How should resilience be quantified? Is there a context independent metric?

Ingrid van de Leemput

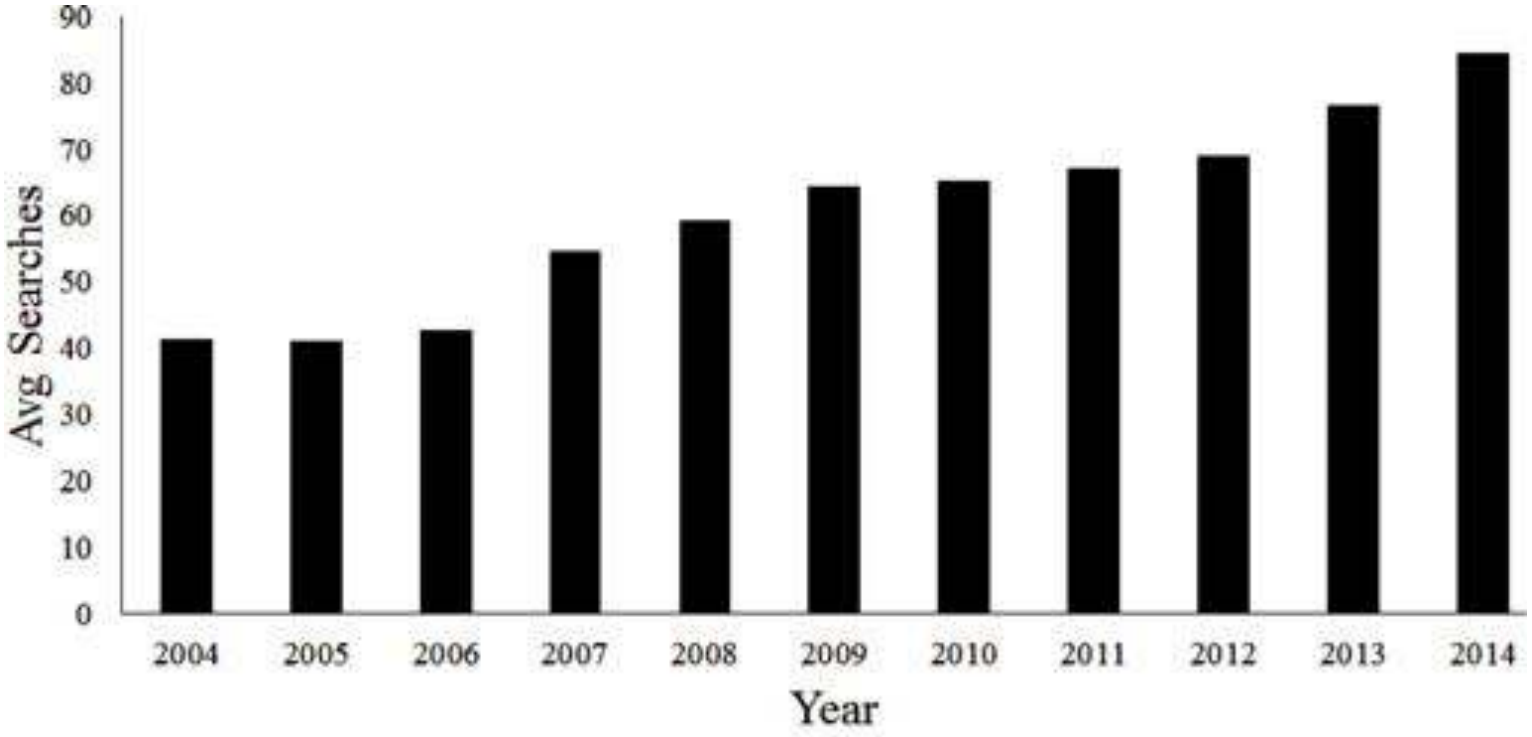
Session 1. Workshop Resilience of Complex Systems

