Ecological Stoichiometry of the Black Widow Spider: From Solitary Desert Predator to Urban Pest

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INTRODUCTION

•Urbanization often reduces native species diversity at the expense of a few urban-adapted taxa termed 'urban exploiters'[1].

•Unfortunately, the mechanisms driving biodiversity patterns in cities are poorly understood[2]. For example, how do urban exploiters cope with changes in nutrient availability typical of urban habitat?

•Ecological stoichiometry (ES) quantifies nutrients (nitrogen (N) & phosphorus (P)) and identifies the role of elemental imbalances (e.g., C:N ratios) in shaping key ecological processes (e.g., food web dynamics)[3].

•The western black widow spider (*Latrodectus hesperus)* is a native urban exploiter that often forms dense subpopulations (i.e. infestations) across Phoenix. We have previously shown that these aggregations vary significantly in terms of prey abundance, spider body mass and population density, and that widow population ecology is well predicted by prey abundance[4].

•Here we examine the ES of black widows from urban habitat, desert habitat and a laboratory diet regime. We predict that

1. **Black widows will exhibit spatial variation in their nutrient composition across urban Phoenix.**
2. **Urban black widows will be more nutrient poor than desert black widows as a result of limited urban prey diversity.**
3. **Lab-reared spiders (fed a single-species diet) will be more nutrient poor than a) field-caught spiders, and b) lab-reared spiders allowed to cannibalize conspecifics.**

METHODS

Field Collection

•Widows and potential arthropod prey were collected from 10 urban sites within Phoenix, AZ in Sept. 2010 (Fig. 1a) and 5 urban sites and 5 desert sites across AZ in Sept. 2011 (Fig. 1b).

Lab Diet Treatment

•Nineteen F1 lab-reared adult spiders were fed lab-reared crickets (*Gryllodes sigillatus*) for 4 weeks. Cricket prey were fed a nutrient-rich diet.

•After these 4 weeks, 9 spiders were switched to a diet of one conspecific per week for 4 weeks and the remaining spiders continued on the cricket-only diet.

•One week later spiders were subject to nutrient analysis (see below).

Nutrient Analysis

•Samples were stored at -20°C and then dried at 60°C for 120 hours.

•A Perkins-Elmer 2400 CHN analyzer was used to obtain % C and % N. Acid microwave digestion and an inductively coupled plasma optical emission spectrometer were used to obtain % P.

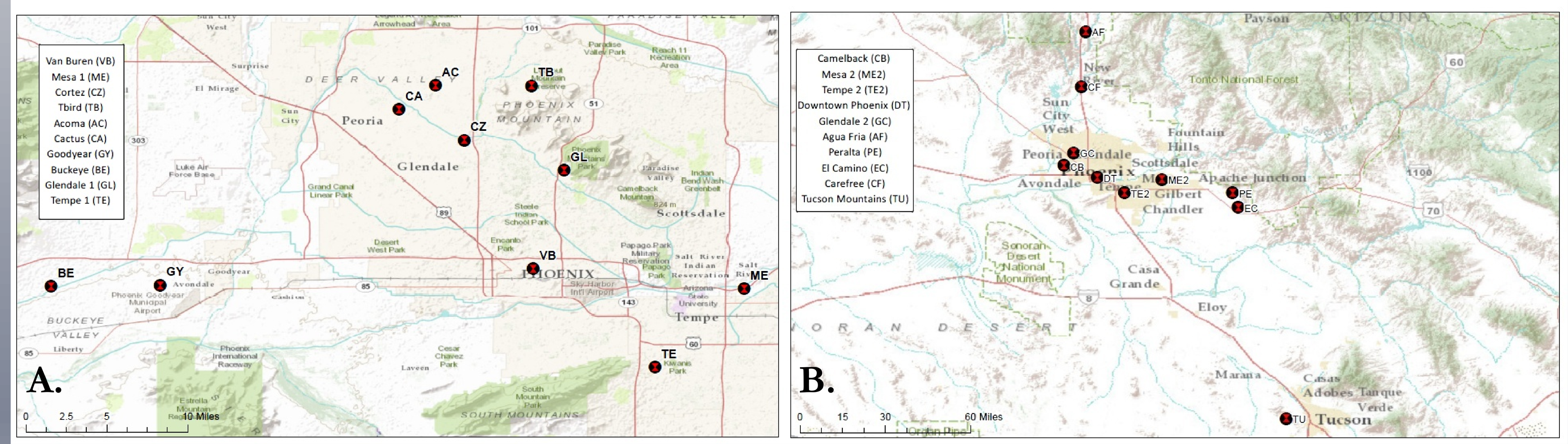

Fig. 1 Collection sites **A.** across urban Phoenix in 2010 and **B.** urban and desert sites in 2011.

