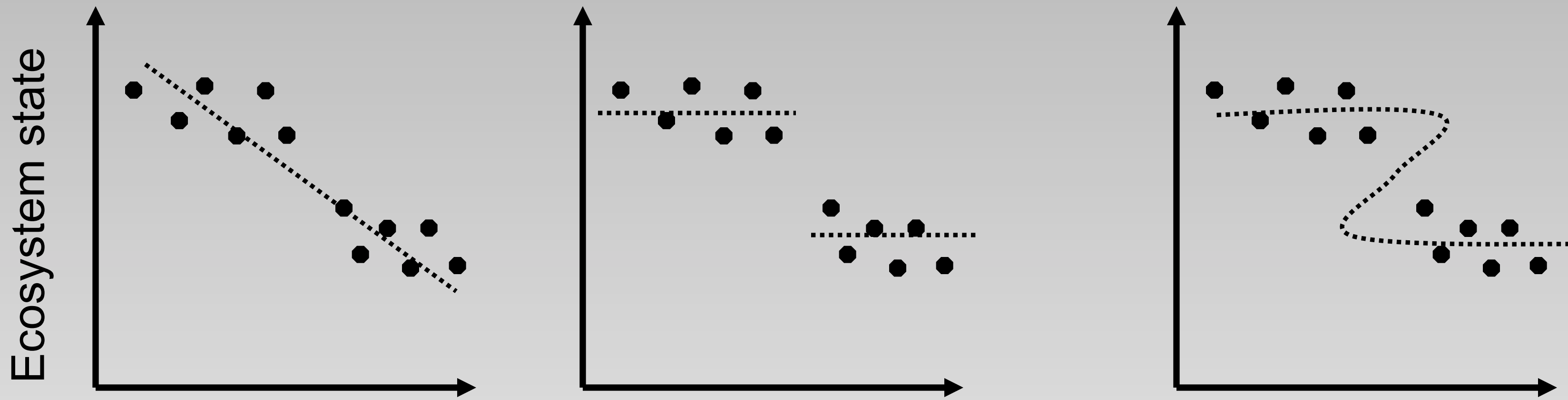


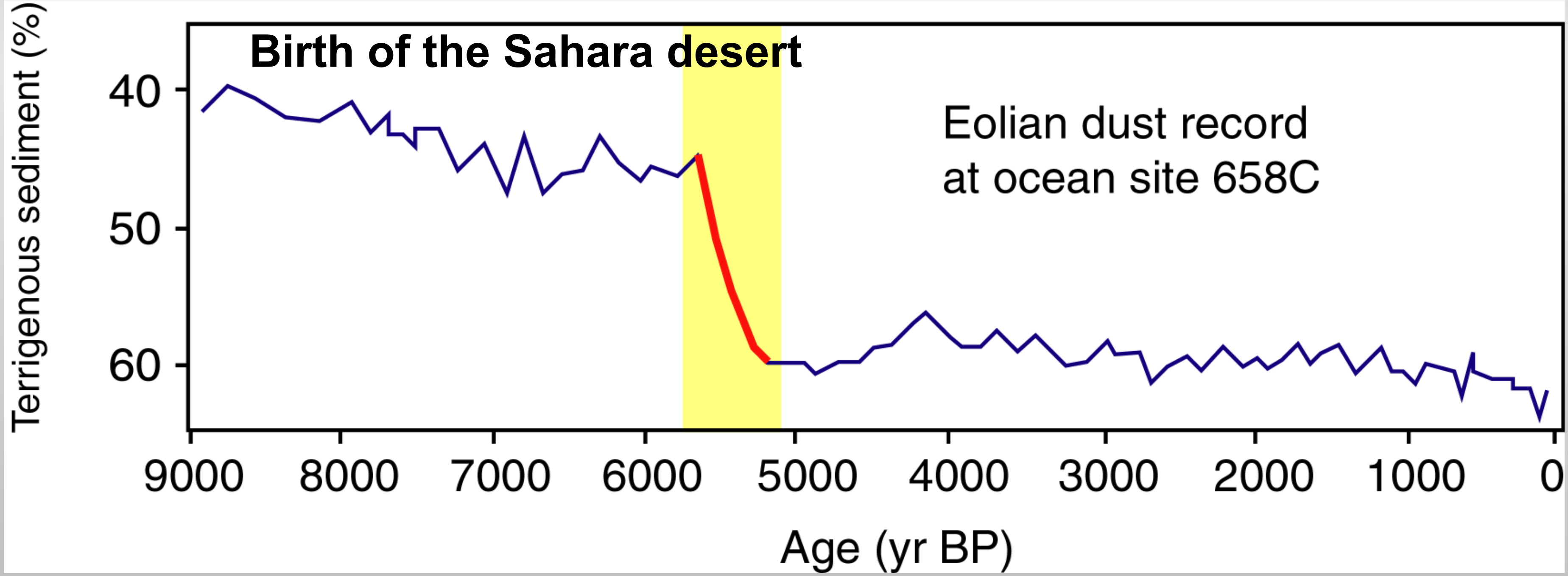
Regime Shifts in Marine Ecosystems: What Could Happen?

Brad deYoung

MEMORIAL UNIVERSITY

DEFINITION OF REGIME SHIFT

A regime shift is a relatively abrupt change between contrasting persistent states in an ecosystem

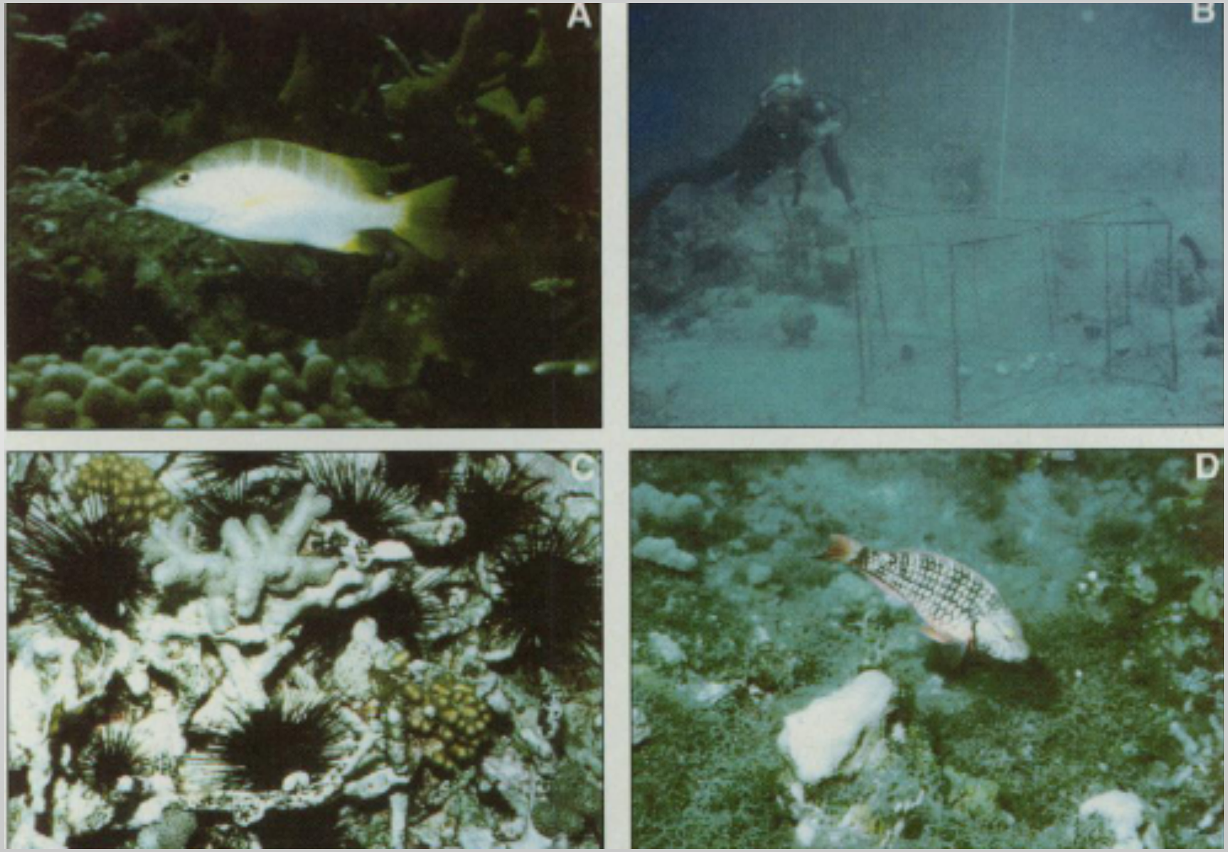


Claussen, et al (1999) *Geophysical Research Letters* **26**, 2037-2040.

Scheffer, et al. (2001). *Nature* 413: 591-596

“Simple” example

Jamaican coral reef systems



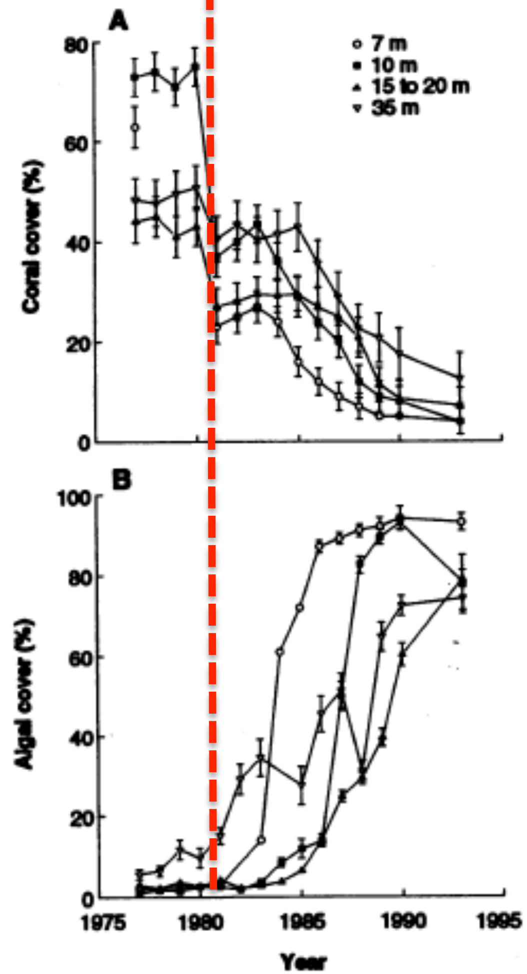


Fig. 3. Degradation of Jamaican coral reefs over the past two decades. Small-scale changes in (**A**) coral cover and in (**B**) macroalgal cover over time at four depths near Discovery Bay (*32*).

