Understanding ecosystem transformations: linking species interactions and resilience

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## Proposed research

From food and fresh water production, to recreation and carbon sequestration, ecosystems provide a wide range of services we value. When ecosystems transform, their ability to provide those services we depend on is undermined. The frequency of undesired ecosystem transformations---like the (often sudden) shift from a transparent to a turbid lake or from a self-sustaining fishery to a collapsed one---is dramatically increasing1. A necessary step to anticipate, prevent and reverse those unwanted transformations, is to understand the processes that support or undermine ecosystem resilience2,3.

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 structure4,5. Ecosystem functioning, structure, and ultimately its response to disturbances is largely determined by the network of interactions formed by species in an ecological community3,6–8. **Therefore, the overall objective of my proposed research is to quantify the role played by species interactions in modulating ecosystem resilience**.

Because of its importance for food production and the maintenance of global biodiversity6,9,10, I will focus on the network of mutualistic interactions between plants and pollinators. Biotic invasions are a significant component of human-caused global change11 The first objective of my research is to determine how the properties of the networks determine the susceptibility of an ecosystem to biotic invasions. I will use a combination of complex network theory---built upon tools from statistical physics and the social sciences---and dynamic models of the populations of the species in the community12,13. This approach will allow me to to determine when invasions are likely to lead to a regime shift14–16.

Biotic invasions often occur in ecosystems that have already been degraded17. Also, theoretical and empirical evidence shows that the degree of species functional redundancy has major effects on ecosystem stability18–23. My second objective is to determine how biodiversity loss---from a functional perspective---affects the resilience of an ecosystem. To answer that question I will extend the theoretical models I will develop and contrast them with previously collected empirical data. I will compare the role of species in invaded vs. non-invaded ecosystems, and before vs. after regime shifts. I aim to to quantify how ecosystem's resilience changes due to the structural and dynamic changes generated by the loss of species and invasive species. In turn, I will be able to determine how diversity within species functional groups affects ecosystem resilience15.

I will use a similar approach 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 disturbances24. Because this approach has never been used in ecology, I propose to build upon it to find how ecosystems can be managed to maximise resilience, rather than managing for 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.

## Impact

It has been recently shown that the architecture of networks of species interactions is essential for the maintenance of global biodiversity and ecosystem functioning, and therefore it can mediate the respose of ecosystems to disturbances12,25–28. However, very few studies have investigated the link between species interactions and reslience16,29. My proposed research aims to improve our current understanding of the ecosystem responses to multiple anthopogenic drivers and their cumulative impacts. In particular, I will quantify the role played by species interactions in modulating ecosystem resilience.

To answer those questions, I will center on model systems and drivers that have global relevance, but are particularly important for New Zealand. Specifically I will focus on 1) mutuallistic plant-pollinator networks which are of tremendous importantance for the maintenance of biodiversity and production of crops9,10; and 2) biotic invasions and defaunation wich are top components of human-caused global change for which New Zealand has both suffered and remains notably vulnerable11. About two thirds of New Zealand plants are pollinated by birds or insects. Moreover they are responsible for the pollination of iconic native plants (like kowhai and pohutukawa), and economically important crops (like kiwifruit, apples and grapes). This implies that New Zealand flora is particularly vulnerable to declines in pollination services30, and those services have already been distorted by the introduction of foreign bees31 and the population depeltion of native birds32,33. Also, in contrast with other locations, pollination networks in New Zealand are dominated by generalist species34,35---plants that attract a wide range of pollinator species, and pollinators that visit a wide range of plants. My proposed research will help elucidate how this structural differences are reflected on the resilience and stability of New Zealand's pollination systems when considering that original ecosystems have been changed by invasive species. Understanding how invasions interact with defaunation in ecological networks is a global research priority, and essential for conserving, restoring and managing New Zealand ecosystems30.

The results of my research will also have direct application to ecosystem management, and in the future clear conservation benefits not only for New Zealand, but also ecosystems elsewhere. For example, the introduction, and posterior invasion, of stoats in New Zealand was an expensive mistake in which species interactions were not taken into account. What is more, although we know the effects of this invasion on iconic native species, we currently do not understand how the changes on ecosystem dynamics is affecting the resilience of the ecosystems as a whole. The research I propose intends to establish a general theory neccessary to answer this question. This is particularly important when the ecosystem response might be inconspicous until transformation is inminent. By better understading the dynamics behind species interactions, we will hopefully be better prepared to anticipate, prevent and reverse unwanted ecosystem transformations.

My PhD will take place at [Dr. Daniel Stouffer's lab](http://www.stoufferlab.org/)---a Rutherfurd Discovery Fellow at the University of Canterbury. His interdisciplinary research group is very active internationally and regularly receives visiting scientists. To mention some, current collaborations include scientist from the Universidade de Sao Paulo (Brasil), the Ecole Normale Superieure (France), and the University of Queensland (Australia). My proposed project also aligns nicely with the interests of several highly cited researchers with whom collaborations might be very advantageous: [Jason Tylianakis](http://www.tylianakislab.org/) (University of Canterbury), [Jordi Bascompte](http://www.bascompte.net/) (University of Zurich), [Martin Scheffer](http://www.sparcs-center.org/) (Wagenigen University), and [Carl Folke](http://www.stockholmresilience.org/21/contact/staff/1-15-2008-folke.html) (Stockholm Resilience Center).

With your support, I will tackle fundamental, globally important, ecological questions that are of especial relevance for New Zealand's natural heritage and agricultural sector.

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