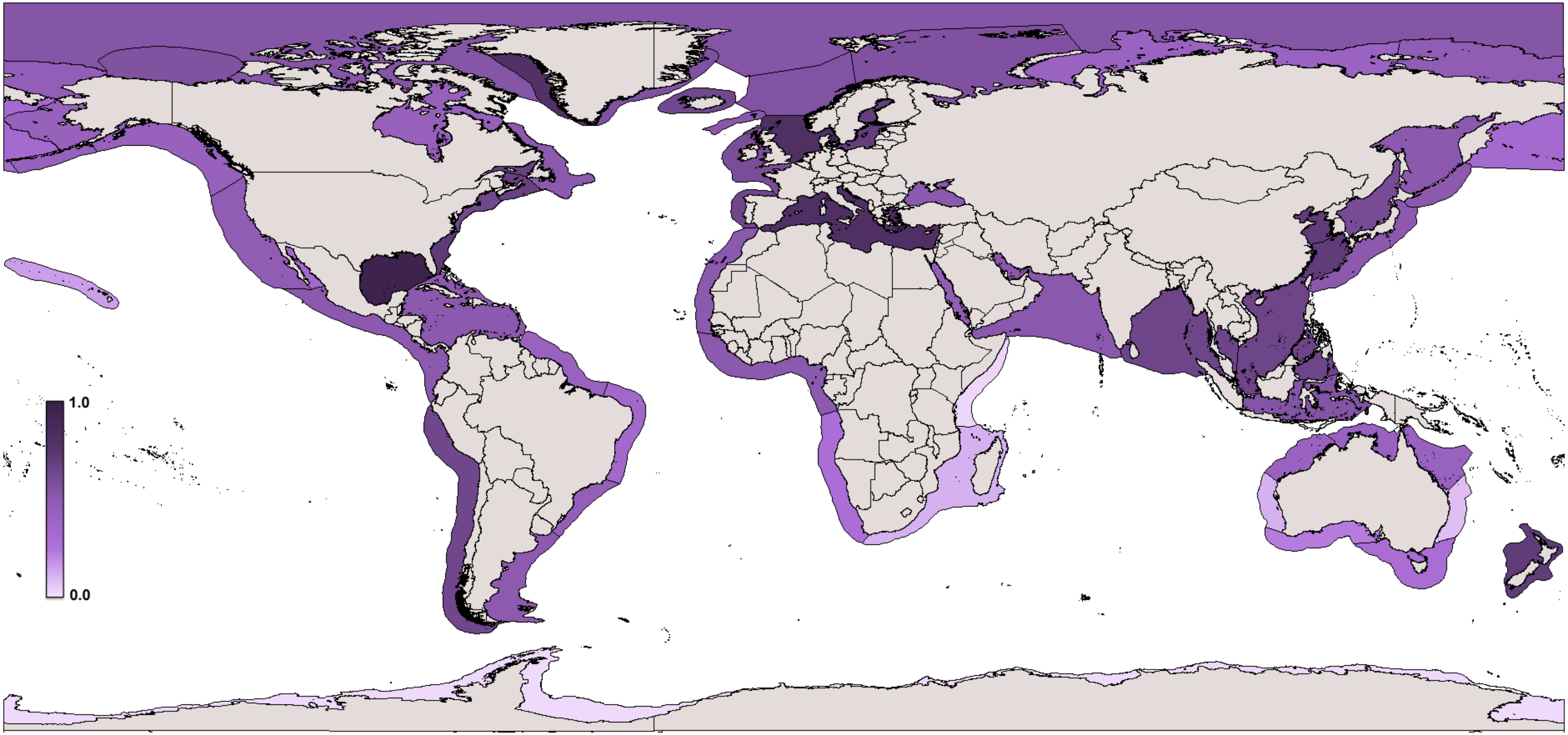
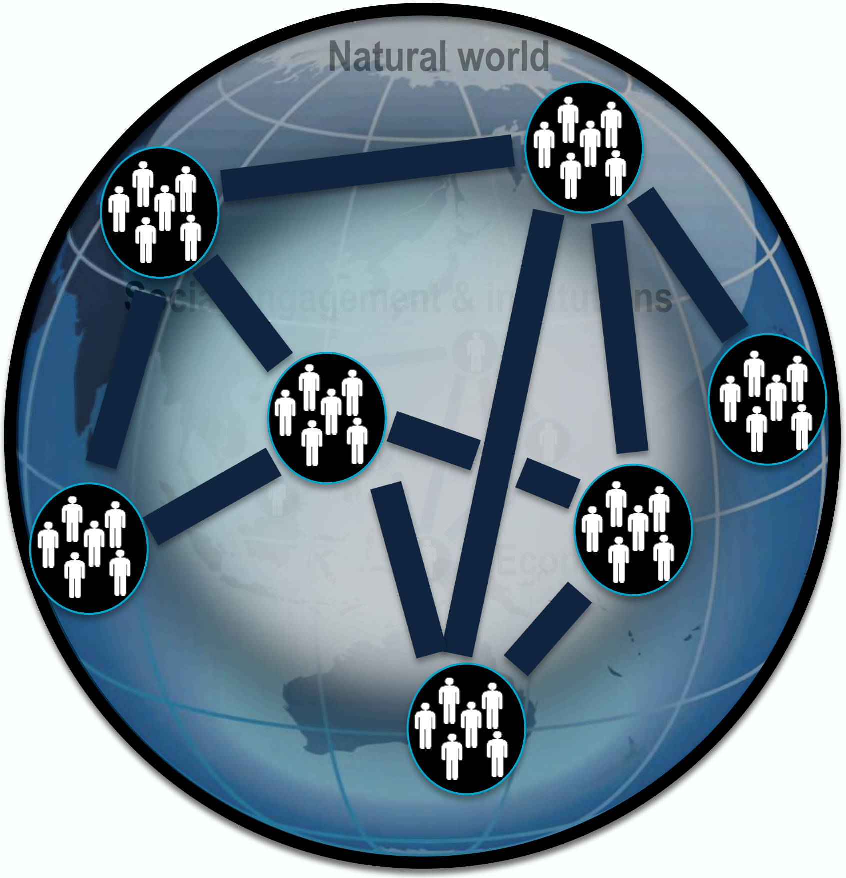
Exactly how resilient are ecosystems?

Beth Fulton | Head of marine ecosystem modelling, CSIRO Australia
2014

Competing use of space & pressures



Planetary Boundaries



- Socioecological universal theory requires unification of cognitive science, psychology, economics, ecology, biogeochemistry, mathematics, physics…