Hughes Science 1994

Sequence of events

Removal of fish &
Eutrophication

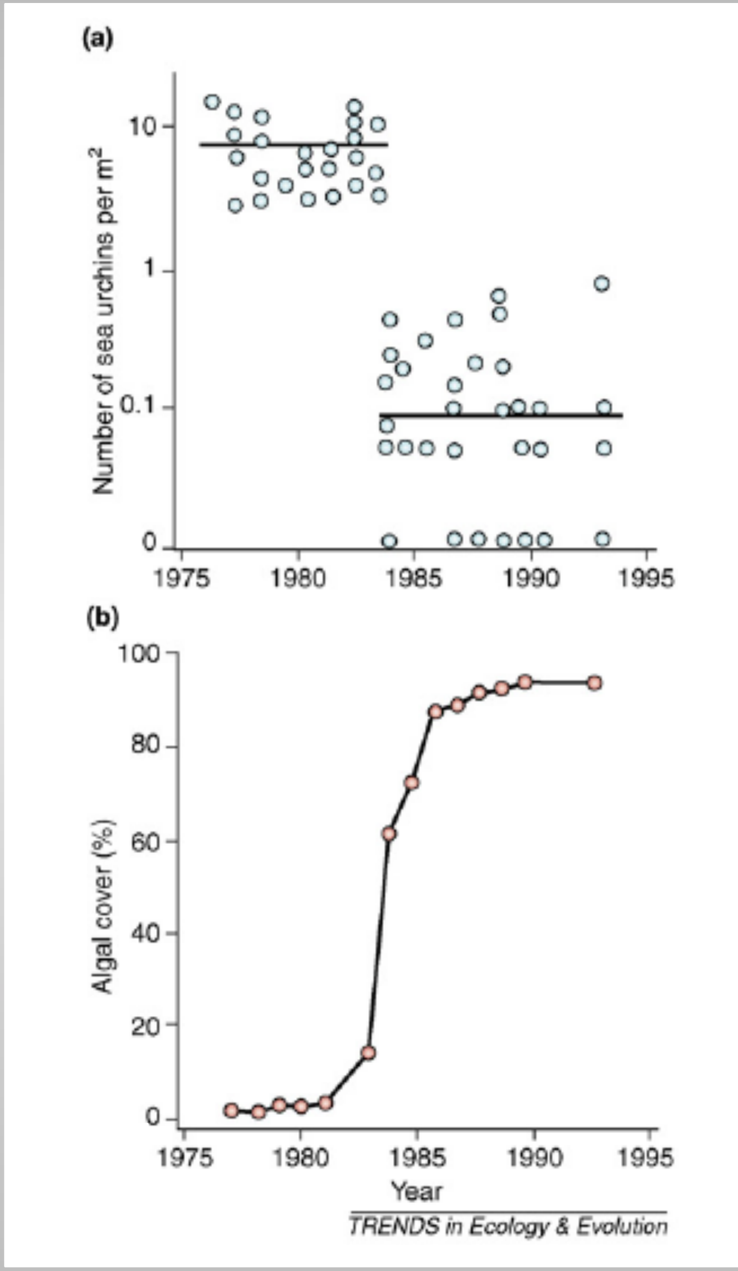
Sea urchins #'s increase

Hurricane in '81
(urchins recolonized)

Pathogen

Fleshy brown algae took over

Hughes Science 1994



North Pacific regime shift

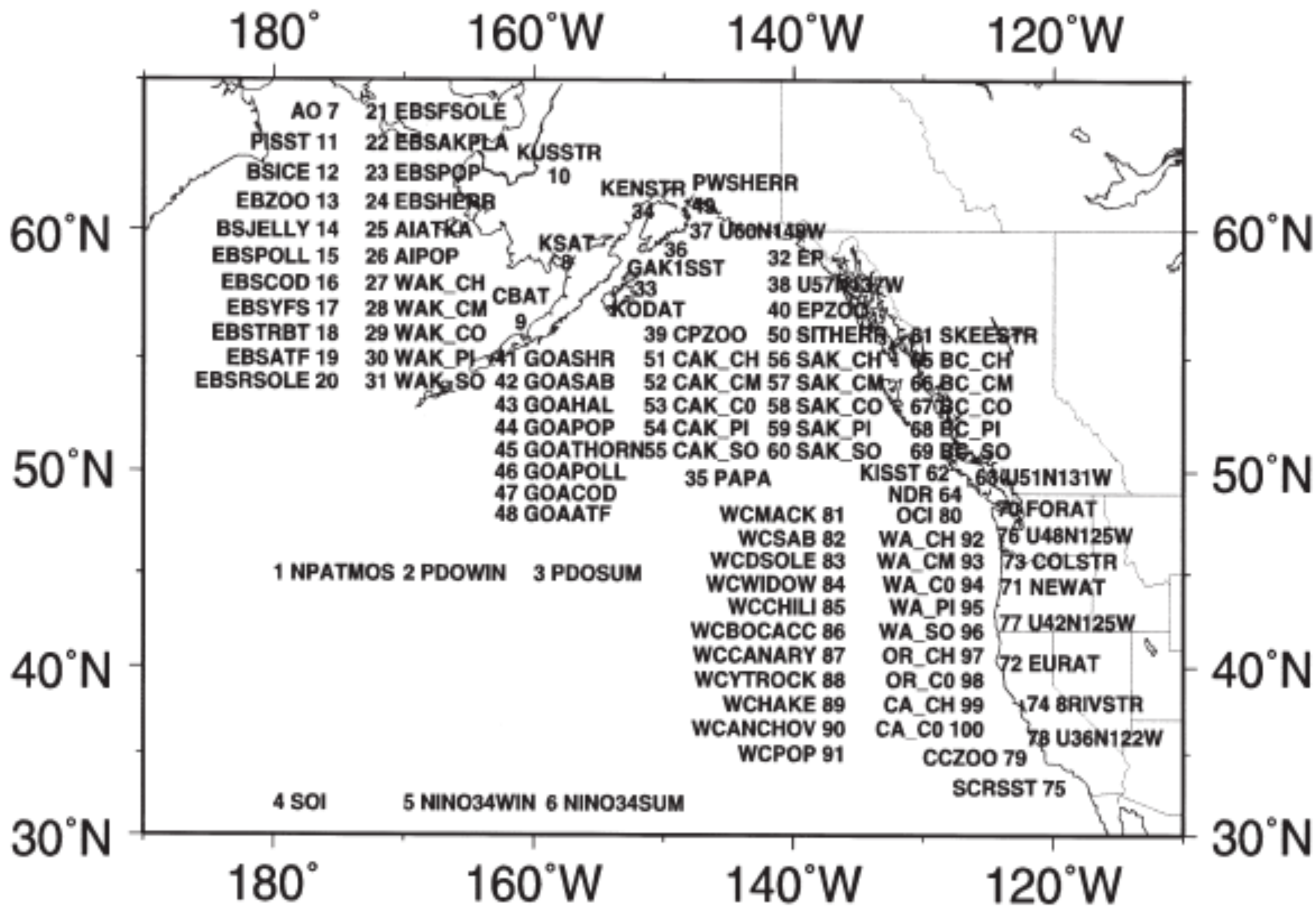


Fig. 1. Numeric and alphabetic abbreviations for the 100 time series used in this study. Geographical arrangement gives a general indication of where each variable is measured or has influence. See Table 1 for a definition of each abbreviation.

