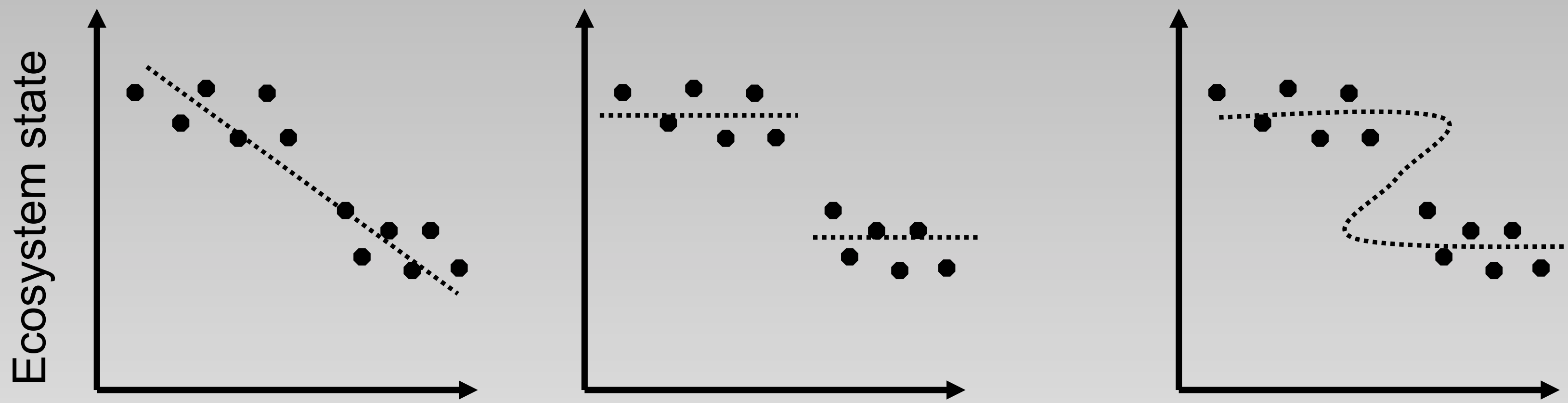


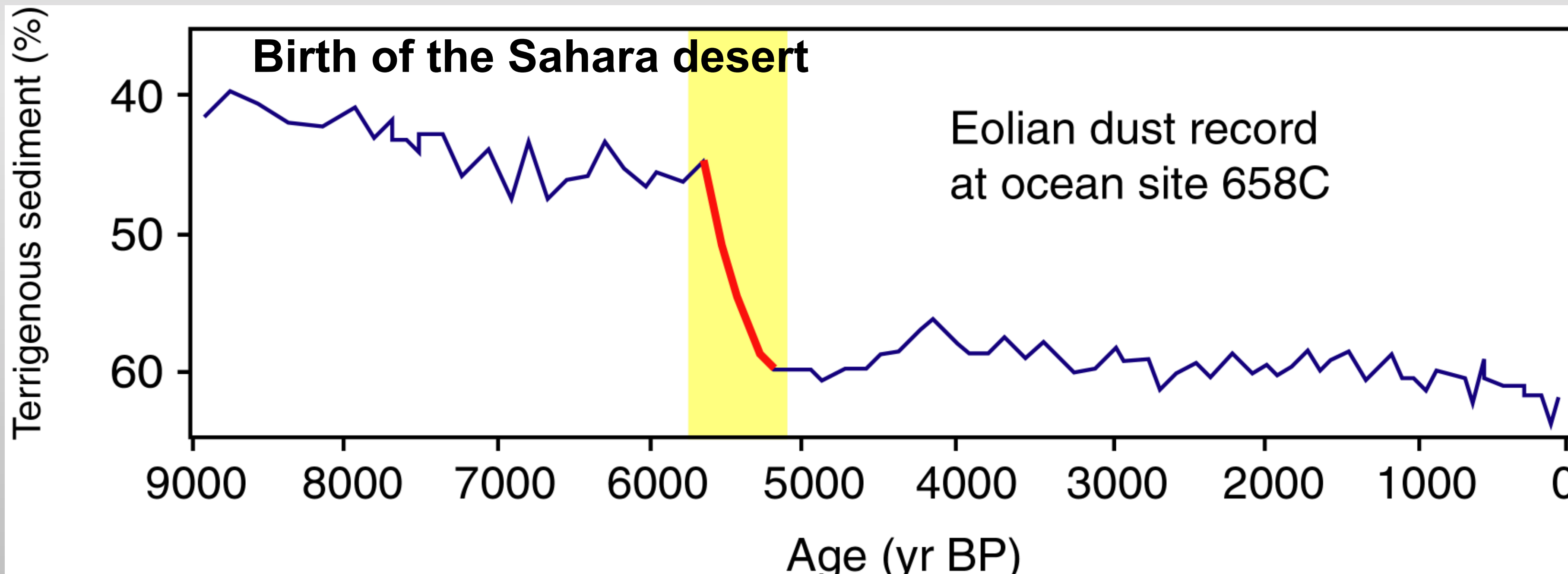
Thinking About Regime Shifts in Marine Ecosystems

