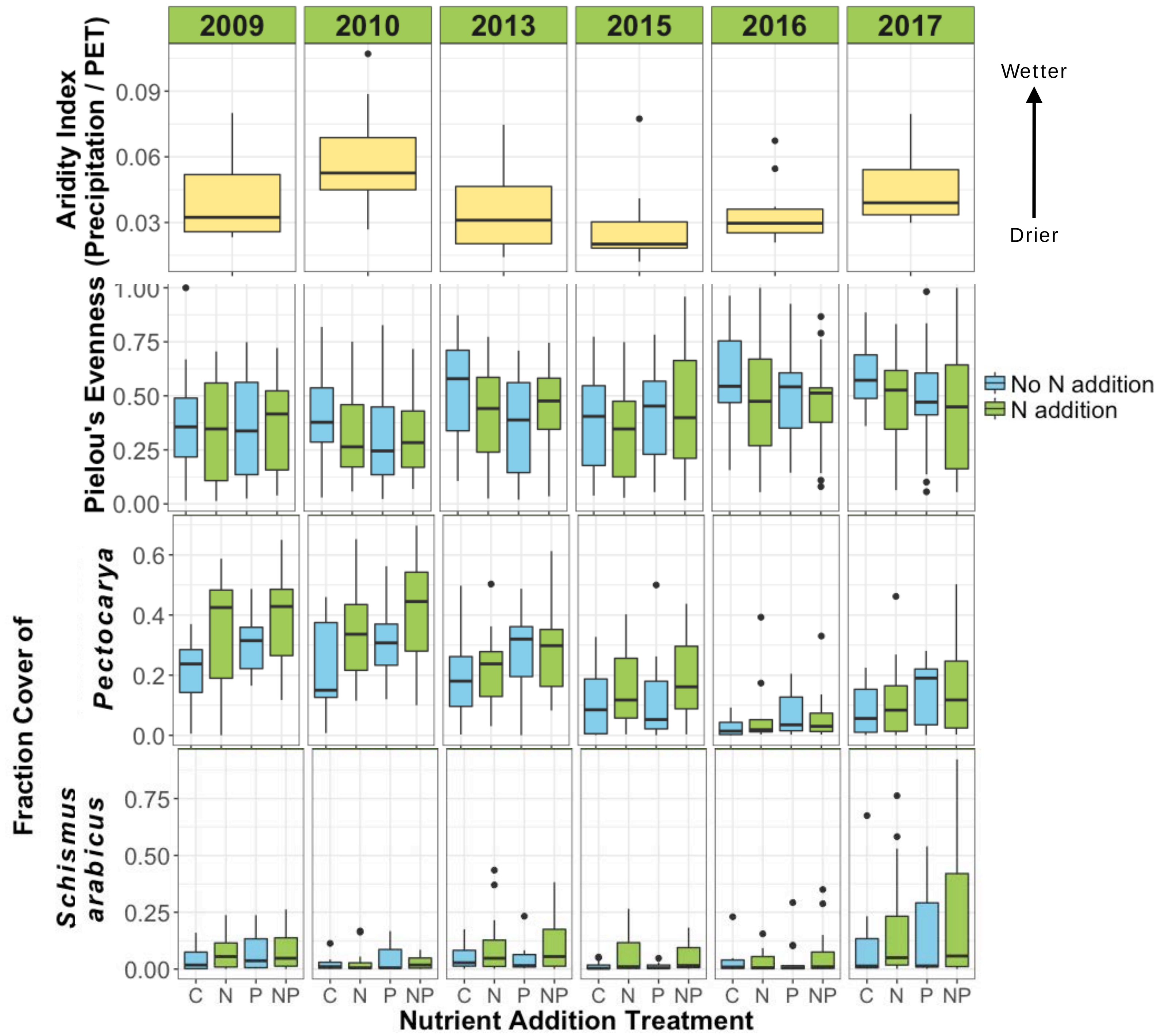

Figure 4. Evenness of all species and cover of the two most common species – the small native forb *Pectocarya* sp. and the non-native grass *Schismus arabicus*.

Conclusions

- N and water availability independently affect annual diversity. This is contrary to expectations that increased N would only have a significant effect in high precipitation years. The threshold for water limitation may be lower than measured in these 7 years – measurements were not made in very dry years due to minimal annual plant growth.
- Urban desert remnants show decreased annual plant diversity that may be explained by higher N deposition. Other factors not tested here may also be important, such as elevated ozone and CO_2, urban heat island effects, and altered dispersal.
- Shrubs have a small effect on annual diversity and do not change the effects of N addition. Shrubs do not concentrate or reduce the effects of N as expected if they act as islands of fertility.

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