Resilience & Complex Adaptive Systems

- One facet of complex systems science

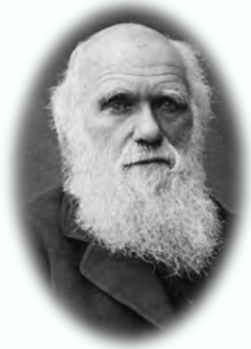
Joshua Epstein

Benoît Mandelbrot

Buzz Holling

Stuart Kauffman

Charles Darwin



John Conway

Edward Lorenz

Karl Ludwig von Bertalanffy

Jay Forrester

John von Neumann

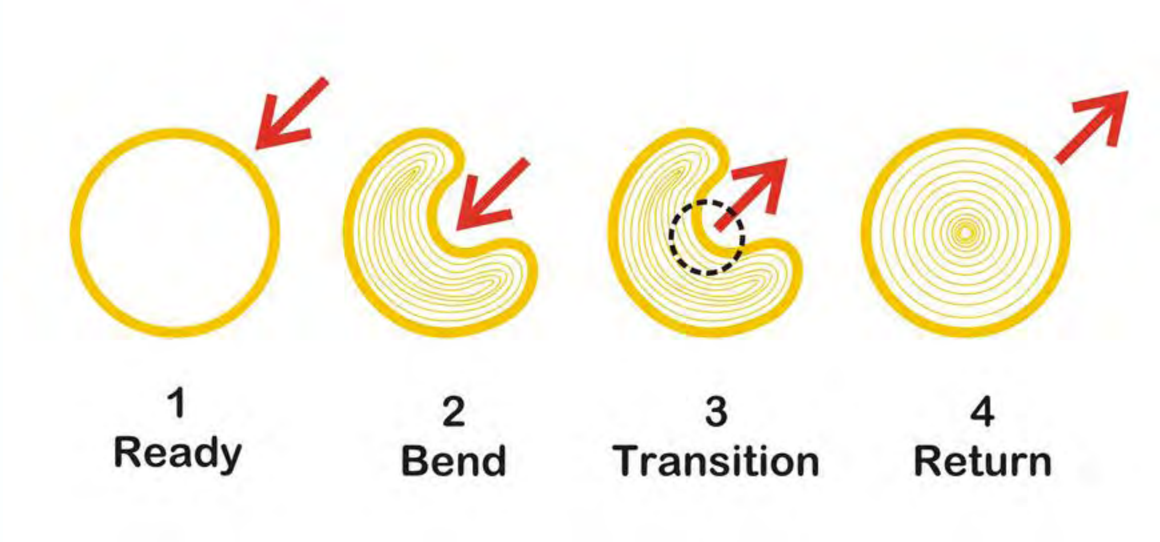
… plus economists, anthropologists and many more

“Lies for children”

They're not exactly lies, but are, nevertheless, untrue…. It's close enough to true, for everyday things.

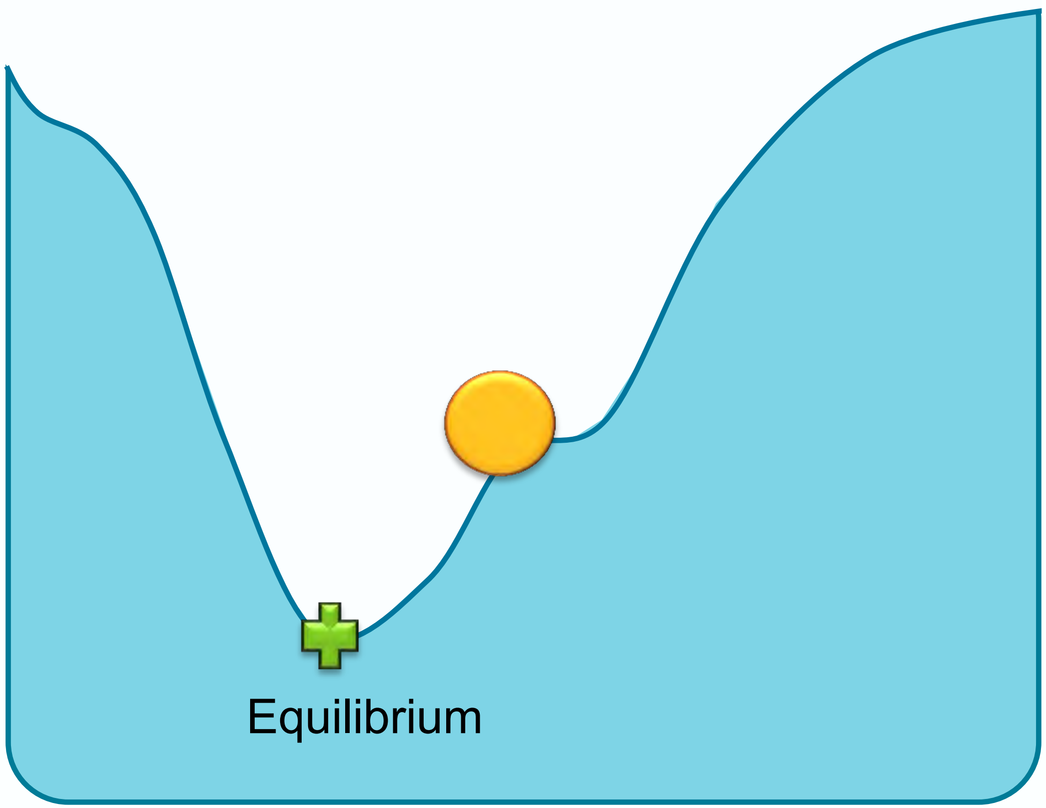
Terry Pratchett, Jack Cohen and Ian Stewart (2000)

