Proposal - Ecosystem responses to escalating drivers: linking species interactions and resilience

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The intensity of human generated drivers, such as climate change, land use, defaunation, nutrient enrichment, and biotic invasions, is increasing, and the trend is likely to continue1. These drivers are heavily modifying the functioning of many of the ecosystems we depend on2. On the other hand, species in an ecological community form networks of interactions pivotal for the provision of ecosystem functioning, the provision of services, the maintenance of global biodiversity, and biogeochemical cycles3–6.

The overall objective of my research is to improve our current understanding of the ecosystems response to multiple anthropogenic drivers and their cumulative impacts. In particular, I will focus on the role played by species interactions networks in ecosystem resilience ---the amount of disturbance a system can withstand without entering a regime shift7.

Regime shifts are large, persistent changes in the function and structure of the ecosystem8---such as the (often sudden) shift from a transparent to a turbid lake, from a woodland to a grassy landscape, from a self-sustaining fishery to a collapsed one, or from a coral dominated reef to one dominated by algae9. A necessary step to anticipate, prevent and reverse unwanted regime shifts caused by drivers of environmental change, is to understand the processes that support or undermine resilience, and the role played by species interactions10,11.

Even though the effect of those drivers permeates across entire communities, our understanding of their impacts is mostly based on studies based on one or few species. In this research I will use a complex network approach, which recognizes that species that live within a community are connected through interactions. This approach---built upon tools from statistical physics and the social sciences---has been key in revealing structural patterns that go beyond specific ecosystems12–14. Using a combination of complex system theory, population models, resilience theory and published empirical data I aim to explore the mechanisms linking species interactions to ecosystems' resilience and environmental drivers of change.

I will use mutualistic plant-pollinator networks as my model system. Mutualistic networks are one of the most ubiquitous types of interaction and are critical for global food production and biodiversity maintenance15,16. Initially I will use biotic invasions as the environmental driver. Because of the paucity of empirical observations of network dynamics subject to invasions, I will simulate community-wide interspecies coexistence dynamics, and explicitly quantify the stability of the system from population fluctuations17,18. This approach will enable me to predict how the structural and dynamic characteristics of the network determine how easy it is to invade an ecosystem, and when invasions are likely to lead to a regime shift19–21.

Biotic invasions often occur on ecosystems that have already been degraded22. Using a similar methodology as for the species invasions driver, I will follow by studying how defaunation---from a functional perspective---affect the pre-invasion ecosystem resilience. Although some species (beavers for example) are functionally unique in the ecosystem, others are redundant in the sense that they contribute in similar ways to an ecosystem function23. Despite theoretical and empirical evidence showing that the degree of functional redundancy has major effects on ecosystem stability and species coexistence24–29, it is still unknown how diversity within functional groups affects ecosystem stability 20.

The final objective of my proposed research is to apply my results to ecosystem management. Recent work has shown / suggests? that it is possible to control complex networks by inducing perturbations that can compensate previous disturbances30. However, this approach has never been used in ecology. I propose to expand this method to find, for example, the minimum number of species that have to be directly managed to move the ecosystem from one state to another, or to rescue one ecosystem at the brink of failure. To do that, I will use empirical and simulated networks from ecosystems that have undergone a regime shift to evaluate the feasibility of such approach and its management consequences.

Over the last years I have been focused on studying the ecology of tropical marine organisms. Through my previous research I have witnessed how entire ecosystems transform due to human pressures. Understanding what makes ecosystems vulnerable, and how to prevent and revert those undesirable transformations---not only on marine ecosystems---became my primary scientific goal; I want to answer fundamental questions in ecology and ultimately improve the management of the ecosystems I love. I am aware that this is a long term goal, and it will likely guide my scientific career for the next decade. The support from the NZIDRS to my proposed PhD research is instrumental to reaching those goals.

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