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

- Introduction
  - 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 ⇒ 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 ⇒ 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 $\Rightarrow$ Time before change once perturbation starts
    - Resilience $\Rightarrow$ Return to state after perturbation
    - Resistance $R \Rightarrow$ Amount of change after perturbation
    - Variabiltiy $\Rightarrow$ 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

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*