N-dimensional hypervolumes to study stability of complex ecosystems (Barros et al. 2016) - ***Read in detail!***

Although our knowledge on the stabilising role of biodiversity and on how it is affected by perturbations has greatly improved, we still lack a comprehensive view on ecosystem stability that is transversal to different habitats and perturbations. Hence, we propose a framework that takes advantage of the multiplicity of components of an ecosystem and their contribution to stability. Ecosystem components can range from species or functional groups, to different functional traits, or even the cover of different habitats in a landscape mosaic. We make use of n-dimensional hypervolumes to define ecosystem states and assess how much they shift after environmental changes have occurred. We demonstrate the value of this framework with a study case on the effects of environmental change on Alpine ecosystems. Our results highlight the importance of a multidimensional approach when studying ecosystem stability and show that our framework is flexible enough to be applied to different types of ecosystem components, which can have impor- tant implications for the study of ecosystem stability and transient dynamics.

<u>Introduction</u>

- Ecosystem components range from species/functional groups through to habitat types and structure
- Ecosystems are changing and we need to understand there responses
- Stability is multifaceted...
- Biodiversity-Ecosystem Functioning (BEF)
  - Understanding how biodiversity maintains and promotes productivity
- Fewer studies have looked at perturbation-biodiversity
  - Functional diversity can change across environment /disturbance gradients
  - Relationship of ecosystem function and biodiversity
- **Ecosystem stability is no easily summarised by a single metric**
  - Using multiple components should provide better results...
  - Components often have temporal oscillations..
    - In 2D these converge on a point...
    - in 3D (and n-dimensions) it becomes more complex $\Rightarrow$ N-Dimensional Hypervolumes!
- N-Dimensional Hypervolumes
  - These oscillations become a trajectory in n-dimensional space
  - A cloud of points...
  - If conditions are disturbed than the trajectory will change $\Rightarrow$ new hypervolume
  - They can be used to test departure from a stable state
  - Also convergence on new stable state or return to old (i.e. different measure of stability can be tested)
- Choosing components (Choice of components depends on the kind of study)
  - Stability of biodiversity at community scale
    - Time series of species abundances
    - Community weighted means (CWMs) and varience (CWVs) of functional traits
  - Larger Scale
    - Taxonomic functional traits

    * Phylogenetic diversity metrics
  - Ecosystem Mosaics
    * Proportions of habitat patches

The Framework!

- Step 1 - Choice of Components
  - Their example contructs n-dimensional hypervolumes in time-series of n-ecosystem traits at equilibrium.
  - My study will also look at space
- Step 2 - Data Treatment and Hypervolume calculation
  - Number of dimensions must be fixed to maintain comparability
  - Need comparable units (centred and scaled)
  - Not correlated!! (Look at PCAs, PCoAs etc to get around this?)
  - Try not to exceed 5-8 variables to avoid disjointed and holey hypervolumes
  - Hypervolume calculations follow a multi-dimensional kernal density estimator procedure. See Blonder et al. (2014)
- Step 3 - Comparing hypervolumes and analysis of community changes
  - Sufficiently large changes in environmental conditions should produce shifts in community structure. ⇒ These should be seen in the constructed hypervolumes...
  - Three possible measures
    * Overall similarity ⇒ Overlap
    * Changes in mean values of components ⇒ Distance between centeroids
    * Changes in Variance ⇒ Changes in hypervolume size
- Step 4 - Complementary metrics for more detailed analysis
  - Hypervolume comparisons don't really tell you what changed so there is need for further analysis looking at the specific components used...

  Working Example

  - Based on simulated data (Don't really understand this!)
  - Habitats under climate change (CC) and land use change (LUC)
  - calculated hypervolume every 15 years of simulation
  - used actual abundances instead of relative - not interested in dominance/structural changes.
    * This also meant the differences between hypervolumes were bigger (easier to see)
  - hypervolume overlap was significantly affected by CC & LUC
  - hypervolumes on traits and on Plant Functional Diversity (PFDs)
  - Trait hypervolumes tended to be smaller

Discussion

- Environmental changes impact biodiversity at many levels
- Need to measure contribution of different taxanomic, functional or landscape entities
- Analysing Magnitude of Change
  - Size ⇒ Variance

- Mean ⇒ Position of centeroid
- Similarity ⇒ Overlap

- **N-dimensional hypervolumes do not summarise components as one metric but describe them as an n-dimensional cloud!**
- Assessing type of change
  - can be informative about what facets of an ecosystem were most affected by ecosystem perturbation
  - complimentary measures are important though!
- Following changes in time
  - Since hypervolumes define different ecosystem structures they can be used to test all types of ecosystem stability
    - Persistence ⇒ Time before change once perturbation starts
    - Resilience ⇒ Return to state after perturbation
    - Resistance R ⇒ Amount of change after perturbation
    - Variabiltiy ⇒ Variation before vs after perturbation
  - Implications for ecosystem services
  - Small overlaps may still indicate changes in ecosystem state. I think this study saw overlaps = 0 this is not as likely on real data!.
- Advantages of hypervolumes
  - Ecosystems are made up of a multiplicity of components
  - Allows for detection of finer changes
  - negates problems with habitat mosaics and ecotone interactions
  - Can be used to predict future responses and resilience to extreme events/perturbations

Predicting ecosystem stability from community composition and biodiversity (de Mazancourt et al. 2013) - ***Something***

As biodiversity is declining at an unprecedented rate, an important current scientific challenge is to understand and predict the consequences of biodiversity loss. Here, we develop a theory that predicts the temporal variability of community biomass from the properties of individual component species in monoculture. Our theory shows that biodiversity stabilises ecosystems through three main mechanisms: (1) asynchrony in speciesâĂŹ responses to environmental fluctuations, (2) reduced demographic stochasticity due to overyielding in species mixtures and (3) reduced observation error (including spatial and sampling variability). Parameterised with empirical data from four long-term grassland biodiversity experiments, our prediction explained 22âĂŞ75% of the observed variability, and captured much of the effect of species richness. Richness stabilised communities mainly by increasing community biomass and reducing the strength of demographic stochasticity. Our approach calls for a re-evaluation of the mechanisms explaining the effects of biodiversity on ecosystem stability.

References

Barros, C., Thuiller, W., Georges, D., Boulangeat, I. & Münkemüller, T. (2016), 'N- dimensional hypervolumes to study stability of complex ecosystems', *Ecology Letters* **19**(7), 729–742.
URL: *http://doi.wiley.com/10.1111/ele.12617*

Blonder, B., Lamanna, C., Violle, C. & Enquist, B. J. (2014), 'The n -dimensional hypervolume', *Global Ecology and Biogeography* **23**(5), 595–609.
URL: *http://doi.wiley.com/10.1111/geb.12146*

de Mazancourt, C., Isbell, F., Larocque, A., Berendse, F., De Luca, E., Grace, J. B., Haegeman, B., Wayne Polley, H., Roscher, C., Schmid, B., Tilman, D., van Ruijven, J., Weigelt, A., Wilsey, B. J. & Loreau, M. (2013), 'Predicting ecosystem stability from community composition and biodiversity', *Ecology Letters* **16**(5), 617–625.
URL: *http://doi.wiley.com/10.1111/ele.12088*