WAGENINGEN
UNIVERSITY & RESEARCH

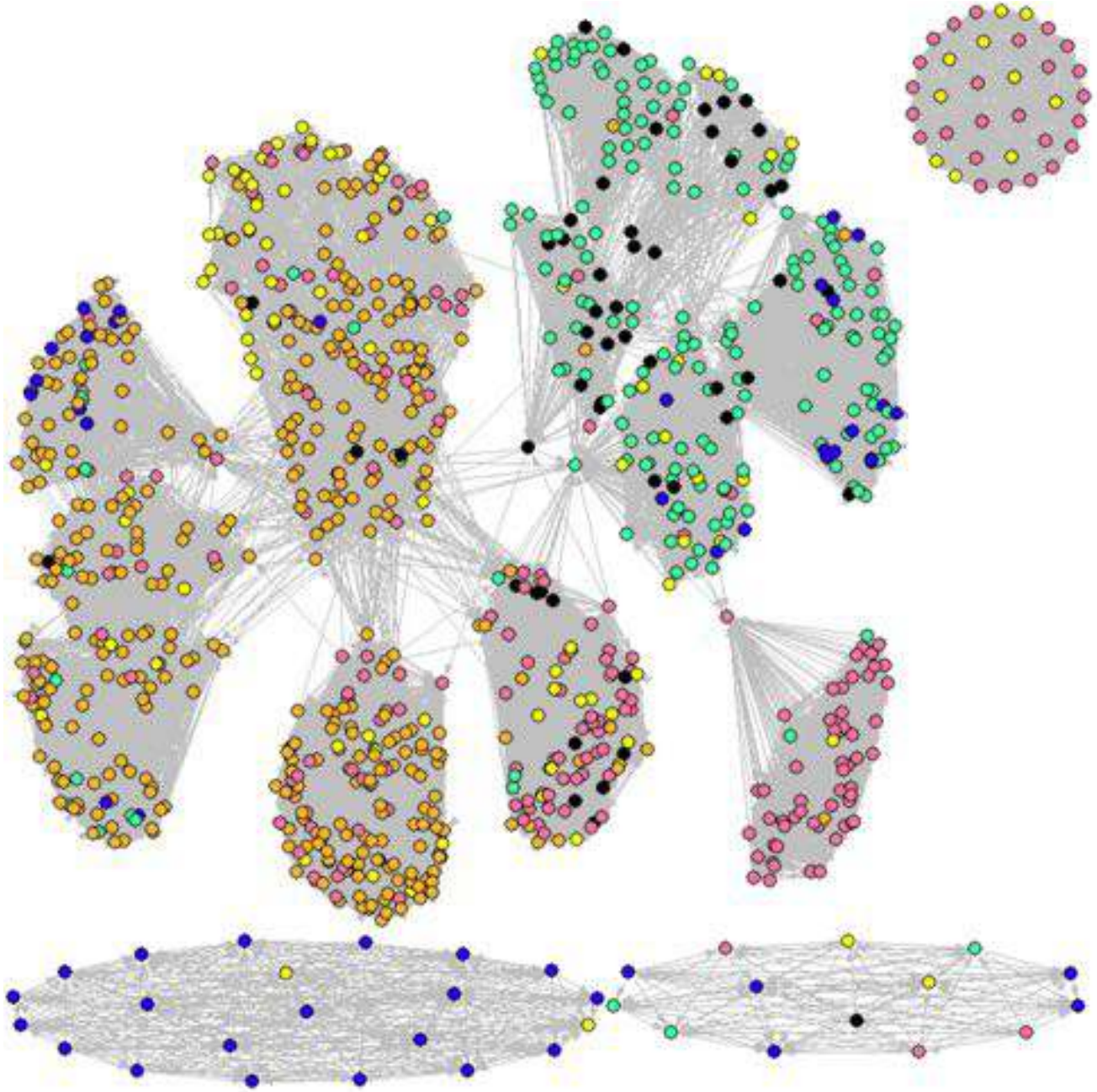
Teaser session 1

- What is ‘resilience’?
- Ecological resilience
- What makes a system resilient?
- Quantifying resilience
- Indicators of resilience
- Input document

Increasing interest in term ‘resilience’



Baggio et al. 2015 *Ecology & Society* 20(2)



Citation network

- **pink** = social sciences;
- **turquoise** = ecology and environmental sciences;
- **orange** = psychology;
- **blue** = engineering;
- **black** = social-ecological systems;
- **yellow** = not defined.

Baggio et al. 2015 *Ecology & Society* 20(2)

Different definitions of resilience in different scientific fields

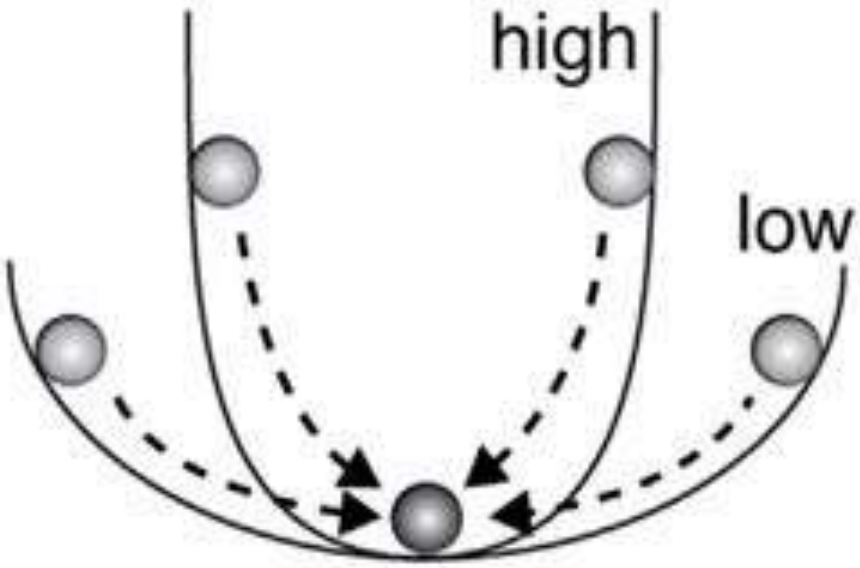
- Psychological resilience
- Physical resilience
- Engineering resilience
- Ecological resilience
- Resilience of social-ecological systems
- Social resilience

All related to:

The ability of a system to respond to change while maintaining specific functions/attributes/controls

Baggio et al. 2015 *Ecology & Society* 20(2)

