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# Measuring Resilience

Wealth from Oceans Flagship

Beth Fulton

April 2011

National Research  
**FLAGSHIPS**  
Wealth from Oceans



# Warnings



J

Jet lag



C

Confusion



M

Mild wearing

# The question

Identify means of determining ecosystem  
resilience or vulnerability

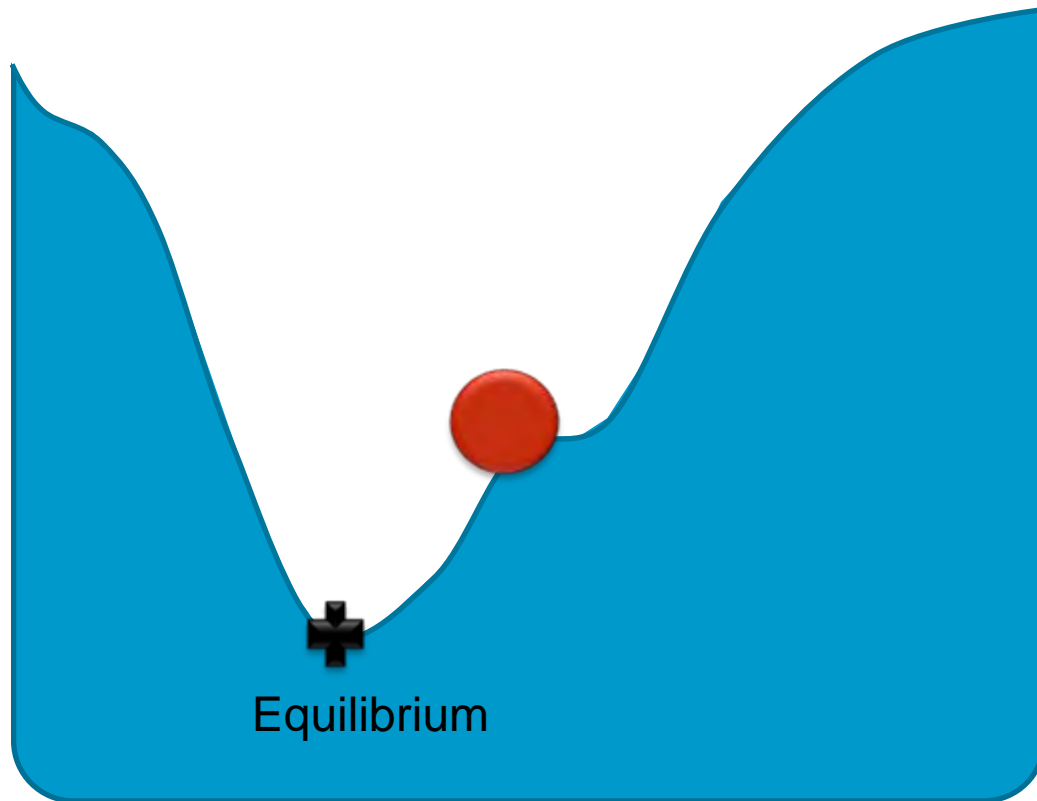


# Resilience



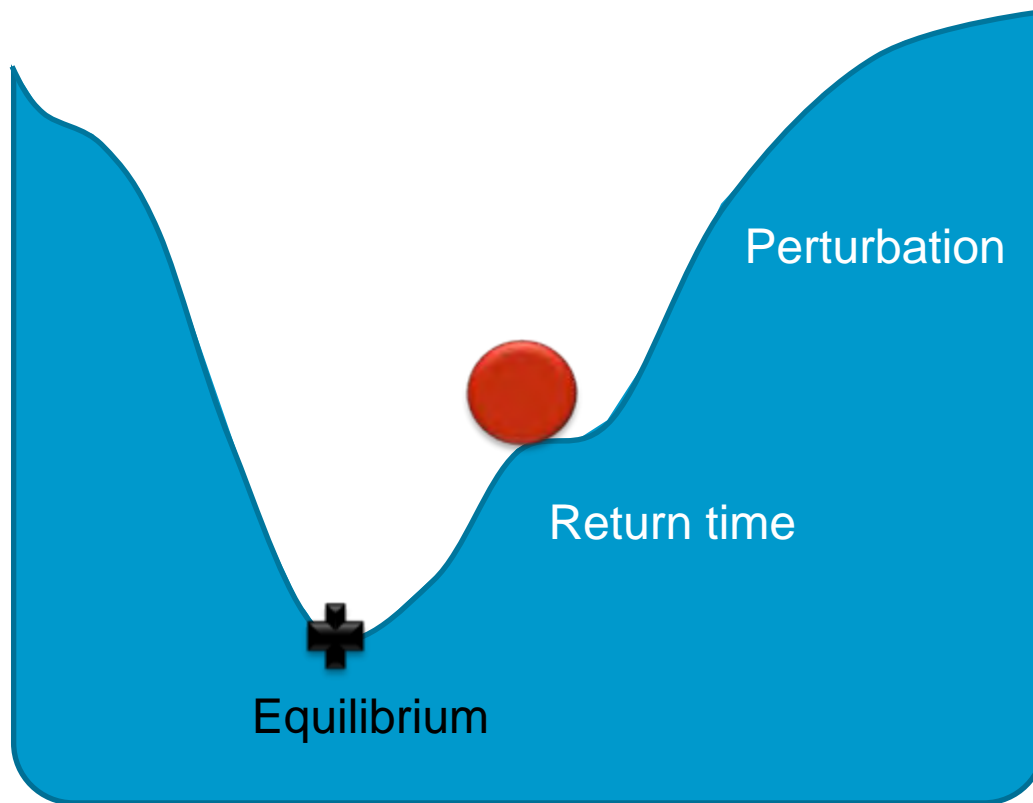
# What is Resilience?

- Engineering resilience = stability around equilibrium



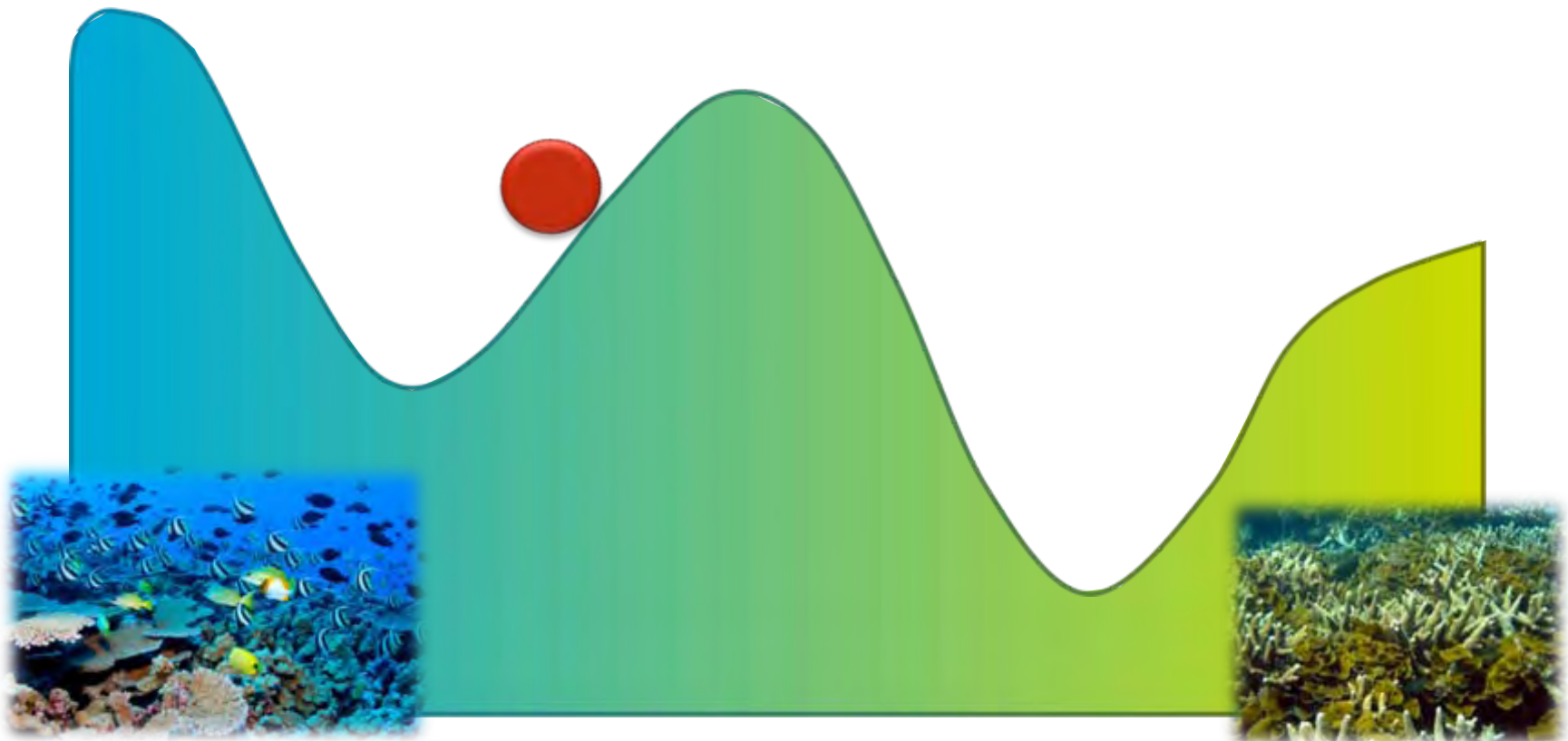
# What is Resilience?