- Diet matrix (feeding relationships)
- Species concept
- Resilience



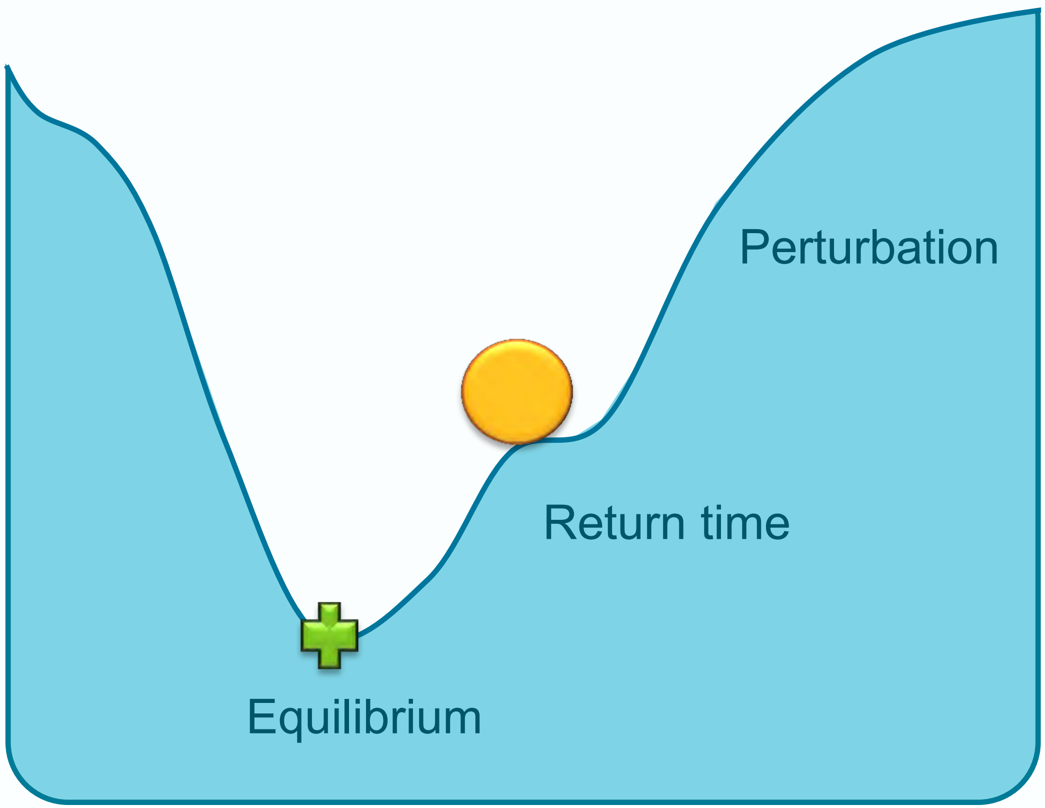
Ecological vs Engineering Resilience

- Engineering resilience = stability around equilibrium



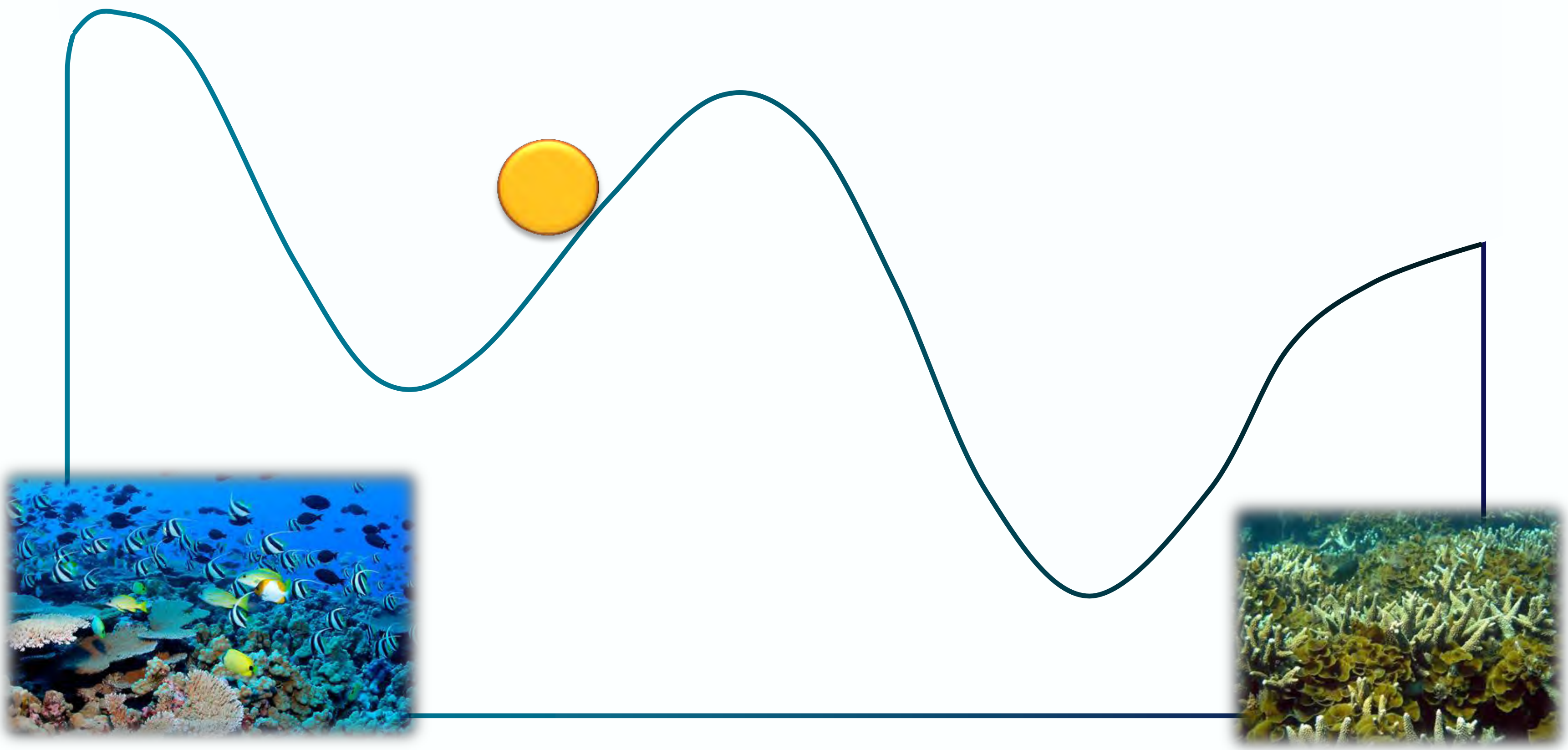
Ecological vs Engineering Resilience

- Engineering resilience = return time
- Can’t really cope with changing systems as equilibrium concept



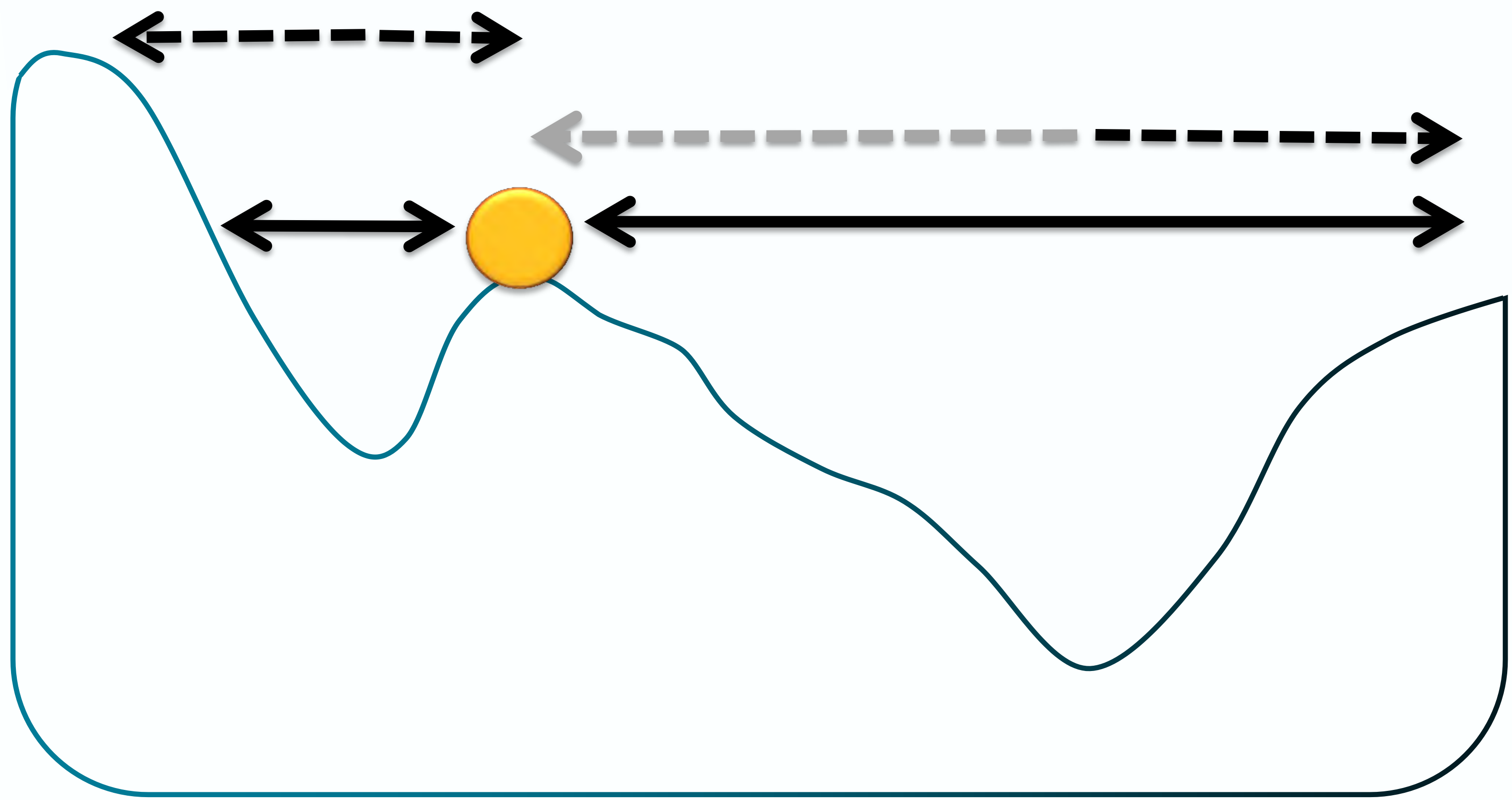
Ecological vs Engineering Resilience

- Ecological resilience = absorb shocks & retain ‘same’ structure & function
- Related to concepts of vulnerability & robustness