Engineering resilience



Recovery rate after a disturbance

Ecological resilience

Size of disturbance needed to push the system into a different state

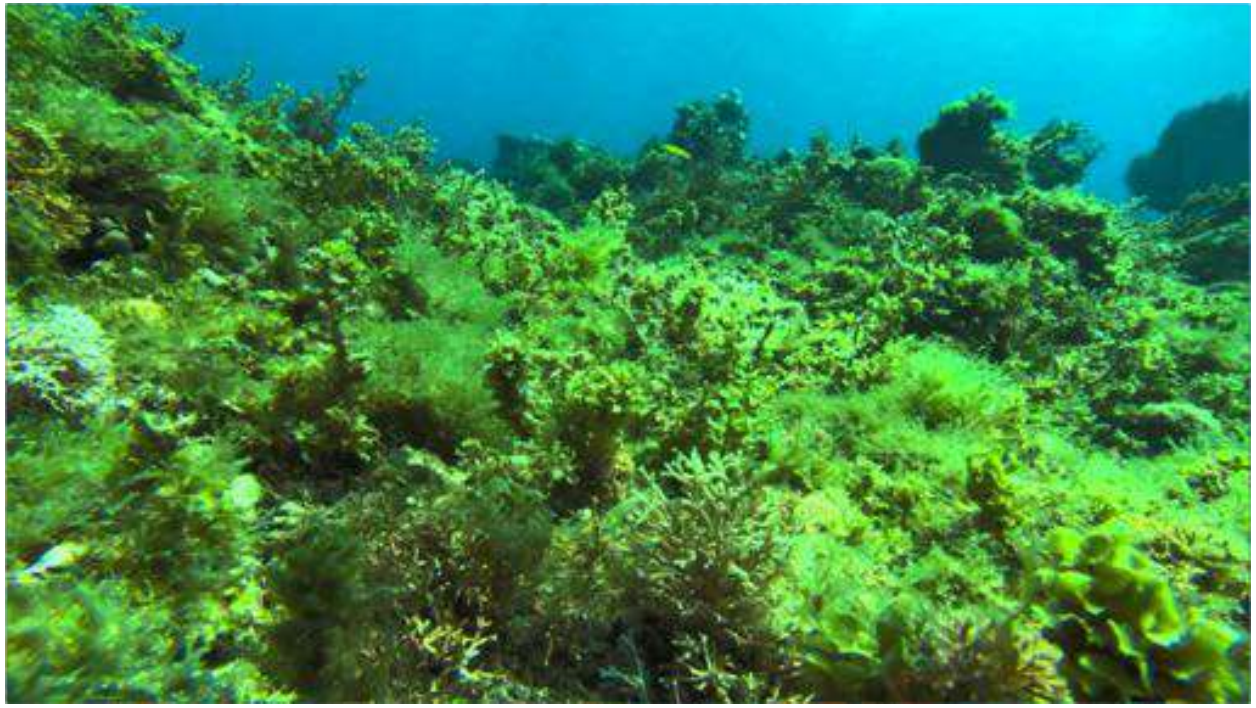
Coral reef A

Bleaching event

Coral reef B

Bleaching event

Coral reef A



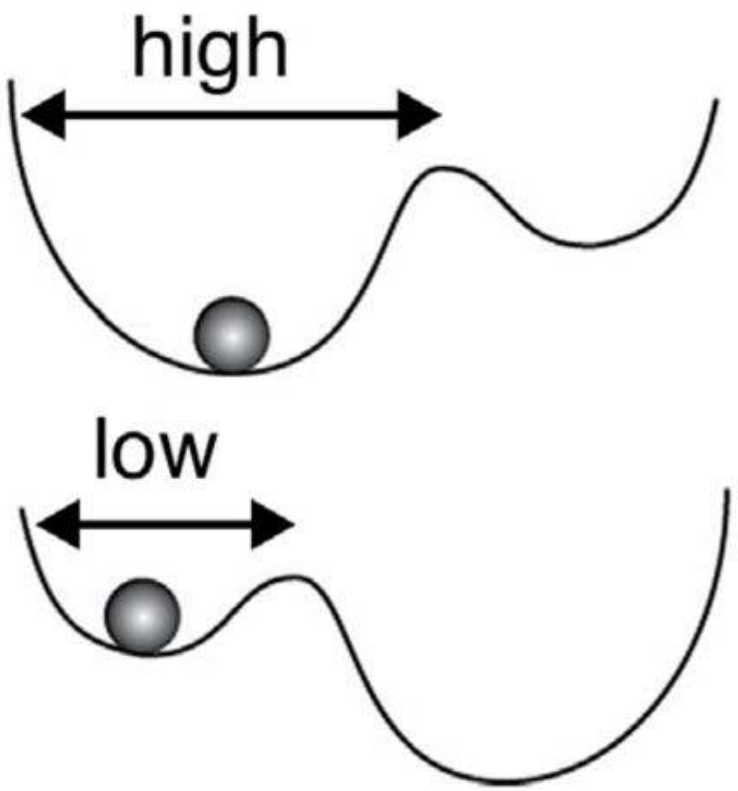
Coral reef B

Bad night sleep

Bad night sleep

What kind of interactions make an (eco)system resilient?

- Diversity and redundancy
- Stabilizing feedbacks
- No or weak reinforcing feedbacks
- Connectivity ..



Biggs et al. 2012 *Annu. Rev. Environ. Resour.* 37

Can we measure resilience in real systems?

Generic indicators of resilience

Vol 461|3 September 2009|doi:10.1038/nature08227 nature

REVIEWS

Early-warning signals for critical transitions

Marten Scheffer[1], Jordi Bascompte[2], William A. Brock[3], Victor Brovkin[5], Stephen R. Carpenter[4], Vasilis Dakos[1], Hermann Held[6], Egbert H. van Nes[1], Max Rietkerk[7] & George Sugihara[8]

Complex dynamical systems, ranging from ecosystems to financial markets and the climate, can have tipping points at which a sudden shift to a contrasting dynamical regime may occur. Although predicting such critical points before they are reached is extremely difficult, work in different scientific fields is now suggesting the existence of generic early-warning signals that may indicate for a wide class of systems if a critical threshold is approaching.