- Engineering resilience = return time



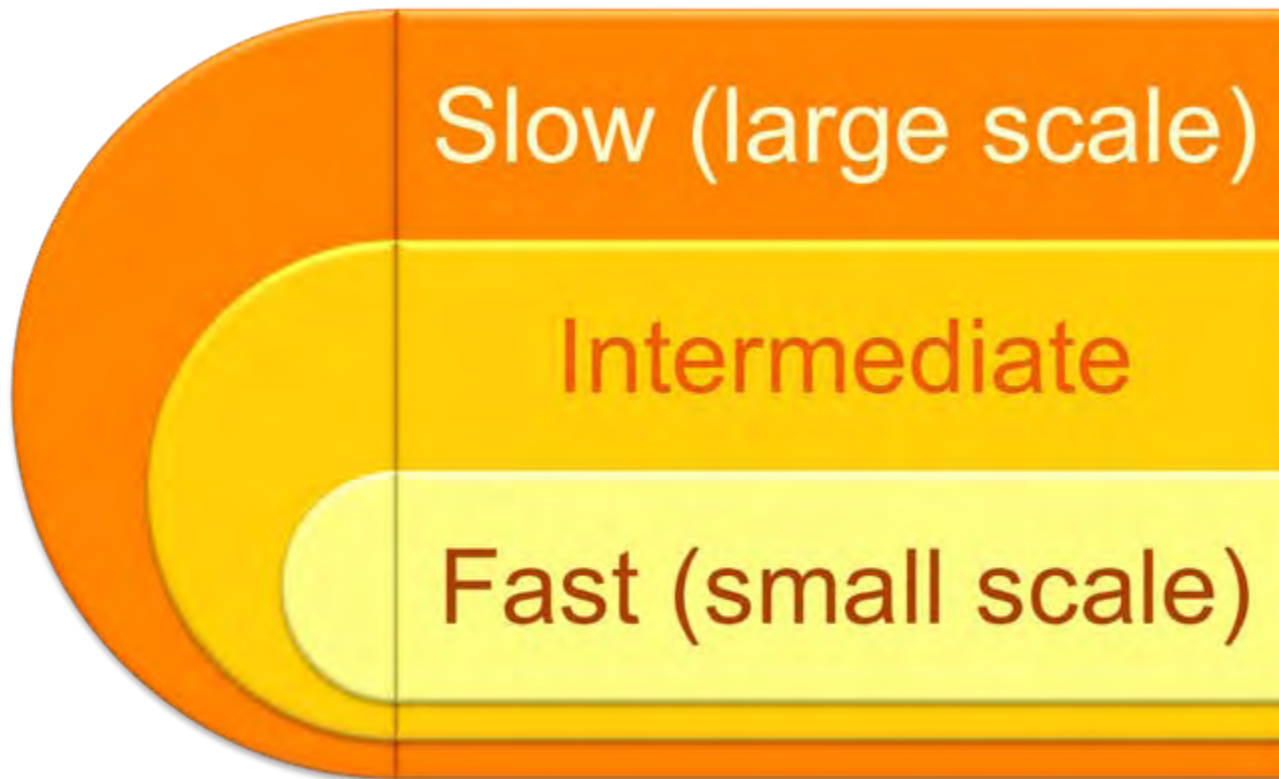
# What is Resilience?

- Ecological resilience = absorb shocks & retain 'same' structure & function



# Panarchy

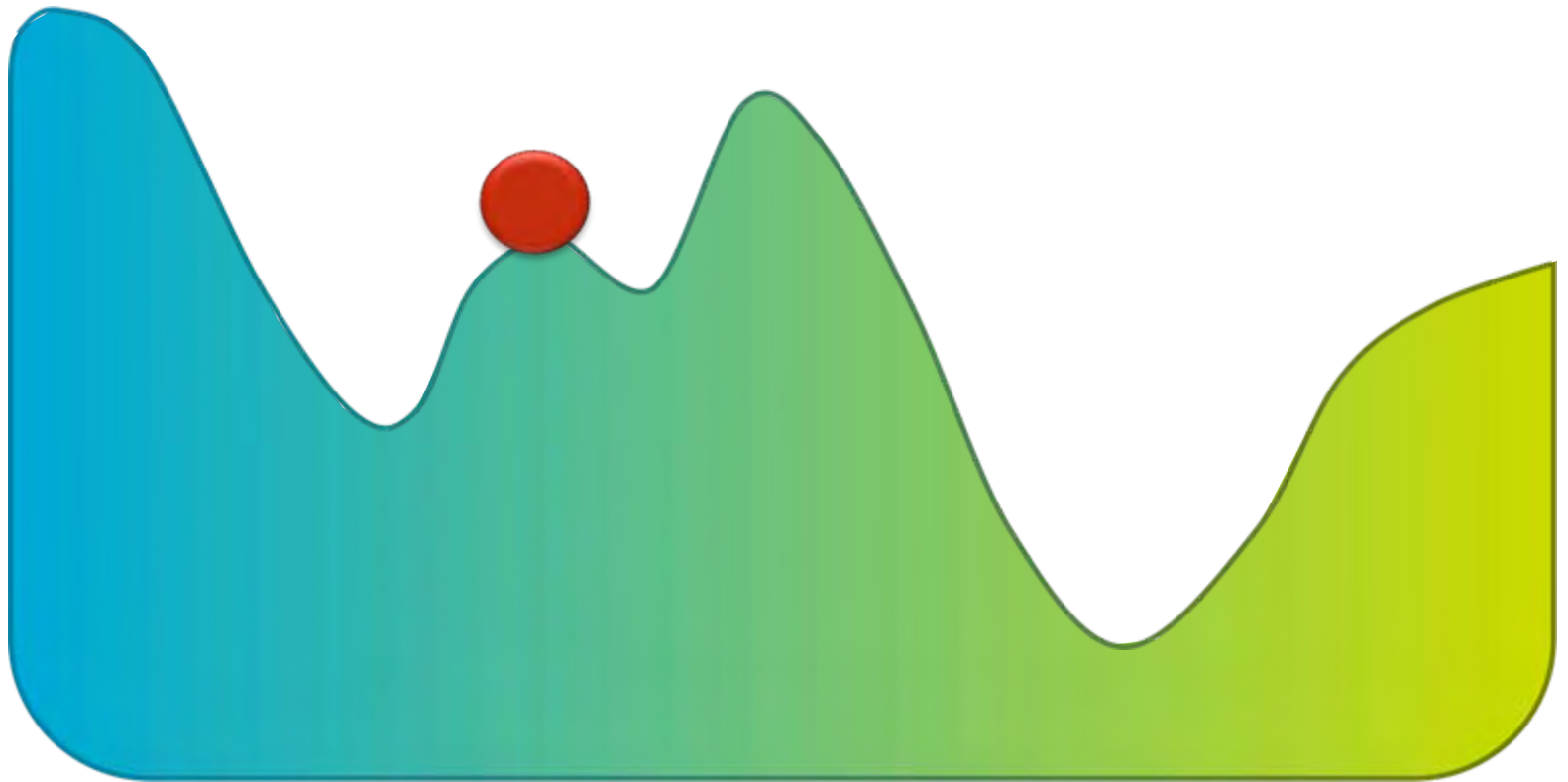
- Set of dynamic systems nested across scales