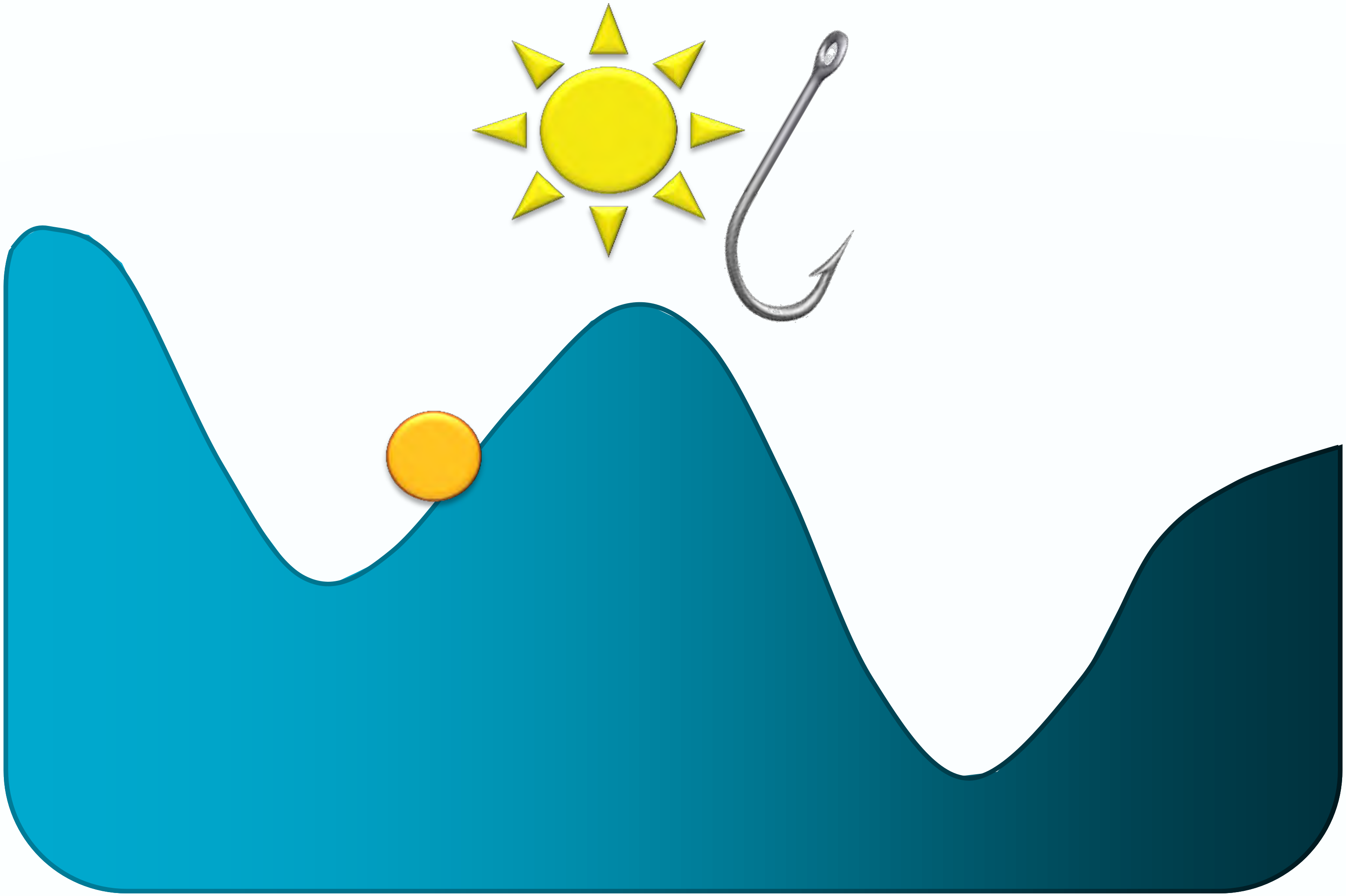


Ecological vs Engineering Resilience

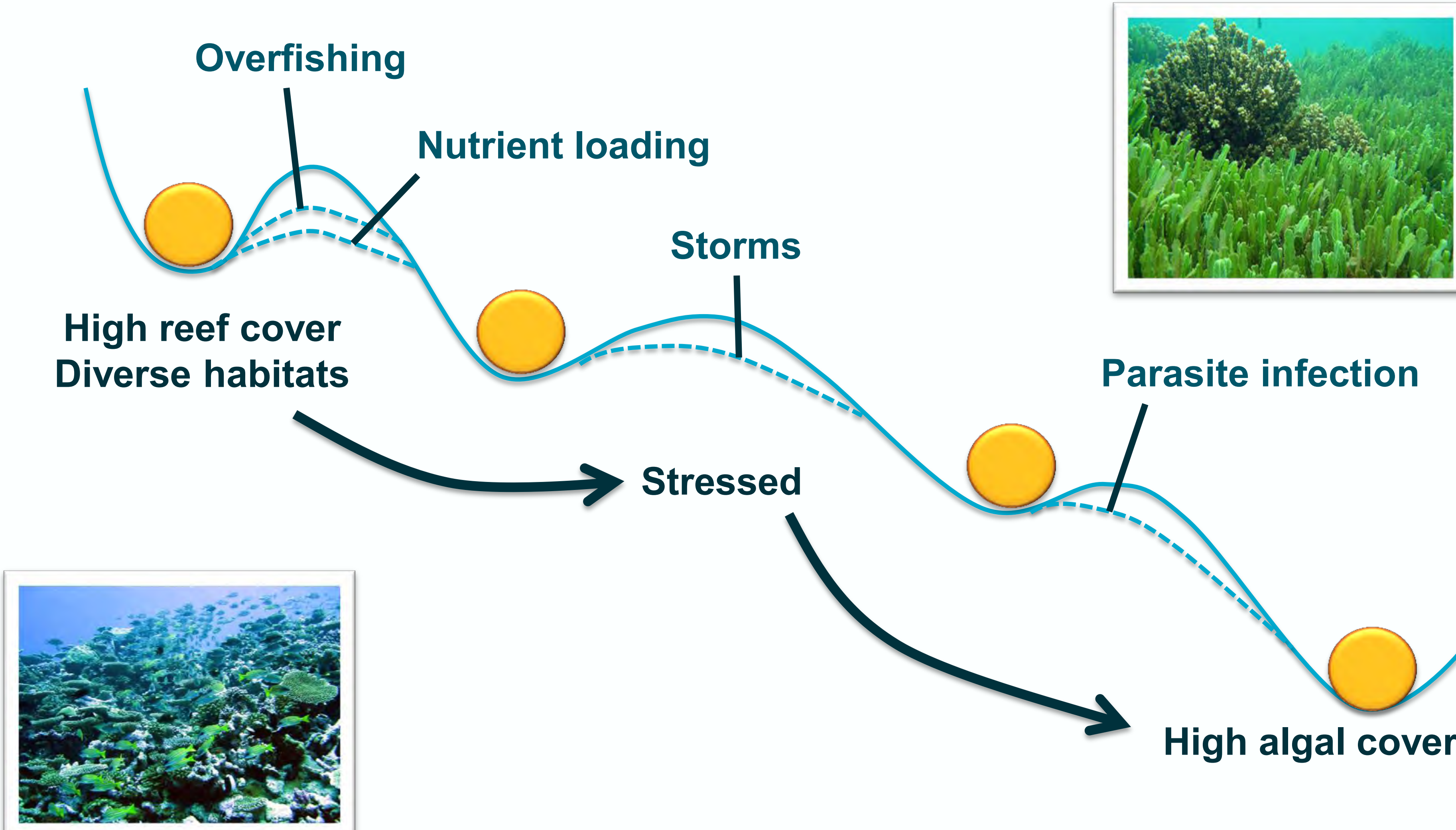
- Ecological resilience = different in each dimension (& variable)
- Due to external drivers and internal processes