Hare and Mantua 2000

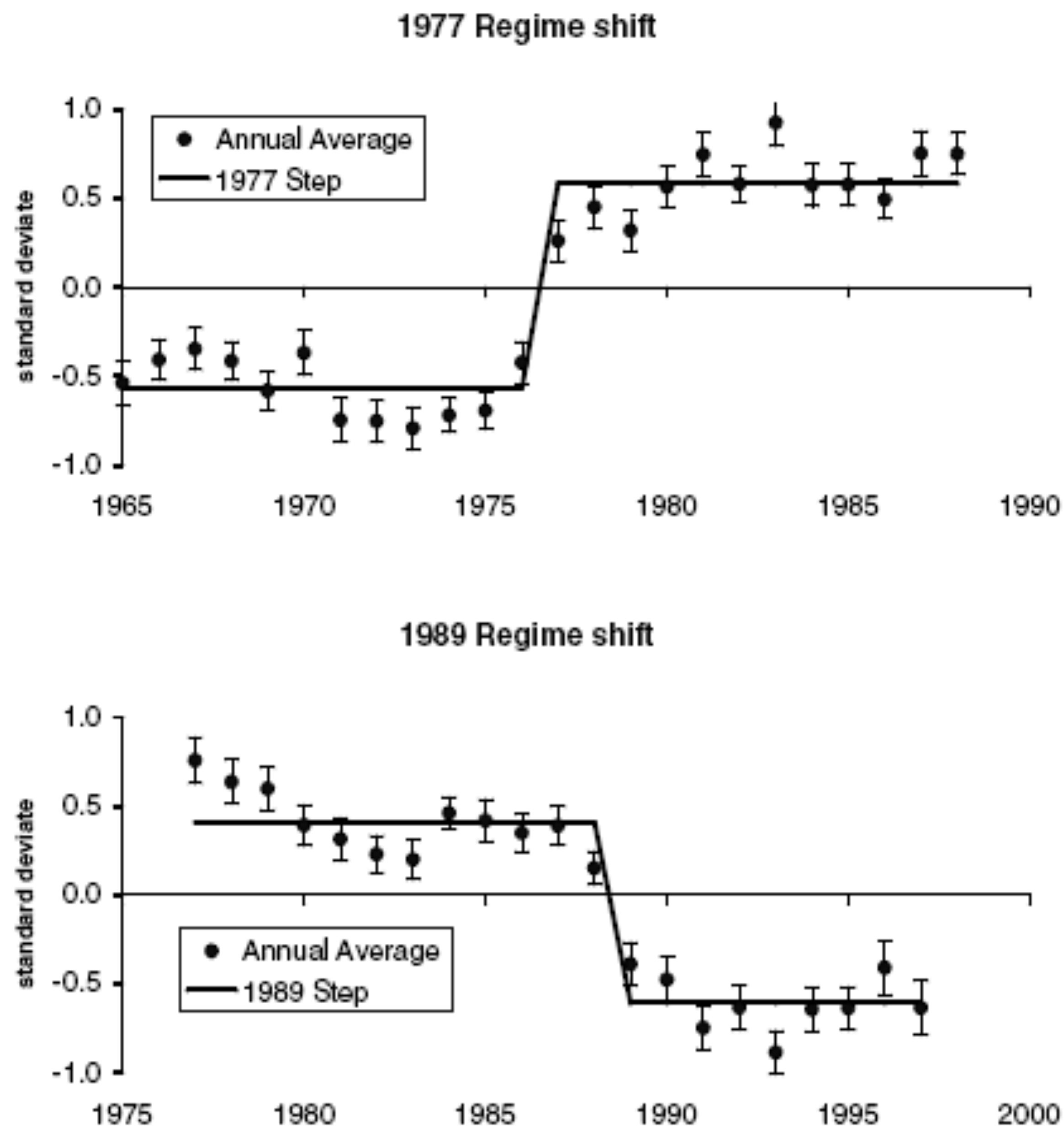
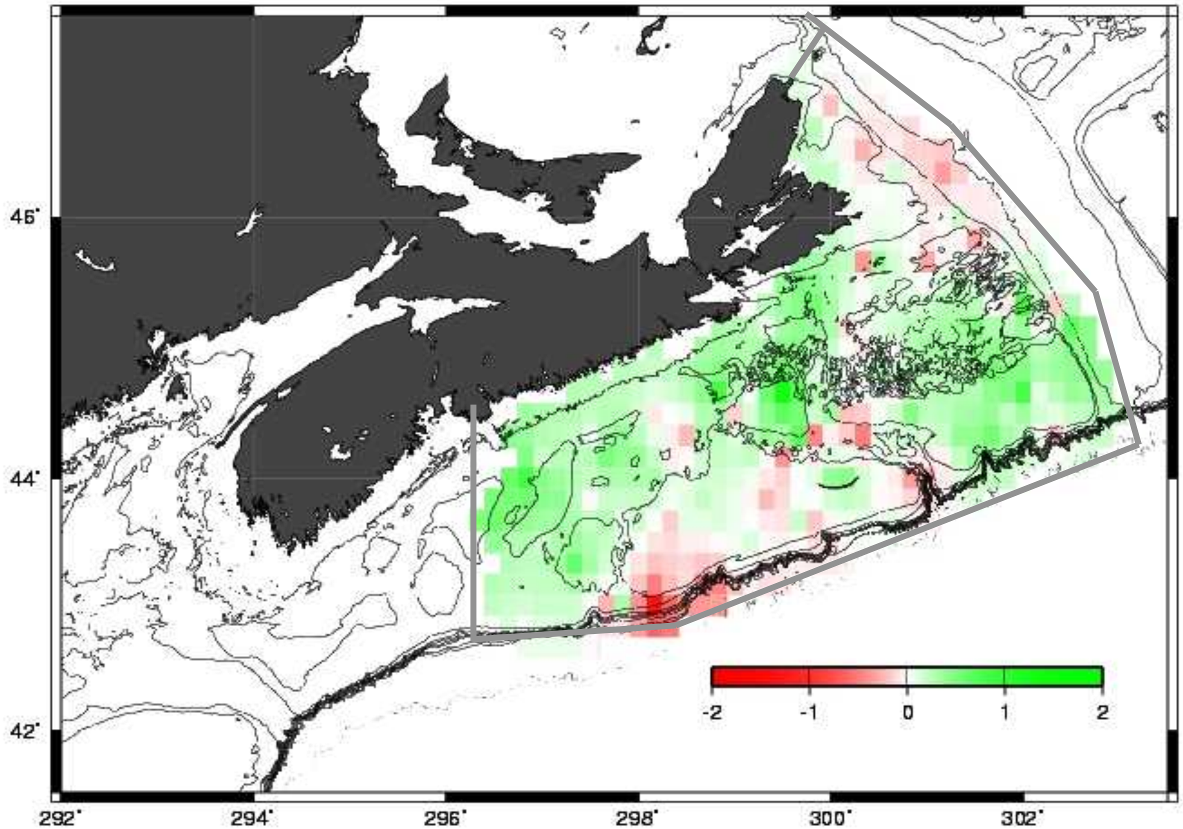


Fig. 4. Results from two regime shift analyses of a composite of the 100 environmental time series. The step passes through the mean standard deviate within each regime. The standard error of the 100 time series is illustrated for each year. After Hare and Mantua (2000).

Fish community condition (1970-1982)