RESULTS

We pooled urban sites sampled in 2010 and 2011 because they did not differ significantly in C:N, C:P, or N:P (all p>0.1). Spider C:N ratios did not differ significantly between urban and desert habitats ($F_{1,142} < 0.001$, $P = 0.988$). Therefore, we pooled urban and desert sites and found significant C:N spatial variation across these 20 sites (Fig. 2). In contrast, desert spiders were significantly richer in P than urban spiders (see Fig 3b and 3c). Urban black widow biotic population parameters measured previously[4] (e.g., prey abundance, spider mass & population density) were poor predictors of urban black widow stoichiometry (all p>0.1). In addition, prey stoichiometry in field- and lab-fed diet treatments proved to be a poor predictor of black widow stoichiometry in those treatments (all p>0.1).

Lab-reared spiders fed solely on lab-reared crickets were more nutrient (N & P) limited than field-captured spiders (urban & desert) that fed on available field prey (Fig. 3). Cannibalism supplementation for this lab-reared spider group did not relax N limitation (Fig. 3a). In contrast, cannibalism supplementation significantly relaxed P limitation (C: P--$F_{3, 159} = 26.24$, $P < 0.001$; N: P--$F_{3, 163} = 19.52$, $P < 0.001$) to levels seen in field-caught, urban spiders (Fig. 3b, c).

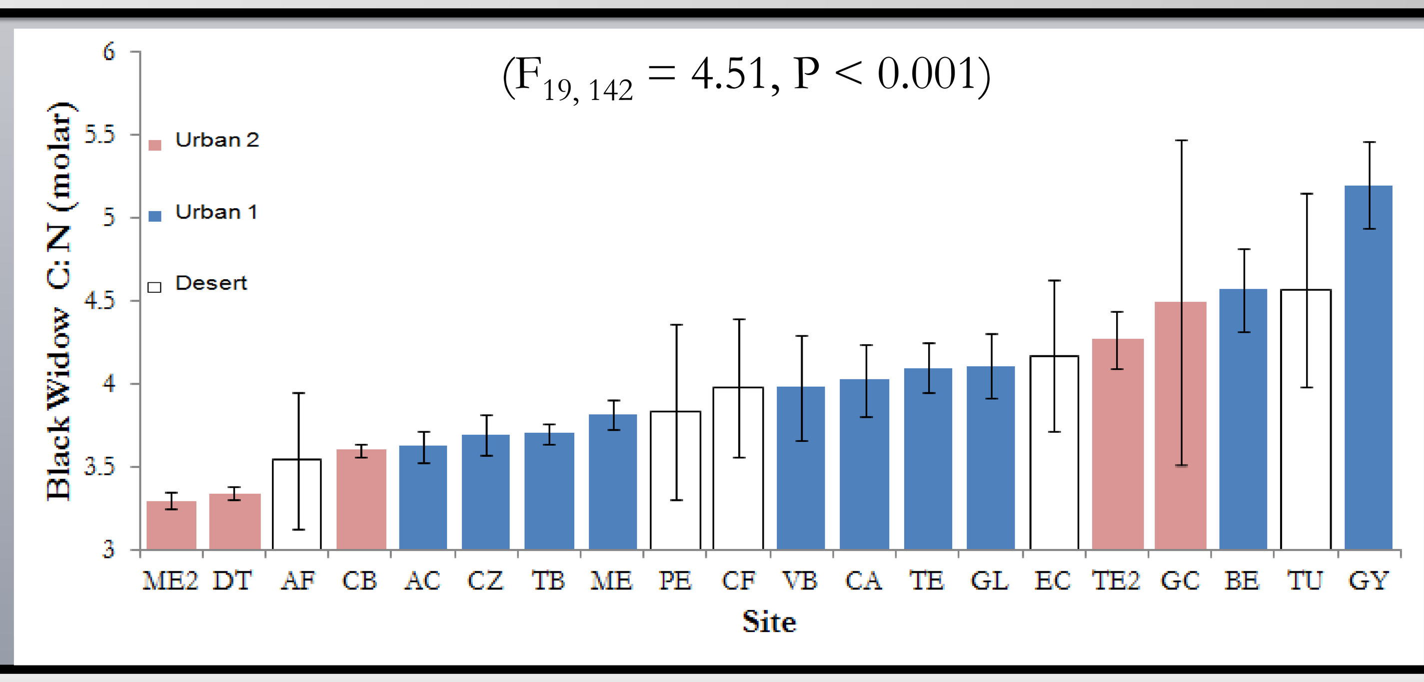

Figure 2. Spatial variation in C:N ratios among black widow spiders from 2010 and 2011 across urban and desert habitats (N = 2-14 females/site). Values represent mean ± se. For site location see Fig. 1.