How Resilience Fails



Cascading failure most obvious



- Cascading effect –> VERY resilient final state

Hughes 1994; deYoung

Cross scale interactions

- Hierarchy of change (cross scale interactions)
- Path dependency

	Patch	Local	Regional
Ecological			
Economic			
Social/Cultural			

Kinzig et al 2006

Cross scale interactions

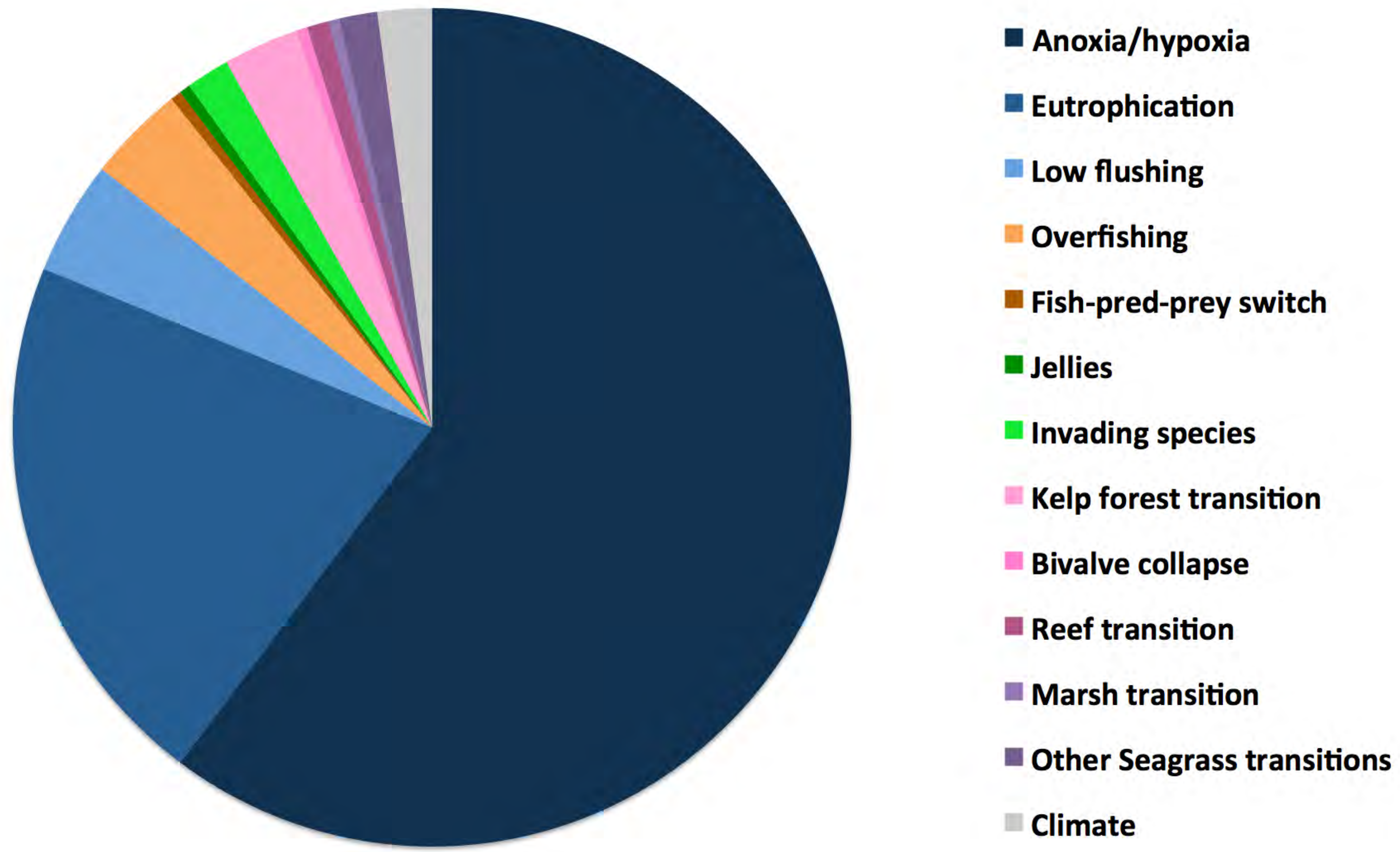
	Patch	Local	Regional	Global
Physical				
Ecological				
Economic				
Social/Cultural				

Cross scale interactions

	Patch	Local	Regional	Global
Physical		**Storm**	**Weather & Climate**	**Climate**
Ecological	**Infection, Competition Feeding**	**Connectivity**		
Economic		**Fishing**	**Economy**	**Trade**
Social/Cultural	**Families**	**Land use**		

How resilient are ecosystems?

- Literature search & www.regimeshifts.org



n = 230

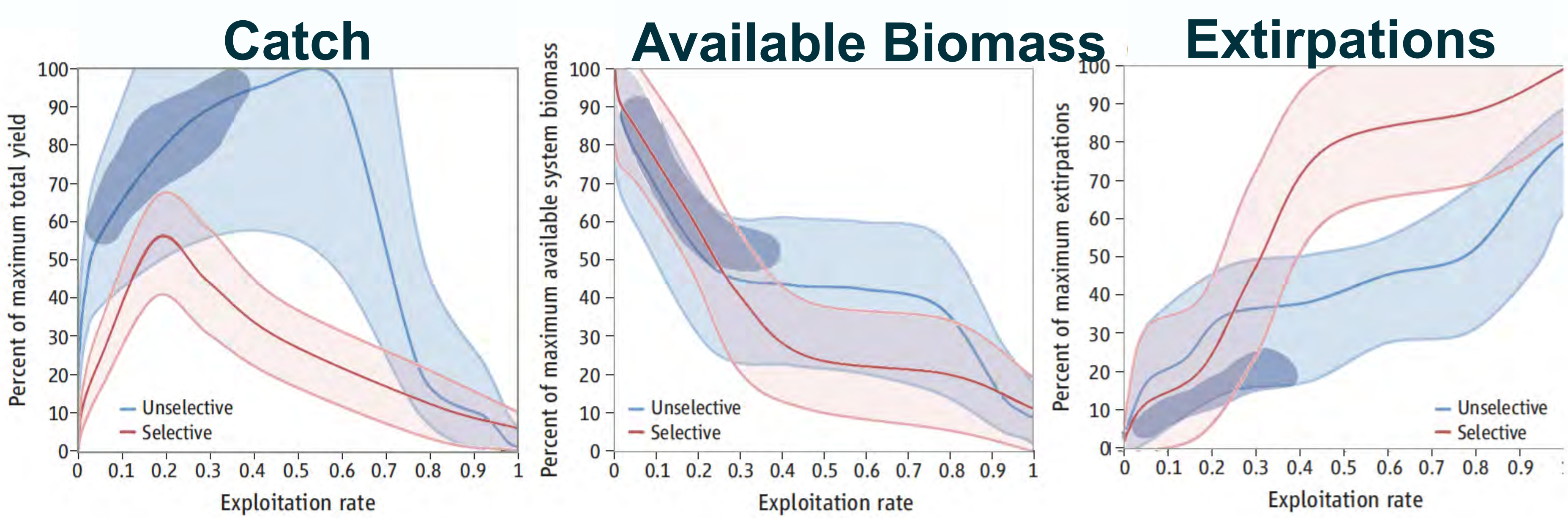
How resilient are ecosystems?

