Proposal - Anticipate, prevent and reverse ecosystem transformations: linking species interactions and resilience

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The frequency of undesired ecosystem transformations—like the (often sudden) shift from a transparent to a turbid lake, from a woodland to a grassy landscape or from a self-sustaining fishery to a collapsed one[1]— is dramatically increasing. Most of our current understanding of 'why', 'when' and 'how' these transformations occur are based on studies of one or a few species. However, species in an ecological community form a network of interactions that underpin ecosystem functioning, structure, and ultimately its response to disturbances[2–5].

Resilience is the amount of disturbance that an ecosystem could withstand without tipping into a regime shift—a large, persistent transformation in its functioning and structure[6,7]. A necessary step to anticipate, prevent and reverse those unwanted transformations, is to understand the processes that support or undermine resilience[4,8]. **The overall objective of my proposed research is to quantify the role played by species interactions in modulating ecosystem resilience**.

The intensity of drivers of ecosystem transformation—like climate change, land use, biodiversity loss, nutrient enrichment, and biotic invasions—is escalating, and the trend is likely to continue[9]. Even though the effect of those drivers permeates across entire communities, most of our understanding of the ecosystems response is based on studies of one or few species. Throughout my research I will use a complex network approach, which recognises that species actually live within a community and are connected to each other. This approach—built upon tools from statistical physics and the social sciences—has been key in revealing structural patterns that transcend specific ecosystems[10–12].

Because of its importance for the provision of ecosystem services and the maintenance of global biodiversity[2,13,14], I will focus on mutualistic interactions between plants and pollinators. The first objective of my research is to determine how the structural and dynamic characteristic of ecological networks determine the susceptibility to biotic invasions of an ecosystem—a significant component of human-caused global change[15]. I will use recently-developed simulation methods to model community-wide coexistence dynamics to explicitly quantify the ecosystem's stability from population fluctuations[16,17], and to determine when invasions are likely to lead to a regime shift[18–20].

Biotic invasions often occur in ecosystems that have already been degraded[21]. Also, theoretical and empirical evidence shows that the degree of species functional redundancy has major effects on ecosystem stability[22–27]. My second objective is to determine how biodiversity loss—from a functional perspective—affect the pre-invasion ecosystem resilience. To answer that question I will take advantage of my supervisor's access to over seventy empirical ecological networks. I will combine this empirical data with a theoretical approach. By comparing the role of species in invaded vs. non-invaded ecosystems, and before vs. after regime shifts, I will determine how diversity within species functional groups affects ecosystem resilience[19].

I will use a similar approach and combine it with theoretical for my third objective: to translate the gained insight into useful lessons for ecosystem management. Recent work in theoretical physics has highlighted the possibility of controlling a complex system, by inducing perturbations that compensate for previous disturbances[28]. Because this approach has never been used in ecology, I propose to build upon to to find how ecosystems can be managed to maximise resilience, rather than individual species. I aim to determine the feasibility of using this approach to modify an ecosystem state, or to rescue it from the brink of collapse.

Over the last years I have focused on the ecology of tropical marine organisms, and witnessed how entire ecosystems are transformed due to human pressures. Understanding what makes ecosystems vulnerable, and how to prevent and revert these undesirable transformations became my top scientific interest. I want to answer fundamental questions in ecology, and ultimately improve the management of the ecosystems I love. I am aware that this is likely to guide my scientific career for the next decade. The support from the NZIDRS is going to be instrumental to reach this goal.

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