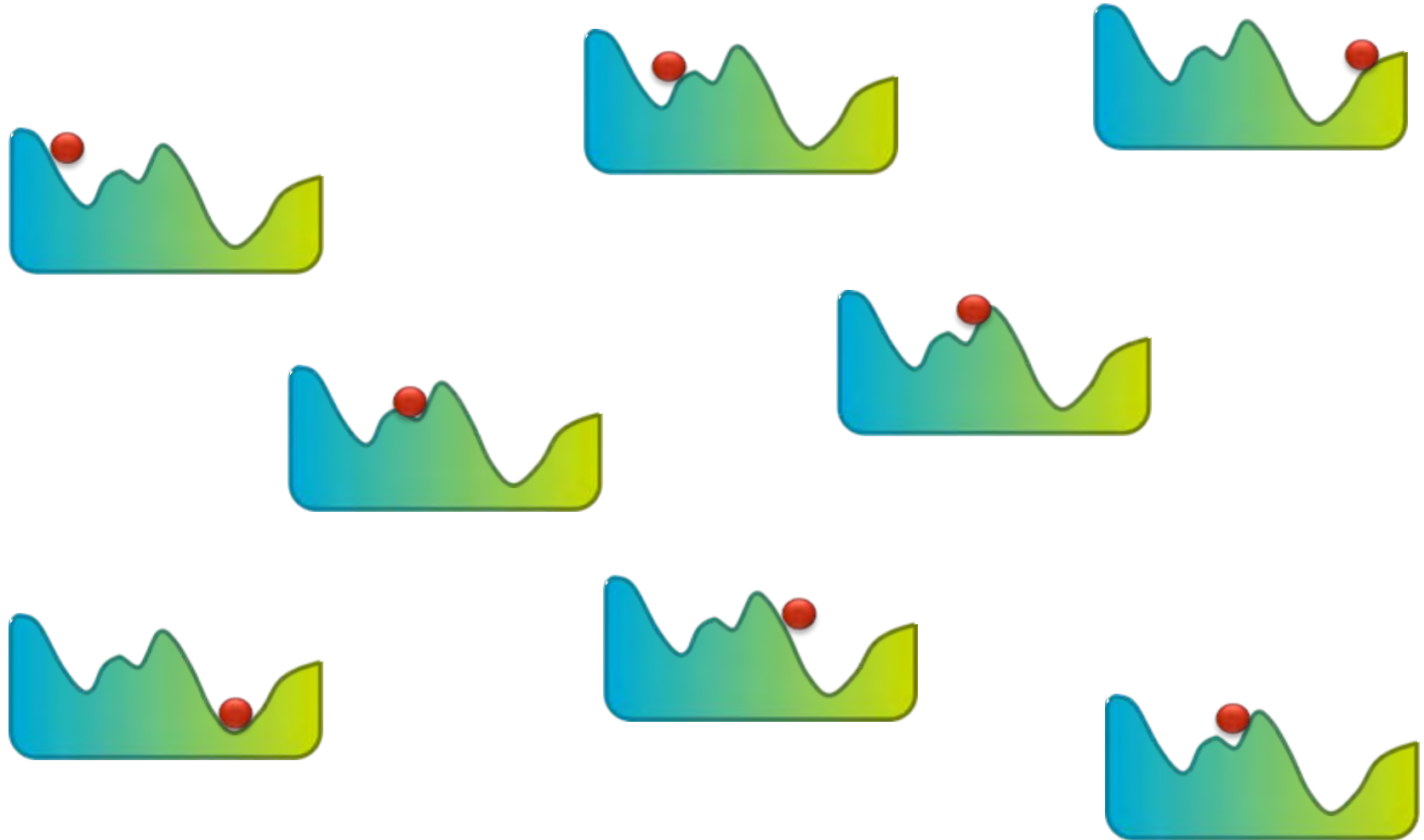


# Includes Variance

- Ecological resilience

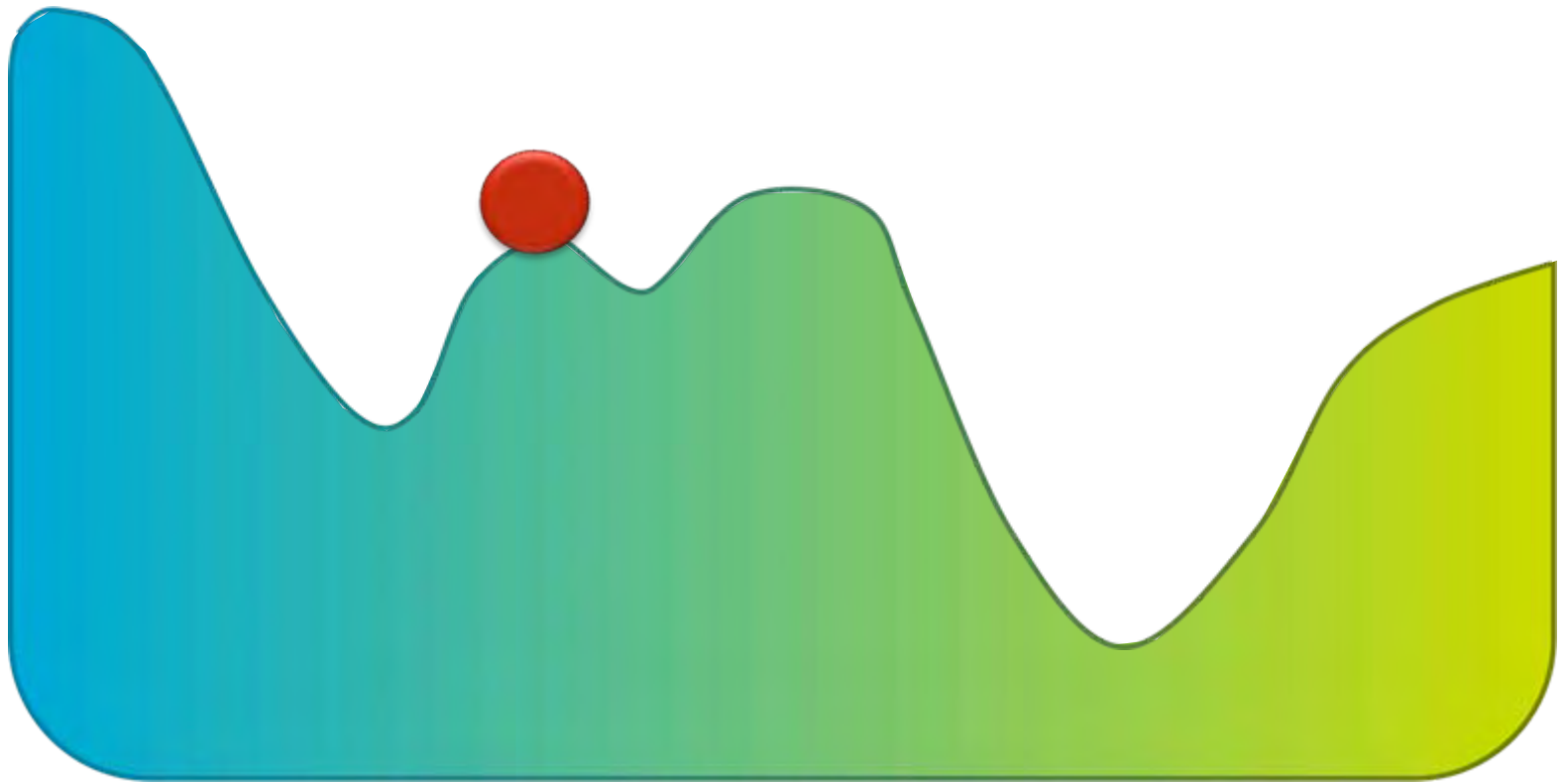


# Space & Time



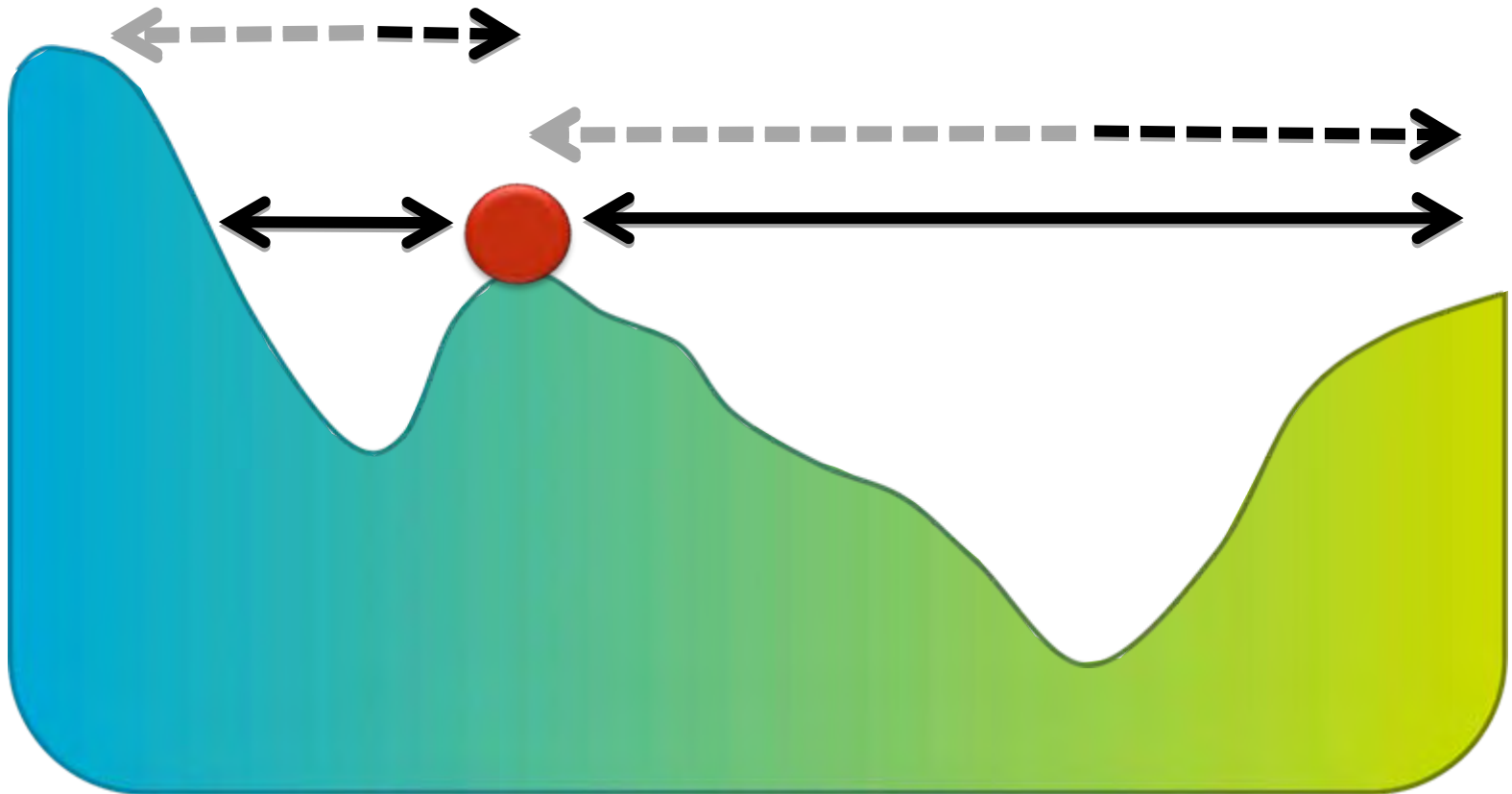
# What is Resilience?