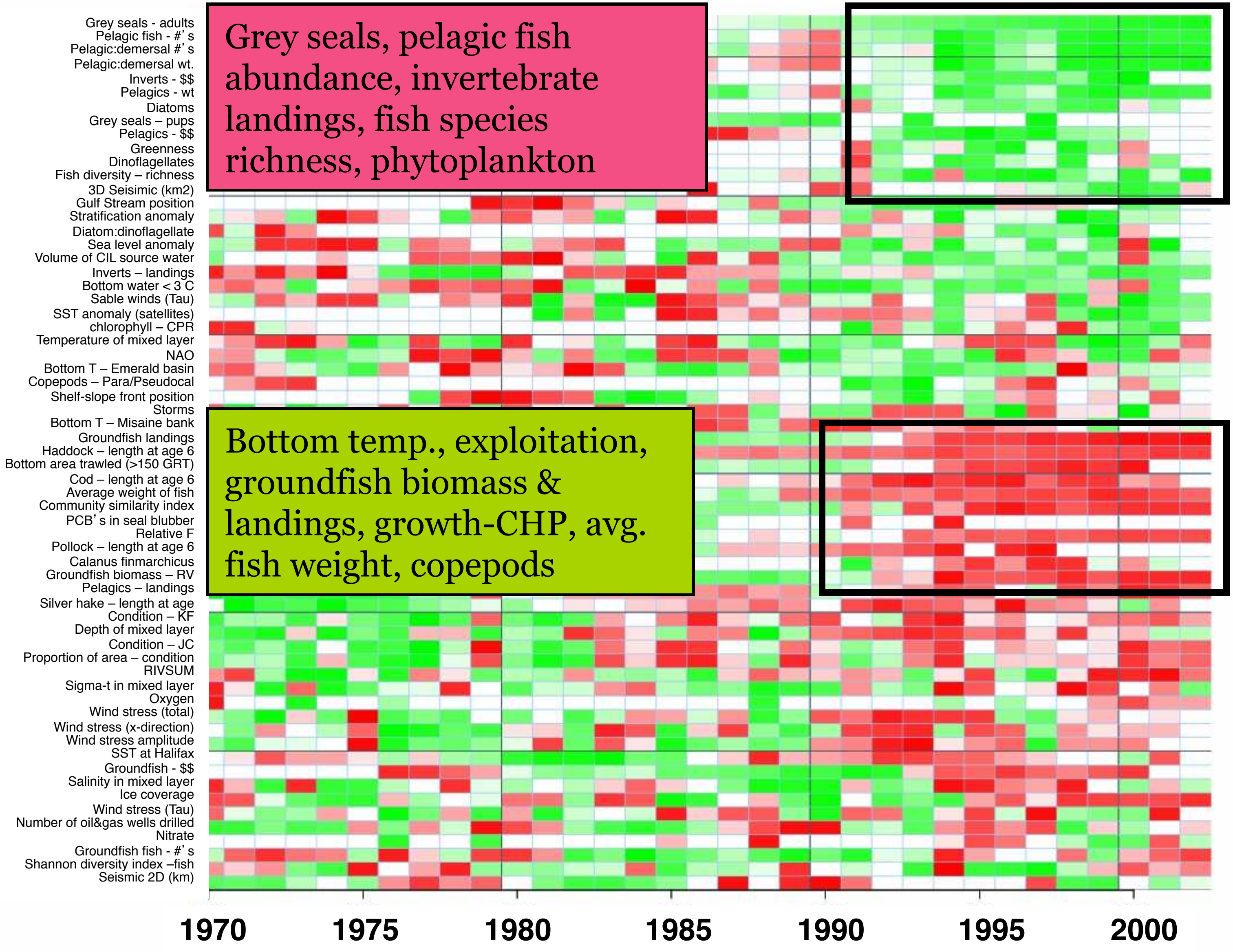


-30% **+30%**

Scotian Shelf – **Frank *et al.* 2005**

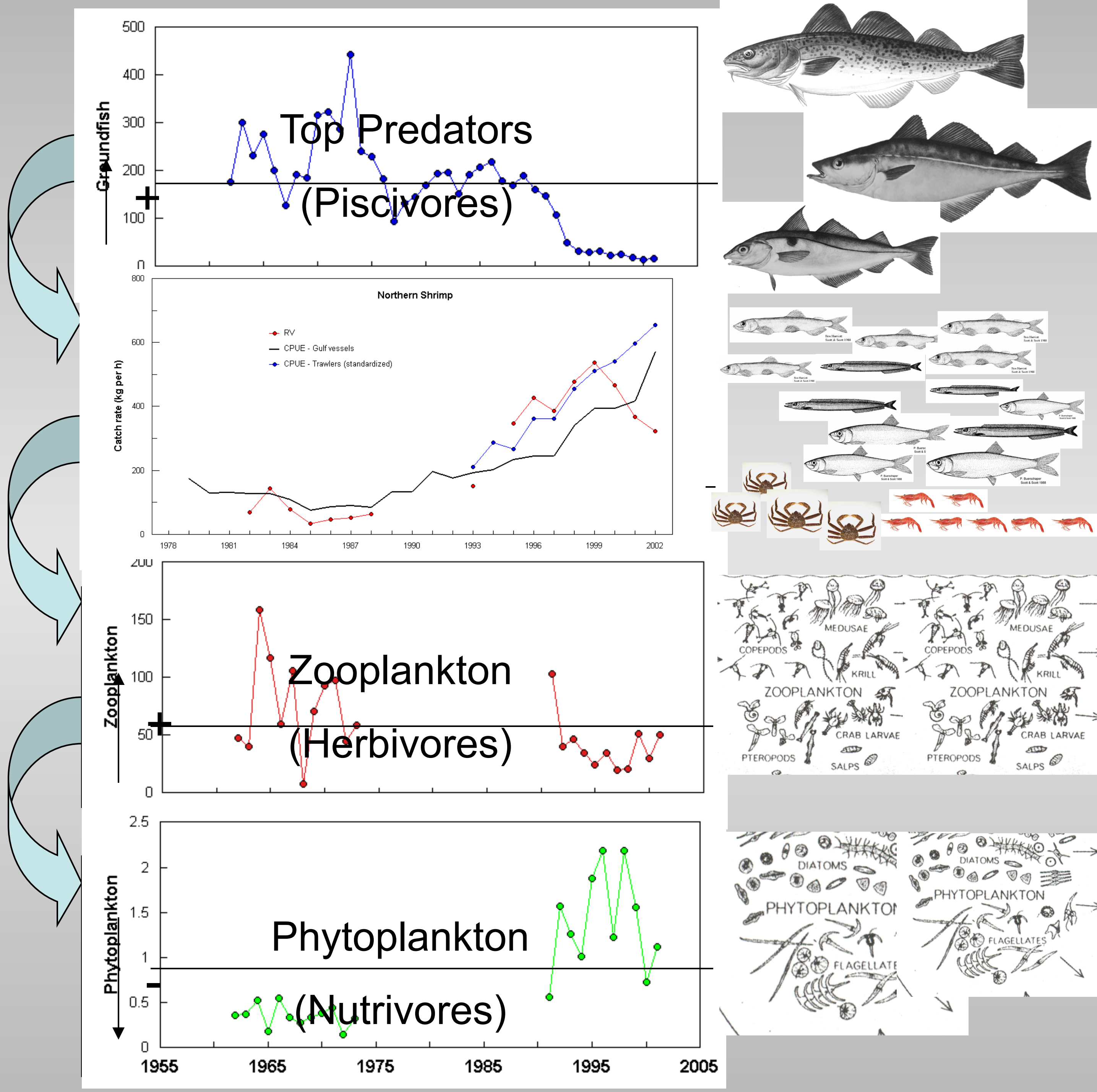
Colour display of 60+ indices

for Eastern Scotian Shelf



Red – below average

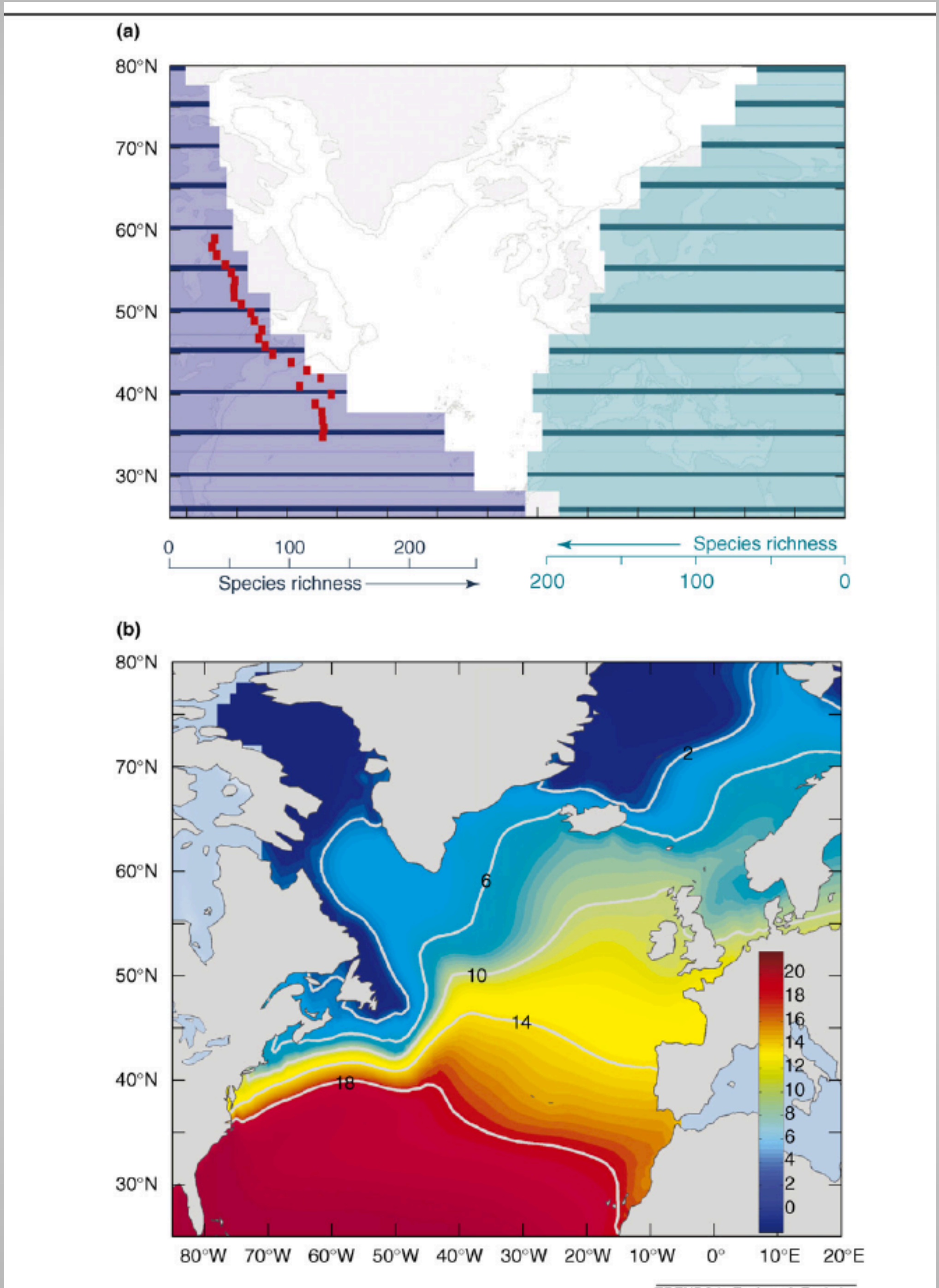
Green – above average

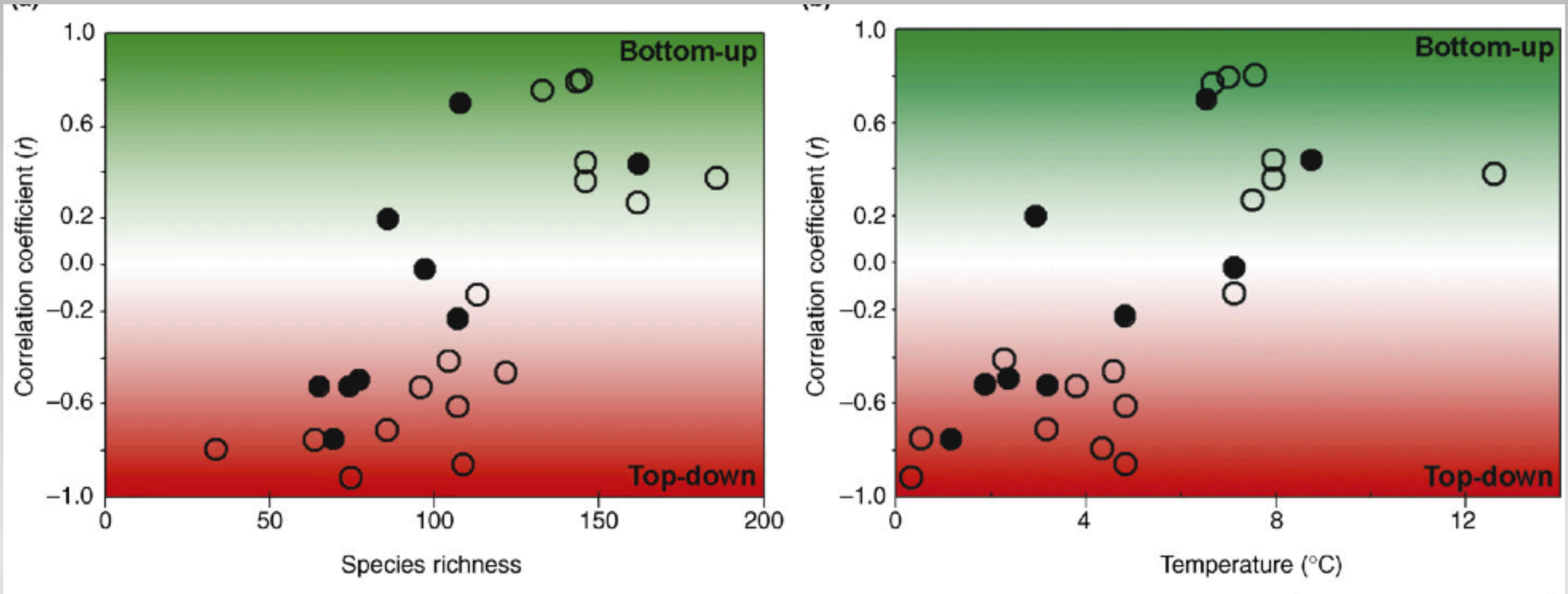

Top Predators
(Piscivores)
Groundfish
Northern Shrimp
RV
CPUE - Gulf vessels
CPUE - Trawlers (standardized)
Catch rate (kg per h)
Zooplankton
(Herbivores)
Phytoplankton
(Nutrivores)
MEDUSAE
COPEPODS
KRILL
ZOOPLANKTON
CRAB LARVAE
PTEROPODS
SALPS
DIATOMS
PHYTOPLANKTON
FLAGELLATES
1955
1965
1975
1985
1995
2005

Is there something that determines the balance between top down and bottom up control?