Gets the attention in the stories

Less resilience to "plenty"

Model evidence – Balanced Harvest

- Spread the pressure = ecologically sustainable (resilient)

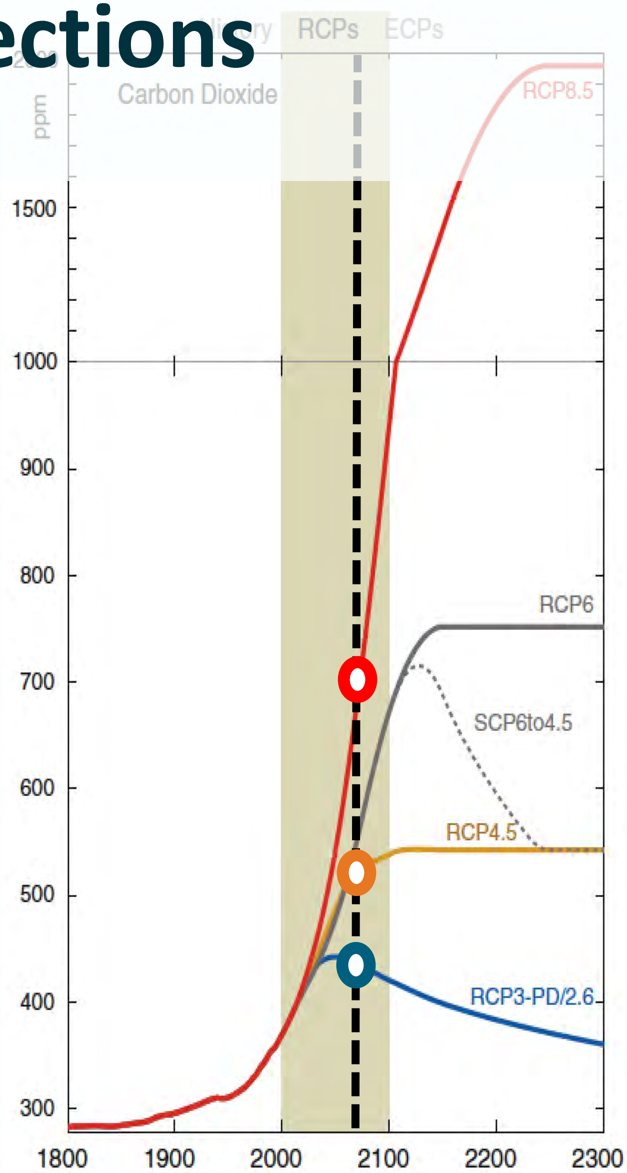


- Technically feasible?
- Possible culturally and economically?

Garcia et al 2012

Model evidence – Future projections

- Potential futures in SE Australia

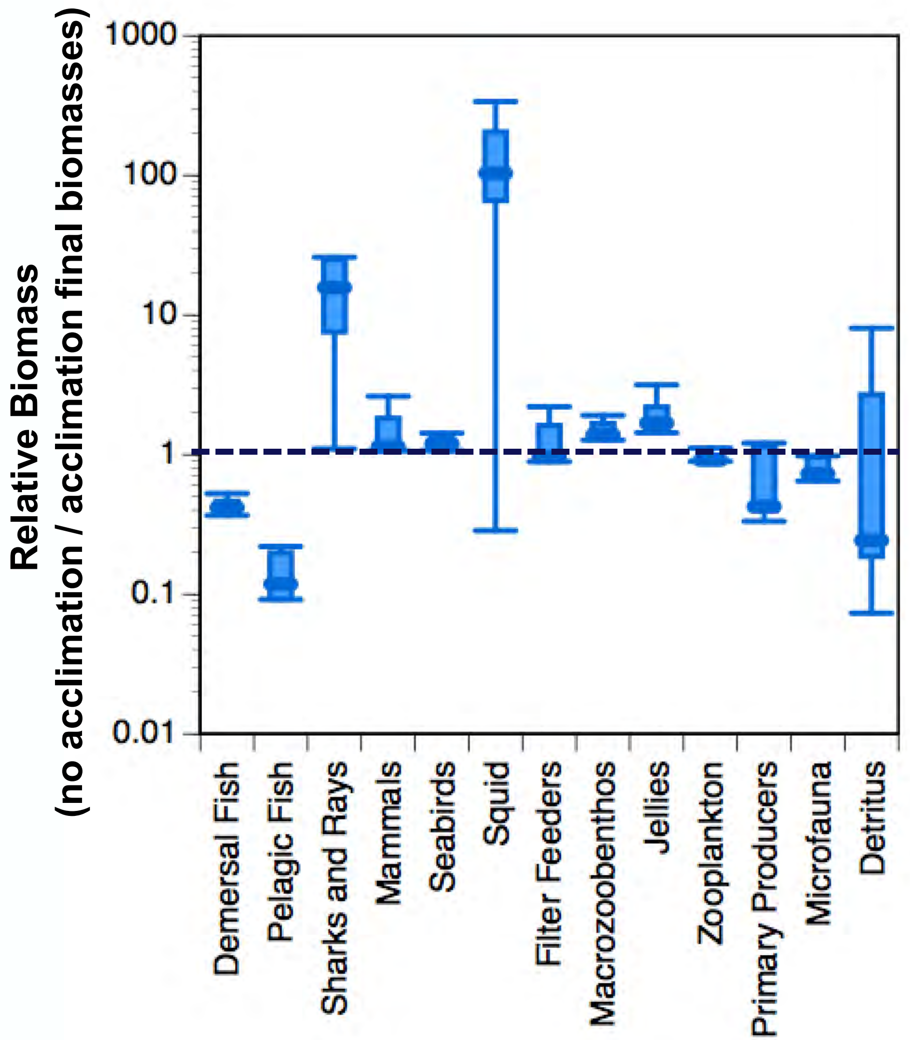


Meinshausen et al (2011)

CSIRO

Not as dire with acclimation

- No acclimation
  - Squids boom/bust
  - Jellies & non-calcifiers win
  - Weedy & pelagic
  - Fast turnover system
- With acclimation & evolution
  - While system copes, little gross change (some turnover in dominant spp)
  - Tipping point exists (~550-700ppm)



Ecosystems

An ecosystem composes of physical-chemical-biological processes active within a space-time unit
Lindeman 1942

- Humans too

Barriers to adaptation

① **Biological and ecological**

– distribution, composition & productivity change; thresholds

② **Behavioural, cognitive and social**

– flexibility & personality; intuition & perception; cultural influence

③ **Governance and regulation**

– supportive vs constraints & delays (hardship potential)

④ **Economic and markets**

– compound barriers; larger operators typically have more capacity

⑤ **Technological**

– facilitate change vs lock in maladaptive behaviour; info access

⑥ **Scientific**

– remaining gaps; more change focus needed

Measuring Resilience

… key components and relationships (networks) and their continuity through space and time.