REVIEW

CORRECTED 23 NOVEMBER 2012; SEE LA

Anticipating Critical Transitions

Marten Scheffer,[1,2*] Stephen R. Carpenter,[3] Timothy M. Lenton,[4] Jordi Bascompte,[5] William Brock,[6] Vasilis Dakos,[1,5] Johan van de Koppel,[7,8] Ingrid A. van de Leemput,[1] Simon A. Levin,[9] Egbert H. van Nes,[1] Mercedes Pascual,[10,11] John Vandermeer[10]

Generic Indicators of Ecological Resilience: Inferring the Chance of a Critical Transition

Marten Scheffer,[1] Stephen R. Carpenter,[2] Vasilis Dakos,[3] and Egbert H. van Nes[1]

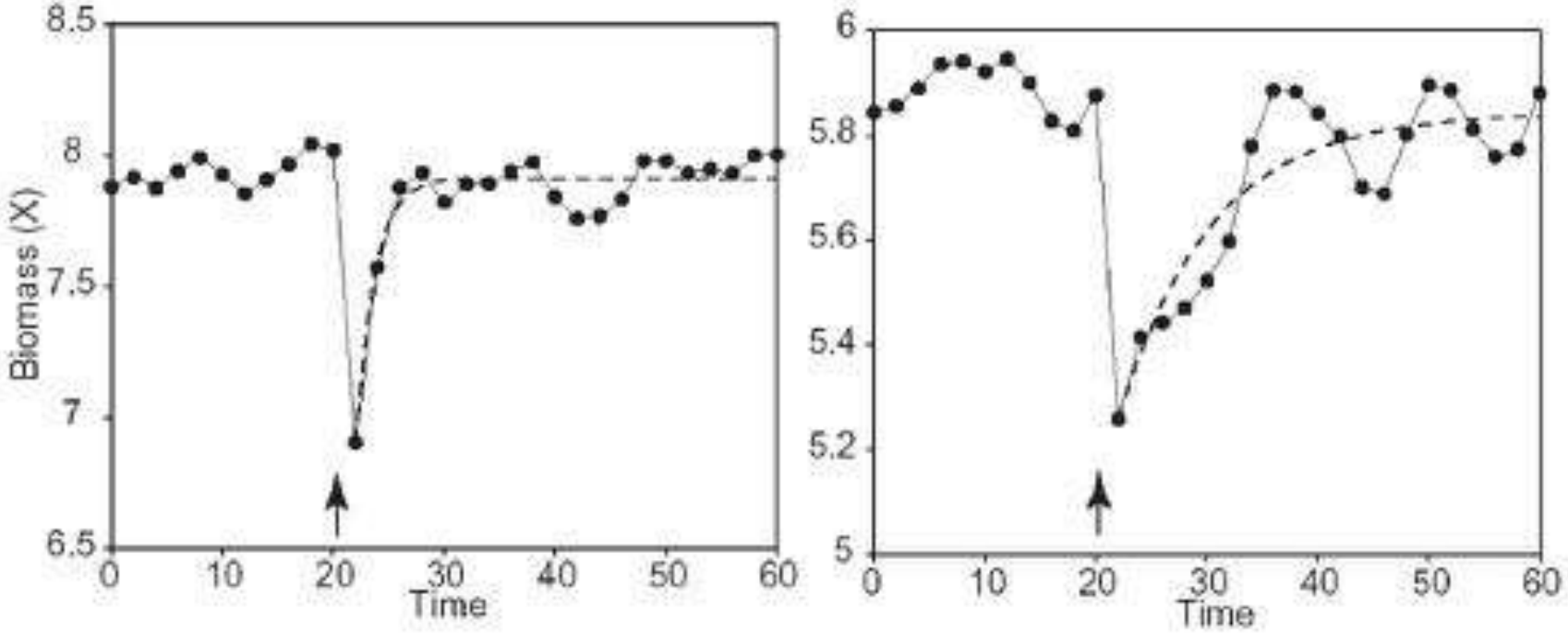
OPEN ACCESS Freely available online PLOS one

Methods for Detecting Early Warnings of Critical Transitions in Time Series Illustrated Using Simulated Ecological Data

Vasilis Dakos[1,2*], Stephen R. Carpenter[3], William A. Brock[4], Aaron M. Ellison[5], Vishwesha Guttal[6], Anthony R. Ives[7], Sonia Kéfi[8], Valerie Livina[9], David A. Seekell[10], Egbert H. van Nes[1], Marten Scheffer[1]

