Seasonality and Land Cover Type Drive Aphid Dynamics in an Arid City

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Background

- Urbanization creates habitats comprised of unique community assemblages and interactions (Hobbs 1994).
- Aphids are an arthropod urbanophile (Bang and Faeth 2011) and are able to thrive in urban and disturbed habitats.
- Phoenix is a unique urban ecosystem comprised of a heterogeneous mosaic of land use and land cover patches categorized into "habitat types" by McIntyre et al. (2001).
- Quantifying aphid dynamics in Phoenix will help explain biodiversity impacts and patterns of urbanophiles.

Research Objectives

We used the CAP LTER 'Long-term monitoring of ground-dwelling arthropods' dataset to:

1. Compare aphid abundance across habitat types.
2. Quantify how temporal aphid dynamics are effected by seasonal controls.
3. Develop a theoretical model of aphid dynamics in an urban ecosystem.

Study Area

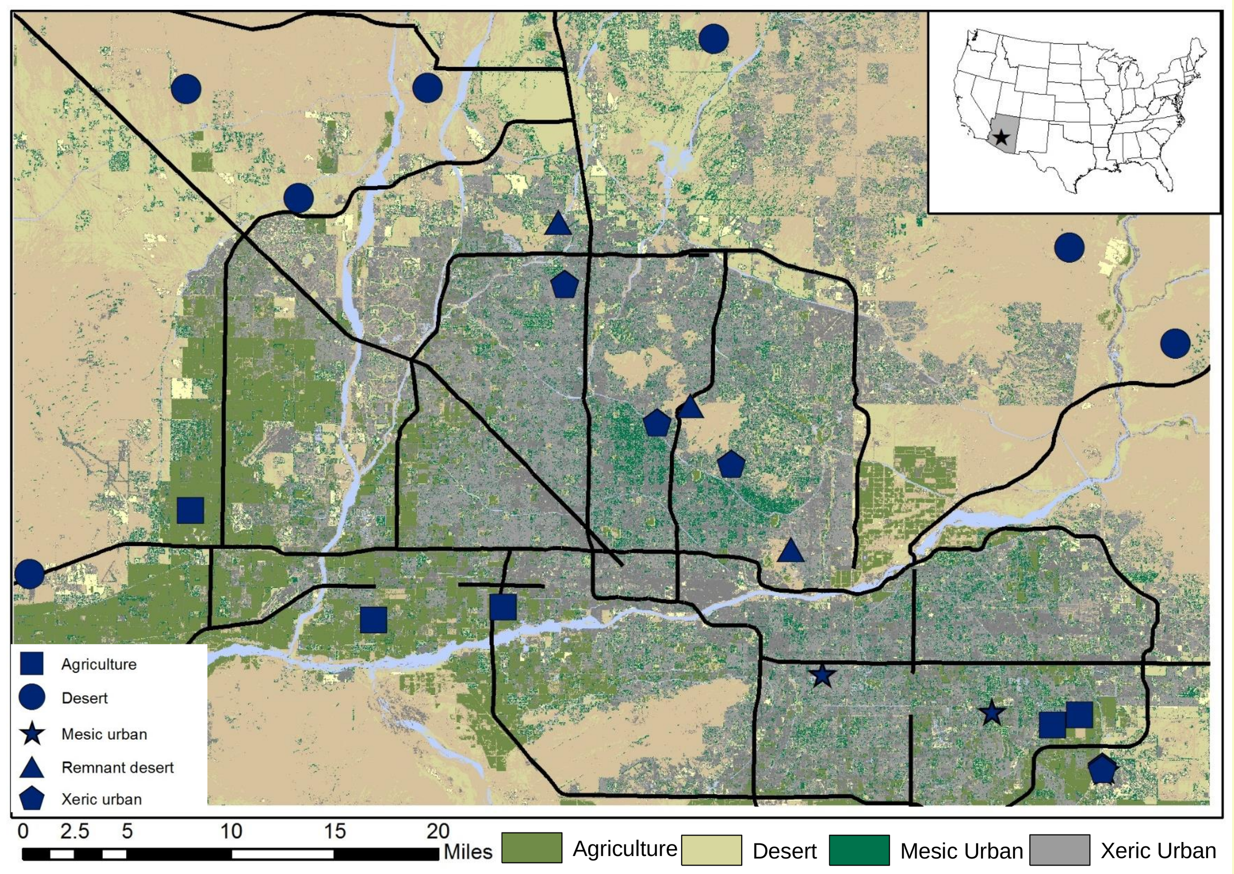

Figure 1 Study area testing the effect of habitat type and seasonality on aphid abundance in Phoenix, Arizona from 2002 to 2013. Habitat types are defined as: agriculture (n=5), mesic urban (n=4), xeric urban (n=6), remnant desert (n=3), and desert (n=7)

Results: Habitat and Seasonality

- Aphid abundance varied among habitat types (F= 8.40, df=4, p < 0.001, Fig 2 ; GLM repeated measures) and season (F=88.33, df= 3, p<0.001; GLM repeated measures).
- Abundance was distinctly separated along a gradient of water availability and productivity.
- Habitat types that are irrigated maintain high vegetation levels (agriculture and urban mesic) and supported higher abundances of aphids compared to habitats with drier land cover characteristics (Table 2).

Table 1 Mean (±SE) aphid abundance per season per site in Phoenix, Arizona.

Habitat Type	n	Abundance
Agriculture	5	27.0 ± 14.6
Desert	7	9.9 ± 8.1
Mesic Urban	4	12.5 ± 5.2
Desert Remnant	3	4.0 ± 2.1
Xeric Urban	6	4.7 ± 0.5

