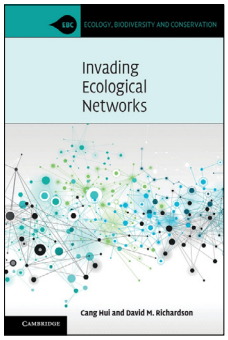
BOOK TITLE:
Invading ecological networks



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Attacking the role of invasion in ecology: A holistic approach

This book is a *tour de force* of invasion science and to some extent the entire science of understanding ecology through the interplay of ideas and empirical studies mediated by models. Ecological systems are clearly complex entities with interrelated components. The authors take the non-reductionist approach of studying ecology through the lenses of network analyses. In this they focus on biological invasions. While I was very aware of the relevance of invasion biology and especially that of alien invasions, I tended to view the latter as an important evil to be avoided. Hui and Richardson place invasion science firmly as a central player in current ecological systems as almost all are affected by the biological invasions brought on by the dominant presence of *Homo sapiens*.

The authors "view 'ecological networks' as entangled webs of distinct, interdependent, and complex biotic interactions among co-occurring species in a landscape". While this approach appears obvious, biological invasions are often researched in a straightforward progression of introduction, establishment, and spread. This book develops modern network and complexity science to consider invasions more holistically. For this approach, ecosystems are modelled as open adaptive networks with states governed by multiplayer eco-evolutionary games. The authors stress that it is not a textbook but rather a 'cloud atlas' to the study of invasion science, which I take to mean a guide to methods toward any successful understanding of the subject. This claim might appear somewhat ambitious or even arrogant, but they definitely make a strong claim to having provided an atlas for the study of invasion science.

Chapter 1 covers the key concepts basic to understanding biological invasions. Here the foundations are set as to why a more comprehensive approach is necessary. Chapter 2 introduces the importance of using network approaches for studying these systems. Described is an understanding of ecosystems as a group of entities in a type of game of survival. These entities exist in different states, but at the most basic, the individual strives to survive and pass on its genetic material. As there are many players, this requirement depends on each individual having strategies to optimise their survival when in competition or cooperation with others. The chapter maps out how these strategies can be studied as scenarios of multiplayer games and using network science. Using standard mathematical methods developed mostly around differential equations, but applied to the network, the stability of the system can then be assessed toward an understanding of the coexistence and invasions between species in an ecological system. Chapter 2 is titled 'Relentless Evolution' and the breadth of the methods is a relentless coverage.

Chapter 3 covers in what way networks assemble. A lot of knowledge has been developed in the past decades around how real-world networks evolve and function. For ecological systems, the chapter highlights the importance of three network types: competitive, antagonistic, and mutualistic. Mutualism tends toward nested networks and antagonism toward compartmentalised networks and this framework of network structure leads onto Chapter 4 where the dynamics that play out are described. Chapter 3 also covers in what ways networks emerge.

Chapter 4 describes how the stability of complexity networks can be applied to ecosystems and especially how invasions can disrupt stability driven dynamics. First, the authors point out the importance of viewing ecosystems as open adaptive systems rather than superorganisms to avoid the danger of applying evolutionary concepts to these superorganisms. This approach then allows for the application of a theoretical framework based on complex adaptive systems to consider ecosystems and their stability. Structural stability is considered by measuring the possible persistence of the system when removing or adding species. Invasions can disrupt ecosystem stability toward a new state or an unstable state and ultimately collapse. Large changes can result from small invasions if at some critical point. Chapter 4 offers much greater detail to the theoretical methods used to study these complex systems and a strong case is laid out to support the view of ecosystem networks as a 'jammed complex system self-organised at marginal instability due to the flow from biological invasions and resulting species extinctions'.

Chapter 5 goes into the difficulty of predicting future ecosystem states and dynamics with different possible ways to attempt prediction presented. The authors present a novel method to measure the short-term direction of an ecosystem, again using the dynamical systems analyses of differential equations. A counterintuitive result from this chapter is how rare species might control resilience of the system, with some evidence from actual ecosystems. I think this is overstated but am happy to be corrected by the authors. However, overall, this chapter describes how common and rare species can drive the system in various ways.

Chapter 6 discusses how biomes dominated by alien species emerge. This chapter also considers how spatial and temporal scales can affect network structure and stability and how propagation by dispersal affects the stability and dynamics of meta-networks. Chapter 7 summarises and pulls together a lot of the concepts of the book.

As I stated at the start, this book is a *tour de force* of the subject. However, as such, it is rather overwhelming. Many aspects of nonlinear mathematics and science are touched on. While I, over many years, have studied a lot of the mathematical theory presented, it is daunting to see it applied in so many ways to a particular, if complex, question in science. The authors themselves suggest at the end of Chapter 5 that the reader might be a bit giddy by this stage (as Alice in her Wonderland was). I certainly was. They suggest staying the course. For an ecological scientist this could be good advice. For the general reader, I would suggest picking out what they can from the many interesting ideas, and if giddy happily go back up 'the rabbit hole'. Without a doubt, the book clearly shows the importance of invasion biology for the planet and its inhabitants.