Resilience metrics are robust across data qualities but sensitive to community size

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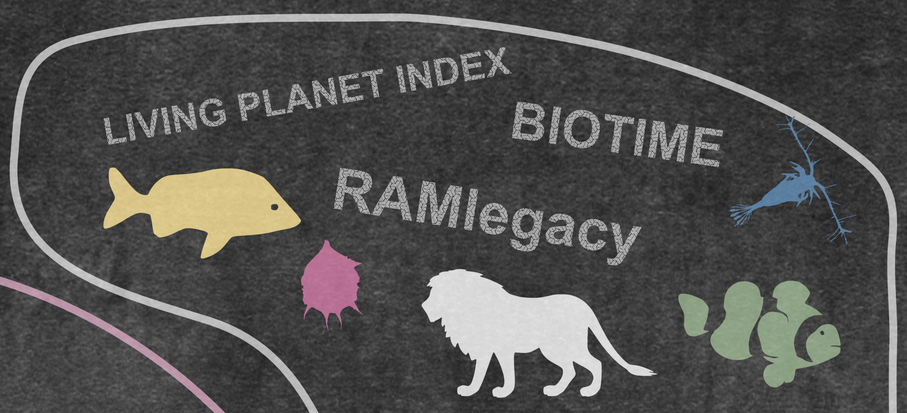
Ecosytem resilience is a key target for conservation monitoring but has been challenging to generically quantify.

Recently, generic tools have been suggested to estimate the system's **Jacobian** - which allows us to predict species interactions and future dynamics.

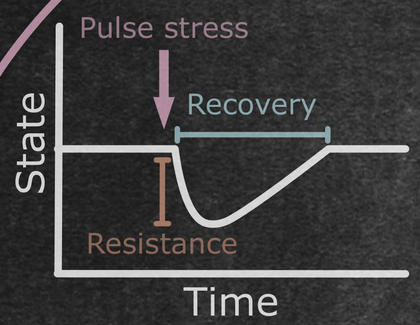
Here, we identify the behaviour of resilience metrics across **realistic data corruptions** such as short time series combined with systematic sampling error.

Rationale



Can resilience be estimated from global biodiversity time series?

What is resilience?



Resilience is '*the capacity to **persist** and **maintain** state and function in the face of **exogenous disturbance***' (Hodgson *et al.* 2015). Resilience/stability therefore should decrease when under stress.

The eigenvalues of the **Jacobian matrix** quantifies this stability. E.g. for a two species system (**x** & **y**), the Jacobian combines the species abundances, their growth rates, and response to the other species.

$$\mathbf{J}(x,y) = \begin{bmatrix} r_x - \alpha_{yx}y & -\alpha_{yx}x \\ \alpha_{xy}y & \alpha_{xy}x - r_y \end{bmatrix}$$

Jacobians have typically only been available to simulation/ mathematical systems due to real-world growth rates and species interactions often being unknown.

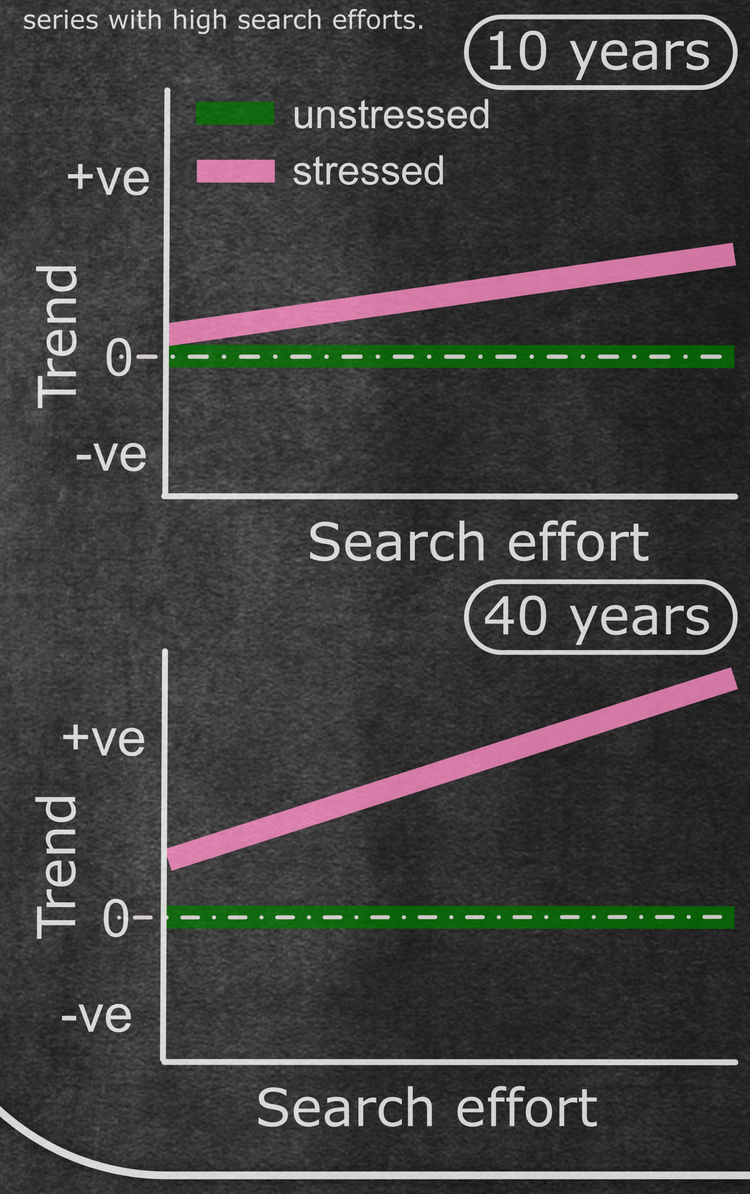
HOWEVER, novel metrics have emerged (Grziwotz et al. 2023; Ushio et al. 2018) capable of estimating real-world Jacobian matrices, and their resilience dynamics.