… by no means obvious what leads to resilience in a complex system, or which variables should be measured in a given study of resilience

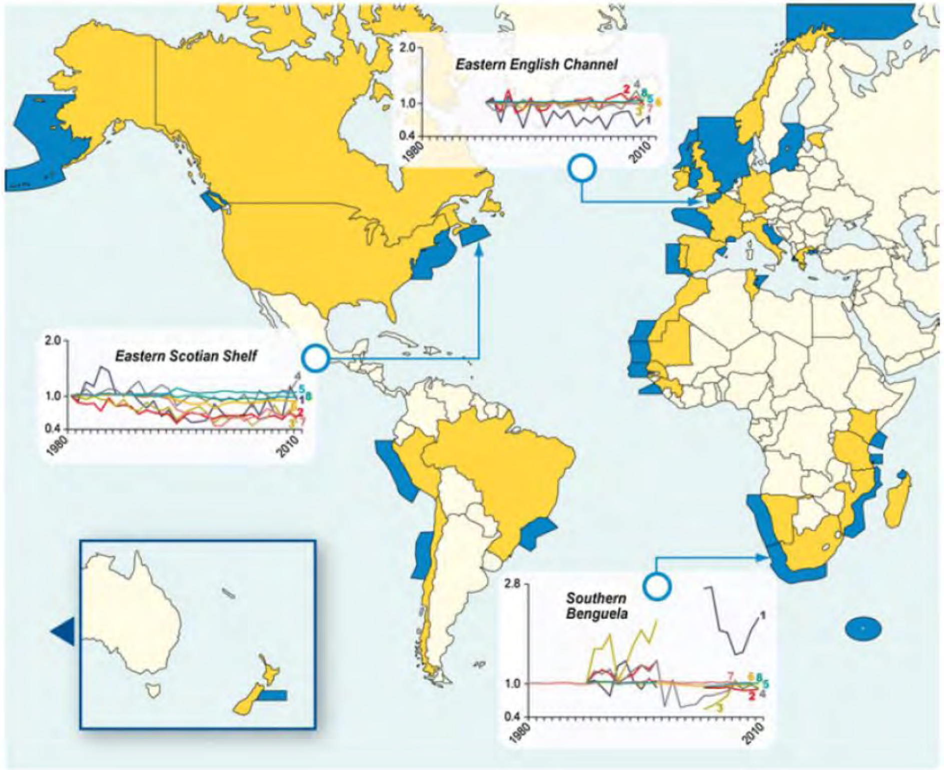
Cummings et al 2005

▪ Components (& drivers)	**abiotic, ecological, habitats, human actors**
▪ Processes	**nutrient cycles, flows, economics, social**
▪ Networks (linkages)	**food webs, trade, friendship**
▪ "Innovation"	**diversity, movement, learning**
▪ Continuity (buffers)	**longevity, seed banks, rules, repositories**

- Also identify surprises & potential alternative states

Monitoring & indicators

- Multiple groups looking at indicators (national, international)
- PICES S1, ICES, SCOR
- Indiseas (www.indiseas.org)
  - Biomass
  - Community indices (size, age)
  - Vulnerability index
  - Trophic level (biodiversity proxy)
  - Abiotic indices (system-specific)
  - Economic indices
  - Human community dependency
  - Reference levels for each
  - Harvest control rules

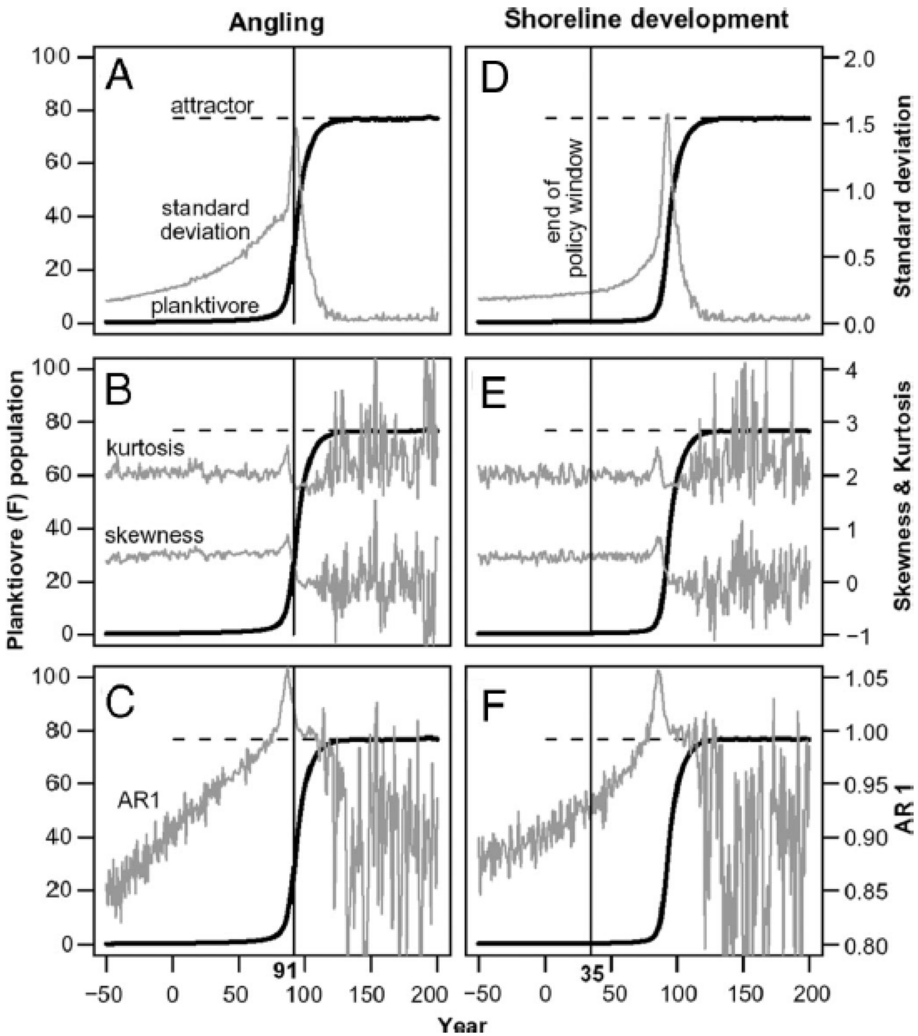


Monitoring & indicators

- Essential Ocean Variable (EOVs)
- 726 indicator recommendation (>100 documents)
  - General types known (relative biomass of key groups, habitats, structure, longevity, productivity, abiotic, social & economic)
  - Desire universal set
  - System specific

Hayes et al in prep

Monitoring & indicators



- Loss resilience = regime shift
  - Early warning indicator = shift in variance or skew
- Muffling & magnification (due to how components interact & how correlated to the shock)
  - Monitor bits with different vulnerabilities and responses

