Empirical modelling and a revised community assembly framework for predicting climate change impacts on plant communities

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Background & Aim: An emerging impact of climate change is altered species composition in ecological communities. Accurate forecasting of species composition is important for prioritising the conservation of vulnerable communities, and for devising de novo species composition in revegetated landscapes to promote resilience. Spatial climate gradients can be used as analogues to model temporal climate change and predict future composition. The simplest types of such models are based on species sorting: the concept that species occurrences are determined to some degree by the environment and can be predicted from redistributed climatic variables. This approach is powerful because species inventory data are readily obtainable. Here, I present recent empirical examples that measured climatic influences on spatial and temporal variation in plant community composition and function, and develop a predictive framework for plant communities under climate change that relaxes some of the unrealistic assumptions of species sorting.

Materials & Methods: Plot-based datasets from the Mount Lofty Ranges and Flinders Ranges regions of southern Australia were used to evaluate the influence of climatic gradients on species composition, while controlling for confounding geographic factors. Compositional, spatial and environmental data were analysed using ordinations and regressions where ordination axes (representing composition with reduced dimensionality), pairwise dissimilarities or multivariate species occurrences were the response variables. Purely spatial influences on composition were accounted for by the inclusion of geographic distances or their principle coordinates as spatial covariates. Phylogenetic correlations to environmental variables were also assessed. In parallel, leaf traits in *Dodonaea viscosa* (*Sapindaceae*) were investigated across the same gradients. These studies and the wider literature informed the development of a quantitative model of plant community composition under climate change that has more realistic assumptions than species re-sorting.

Main Results & Interpretation: The community level analysis quantified the influence of climate on composition, which suggested that climate change will drive significant species and phylogenetic turnover. Observed turnover along spatial climate gradients involved ecotones between mesic and arid habitats suggesting that there are climate tipping-points. However, when these spatial climate models are applied to temporal change, they assume that a static set of species, with fixed traits and responses, are available to be re-sorted. These assumptions are flawed – or at least imperfect – due to species introductions and extinctions, and phenotypic variation. For example, leaf traits within *D. viscosa* varied significantly and were correlated with spatial and temporal climate gradients. Recognising the limitations of spatial models for predicting future composition, I propose a framework in which shifting environmental constraints on mean community traits can be broken down into intraspecific components (i.e. phenotypic variance/clines) and interspecific components, including changes to relative species abundance, and species replacement from a shifting species pool (Guerin et al. 2014). Basing predictions of composition on community metrics, rather than the sum of predictions for individual species, reduces complexity, is more realistic in its assumptions, and allows ecosystem function to be predicted independent of future species pools.

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Guerin, G.R., Martín-Forés, I., Biffin, E., Baruch, Z., Breed, M.F., Christmas, M.J., Cross, H.B. & Lowe, A.J. 2014. Global change community ecology beyond species sorting: a quantitative framework based on mediterranean-biome examples. *Global Ecology and Biogeography*. doi:10.1111/geb.12184

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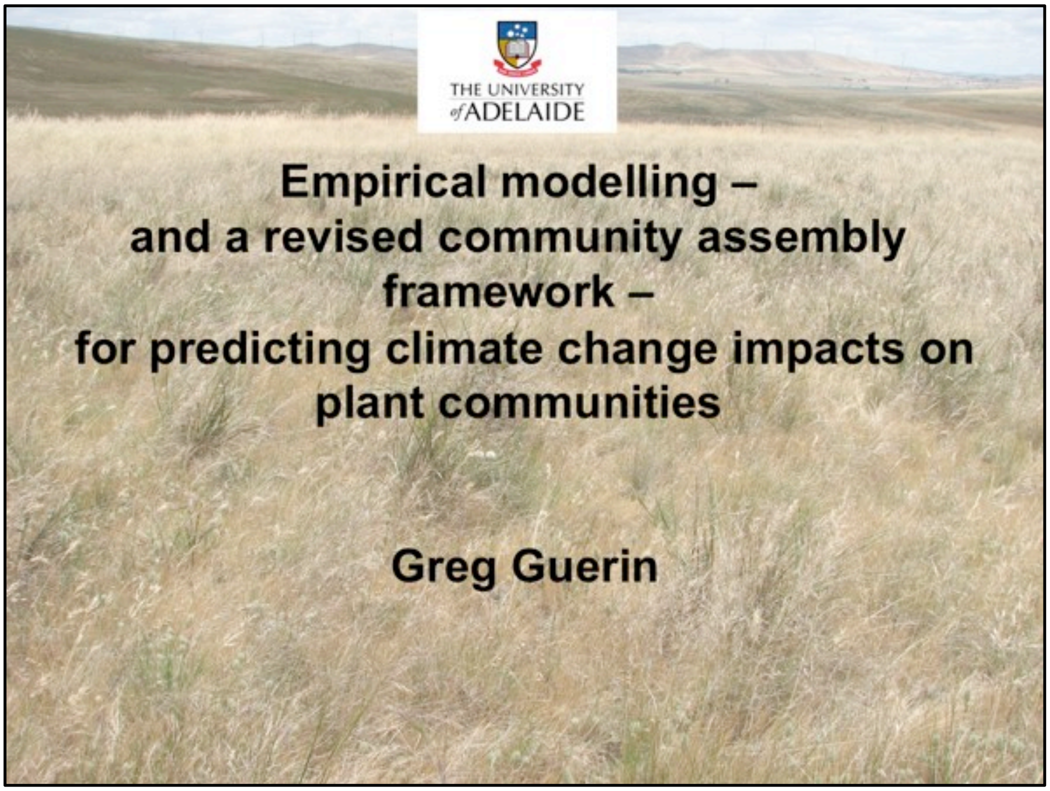