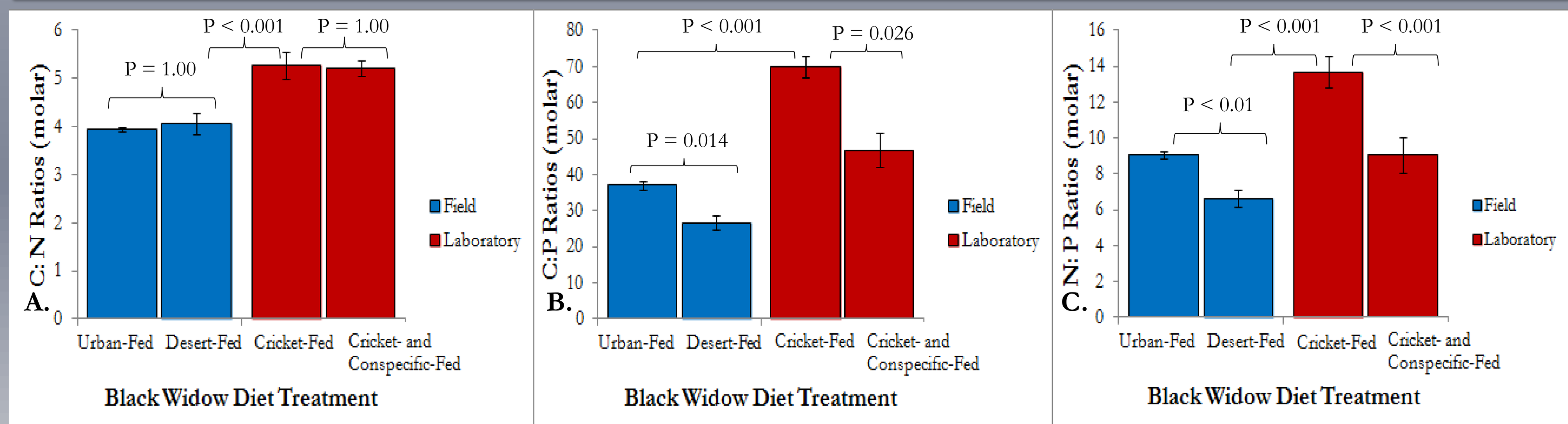

Figure 3. Diet treatment influences black widow stoichiometry in the field and laboratory **A.** C:N ($F_{2, 133} = 17.218$, $P < 0.001$), **B.** C:P($F_{1,129} = 27.584$, $P < 0.001$) and **C.** N:P ratios ($F_{2, 138} = 29.451$, $P < 0.001$). Values represent mean ± se.

DISCUSSION

•Urban widow aggregations exhibit strong spatial variation in C:N ratios, similar to the heterogeneity we have shown previously in widow population ecology parameters[4]. Thus, urbanization (habitat fragmentation) can yield high levels of spatial complexity that influence the organisms that surround human habitations.

• Desert spiders proved to be significantly more P-rich, but not N-rich than urban spiders. Thus, urban spiders may face strong P-limitation. Recently, dietary P in invertebrates has been linked to fitness-related traits such as growth rate and reproduction[5,6,7,8].

•Cannibalism may be a behavioral mechanism that allows widows to cope with P-limitation in urban habitats. Thus, population growth of P-limited, urban spiders may be restricted to the extent that P-limitation both a) limits spider growth, survival and reproduction, and b) promotes cannibalism.

•Deviation from a strict elemental homeostasis may allow for black widows to thrive (e.g., infestations) in urban ecosystems despite potential nutrient constraints (e.g., reduced prey diversity). Future work should search for adaptive explanations for ES variation in widow infestations across urban sub-habitats.

• Our integration of ES and urban ecology provides novel insights into the mechanisms driving urban exploiter populations. By identifying such mechanisms we can better control and/or manage urban pest populations and develop sustainable development practices.

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