Brad deYoung

MEMORIAL UNIVERSITY

DEFINITION OF REGIME SHIFT

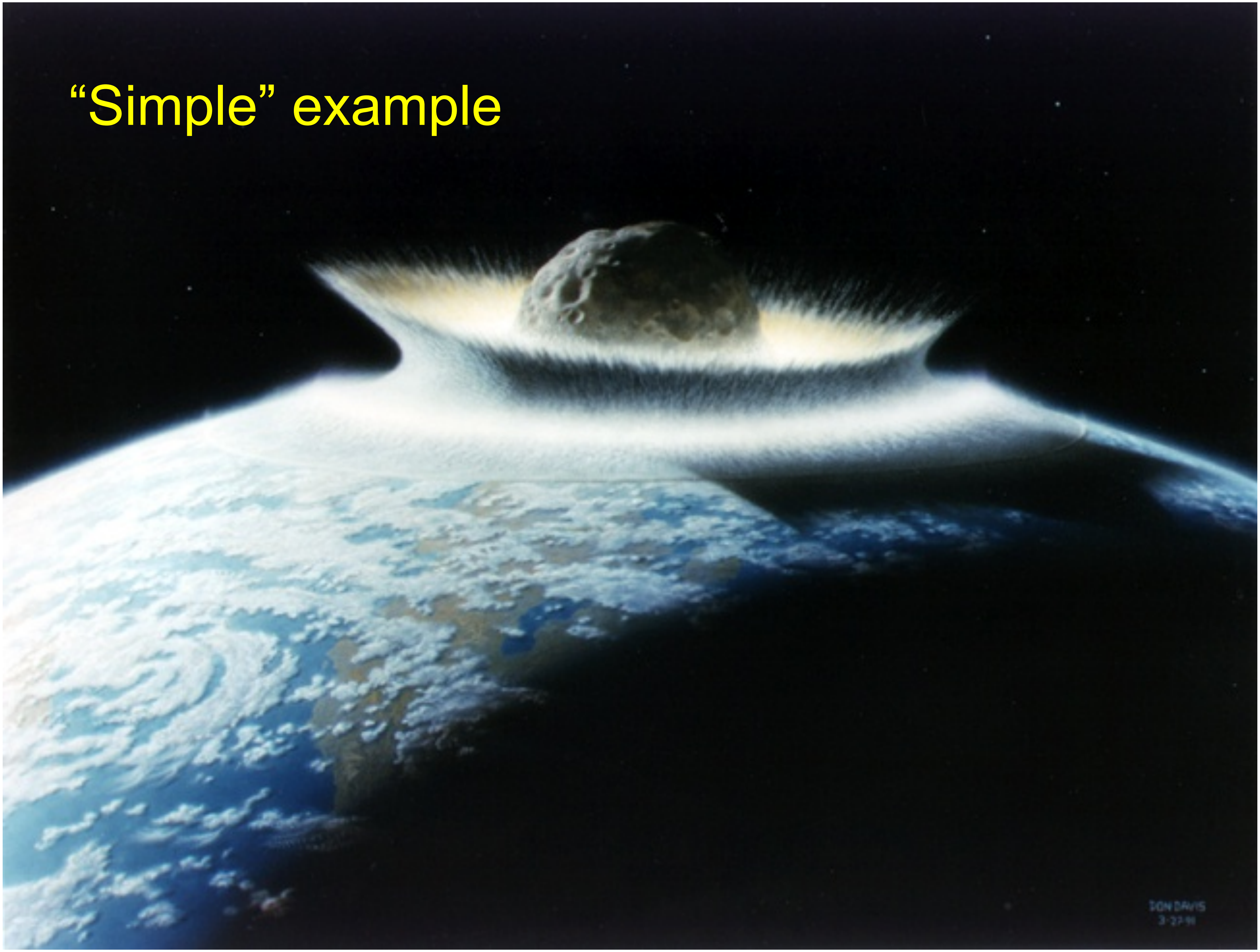
Working definition: a regime shift is a relatively abrupt change between contrasting persistent states in an ecosystem