- Ecological resilience



# What is Resilience?

- Ecological resilience



# System Dynamics

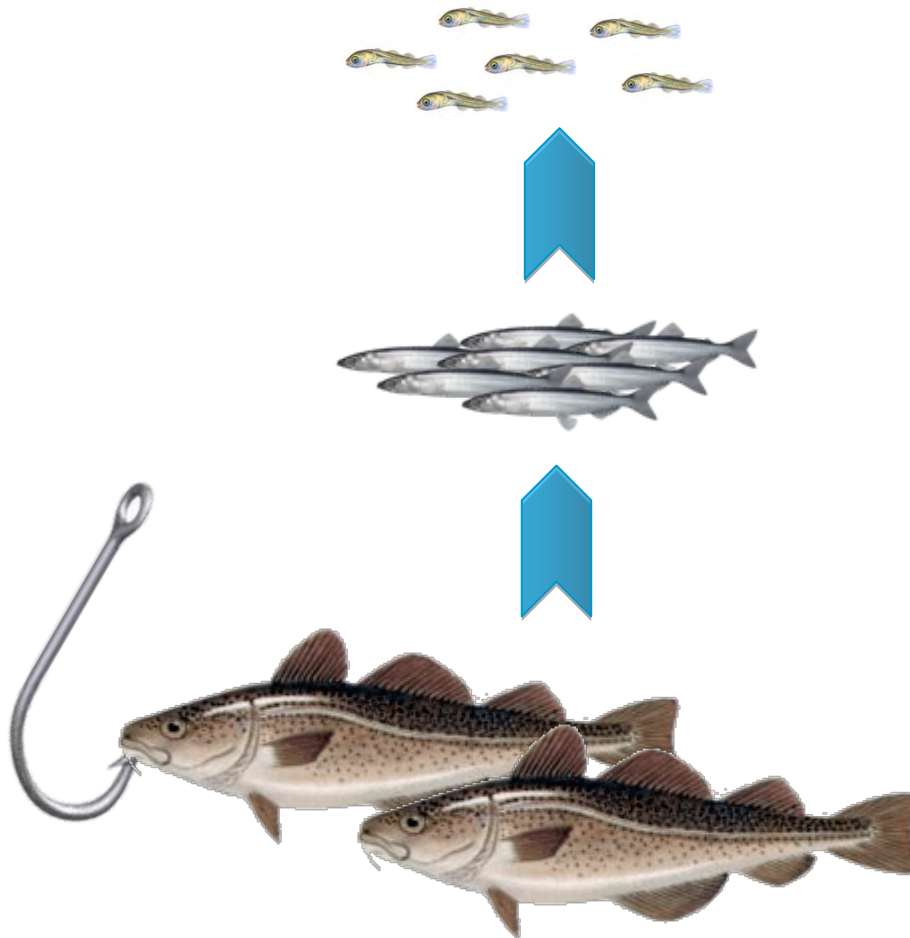
- External drivers





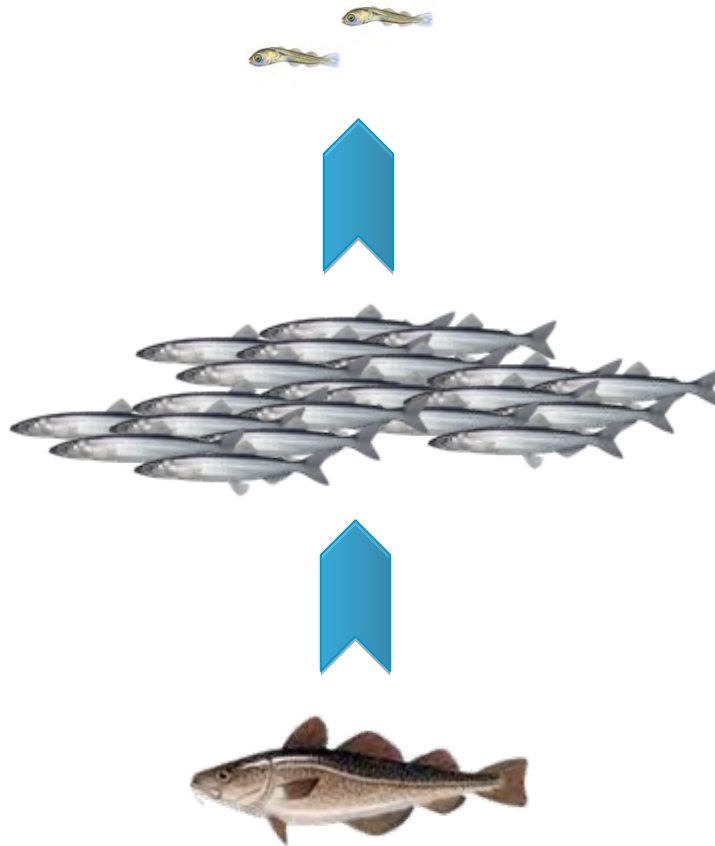
# System Dynamics

- Internal processes

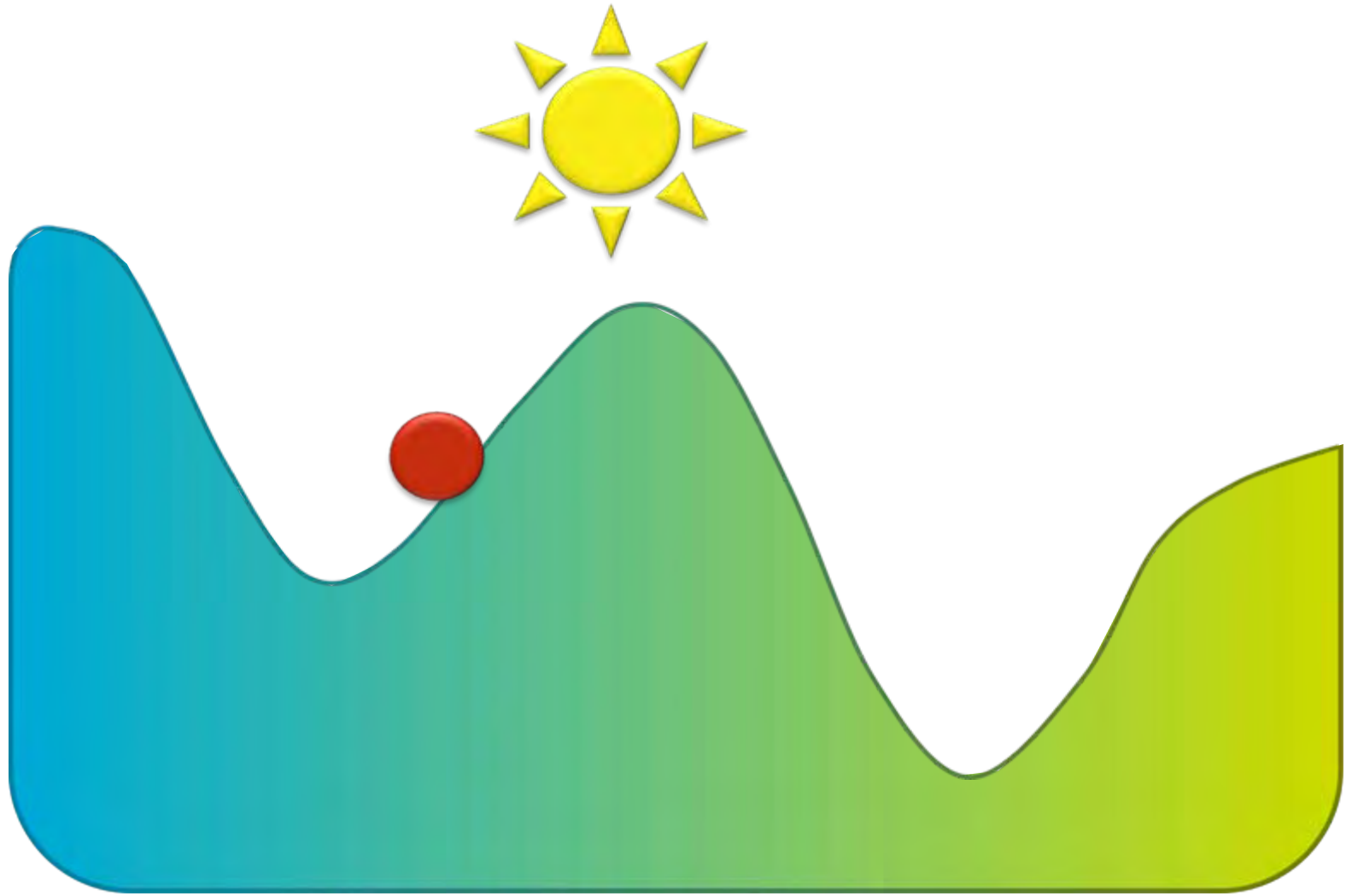


# System Dynamics

- Internal processes



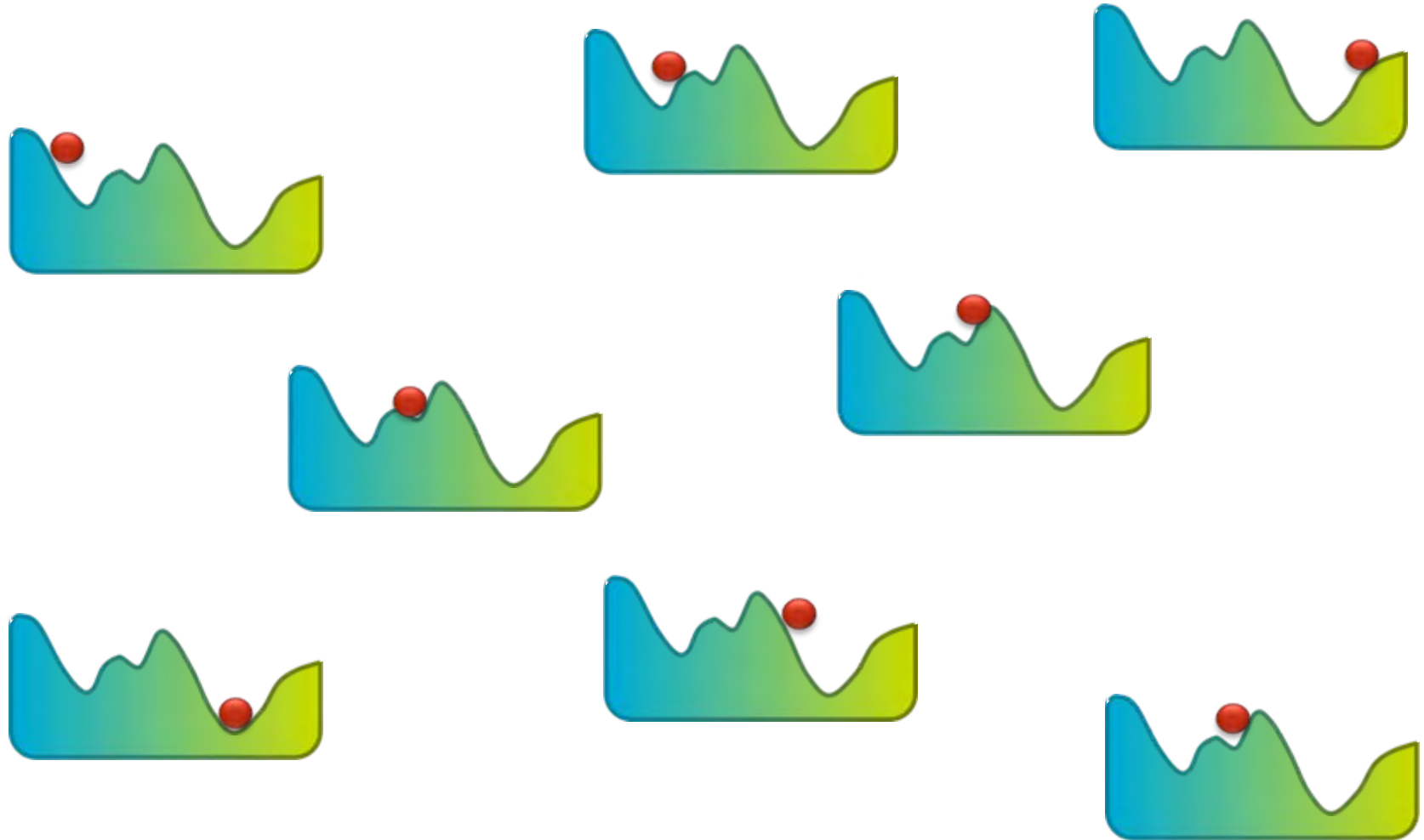
