Chapter 1: Introduction

The interplay between system-specific natural history narratives and ubiquitous ecological or even mathematical rules that combine to determine how abundance, biomass, and resource use are distributed among species and organisms and across different levels of organization in ecological communities lies at the core of community ecology (Brown and Maurer 1989, Lawton 1999). A macroecological approach integrates classic modalities of ecological inquiry with conceptual frameworks drawn from across the scope of complex systems studies to disentangle phenomena specific to particular systems from general phenomena that reflect processes that operate across diverse taxonomic, geographic, and temporal contexts (Brown 1995, McGill 2019). In this dissertation, I adopt a macroecological perspective to understanding the structure and function of ecological communities, working from a narrow, system-specific focus on a well-studied long-term experiment, to a broad taxonomic and conceptual perspective on the interplay between combinatorics, statistical mechanics, and community ecology.

In chapter 2 (Diaz and Ernest 2022 *in press*), I use 30 years' of accumulated data and natural history knowledge to explore the effects of species loss on community function in an experimentally manipulated desert rodent community. Understanding how community function responds to species loss, and how the effects of species loss interact with shifting environmental conditions, is a key problem for biodiversity science in the current era of unprecedented ecological change. In this system, compensation due to functional redundancy temporarily buffered community function against species loss (Ernest and Brown 2001). However, because similar, but non-identical, rodent species have responded differently to changes in environmental conditions over time, this compensatory effect has broken down, leaving community function highly sensitive to the loss of keystone species.

In chapter 3, I undertake a continental-scale comparison across communities to explore how shifts in community-wide body size modulate the long-term dynamics of individual abundance, biomass, and energy use in North American breeding birds. Although individual abundance and size and energy-based currencies are intrinsically linked, they capture different dimensions of community function, and shifts in community size structure can decouple the dynamics of different currencies (White et al. 2004, Petchey and Belgrano 2010, Hernández et al. 2011). I find that, in nearly 1/3 of communities, changes in the community size structure result in qualitatively different trajectories for biomass and total abundance over the past 30 years. As a result, while trends in individual abundance are dominated by declines, trends in total biomass are evenly split between declines and increases.

In chapter 4 (Diaz et al. 2021), I step further back to examine how fundamental mathematical constraints inform our understanding of ecological "laws". Common patterns in community ecology, such as the "hollow-curve" or J-shaped species abundance distribution (SAD), emerge from a combination of biological processes and ubiquitous mathematical constraints on the emergent properties of complex systems (Nekola and Brown 2007, Locey and White 2013). Disentangling the signal of ecological processes from these mathematical constraints can provide new sources of inferential power linking pattern to process in community ecology (Harte and Newman 2014). I use combinatorics to characterize the mathematical constraint on the SAD, and compare the SADs of 22,000 empirically-observed communities to these "statistical baselines". This reveals that, while empirical SADs often match their statistical baselines, a substantial minority of real SADs deviate from these baselines - leaving an important role for ecological processes in shaping these distributions.

References

Brown, J. H. 1995. Organisms and Species as Complex Adaptive Systems: Linking the Biology of Populations with the Physics of Ecosystems. Pages 16–24 *in* C. G. Jones and J. H. Lawton, editors. Linking Species & Ecosystems. Springer US, Boston, MA.

Brown, J. H., and B. A. Maurer. 1989. Macroecology: The Division of Food and Space Among Species on Continents. Science 243:1145–1150.

Diaz, R. M., and S. K. M. Ernest. 2022. Maintenance of community function through compensation breaks down over time in a desert rodent community. Preprint, bioRxiv.

Diaz, R. M., H. Ye, and S. K. M. Ernest. 2021. Empirical abundance distributions are more uneven than expected given their statistical baseline. Ecology Letters 24:2025–2039.

Ernest, S. K. M., and J. H. Brown. 2001. Delayed Compensation for Missing Keystone Species by Colonization. Science 292:101–104.

Harte, J., and E. A. Newman. 2014. Maximum information entropy: A foundation for ecological theory. Trends in Ecology & Evolution 29:384–389.

Hernández, L., J. W. Laundré, A. González-Romero, J. López-Portillo, and K. M. Grajales. 2011. Tale of two metrics: Density and biomass in a desert rodent community. Journal of Mammalogy 92:840–851.

Lawton, J. H. 1999. Are There General Laws in Ecology? Oikos 84:177.

Locey, K. J., and E. P. White. 2013. How species richness and total abundance constrain the distribution of abundance. Ecology Letters 16:1177–1185.

McGill, B. J. 2019. The what, how and why of doing macroecology. Global Ecology and Biogeography 28:6–17.

Nekola, J. C., and J. H. Brown. 2007. The wealth of species: Ecological communities, complex systems and the legacy of Frank Preston. Ecology Letters 10:188–196.

Petchey, O. L., and A. Belgrano. 2010. Body-size distributions and size-spectra: Universal indicators of ecological status? Biology Letters 6:434–437.

White, E. P., S. K. M. Ernest, and K. M. Thibault. 2004. Trade-offs in Community Properties through Time in a Desert Rodent Community. The American Naturalist 164:670–676.