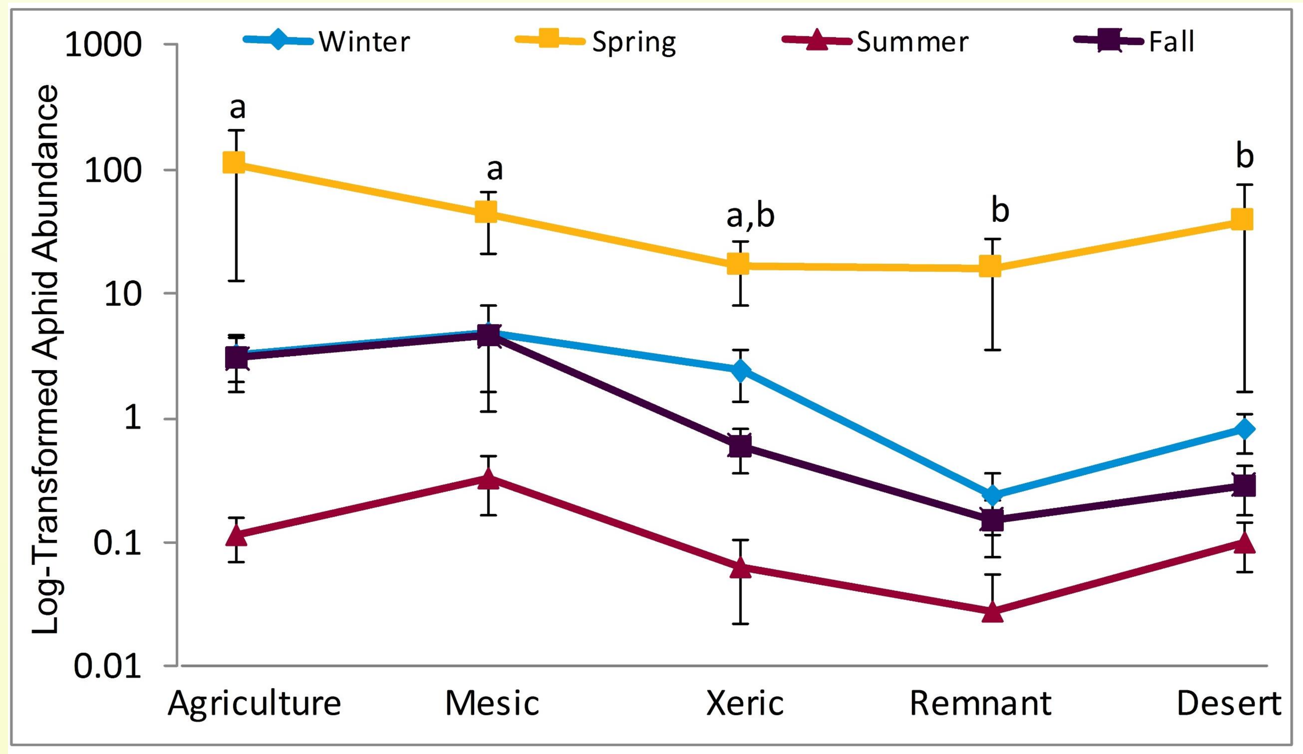

Figure 2 Seasonal abundance of aphids per season per site across habitat types in Phoenix, Arizona from 2002-2013. Habitat groups indicated by letters are significantly different at a p<0.05 level

Model Derivation

We assume the population dynamics of aphids in a season follows a traditional logistic growth function with Holling's Type II predation:

$$A(t+1) = A(t)e^{\bar{r}\left(1-\frac{A(t)}{K}-\frac{\alpha}{1+\beta A(t)}\right)}$$

Let T be temperature. Briere et al. (1999) proposed a temperature-dependent growth rate model that we modified for aphid dynamics in Phoenix:

$$\bar{r} = r(T(t+1))$$
$$= r_0 T(t+1)(T(t+1) - T^A_{min})(T^A_{max} T(t+1))^{0.76}$$

We modeled the temperature T as the following sine function, derived from Sky Harbor Airport data. To model the temperature variation from the predicted values due to the different degrees of urbanization, we incorporated a parameter d:

$$T(t+1) = 10.4\sin\left(\frac{\pi(t+1)}{2} - 0.1\right) + 23.95 + d$$

Results: Mathematical Model

- Our mathematical model was a strong indicator of observed aphid population patterns (r= 0.673, p<0.0001, Figure 3; Pearson's Correlation).
- **Lower temperatures** can drive aphid populations to stabilize, become chaotic, or cause extreme oscillations. **Higher temperatures** can cause aphid dynamics to become chaotic or drive the populations to extinction (Figure 4).
- **Temperature variation by just a few degrees resulted in dramatic differences in population dynamics.**