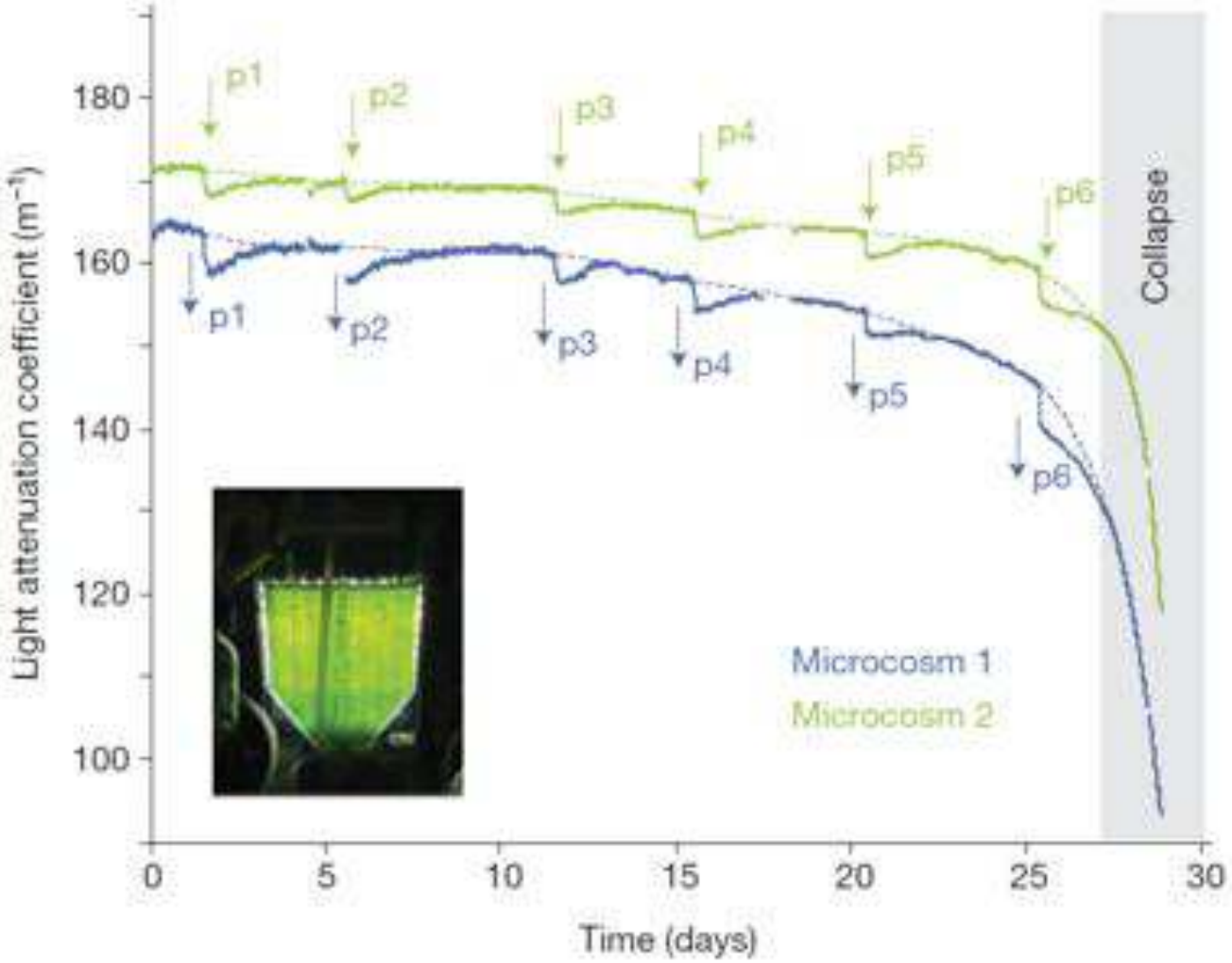
Critical slowing down

Recovery rate from perturbations



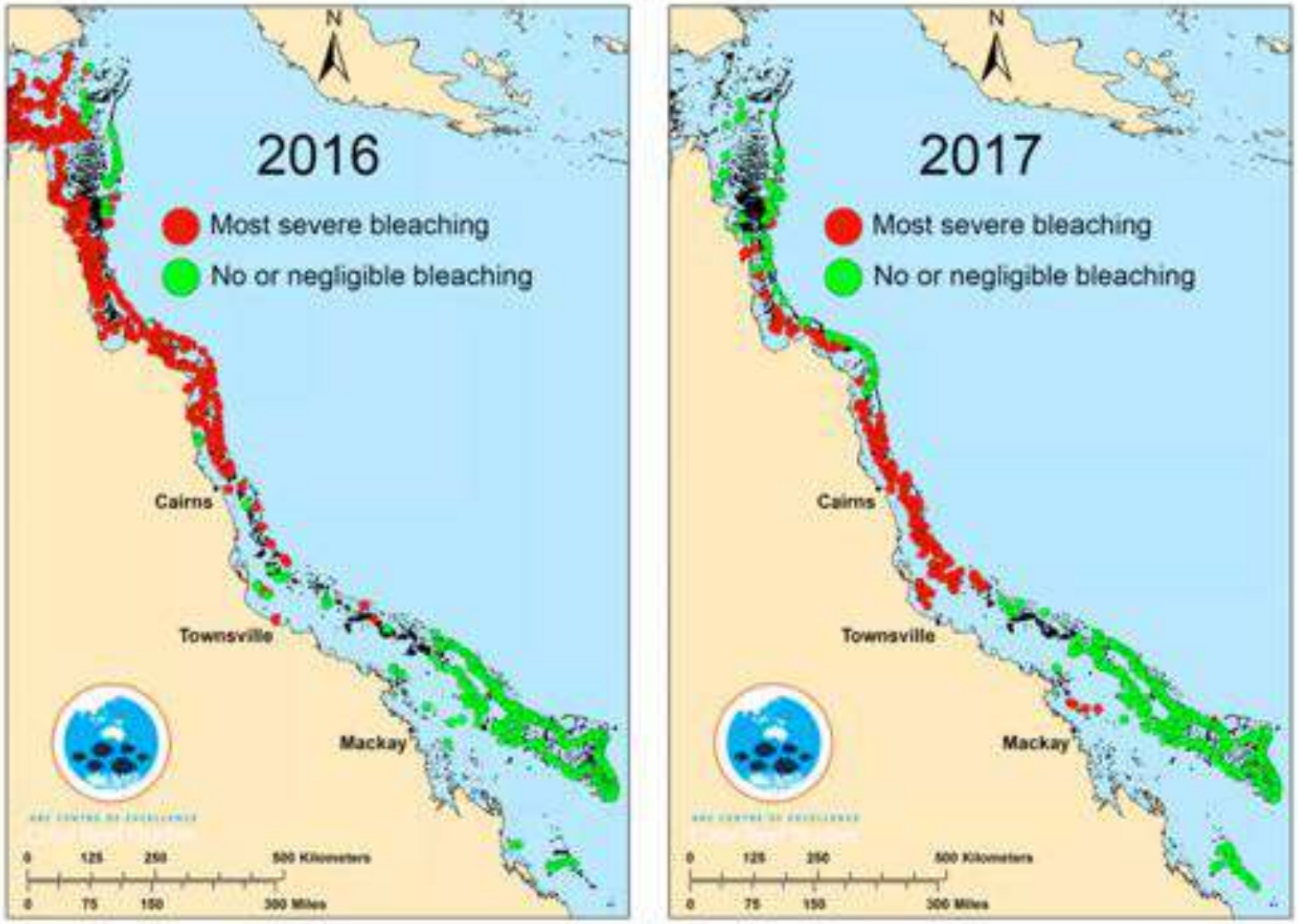
Wissel 1984 *Oikos*
Van Nes & Scheffer 2007 *AmNat*