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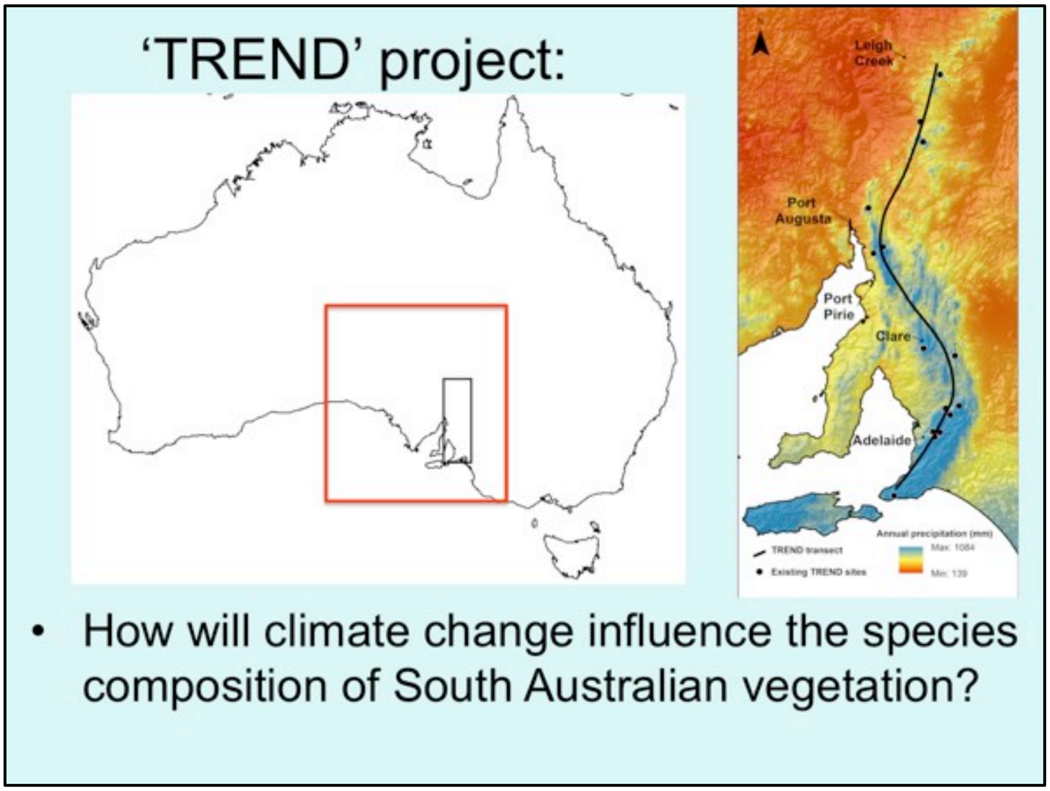
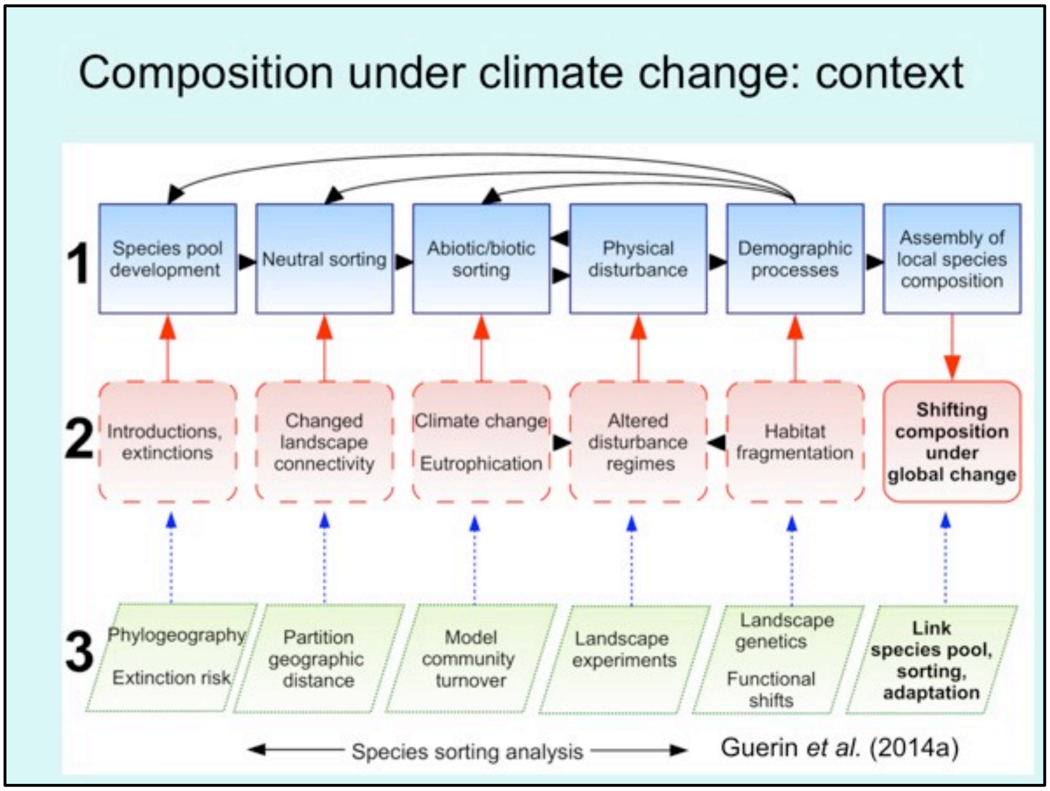
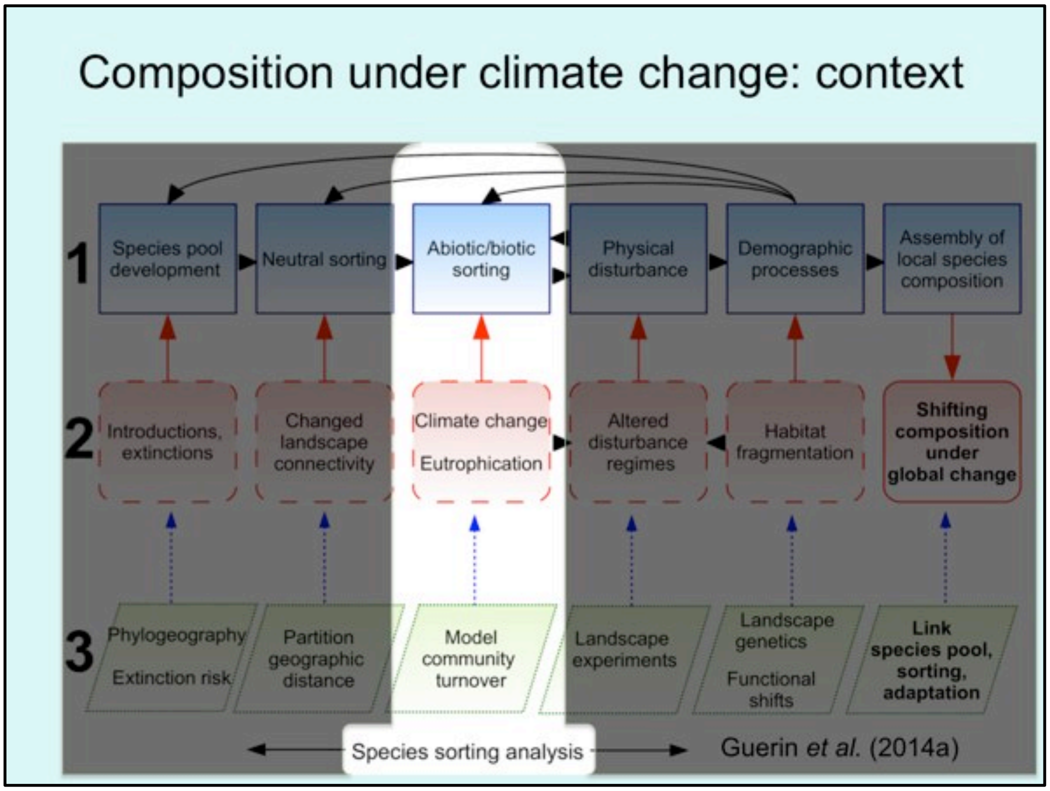