# Management & Resilience



# Management & Resilience

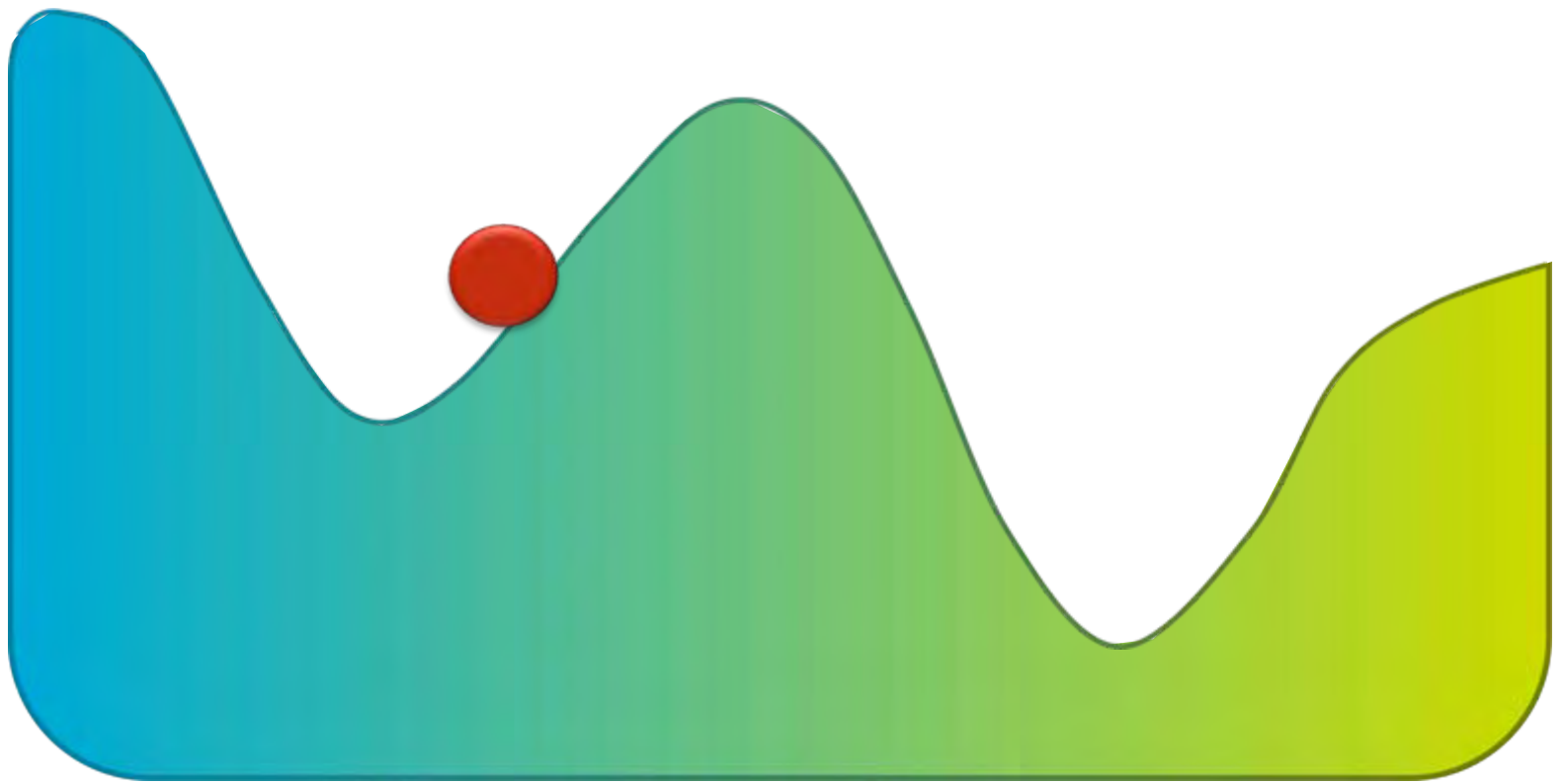


# Removal of Heterogeneity



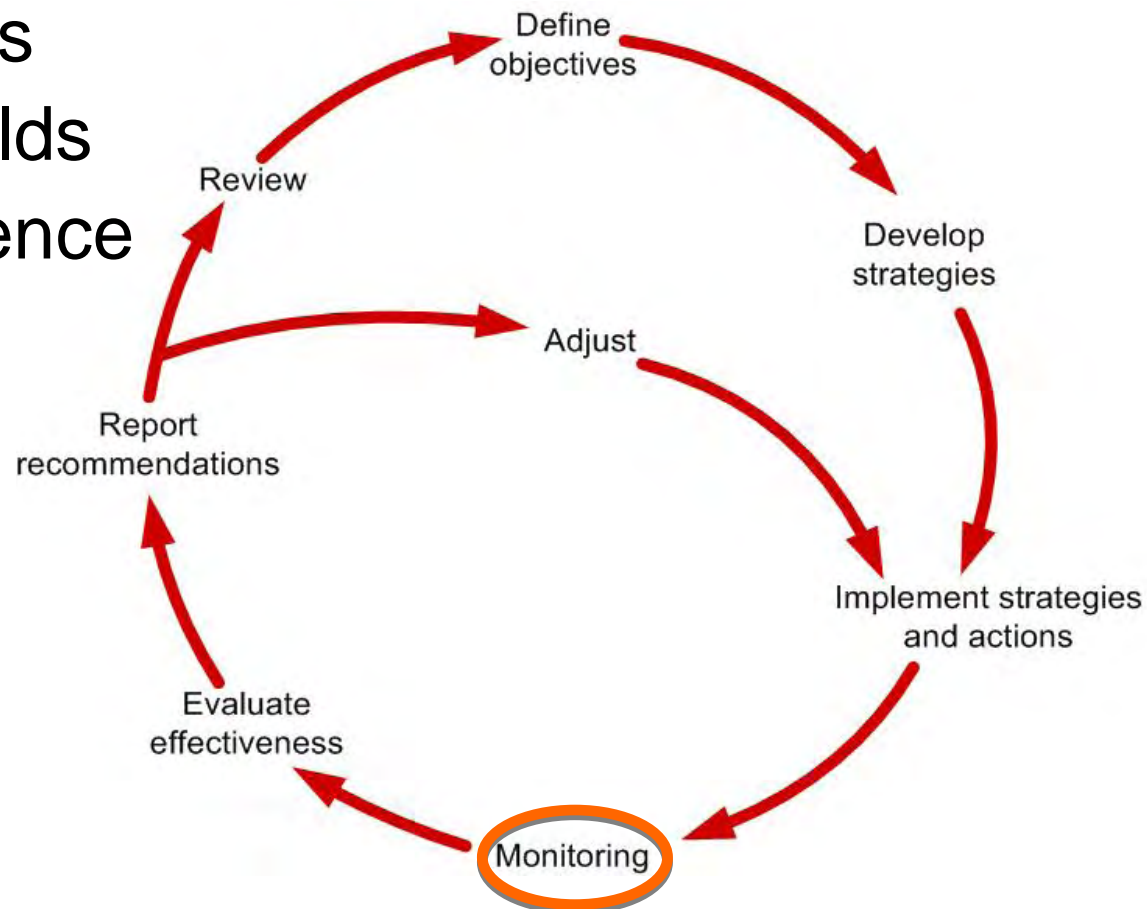


# Homogeneous Change



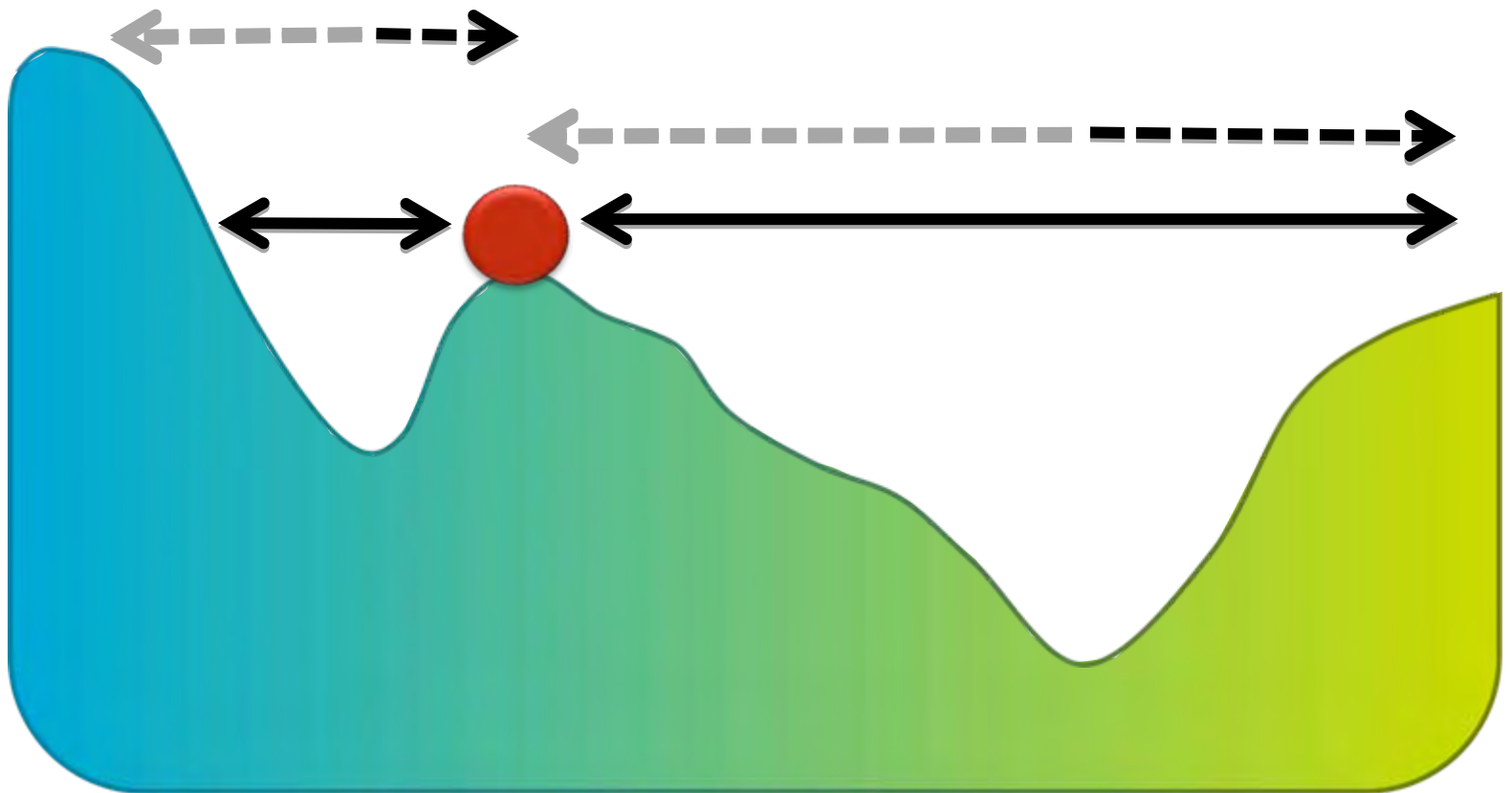
# Management & Resilience

- Adaptive management
  - respond to change
  - find thresholds
  - avoid thresholds
  - support resilience



# Measuring Resilience

- How the heck do you measure it ?!