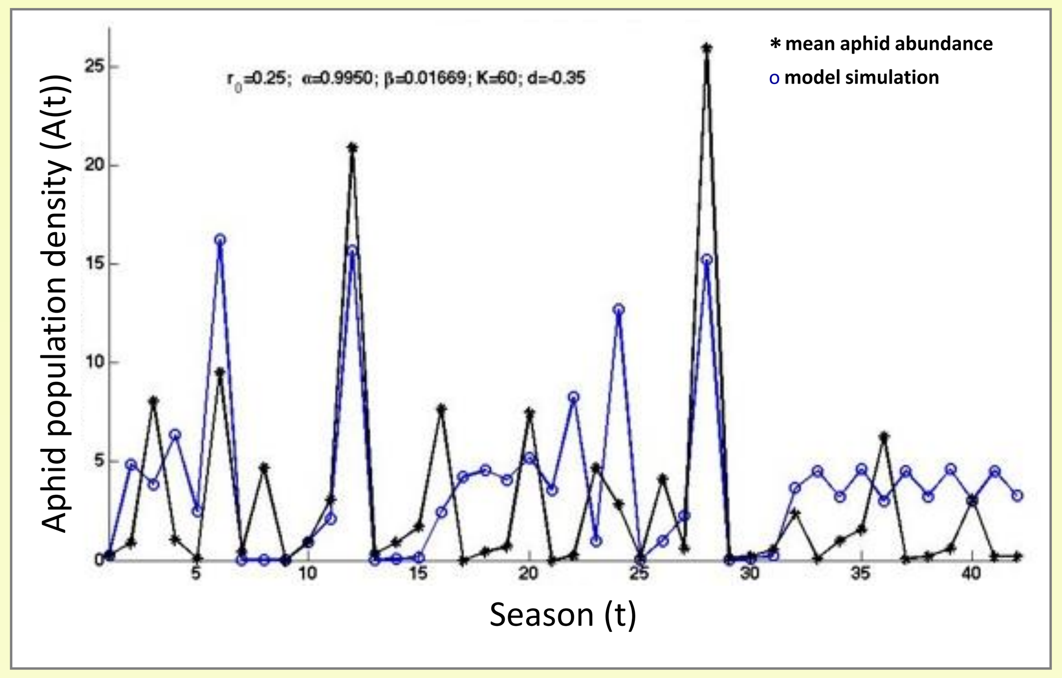

Figure 3 The model validation and parameterization based on the average of population density of aphids in Phoenix from Summer 2003 to Winter 2013

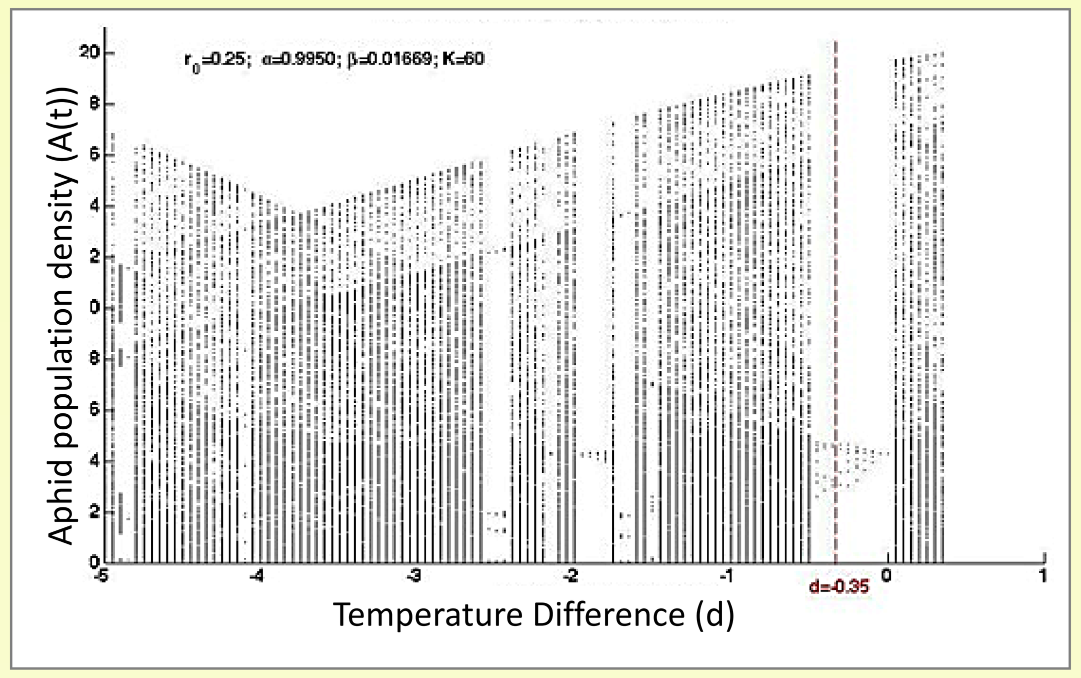

Figure 4 Bifurcation diagram of d versus aphid dynamics based on model. The value of d changes from -5 to 1; the y axis is all possible values of aphid population density

Conclusion

- **Aphid abundance is driven by seasonality and land cover type.** Seasonality has a strong effect and patterns are consistent across all habitat types (Figure 2).
- Subtle differences in temperature, that occur across habitat types, have dramatic effects on aphid dynamics.
- Aphids are able to take advantage of preferred habitat patches, allowing them to thrive in fragmented urban environments.

Acknowledgements

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