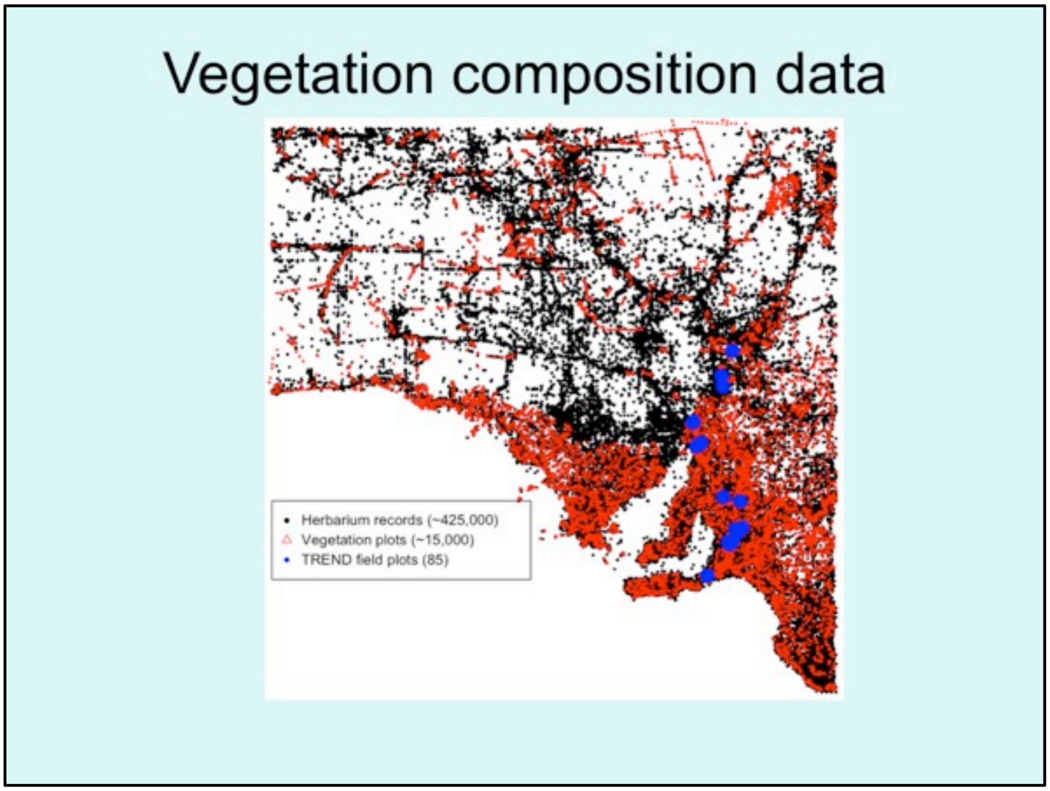
These examples came out of the ‘TREND’ project: Transects for Environmental Monitoring and Decision Making. Analysis concentrated initially on a north-south transect along the Mount Lofty and Flinders Ranges, with expansion to the state of South Australia



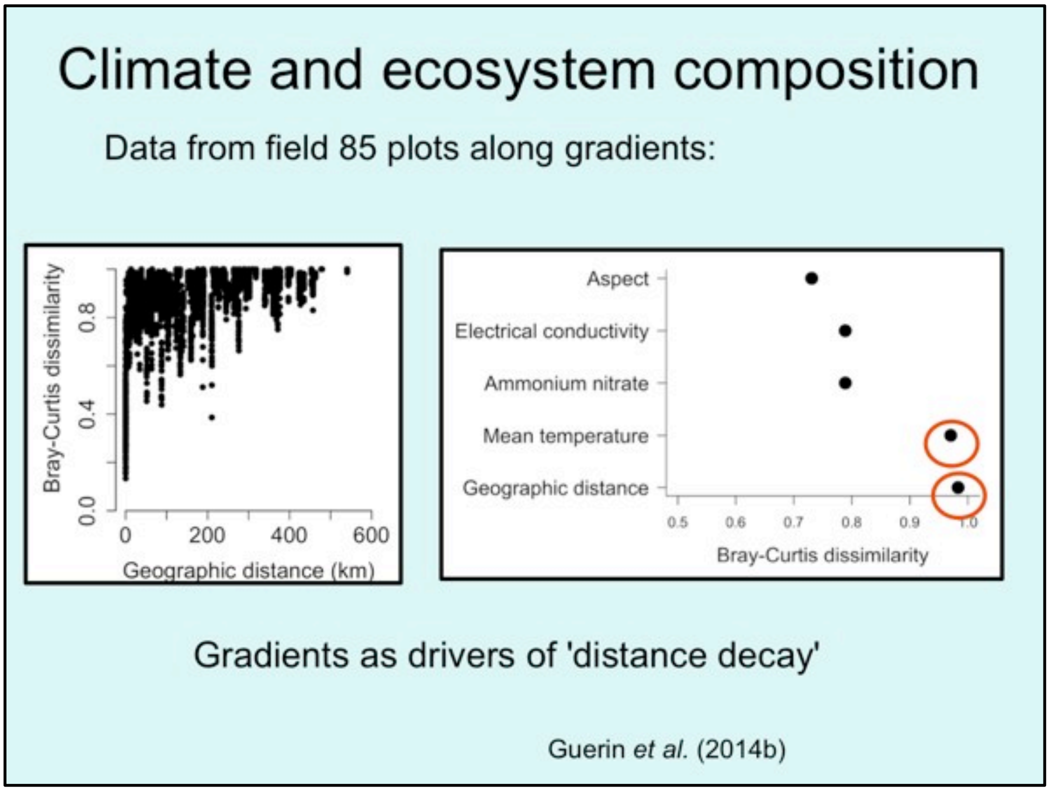
Many things influence the set of observed species in a given habitat patch. 1. Processes. 2. Global change. 3. Means for ecologists to research these components



