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Kotschy, Karen Ann

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Biodiversity, redundancy and resilience of riparian vegetation under different land management regimes

by

Karen Ann Kotschy

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Abstract

Biodiversity is widely thought to enhance resilience in ecosystems by providing 'insurance' which buffers the effects of disturbances on ecosystem functioning. However, little empirical evidence is available to support this assumption. Biodiversity and resilience are both complex, multifaceted concepts, and the mechanisms underlying the relationship between them are far from clear. However, understanding this relationship is important because resilience underpins the ability of ecosystems to continue to provide essential 'goods and services' in the face of increasing human pressure and an uncertain future.

In this thesis I address two properties thought to be important in determining the resilience of ecological assemblages, namely functional redundancy (similarities in ecological functioning between species) and response disparity (differences in species' responses to disturbance). Both are related to biodiversity, being determined by the degree of similarity or difference among the species in an assemblage. After developing a conceptual framework for understanding the relationship between biodiversity and resilience, I provide a critical evaluation of existing methods for measuring redundancy and response disparity, and develop measures of these two properties that better reflect the continuous, multidimensional nature of differences between species. A key element of my approach is the use of different sets of functional traits to describe individual species' contributions to different ecological functions. This is valuable because it explicitly recognises that species have multiple functional roles, an obvious fact that is often overlooked and a source of much misunderstanding about redundancy and disparity. I then use these methods to measure redundancy and response disparity in riparian plant assemblages from different–sized streams and under different land management regimes, providing some of the first empirical evidence for these aspects of resilience in real, species–rich assemblages. In particular, I provide the first empirical confirmation of two hypotheses about the roles of redundancy and response disparity in the resilience of plant assemblages, namely (1) that minor species in the tail of the abundance distribution provide redundancy for functions performed by the dominant species, and (2) that groups of species that provide redundancy for each others' functioning differ in their response traits, thus providing response disparity (Walker *et al.*, 1999, *Ecosyst.* 2:95–113).

This thesis also contributes to our understanding of the effects of land management practices on the resilience of riparian systems, something which is poorly understood but of critical interest to conservation and land managers. Ecosystem–based approaches to management place emphasis on maintaining desirable functioning in ecosystems. However, often it is very difficult for managers to assess whether this is being achieved (the 'manager's dilemma'). The resilience measures developed here are valuable because they provide a measure of the long–term sustainability of the various functions performed by species assemblages.

Both redundancy and response disparity were present in the riparian assemblages studied. Species in the tail of the abundance distribution were particularly important providers of redundancy. These tail species, often inadequately sampled or left out of functional diversity analyses, provided 53–100% (mean 82%) of the redundancy for the functioning of the more abundant species. For most functions performed by a particular species, between 5 and 20 other species were potentially able to perform that function in a similar way, thus providing redundancy. However, all assemblages also had species (1–40%) with low redundancy for one or more functions, suggesting that certain particular aspects of functioning may lack resilience, even in assemblages with high overall resilience.

Species providing redundancy for a particular function were seldom very similar in their contributions to other functions. Functional 'analogues' (species identical or very similar in all functions) were relatively uncommon (42–71% of species across different management regimes and stream sizes had no analogues for the small number of functions studied, and this number was shown to increase with the number of functions considered). Redundancy was usually provided by a large number of *partially similar* species rather than by a few identical species. Redundancy and disparity were therefore simultaneously present in each assemblage, because each species contributed both to redundancy (for some functions) and disparity (for others). This suggests that the commonly held view of redundancy provided by 'identical copies' is far too one–dimensional, and successfully lays to rest the debates about its existence and the concerns that promoting redundancy will somehow be detrimental to diversity. I therefore propose that it is time to put redundancy back on the research agenda as an important aspect of functional organisation which leads to resilience.

The highly distributed nature of redundancy, involving many partially similar species, also has important implications for our understanding of change in ecosystems. It means that functional compensation will seldom be a simple matter of species replacing each other as 'drop–in replacements'. Rather, compensatory changes in species composition or abundance will have knock–on effects that affect many other species and lead to many 'readjustments' in species' functioning, responses to disturbance, interactions and abundances. The results of this study have shown that the way changes in species composition or diversity affect resilience are often idiosyncratic, depending on which particular species are involved. It is therefore not appropriate to try to model the impacts of changes in biodiversity on ecosystem resilience deterministically.

However, ecosystem managers require information about resilience to implement ecosystem–based management. This information needs to be simple enough to be useful, but flexible anough to account for the fact that idiosyncratic species effects frequently make considering the details of a particular situation unavoidable. In this thesis I outline an approach that involves the judicious use of generalisations together with a flexible means of combining compositional, functional and resilience perspectives on species assemblages, allowing exploration of the relationship between diversity and resilience in a particular system. This approach is more flexible, and allows a wider range of questions to be addressed, than commonly used approaches using indices of diversity or ecosystem health. Rather than summarising a large amount of detailed information in the form of an index, my approach retains the detail but concentrates on making it easier to interpret. This provides a flexible way of using the detail to answer specific management questions, thus increasing its usefulness to managers.

The finding of a generally positive relationship between redundancy and species richness in this study is a useful generalisation for managers trying to implement an ecosystem–based approach to conservation and land management. It suggests that, in general, maintaining species–rich assemblages will tend to maintain redundancy. However, this relationship varied with growth form (woody vs herbaceous), stream order (small streams vs main river) and the function being considered. The amount of redundancy and response disparity associated with each species for each function were also highly variable, pointing to the need to use generalisations with care.

Comparison of assemblages under the different land management regimes (Kruger National Park, privately–owned reserves and communal rangeland) suggested that management practices in river catchments do affect the resilience of riparian vegetation, but not always in the manner expected. Management practices in the conservation areas did not necessarily promote higher diversity or resilience than management practices in the communal area, which may come as a surprise to many conservationists. While assemblages from the main river were less resilient in the communal area than in the reserves, assemblages from the small streams were more diverse and resilient than those in the reserves, even though communal rangeland areas are not managed specifically for biodiversity conservation. Far from being 'degraded' as is usually assumed, small streams within these communally managed areas are in fact valuable as biodiversity hotspots, and this should be reflected in conservation planning and ecosystem service assessments in the region.