

## Chapter 5: Concluding remarks

This dissertation traverses the scope of a macroecological lens on community structure and dynamics, across three distinct organizational and spatial scales and contrasting methods of scientific inquiry. Chapter 2 focuses on the link between species interactions and community properties in a single system, using a long-running manipulative experiments to disentangle nuanced dynamics of compensation and competition. Chapter 3 uses modern advances in computational infrastructure and data-intensive ecology to perform an observational, data-driven synthesis of long-term biodiversity dynamics for communities across the continent of North America. Finally, chapter 4 steps beyond the traditional scope of ecology to apply theoretical approaches derived from statistical mechanics to understand the significance of ecological “laws”, using data from communities across the globe and tree of life.

Methodologically, these chapters leverage traditional methods in community ecology - community surveys, manipulative enclosure experiments, population trend monitoring - and combine them with the tools of modern data science to achieve large-scale synthesis. Building from the empirically-grounded Chapter 2, Chapters 3 and 4 use massive compilations of ecological data, and high-performance computational methods, to characterize general trends and phenomena in ecological communities at continental and global scales. These analyses are made possible by a rich and robust ecosystem of openly available and community-maintained ecological datasets and software packages, and have themselves generated R packages implementing new algorithms and data-generating pipelines to facilitate further advances in macroecology and biodiversity science. These methodological synergies are a promising path forward for the development of macroecology and community ecology in an increasingly data-driven world.

At a conceptual level, Chapters 2 and 3 illustrate how manipulative field experiments can spark questions that inspire larger-scale observational synthesis. The long-term dynamics of energy use, community-wide biomass, and community structure of the rodent community that is the focus of Chapter 2 parallel the interrelated long-term trends in total individual abundance, biomass, and energy use that are the subject of Chapter 3. The deep natural history basis of Chapter 2 affords mechanistic insight into the community and population-level processes that modulate community-level properties in a specific community, but cannot establish the generality of these phenomena extending beyond this system. As a complement to this system-specific work, Chapter 3 explores continent-wide trends in how individual abundance, biomass, and energy use fluctuate in bird communities across North America - but at the sacrifice of mechanistic insight into the processes driving these fluctuations. Chapter 4 demonstrates how community ecology stands to benefit from, and contribute to, conceptual developments drawn from the broad and rich fabric of complex systems studies. In applying the concept of a “statistical baseline” to understand the ecological species abundance distribution, Chapter 4 treats ecological communities as analogous to the complex systems more usually studied under the purview of physics or statistical mechanics. However, ecological systems present statistical challenges (“small-N” problems) that are not common in these more traditionally “complex” disciplines. By using novel sampling algorithms, and engaging directly with the statistical irregularities inherent to ecological communities, Chapter 4 begins to address fundamental questions about the nature and inferential power of emergent complex phenomena not restricted to ecology.

Separately, the vignettes presented here illustrate the value, and the limitations, of distinct approaches and scales of inquiry in community ecology. Combined, they demonstrate the unique conceptual and methodological insights gleaned through an integrative macroecological approach. Taken as a unit, this dissertation embodies a macroecology that is empirically grounded, intellectually adventurous, and poised to embrace the breadth and depth of analysis made possible by a cross-disciplinary and data-driven approach to biodiversity science in the 21st century.