Recovery rate as resilience indicator in experiments



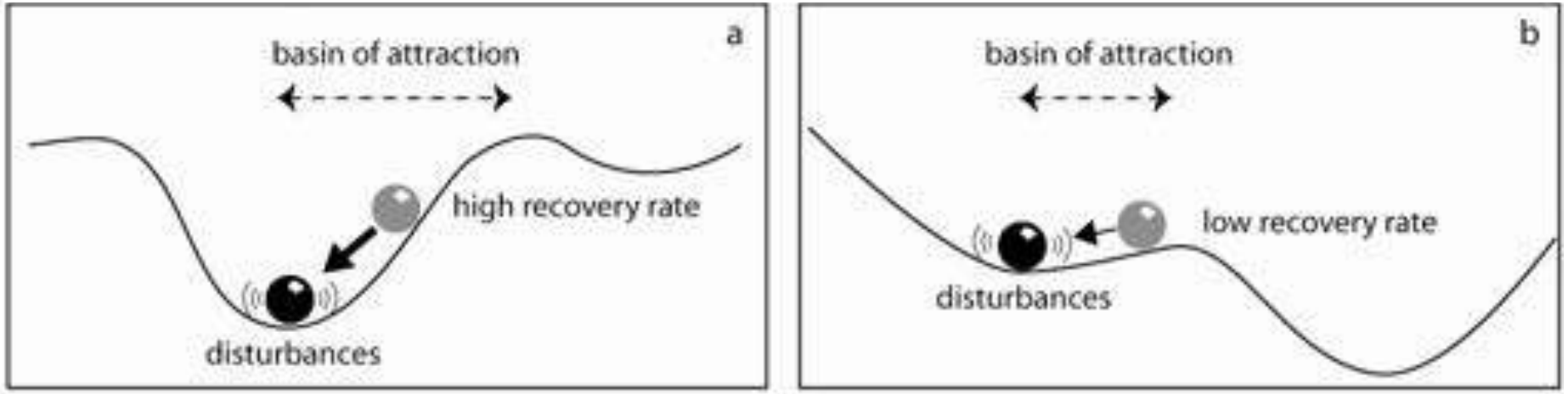
Veraart et al. 2012. *Nature*

Recovery rate as resilience indicator



Indicators of resilience using natural fluctuations

close to 'tipping point'

