Comparing Cross-Scale Resilience Properties Through Data Modelling of State Space

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1. Issues with comparing patterns and inferring resilience properties

Patterns can be represented by different ontologies, like points, lines, and areas.

A particular ontology is often associated with a specific conceptual paradigm, along with its scale of applicability.

Comparing patterns should integrate multiple ontologies and their particular scalar extents (and use different paradigms).

This is especially true when trying to compare patterns and link them to their resilience properties – resilience properties are cross-scalar.

2. Responses to these issues:

The solution of the familiar: we stick to a particular conceptual paradigm

The curse of standardization: we work at one particular scale

The sublimation of process: we focus on how a particular pattern changes with scale

The sublimation of pattern: we concentrate only on the particular scale for which a statistical property peaks

3. An alternative: data modeling of cross-scale resilience properties in state space

Combines different representations of pattern and accounts for the processes that generate resilience properties

Incorporates multiple conceptual paradigms and explanatory variables operating across different scalar extents and resolution

Fosters a multivariate interpretative framework (versus approaches that sublimate pattern and process)

Has a deep theoretical and methodological lineage in ecology

4. Data modeling? State space?

Data modeling: a means of making the phenomena under study more accessible for analysis

Modeling patterns: combining different representations of pattern to represent the phenomena, a strategy of overfitting versus underfitting

State space: a multidimensional volume defined by observations of the phenomena and their dynamical properties

Dimensionality: the number of axes

![Topography as gradient surface and patch](image)

5. What is cross-scale resilience?

A small number of key structuring processes shape ecosystems

These key structuring processes are specified in adaptive cycles that link to form panarchies

Variables representing processes in each adaptive cycle are hierarchically-nested and vary within and across scales

These variables forms the basis for comparing patterns and linking resilience properties to them across scales.

![State space concepts](image)

6. Comparing patterns and their resilience properties in state space

The variance structure of cross-scale data convey differences in observations as well as their resilience properties

Resilience is multidimensional: it consists of two (or more) properties, typically resistance and resilience

Resistance and resilience can be expressed as non-independent dimensions, or axes, in state space

Low dimensions capture resistance, higher dimensions capture resilience

![Resilience properties as dimensions of state space](image)

3. These variables should span the resilience defining the 'template' of the pattern to the resilience arising from adaptive components.

4. Collect data and assemble variables.

5. Perform dimensionality reduction (ordination) to obtain variance structure of data and the location of observations in state space.

6. Use the loadings of variables on the axes of state space to affirm and assign resilience properties to observations.

![Instructions for cross-scale data modelling: an example using dune topography](image)