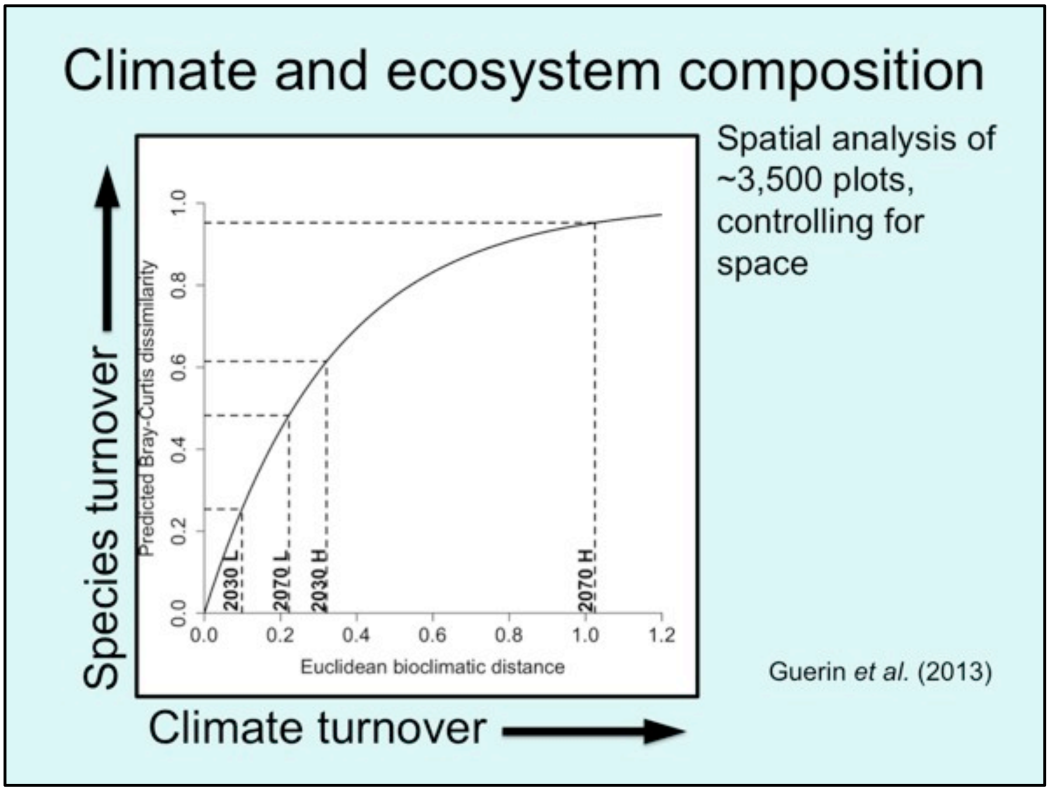
We begin with the species sorting aspects of community composition under climate change.



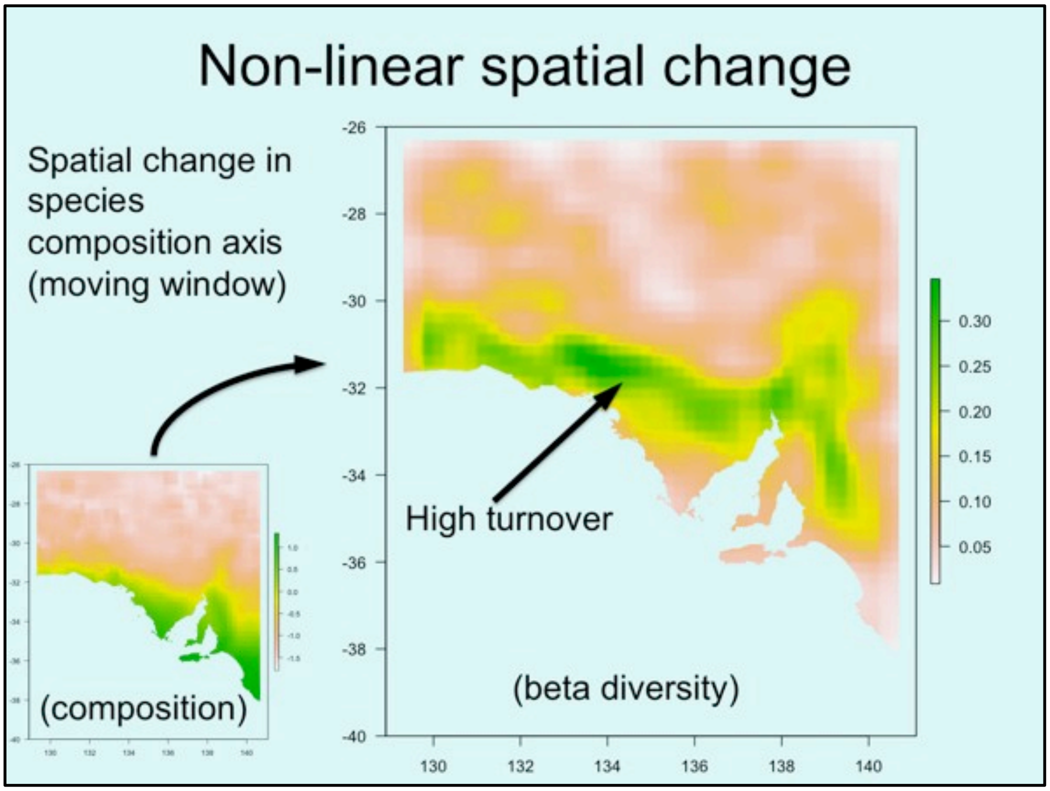
A good reason to do this is a large dataset available in South Australia on species occurrences.