Is there anyway to guess how an ecosystem might respond to a driver?

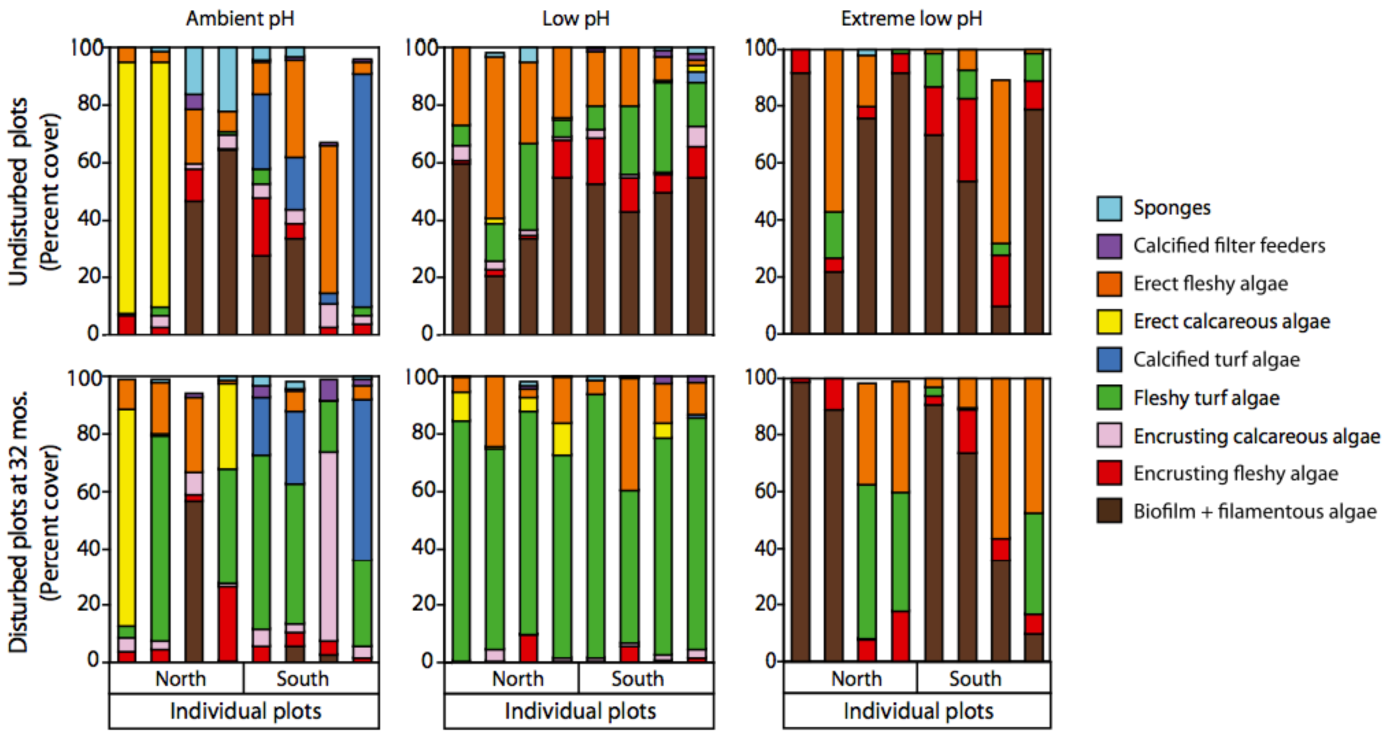
Frank *et al.* (2007 – TREE) looked at temperature and species richness, for the North Atlantic





But here there is really not much difference between temperature and species richness since the two are strongly correlated.

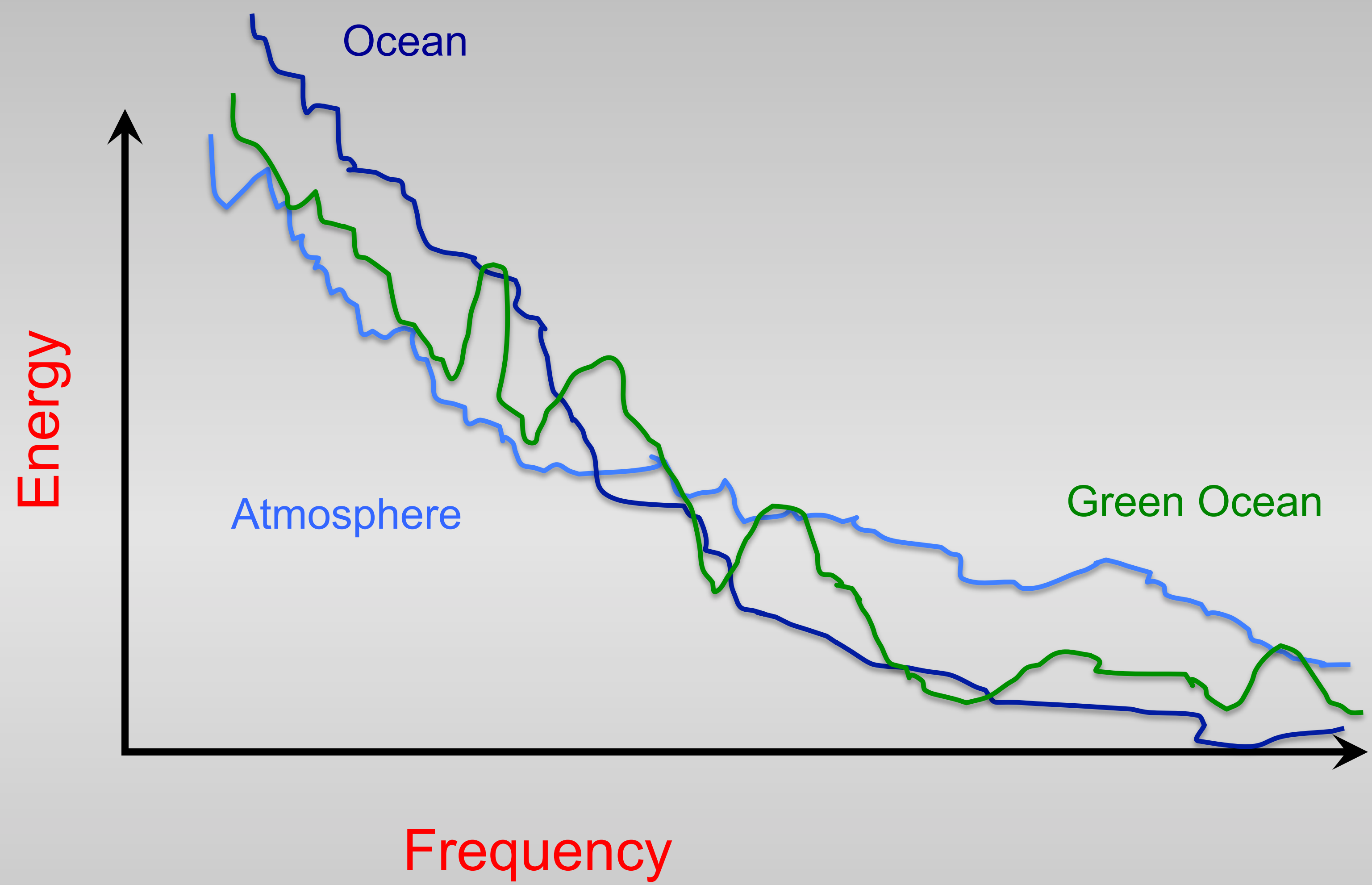
Rocky reef response to pH



Kroeker et al.

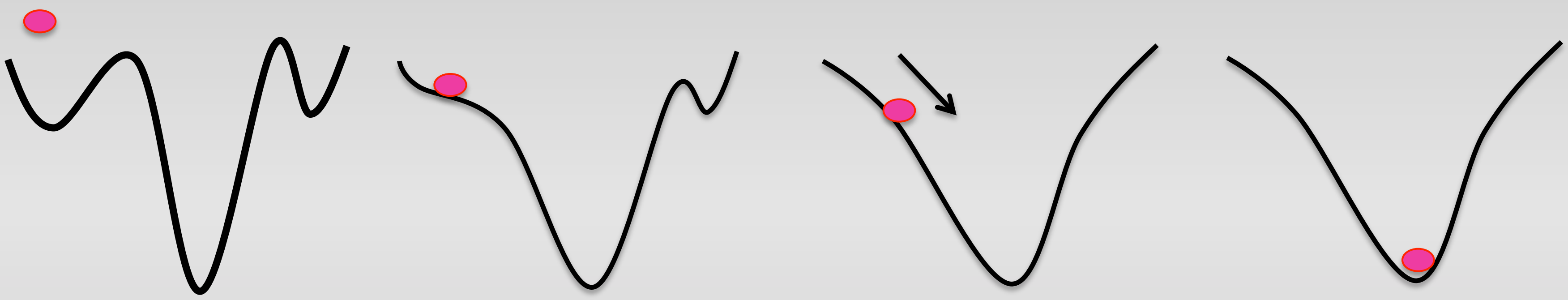
algae). Together, our results highlight how environmental change can cause ecosystem simplification via environmentally mediated changes in community dynamics in the near future, with cascading impacts on functional diversity and ecosystem function.