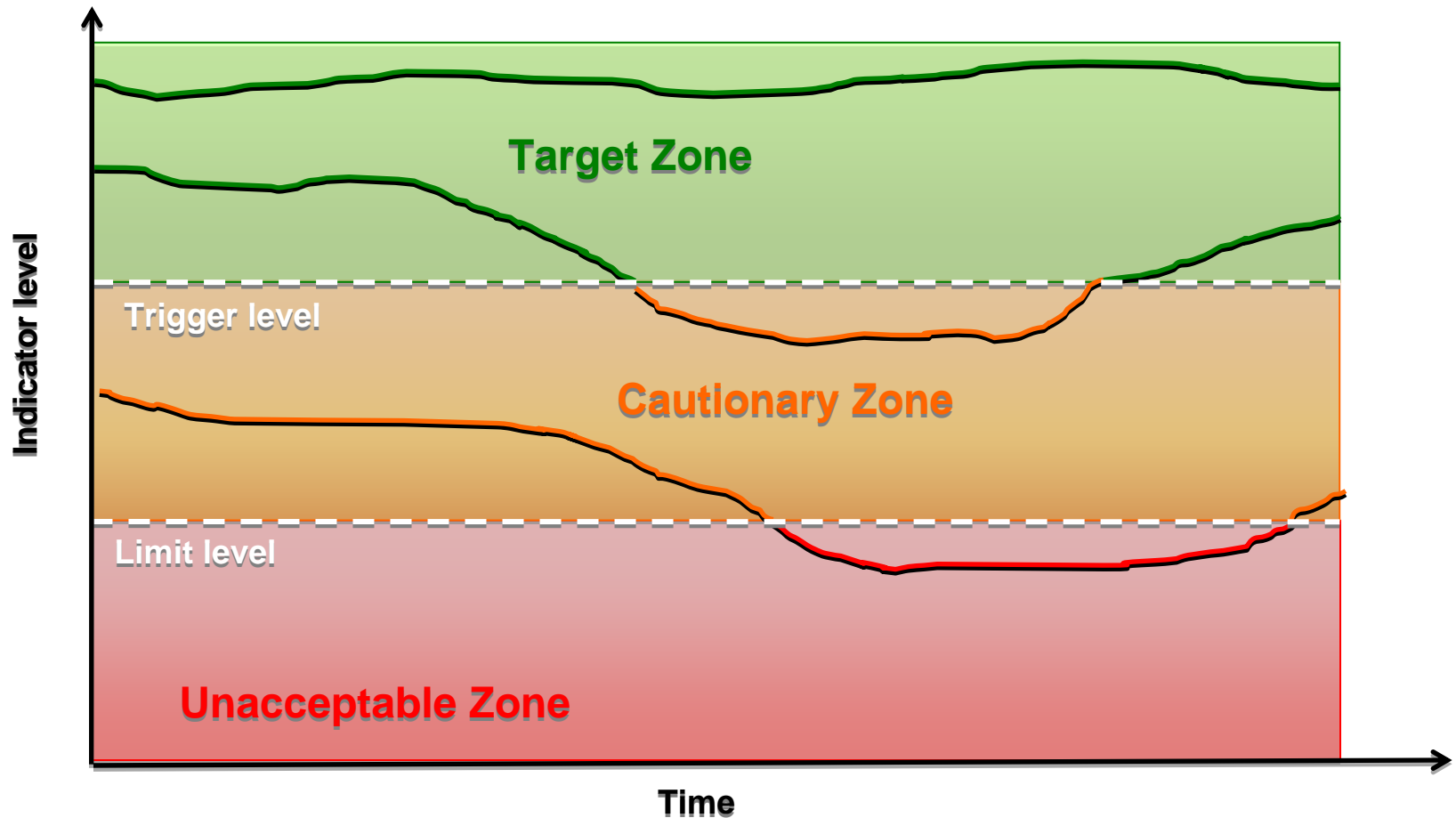
# Impossible?

Ecological resilience is difficult to assess and measure a priori and is often known only after the fact...

Gunderson, Holling and Allen 2010

# Thresholds

- Use thresholds as limits
  - need to know threshold points





# Thresholds

- Existing threshold (if known)
  - threshold value?
  - current state vs threshold value?
  - trajectory of state vs threshold value?
- Slow variables influence thresholds
  - how are slow variables changing?
  - which factors control slow variables?

# Finding Thresholds

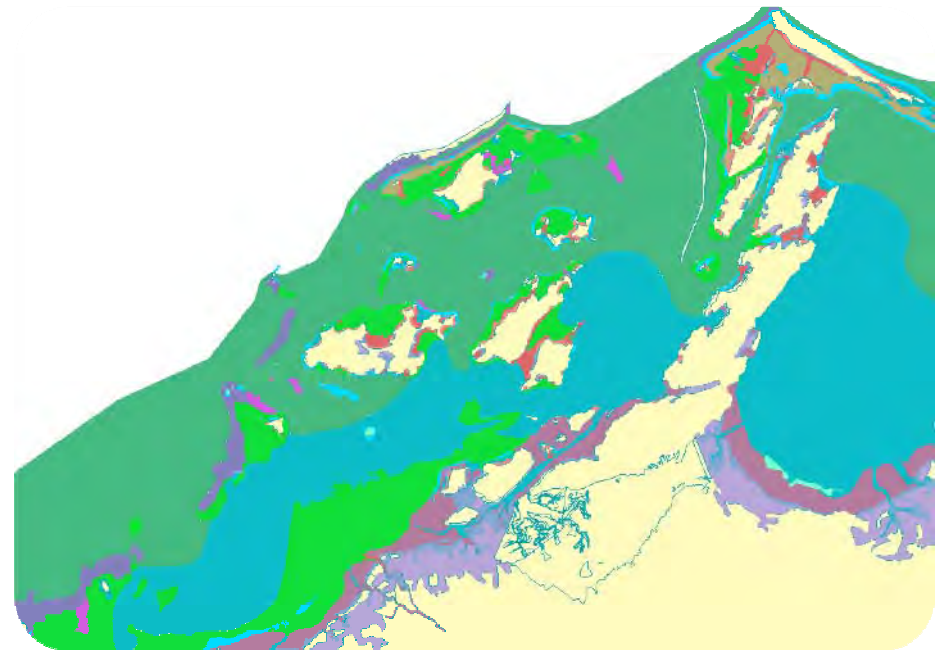
- Observed alternative system states
  - coral reefs (coral vs algae vs urchin barren)
  - kelp forests (kelps vs urchins vs crabs)
  - shallow seas (seagrass vs phytoplankton)
  - benthos (lobsters vs whelks dominant)
  - oceans (vertebrates vs invertebrates, demersal vs small pelagic fish)
  - upwellings (anchovy vs sardine)
  - Antarctic (krill vs salp based)

# Role of Models

- How find thresholds?
- Experiments
  - active adaptive management
  - can be costly (\$ and politically)
  - ethical issues if irreversible
- Explore via models
  - resource intensive
  - archetype models give clues?

# Ecosystem Quantity

- Map alternative ecosystem states
  - often data intensive
  - habitats, satellite detectable, BIG surveys
- Outputs
  - maps (mosaics)
  - mean-variance analysis = phase space



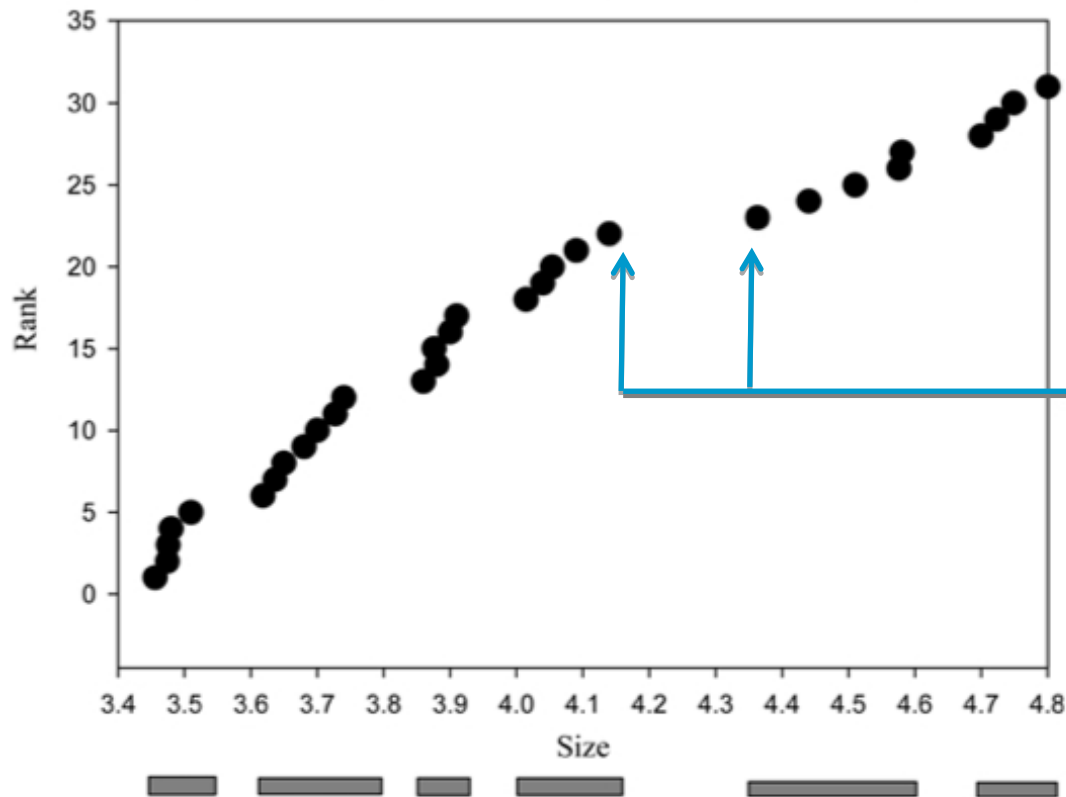
# Looking for Edges - Ecotones

- Ecotones
  - edges of alternative ecosystems
  - poised on thresholds
  - 1<sup>st</sup> places to respond to change (for landscape processes)
  - moderately successful



# Looking for Edges - Size

- Clumps of species around critical process scales – marine examples?