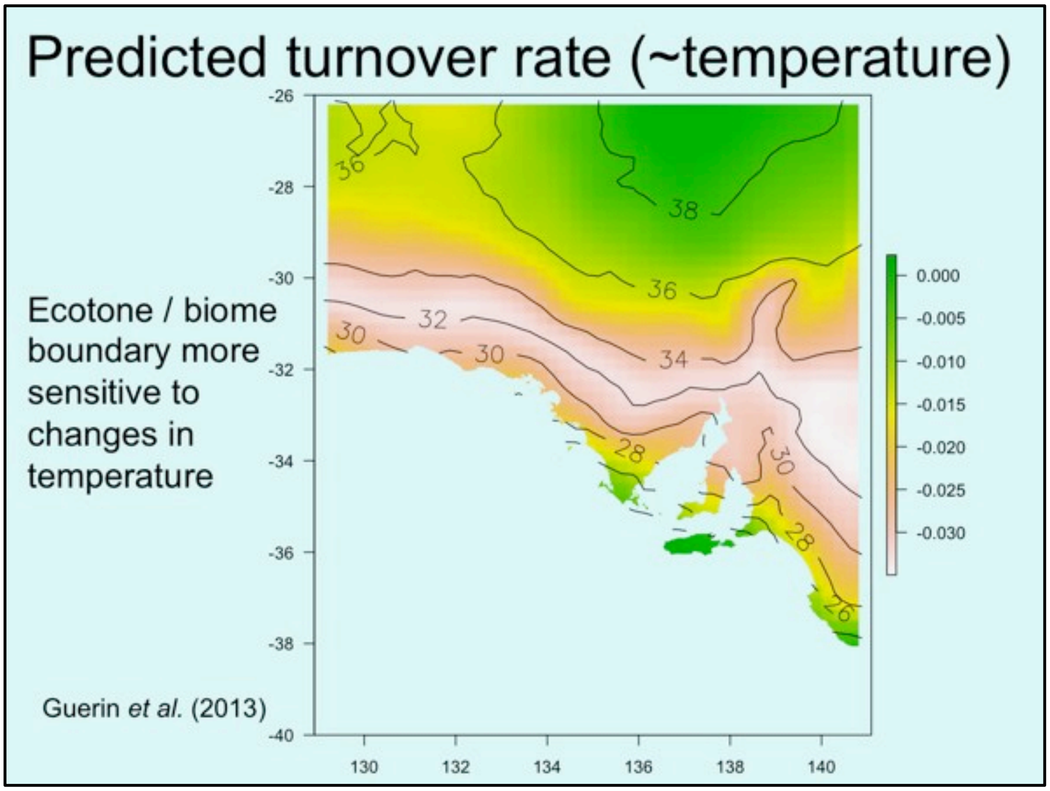
Strong distance-decay in compositional similarity is due to abiotic gradients, especially climate, and the effects of space itself.



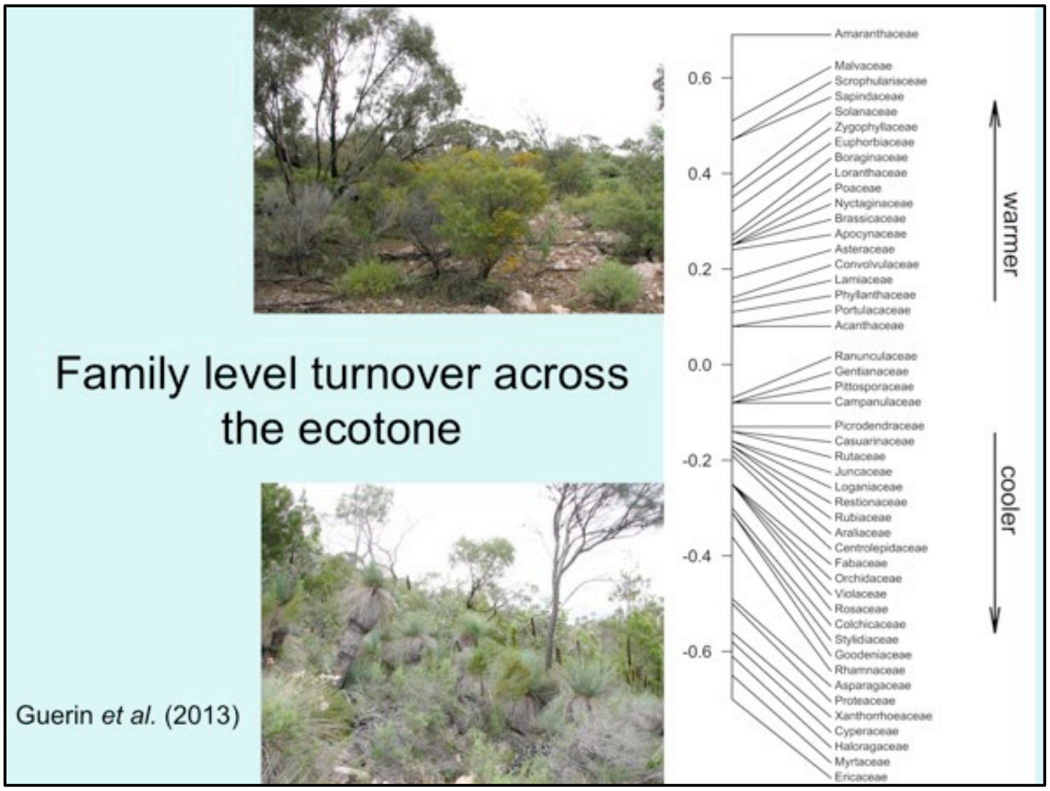
Increasing compositional dissimilarity as a function of increasing spatial climatic differences, controlling for geographic distance, with four future climate change scenarios for 2030/2070 indicated.