Kroeker et al. PNAS 2013


Ocean
Energy
Atmosphere
Green Ocean
Frequency

Moving through a regime shift, the coral reef example

Starting State | Loss Resilience | Trigger for Shift | New State



Starting State	Loss Resilience	Trigger for Shift	New State
Coral dominated reef	Overfishing Coastal eutrophication	Disease Bleaching Hurricane pH	Algae dominated reef

But what is resilience?

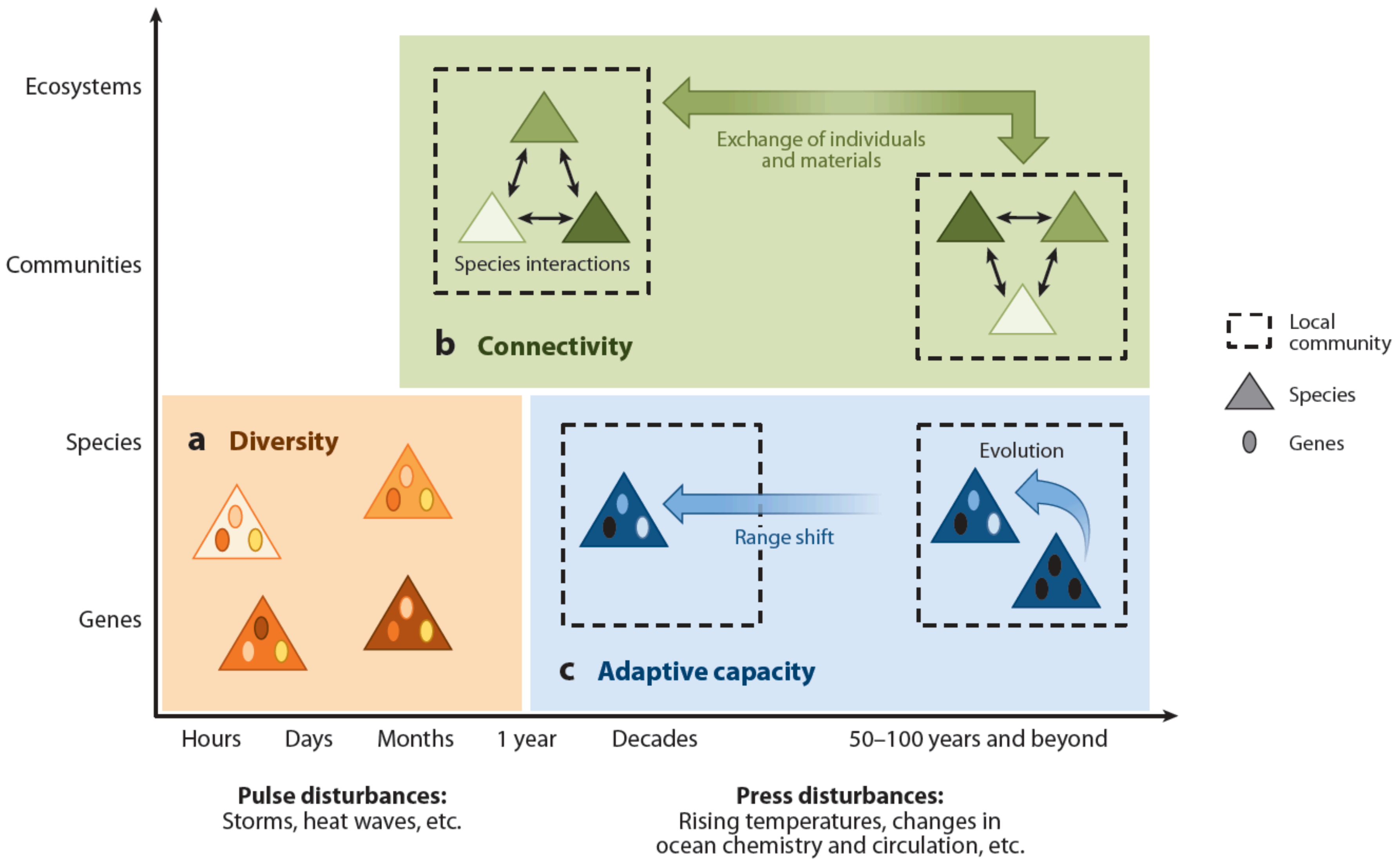
Holling (1973)

- Persistence of relationships within a system
- Ability of systems to absorb changes of state variables, driving variables and parameters and still persist
- Size of a stability domain or the amount of disturbance a system could take before it shifted into [an] alternative configuration

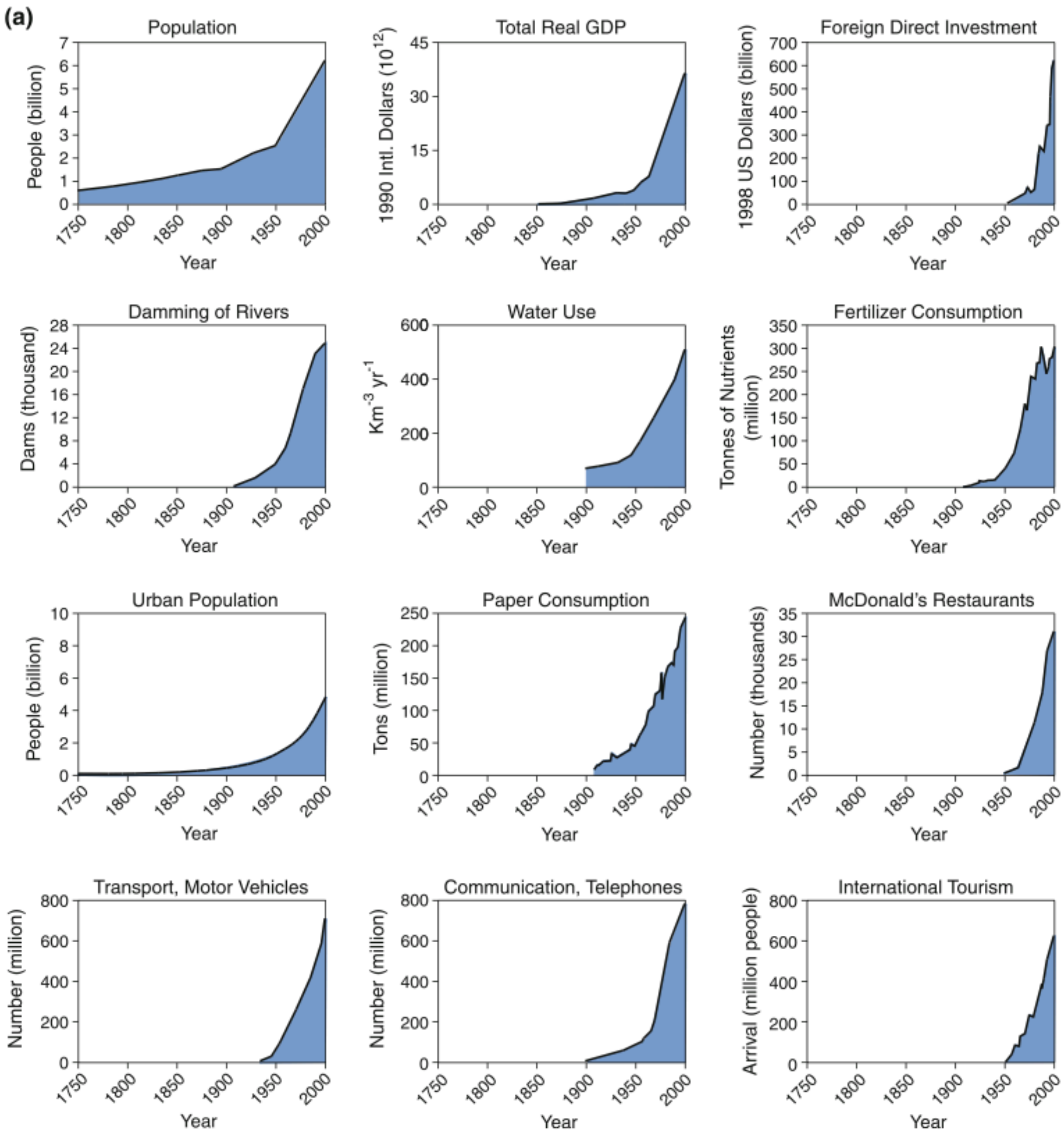
Holling (1996) defined two types

- Engineering resilience – the rate or speed of recovery of a system following a shock
- Ecological resilience – magnitude of a shift that produces a shift between alternative stable states