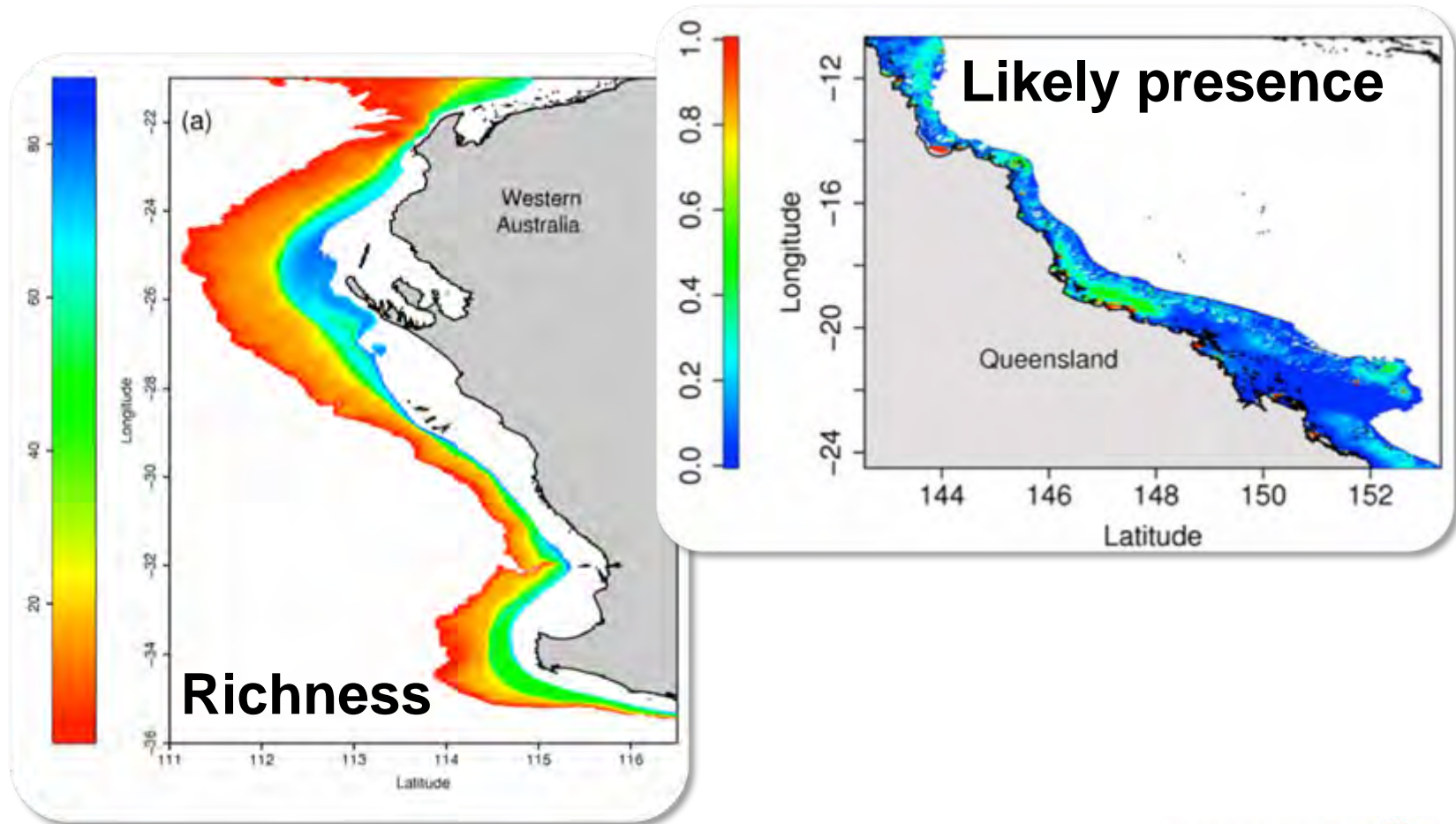


Lose edge species 1<sup>st</sup> when perturbed

Invaders also enter here

# Ecosystem Quality

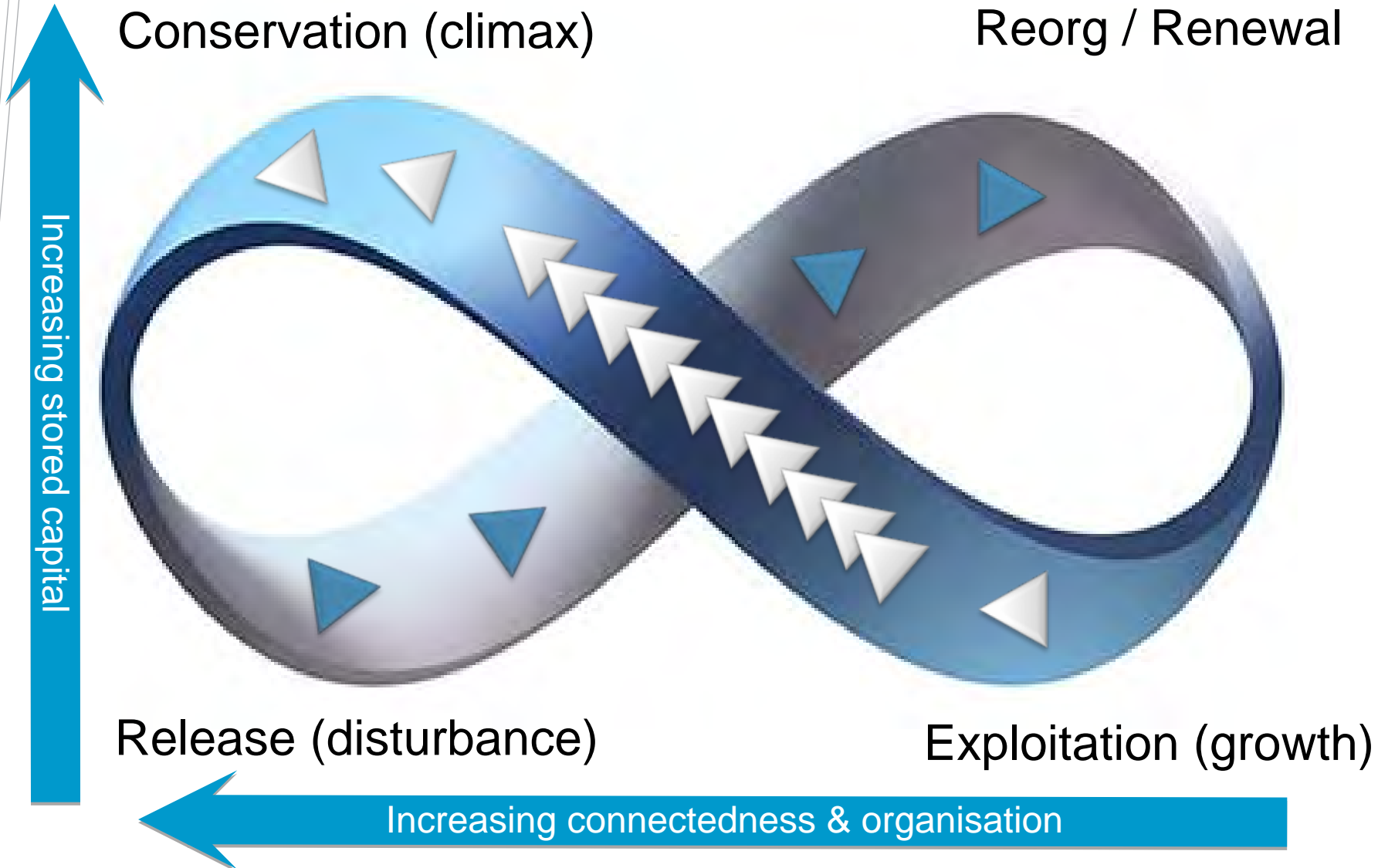
- Diversity (e.g. species counts)



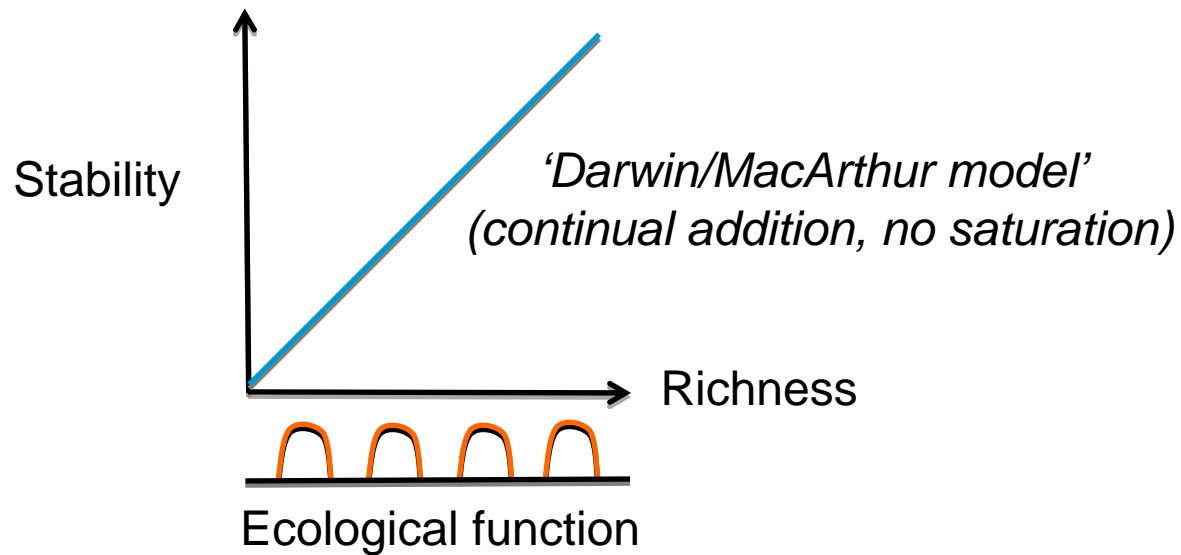
# Redundancy & Diversity

- Diversity = surrogate
  - key processes (determining resiliency)
  - insurance (rebuilding under change)
- Not all species equal
  - drivers and passengers
  - functional diversity (& redundancy)
  - response diversity