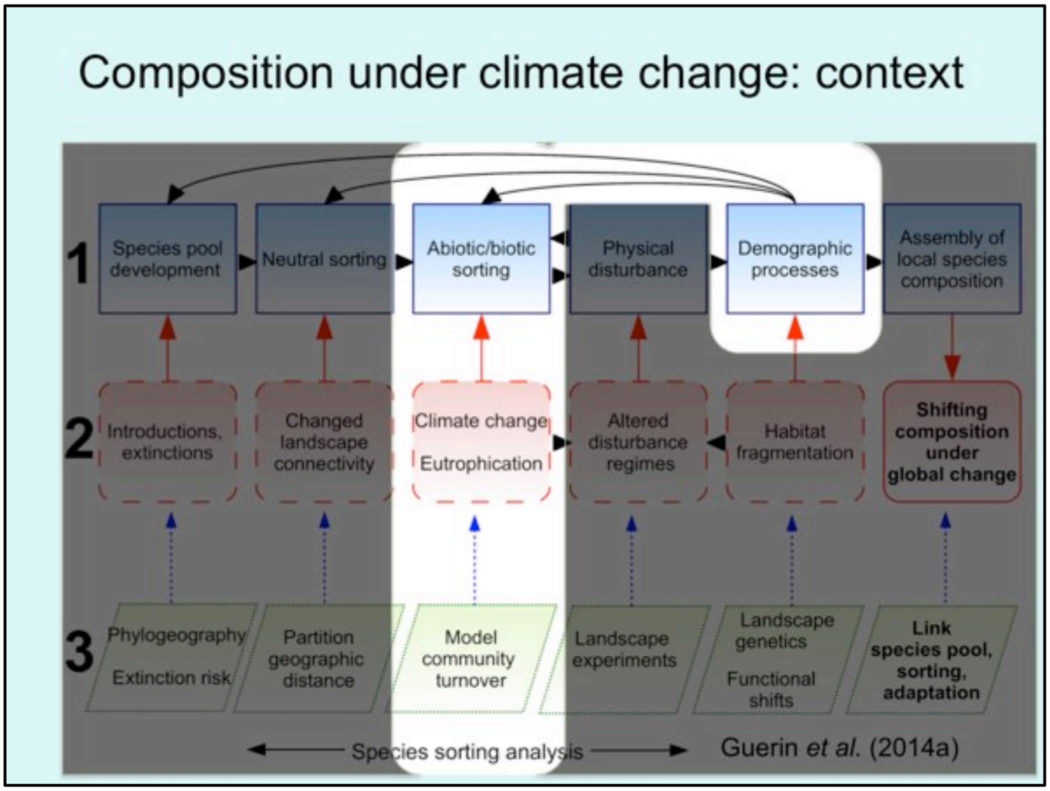
But the observed spatial turnover in plant species with climate is not uniform. Here, the local beta diversity (based on the first compositional axis from a CA ordination) is mapped, showing a zone of much higher change representing the ecotone between arid and mediterranean biomes.



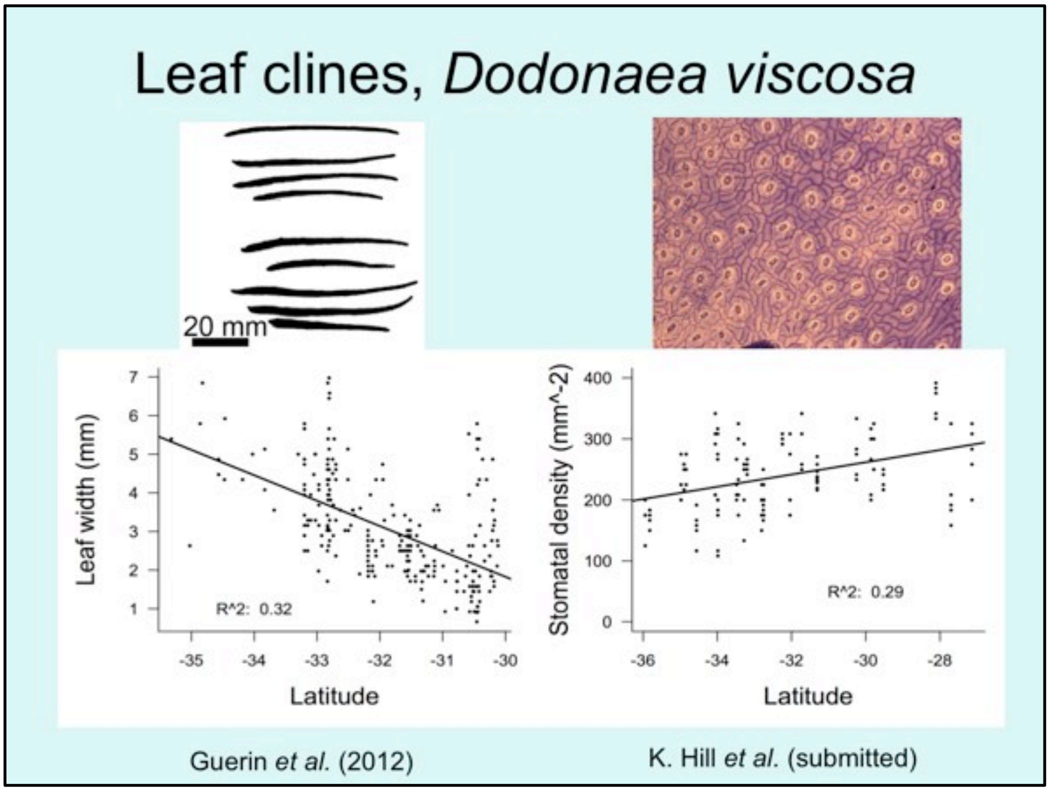
And when the change in this axis is extracted with explicit respect to 'mean maximum temperature of hottest month' using the slope of a flexible regression model, we can see the highest slope corresponds to this transitional zone.