Key Characteristics of Resilience in Marine Ecosystems

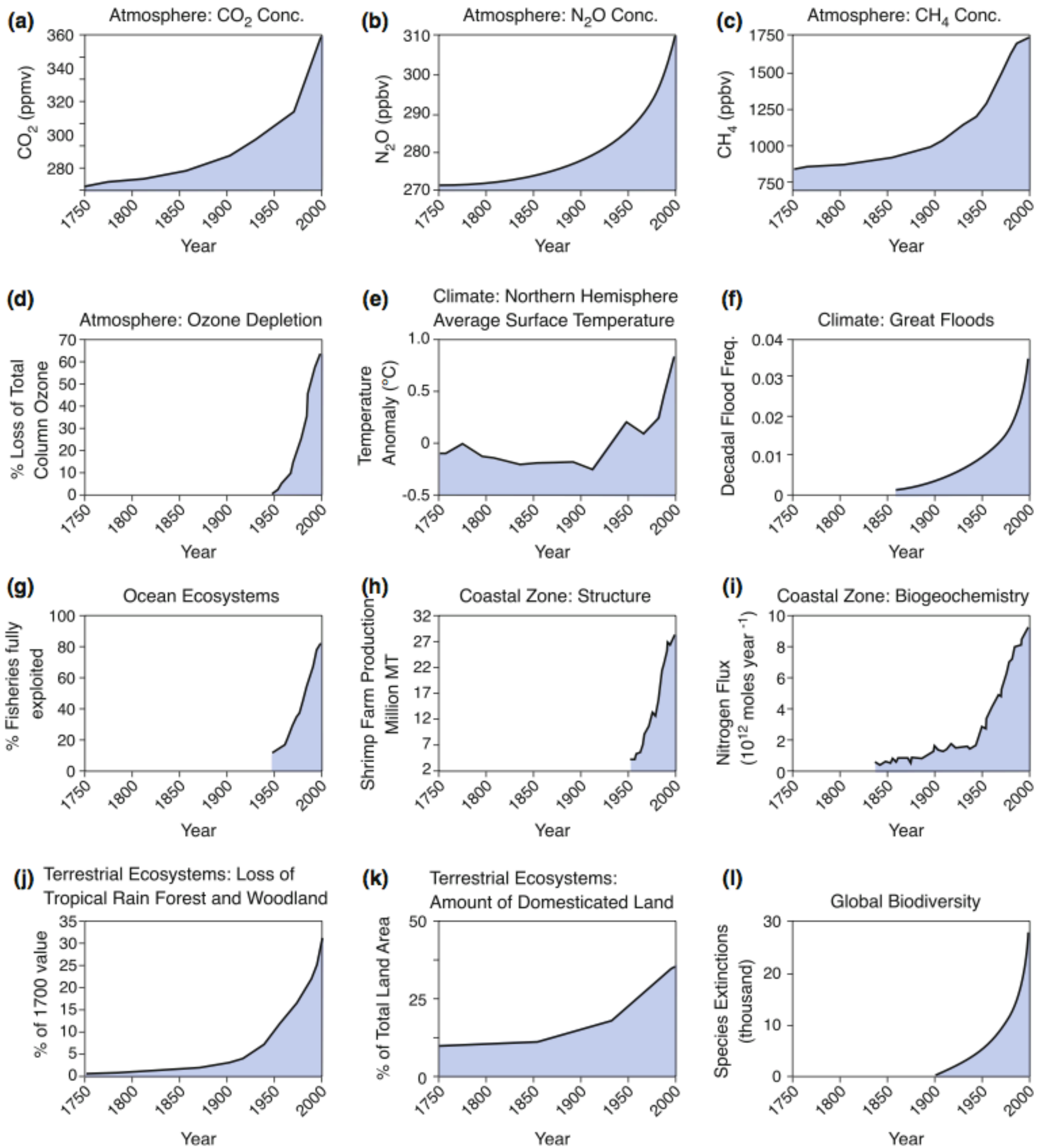


Bernhardt & Leslie 2013



Lots happening on the little planet earth

Steffen et al. 2011



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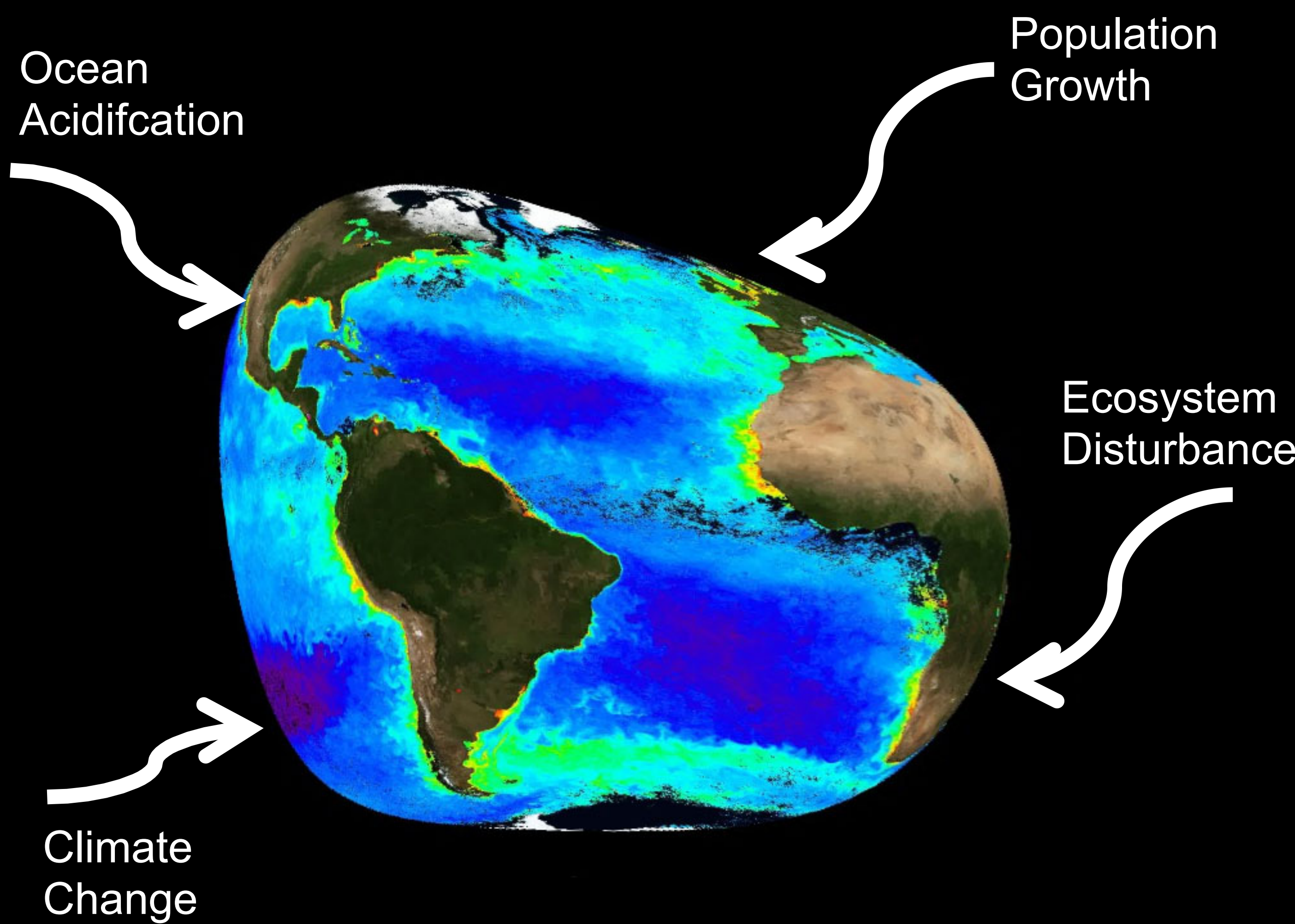
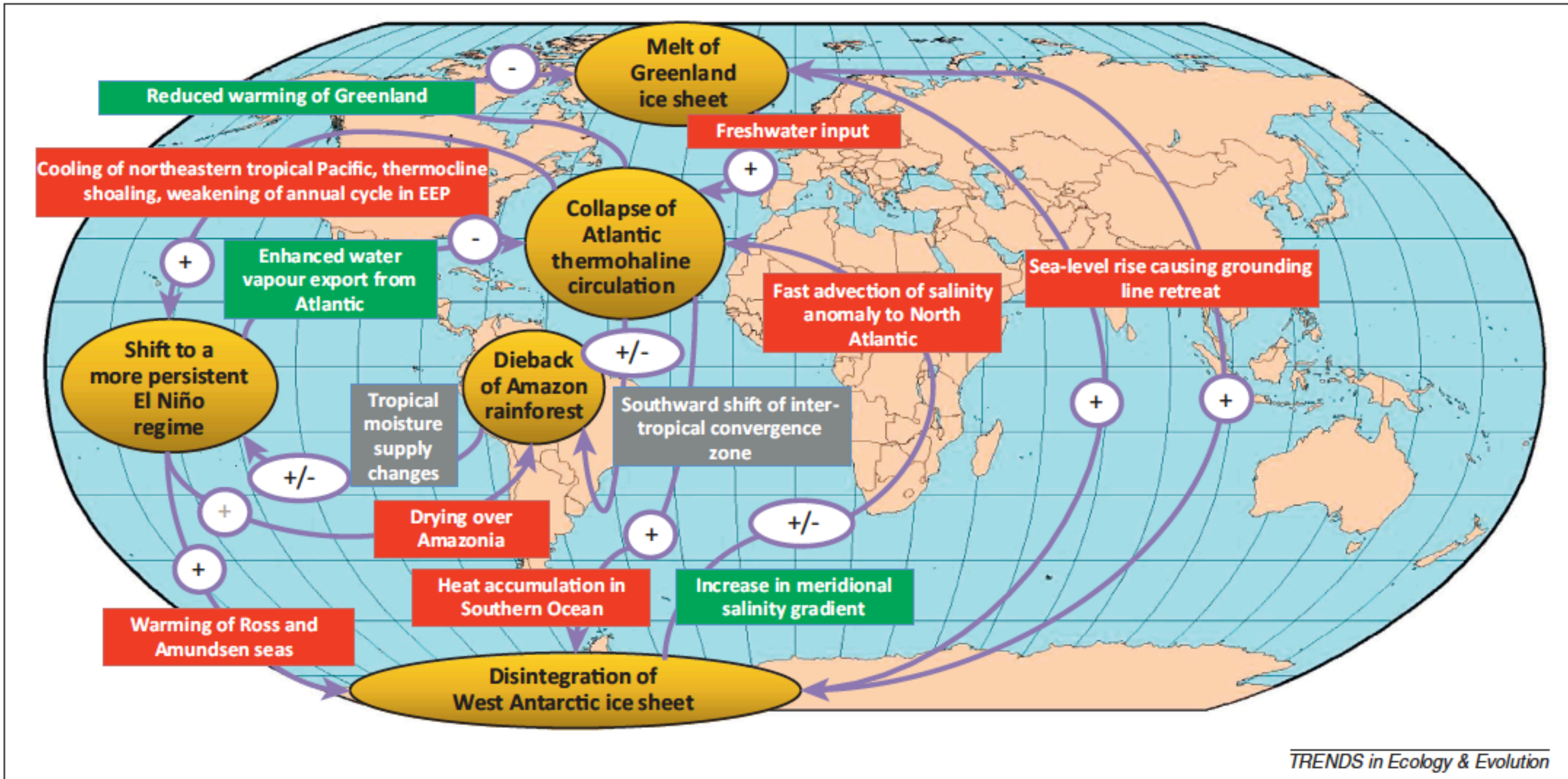
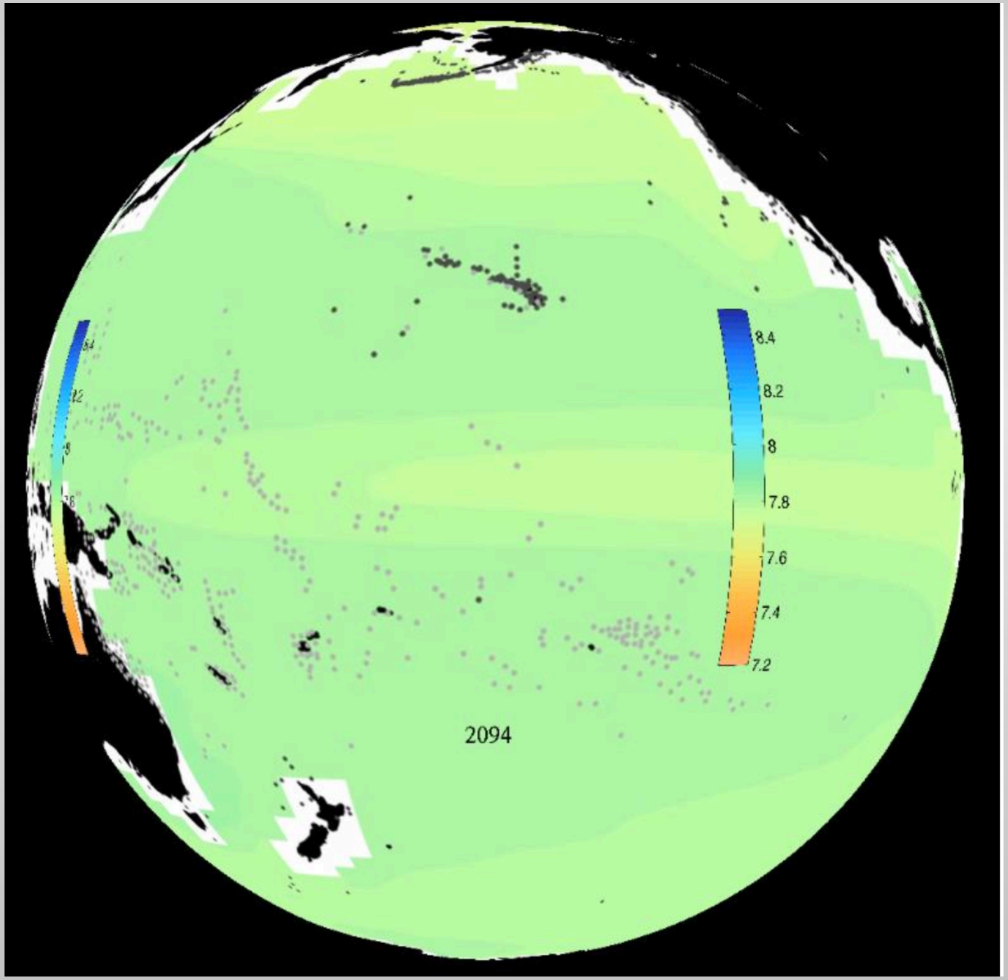