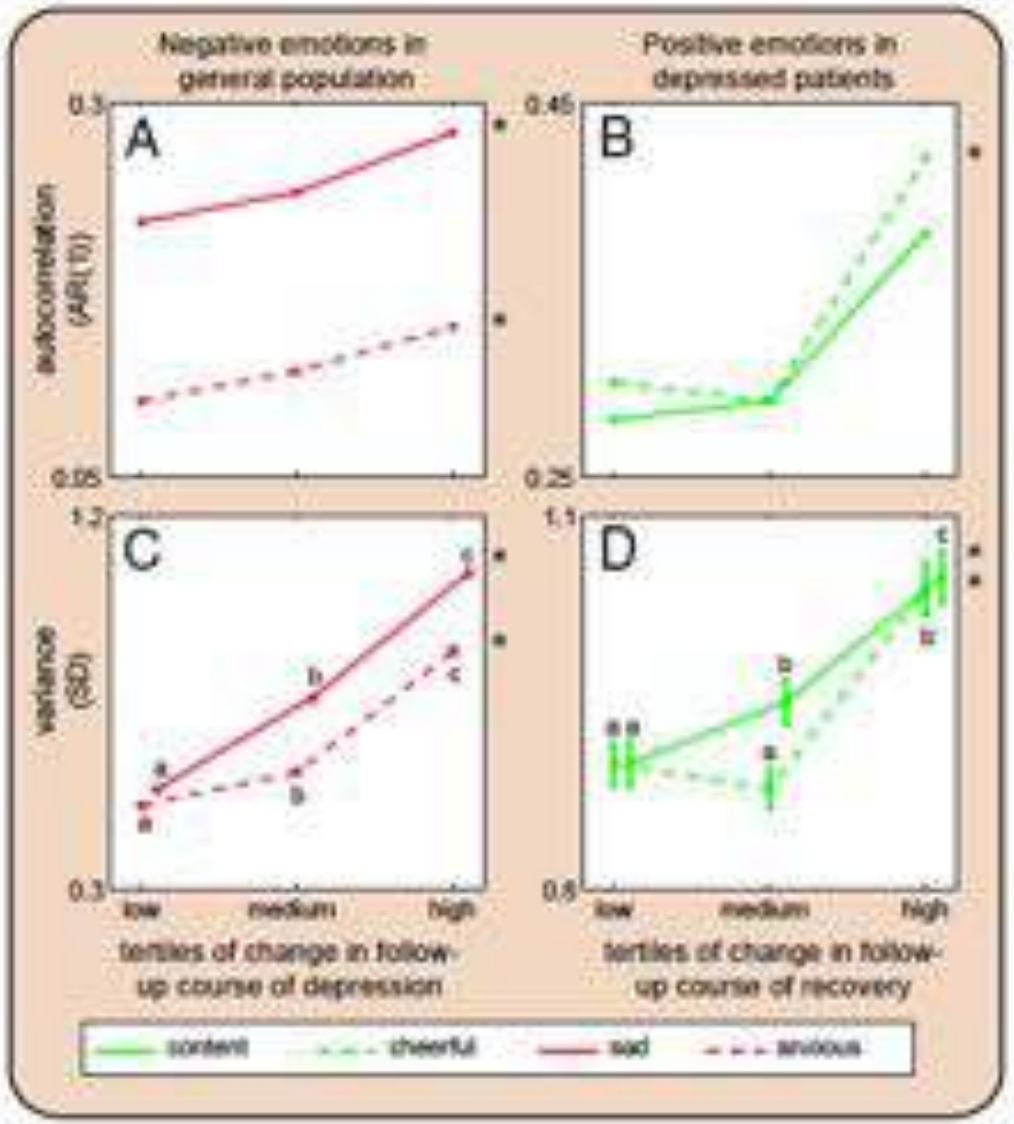


increased variance

increased autocorrelation

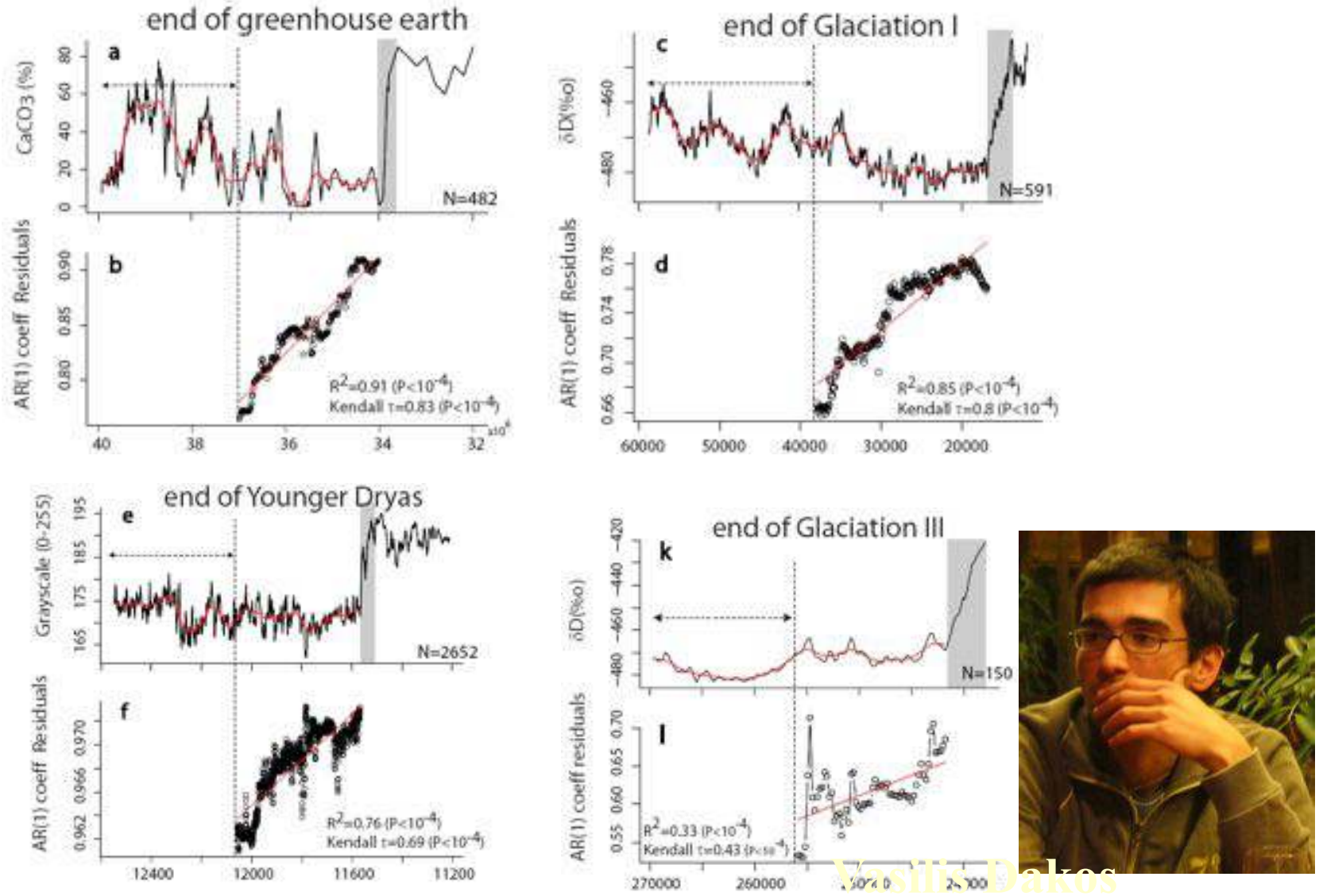
Scheffer et al. 2009 *Nature* 37

Indicators of resilience in mental health



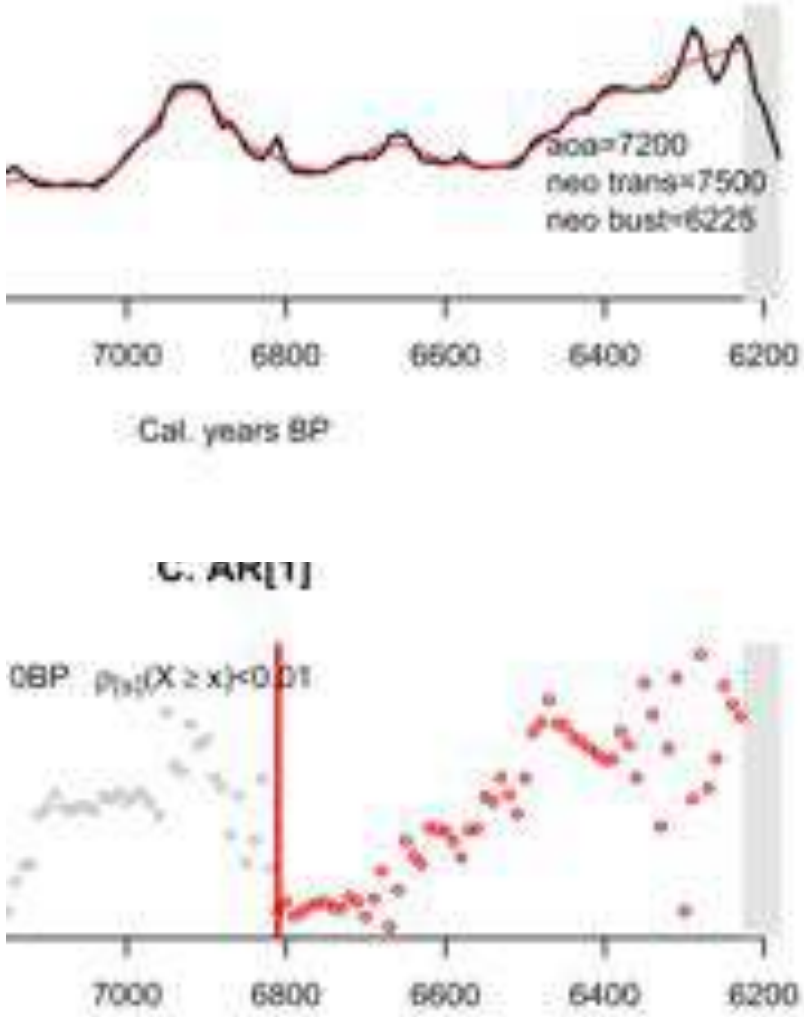
van de Leemput et al. 2012 *PNAS* 37

Indicators of resilience in ancient climate



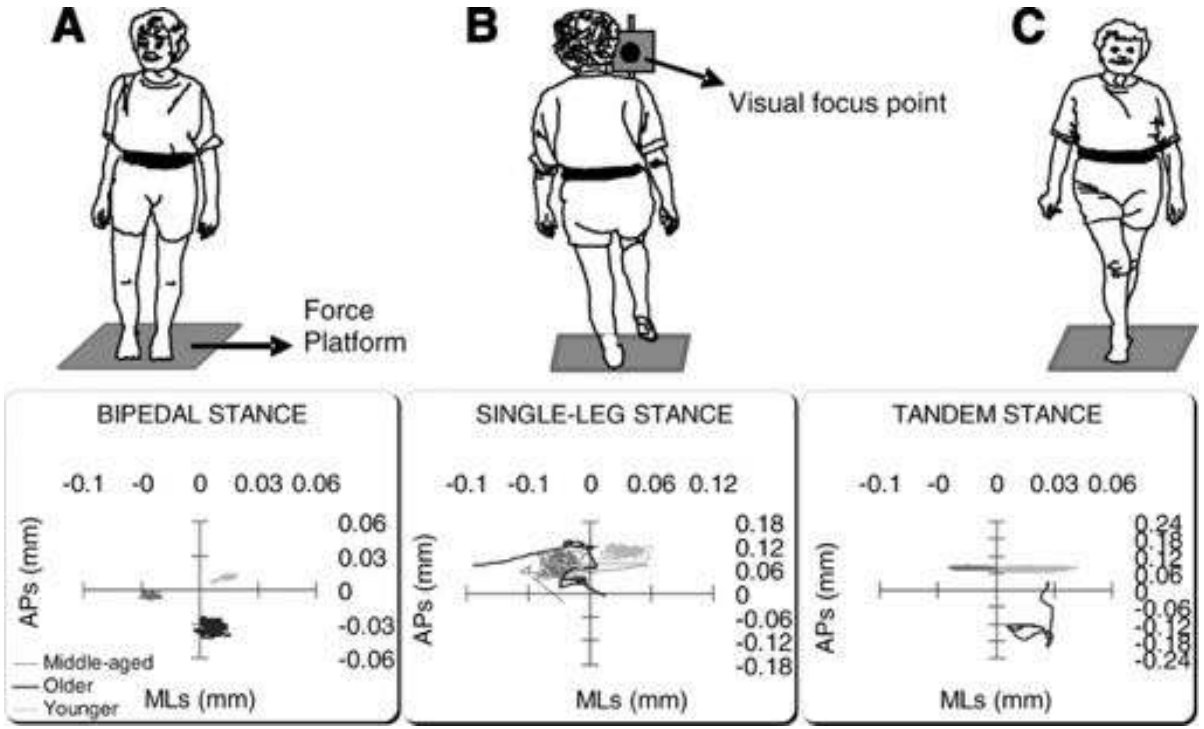
Dakos et al PNAS 2008, Toolbox in R: Dakos et al 2012 (PLOS ONE)

Neolithic human population size



Downey et al. 2016 PNAS 113: 9751-9756

Human body: frailty of elderly



Onambele et al. 2006 Journal of Applied Physiology 100 6, 2048-2056

Sanne Gijzel

Olde Rikkert, et al. 2016.]Critical Care Medicine 44.

Input document

- Guided by the existing research, we propose that resilience captures *the capacity of a system to withstand shocks and its ability to recover from them*.
- In particular, we postulate that resilience can only be measured against a certain perturbation. In fact a system may be resilient with respect to one kind of shock, but not against another one.

Input document

We want to highlight the following shortcomings:

- We lack *a conceptual framework* that would allow us to obtain quantitative measures capturing the *resilience of social organizations* based on the two concepts of robustness and adaptation
- We lack an *understanding of the micro-processes* within social organizations that would allow us to explain why some social organizations are resilient, while others are not.
- The lack of such micro-foundation severely limits our ability to foster resilient system, e.g., by means of implementing suitable incentive mechanisms.

Limitations generic resilience indicators

- non-stationary conditions: system is not in equilibrium
- rapid approach to the transition
- periodically fluctuating environments
- large observation error
- not enough data
- autocorrelated noise
- large process error: the magnitude of environmental shocks may overshadow slowing down
- spatial processes ignored
- measuring the wrong variable in networks

Dakos et al. 2014 *Phil. Trans. R. Soc. B*