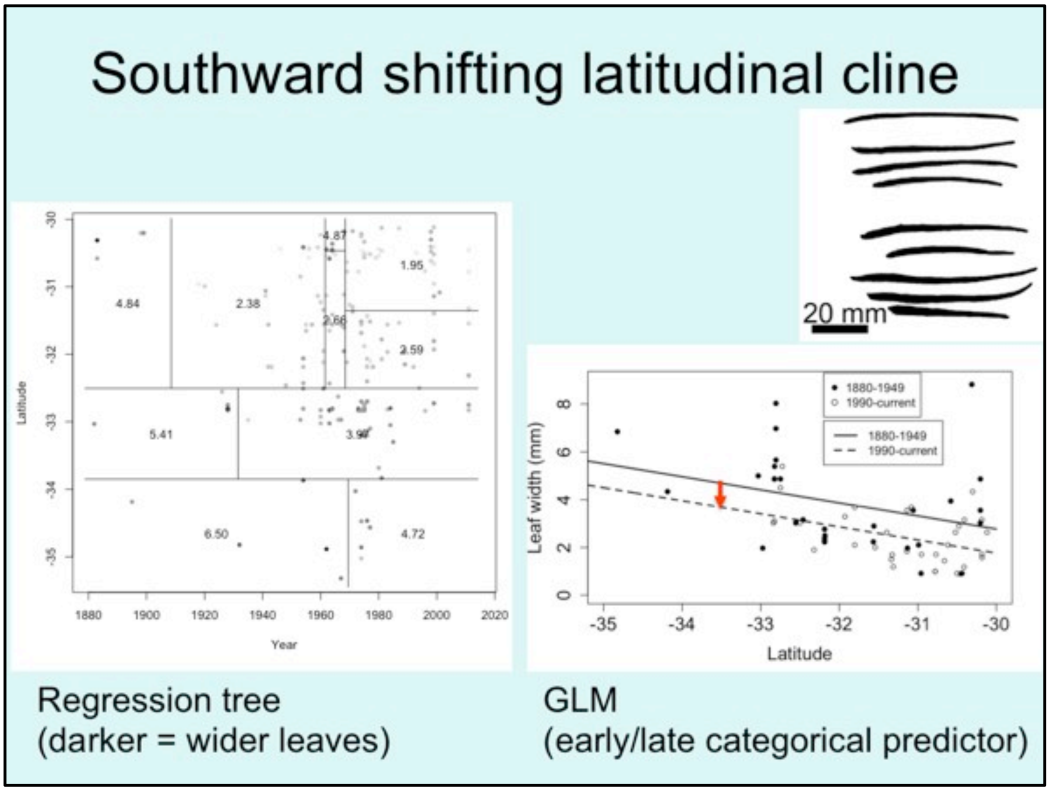
The spatial non-stationarity coincides with non-uniformity across taxonomic groups – across this ecotone, there is a shift in the prevalence of major plant families, here shown as the correlation between family level occurrences and the compositional axis, showing turnover at higher taxonomic levels.



But what happens when we consider possible demographic processes? We know that population shifts can feedback to influence species sorting, and this may influence the temporal translation of these spatial climatic patterns.



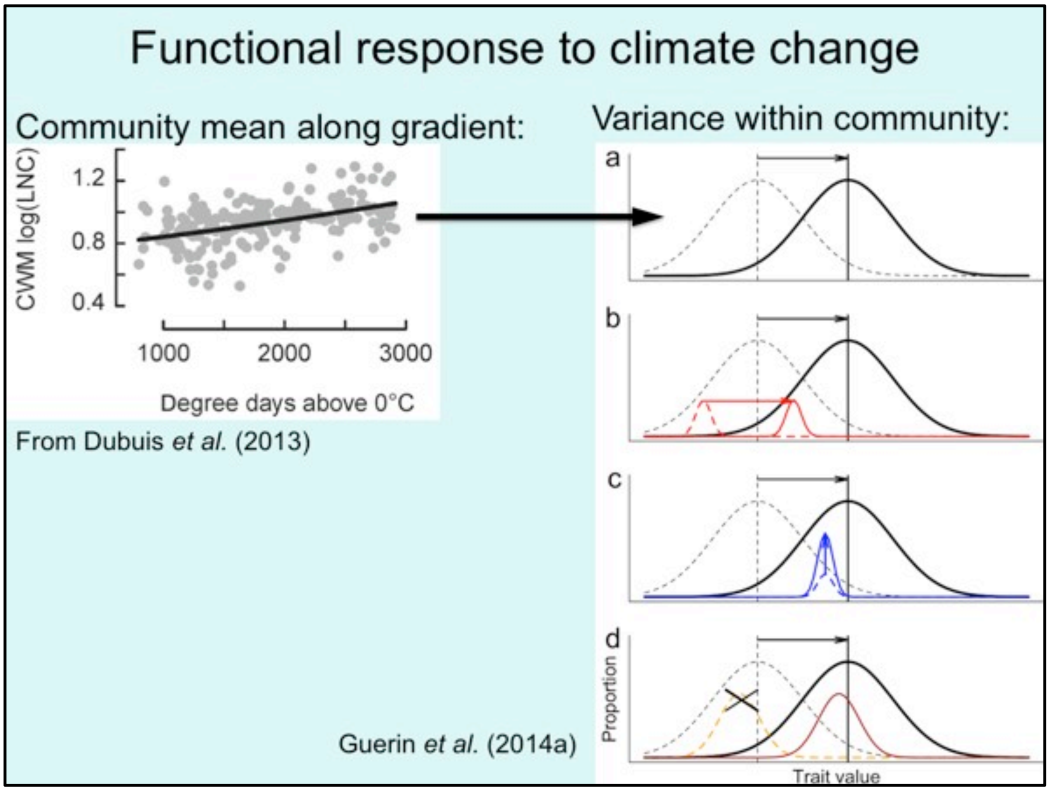
In this species, leaves get thinner but have denser stomata, towards the north of the state, suggesting an ecophysiologically significant response to summer temperatures.. This morphology is good for evaporative and convective cooling, for example.