Ocean
Acidifcation
Population
Growth
Ecosystem
Disturbance
Climate
Change

Key possible tipping points of the earth system



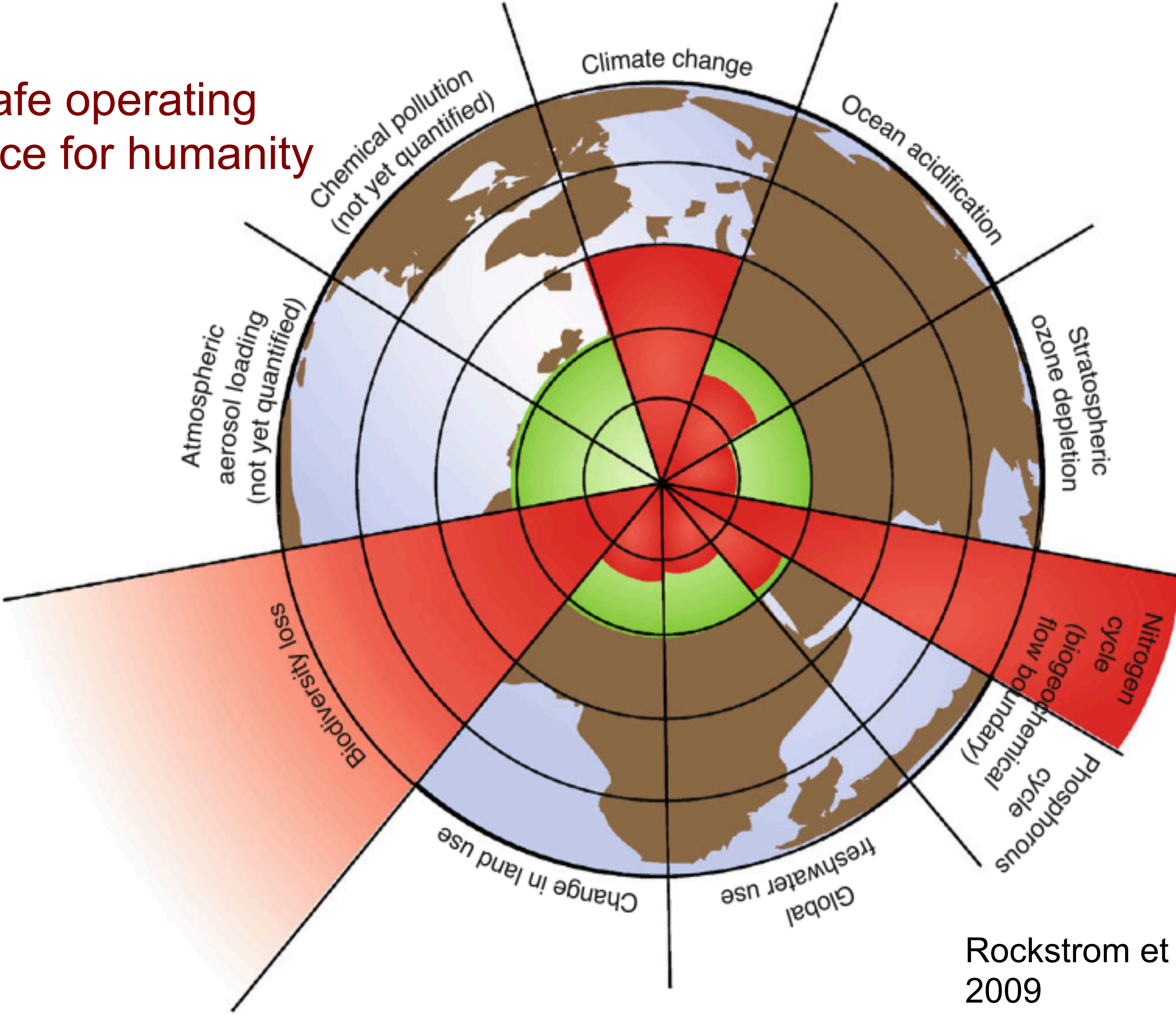
Kriegler et al. PNAS 2009
Lenton & Williams TREE 2013

But what about Ocean Acidification? Could it push global ecosystems beyond a threshold?



Freeley and Cooley

A safe operating space for humanity



Rockstrom et al. 2009

Six Mistakes Executives Make in Risk Management

1. **To think that you can manage risk by predicting extreme events**

   Not only can we not predict the unpredictable but by focusing on it we neglect the predictable and are unprepared for the unpredictable

2. To think that studying the past will help you to manage future risk

   The past often only explains itself and cannot tell us how an evolving system will develop as conditions change

3. Not to listen to advice about what we should not do

   Not doing stupid things (like loading the atmosphere with CO_2) is much better than trying to do good things to deal with problems

4. To assume that risk can be measure by a standard deviation

   In risk terms it is the crazy big events to be really worried about and they lie in the tails of the distribution function, not in the bell of the curve

5. Understanding risk depends on how it is expressed

   Communicating about risk determines how people will respond to it

6. Efficiency and maximizing shareholder value do not tolerate redundancy

   Ecosystems need resilience to survive the unknown

Taleb, Goldstein and Sptiznagle 2009
Harvard Business Review

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Summary

- For sure regime shifts happen and there may be warning signs for some of them
- More regime shifts are likely – decreased resilience
- Hyper-regime shifts, utterly unexpected events could happen
- We need to collect broad range of data and be prepared for surprises
- We need to better understand resilience and work towards enhancing it