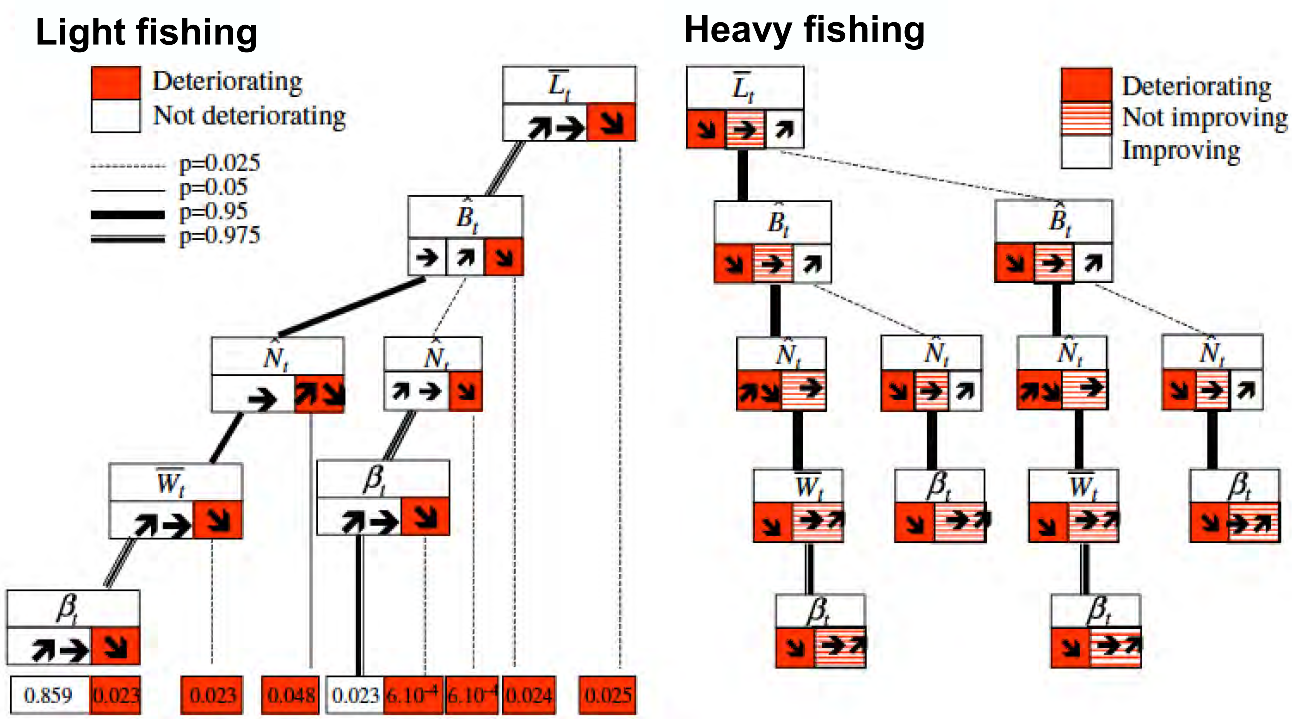
Biggs et al 2009; Brock & Carpenter 2010

Critical management variables

- Effective management has “Rule of hand”
- 3-5 key variables (aggregate ones now preferred, pros & cons)
- Psychology? Back to “lies for children”?

Aggregate indices & the cringe response

- Aggregate indices now preferred (integrate information)
  - Scoring -> simple composite (sensitive to correlations & weighting)
  - Multicriteria decision analysis (transparent, but sensitive to rules)
  - Multidimensional space (math robust, intuitive understanding lost)



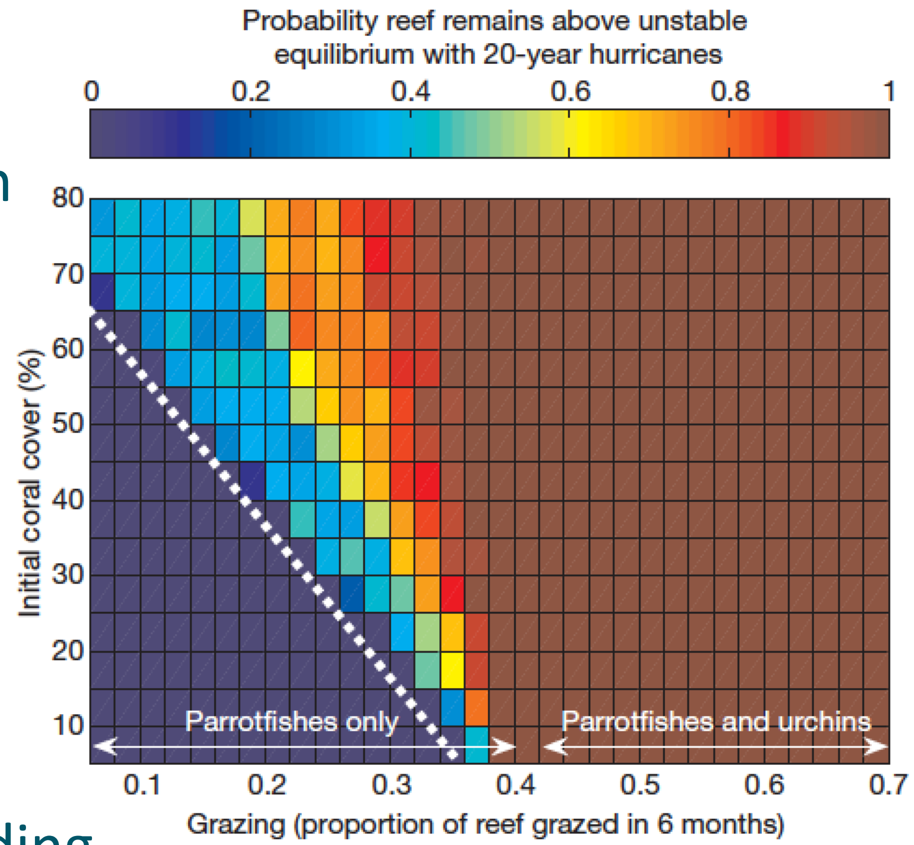
Shin et al 2012; Rochet et al 2005

Aggregate indices & the cringe response

- Model based indicators
  - Can produce resilience indices

  "provided that a parameterization for disturbance events was available"

- Performance can be poor
  - Difficult to collect data
  - Model formulation
  - Lack of transparency
  - Need good systems understanding



Mumby et al 2007; Fulton et al 2005

Adaptive Monitoring

Climate change

Physical features impacted

Species composition changes

Bias, design, coverage, representativeness effected

Adaptive sampling?
Avoid inconsistencies?

- Consistent core + serendipitous supplements?

Managing for resilience

1. Manage for multiple potential configurations & multiple scales
2. Manage for diversity, paying attention to slow variables (as dictate thresholds, responses, adaptive capacity)
3. Accept fore-gone short-term efficiency (but less long-terms crisis management costs; trade-off between time periods or scales)
4. Strategic interventions can work, but timing dependent
5. **Understand underlying mental models**, increasing overlap provides adaptive capacity
6. Adaptive governance (vulnerability can not be eliminated)

Marrying resilience & optimal control

- Management comfortable with optimal control principles
- Modification possible, so that keep successful aspects, but get flexibility (resilience) needed in changing systems?

Summary

- Multiple stressors
- Resilience = means of understanding system state & cycles
  - understanding cross-scale complex systems
- Biology can take care of itself… mostly (don’t forget humans!)
- Indicators
  - Basic needs known in general terms (avoid “physics envy”)
  - more data, but how deal with it?
  - How remain adaptive?
- Managing for resilience **might** be possible

Thank you

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