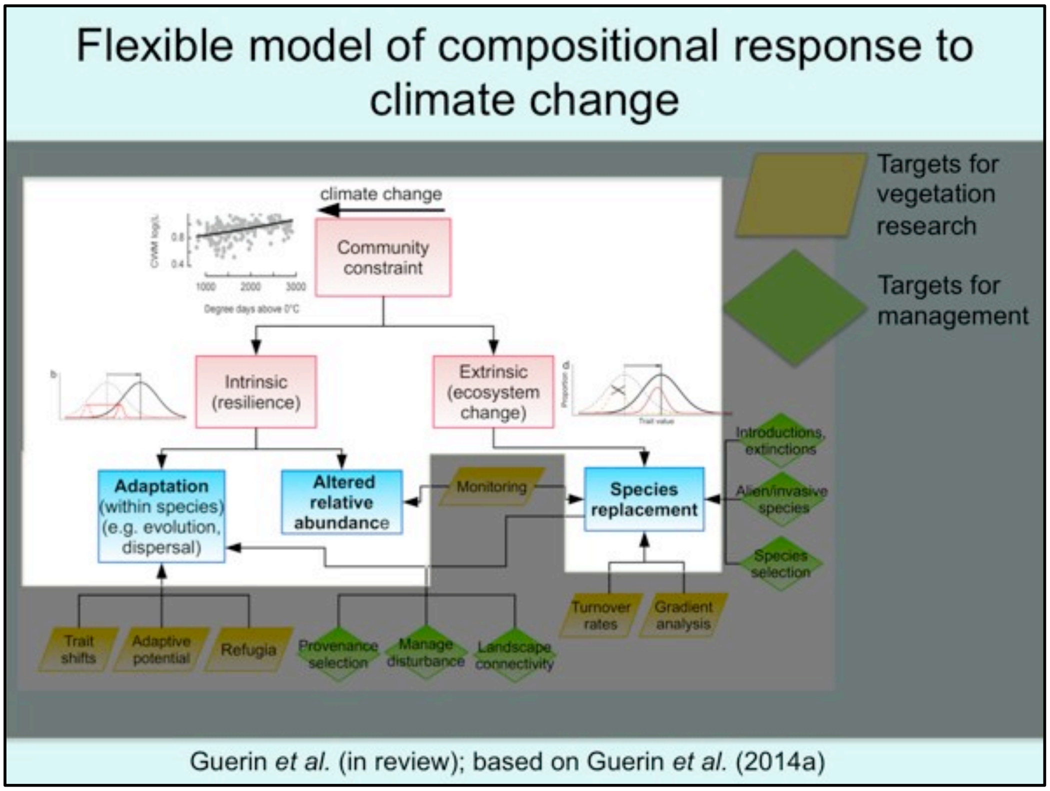
And leaves have become narrower over time, as predicted by the latitudinal cline under climate change. Left: regression tree, showing leaves are narrower at lower latitudes and later times. Right: GLM showing a shift in the cline between early and late collections.

- How to reconcile observed phenotypic clines with species sorting approaches?

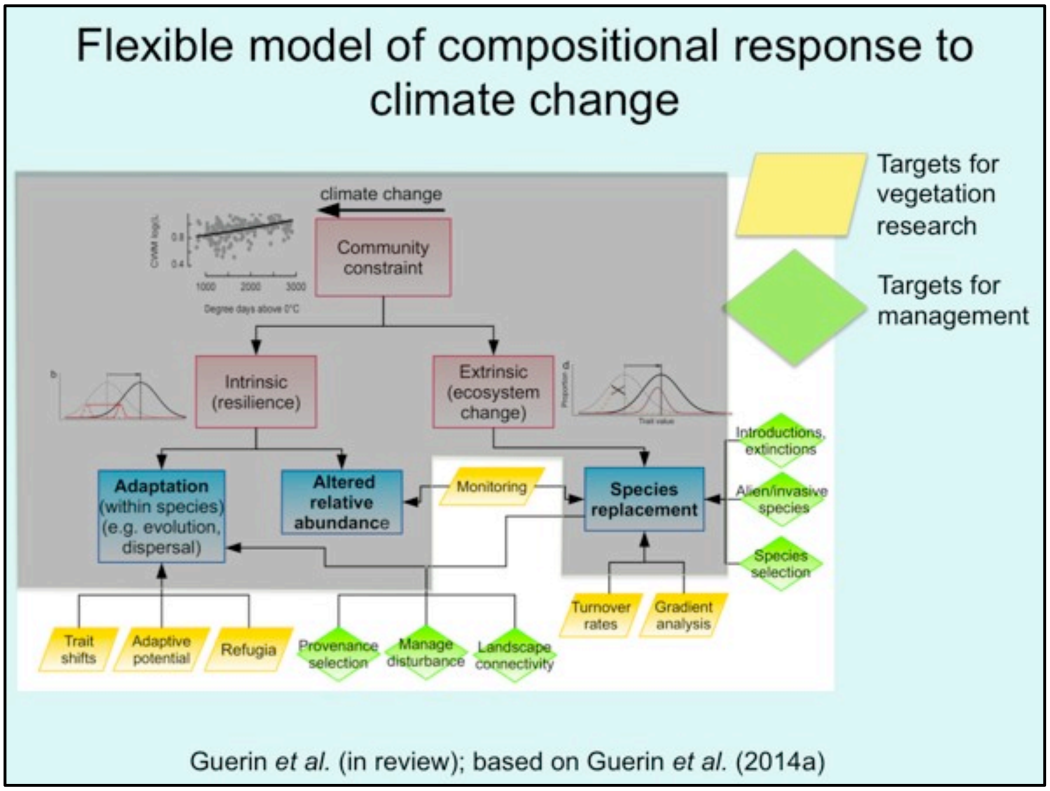
Phenotypic shifts through time may influence predicted species sorting



One way is to consider functional traits at community level. If we understand predictable changes in community means, perhaps we can have more success at breaking down the within-community changes that are causing it? Left: community mean trait changes with a temperature gradient. Right: a shifting constraint (a) is achieved by phenotypic change (b) , altered relative abundance (c) and species replacement (d).



From this you can make a concept of intrinsic resilience to a shifting constraint versus the start of species replacement



And we can look at which factors determine the relative importance of resilience, such as adaptive potential. We can also design research and monitoring to test how much change in species composition is occurring, compared to within-community mechanisms to deal with change, such as shifts in relative abundance in situ.

References & acknowledgements

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