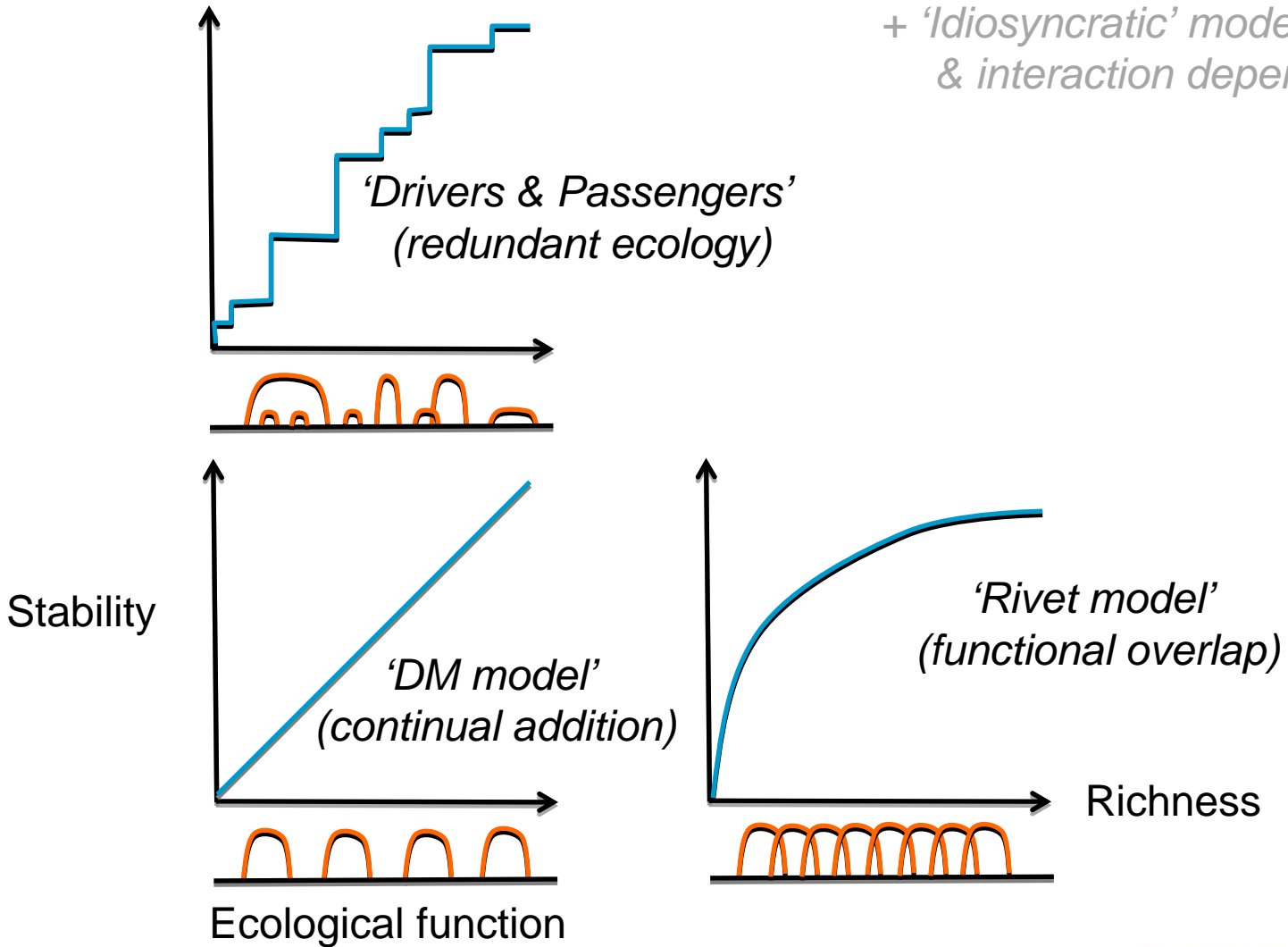
# Ecosystem Function



# Diversity Meta-theory

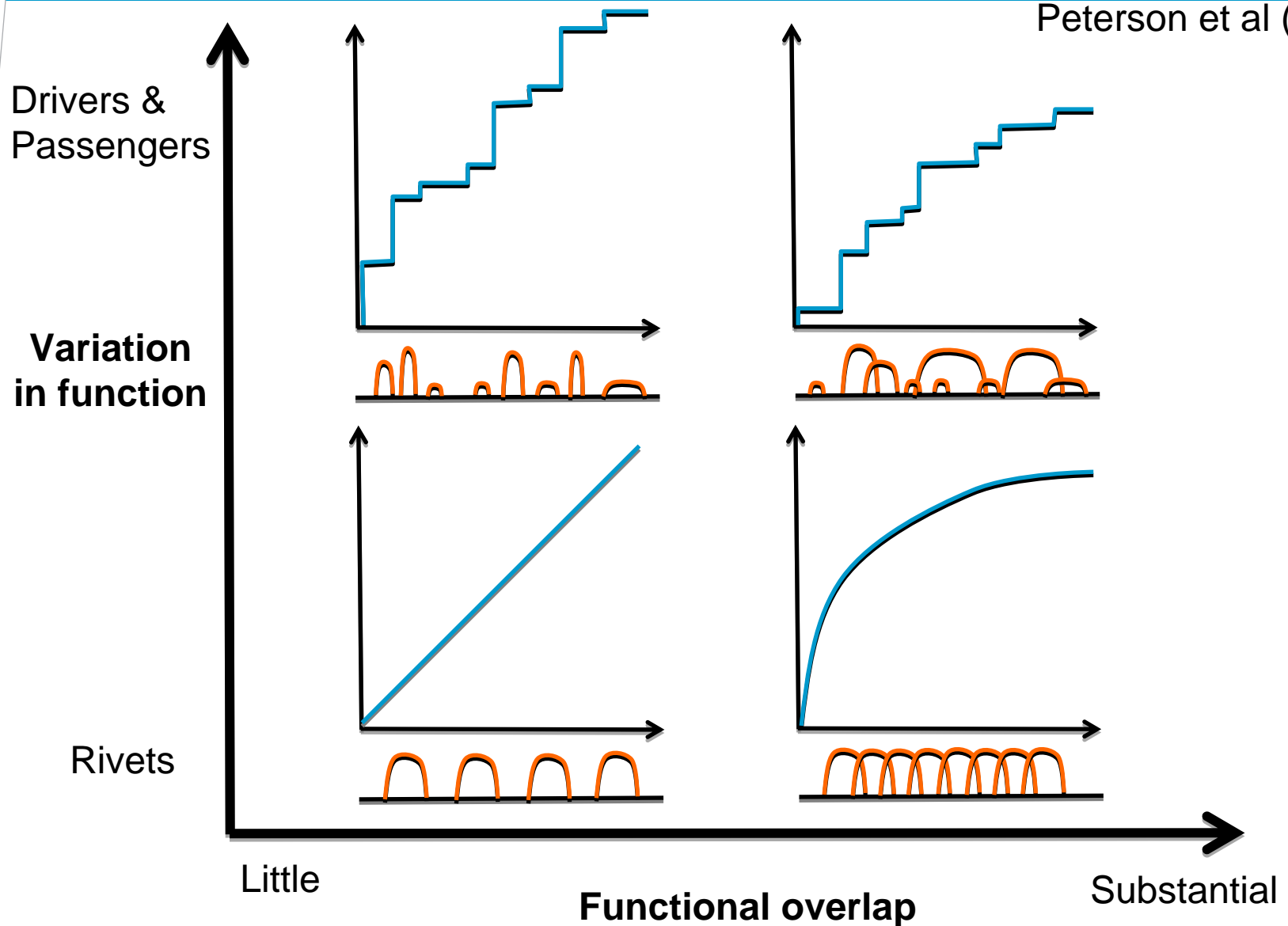


# Diversity Meta-theory



# Diversity Meta-theory

Peterson et al (1998)





# Redundancy & Diversity

- Not all species equal
  - drivers and passengers
  - functional diversity (& redundancy)
  - response diversity



PHOTO: Ron & Valerie Taylor



# What's Needed ?

- Relative biomass
  - fast (plankton, gelatinous, forage)
  - targets (demersal, piscivore)
  - slow (top predators)
- Habitat
- Size spectra
- Diversity
- *Function associated*
- Physical (°C, pH, nutrients)
- Social
- Economic

# Summary

- Resilience = level disturbed before lose identity
- Need knowledge of alternative states
- Surrogates = an option
- We **might** be collecting the right stuff already
  - probably **not** doing correct stats yet



## CSIRO Marine & Atmospheric Research

Dr Beth Fulton  
CEO Fellow

**Phone:** +61 3 6232 5018

**Email:** [beth.fulton@csiro.au](mailto:beth.fulton@csiro.au)

**Web:** [www.csiro.au/wfo](http://www.csiro.au/wfo)  
[www.cmar.csiro.au](http://www.cmar.csiro.au)



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# Thank you

### Contact Us

**Phone:** 1300 363 400 or +61 3 9545 2176

**Email:** [enquiries@csiro.au](mailto:enquiries@csiro.au) **Web:** [www.csiro.au](http://www.csiro.au)

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