90 unique multi-species reef communities were simulated 25 times each under stressful and stable conditions.

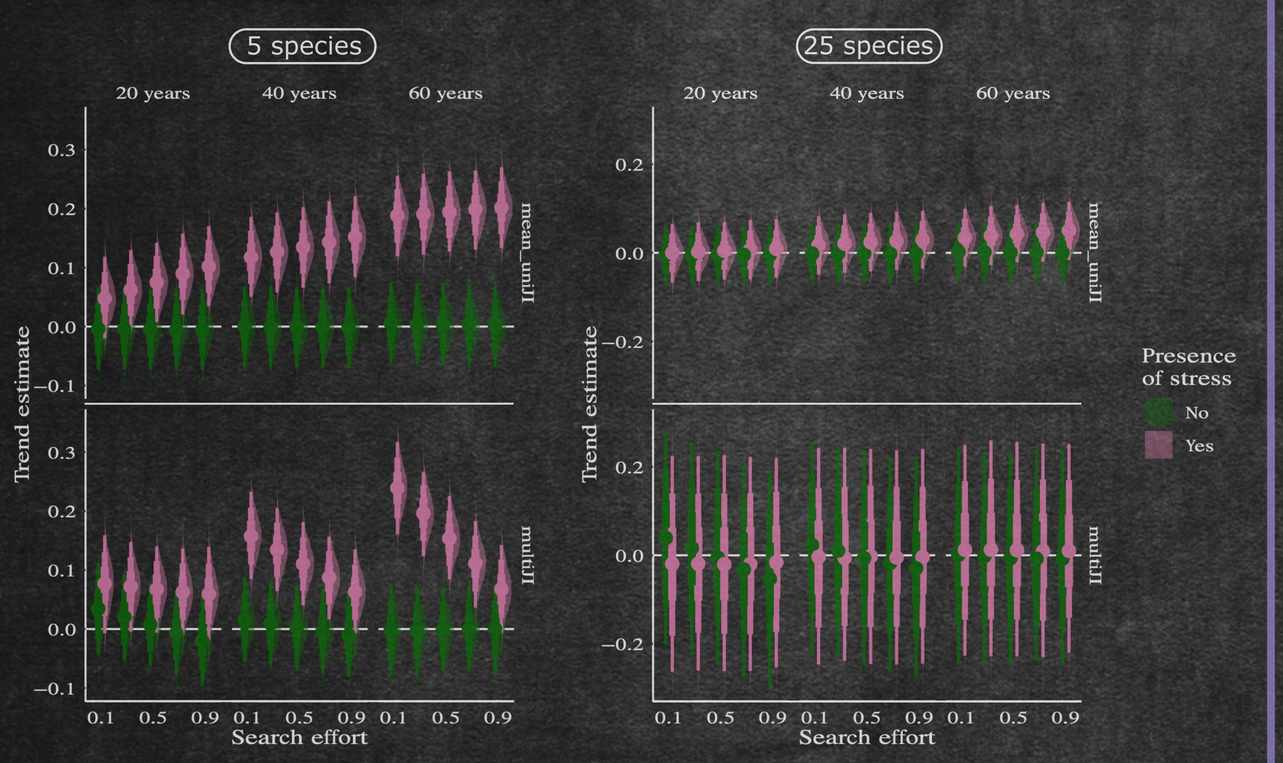
Data was 'corrupted' by trimming time series (10 -> 70 time points) and introducing search effort error (0 -> 100%).

Expectation

All metrics should display a **temporal trend in stressed** simulations, have **no trend in unstressed**, and a stronger trend in longer time series with high search efforts.



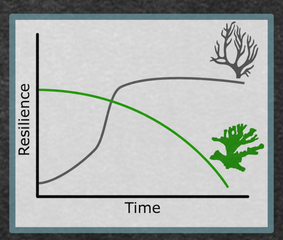
Results



The univariate Jacobian index performs as anticipated across time series length and search effort - The multivariate index correctly indentifies stressed or unstressed communities but weakens with search effort.

Increasing the number of contributing species weakens metric capability - Larger communities contain less influentual species which mask the true resilience of the ecosystem.

Conclusion



Generic resilience metrics behave predictably across data corruptions - Such metrics are appropriate for real-time monitoring.

Choice of species is critical to ensuring accurate resilience estimation - Selecting ecologically important/keystone species is a suitable criterion.

Info

If you want to calculate your own metrics, the R package **EWSmethods** can be found here:

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References: Hodgson *et al.* 2015 *Trends Ecol. Evol.*; Grziwotz *et al.* 2023 *Science*; Ushio *et al.* 2018 *Nature*