Review of the PhD Dissertation "Abiotic and Biotic Processes Shape Species Distributions and Ecological Communities Across Spatial Scales" by Sarah Amundrud

I. Scholarly Merit

Robert MacArthur, arguably the father of modern community and theoretical ecology, articulated a vision in his 1972 book "Geographic Ecology" in which community ecology was an integrative science that blended two ecological scientific enterprises—the study of local interactions among species within communities (process), and the study of species' geographic distributions and abundance (pattern)—in order to predict how process generates patterns of community structure and dynamics. Sadly, modern community ecology has drifted to become largely disintegrated into silos, subdivided between studies of local process or of geographic pattern, with limited exchange between the two enterprises. This siloing was instigated by recurring debate beginning in the 1990's about the merits of taking one or the other singular approach. The strongest arguments against studying local processes was that the insights would come from many, small scale, local experiments which would inevitably mire us in contingency with little hope for gaining general understanding of what shapes broad scale patterns.

This dissertation successfully makes a novel and refreshing contribution to knowledge by embracing both scientific enterprises. It rigorously shows how to productively re-integrate community ecology. The dissertation presents a coherent body of research that reveals how one can use an understanding of broad scale pattern to motivate mechanistic experimental research of process among different locations. These local experiments together enhance understanding of the processes underlying spatial variation (i.e., contingency) inherent in broad scale pattern. The dissertation essentially puts a modern spin on what was classically done in MacArthur's era: use natural history observations to inspire mechanistic experimental research where, in the case here, geospatial "Big Data" analyses become the natural history for the digital age that identifies the pattern in need of mechanistic explanation.

The research focuses on a group of insect species that are important drivers of food web interactions. There is a great demonstrated command of the species' natural history, thus rooting the work in real biology. The research explores how different biophysical conditions along environmental gradients (elevation, temperature, precipitation) influences species occurrences and strength of food web interactions. But while focused on a specific empirical system, the research is nonetheless contextualized within general, modern ecological theory and principles that motivate research in community ecology. The work thus reflects the larger field of inquiry and contributes insights in ways that help advance knowledge.

The methods used in the research run the gamut from sophisticated, advanced statistical analyses of geospatial data to rigorous multifactor, factorial field and laboratory experiments, including addressing recent calls to undertake the kind of logistically challenging transplant experiments advocated by evolutionary ecologists to resolve the adaptive basis for organismal performance in different local contexts. The methods are explained in exemplary detail, which is to say that the reader can understand how the research was executed, as well as understand (based on careful explanation) the limitations of the inferences that can be made based on constraints (due to data limitations or field site conditions) on how the research could be executed. The demonstrated command of each of the methods and their limitations is impressive. This is especially noteworthy given that it is a tall order indeed to become expert in just any one of the methods used. It is rare indeed to see the breadth and scope of this kind of research accomplished in a PhD dissertation. And testimony to the rigor of the work is the fact that most of the chapters are already published in excellent peer-reviewed journals in ecological science.

The dissertation as a whole is clearly written using an engaging style that presents a compelling and coherent story on how to conduct scientific research in ways that are well-justified and integrated into the larger field of knowledge. The work provides leading advances in current understanding of how process—spatially contingent food web interactions—determines patterning across spatial environmental gradients. The dissertation adheres to the highest professional standard. By this I mean that (i) it is motivated by relevant, modern theory, (ii) it explains clearly how that theory is being evaluated via different data analyses; (iii) the research carefully weighs alternative explanations for the processes and patterns observed; and (vi) the inferences do not go beyond what the evidence shows. This is a highly successful PhD Dissertation.

II. Recommended revisions.

I have no recommended revisions.

III. Overall Recommendation.

I recommend that the candidate proceed to oral defence.

a) ~~Only minor~~ No revisions are needed.

Oswald Schmitz

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Questions for oral defence

1) It could be argued that your conclusion about scale dependence—i.e., that biophysical environmental variables influence species distribution at regional scales, and biotic interactions influence distribution at local scales—is simply idiosyncratic to your study system, and not general. For instance, one could argue that if one examined large migratory mammal species, biotic interactions and abiotic conditions do not vary hierarchically across geographic space.

Defend the rationale for taking the hierarchical approach you did and how and why it can lead to general insights.

2) In chapters 4 and 5 you conducted multifactor experiments to evaluate the role of one environmental factor—drought presence/absence and duration—on community structure—which in some sense enables you to generate a statistical response surface (characterizing a gradient) for the interaction between drought and predation effects. It would be altogether possible to calculate interaction strengths along a drought gradient with those experimental data, as well as link that interaction strength to the climatic conditions along the altitudinal gradients on the Atlantic and Pacific side of the study area.

Why didn't you then create a species distribution model using the interaction strengths—aka, a trophic interaction distribution model (*sensu* Trainor and Schmitz 2014 Ecology Letters)—to characterize the role of predation and drought in shaping species occurrence and structure of the community along the two altitudinal gradients? You could have then compared that with predictions based on observational data and path analyses conducted in Chapter 3 to see if there is internal consistency in your dissertation. This gets at my argument in Q1 that biotic and abiotic factors may not necessarily operate hierarchically but instead may covary.

3) Your research approach was to characterize broad scale patterns using statistical analyses of geospatial occurrence data combined with climatic variables. You then conducted experimental research to understand some hypothesized mechanisms that might explain the pattern. One could argue, however, that stronger inference could have been derived if you had (i) used natural history understanding to motivate the mechanistic experiments; (ii) used response-surface experimental designs to understand how species interactions vary in strength and consequently how community composition covaries across experimentally-imposed environmental gradients, (iii) use the experimental insights to <u>predict</u> the pattern of species occurrences you'd expect to see along the two altitudinal gradients and then (iv) do species distribution modeling to deductively test your predictions. This "bottom-up" approach would then allow you to identify a scaling principle that enables one to go from local contingency to the broad scale pattern.

Defend why you chose to take your more inductive "top-down" approach that is more descriptive of pattern and processes as opposed to the one described here that gets at deductive tests. In your answer explain also whether you did indeed identify a scaling principle and the degree to which that principle is scientifically defensible based on the research approach you took with your dissertation.