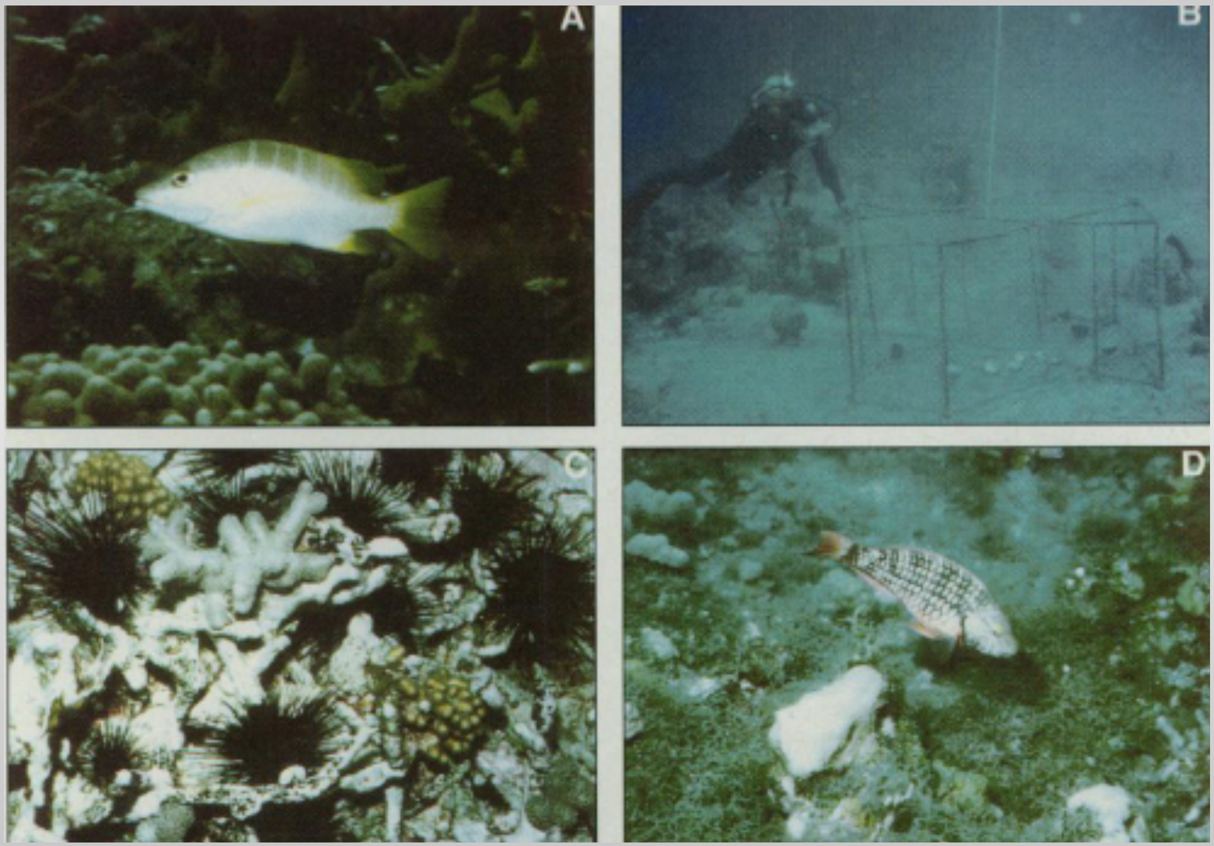
Claussen, et al (1999) *Geophysical Research Letters* **26**, 2037-2040.

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

“Simple” example



Jamaican coral reef systems



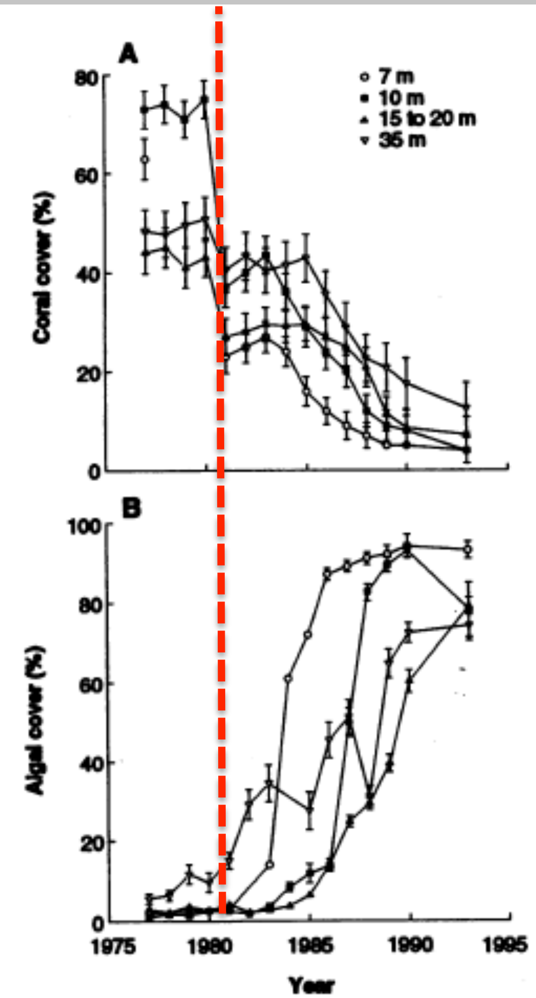


Fig. 3. Degradation of Jamaican coral reefs over the past two decades. Small-scale changes in (**A**) coral cover and in (**B**) macroalgal cover over time at four depths near Discovery Bay (32).

Sequence of events

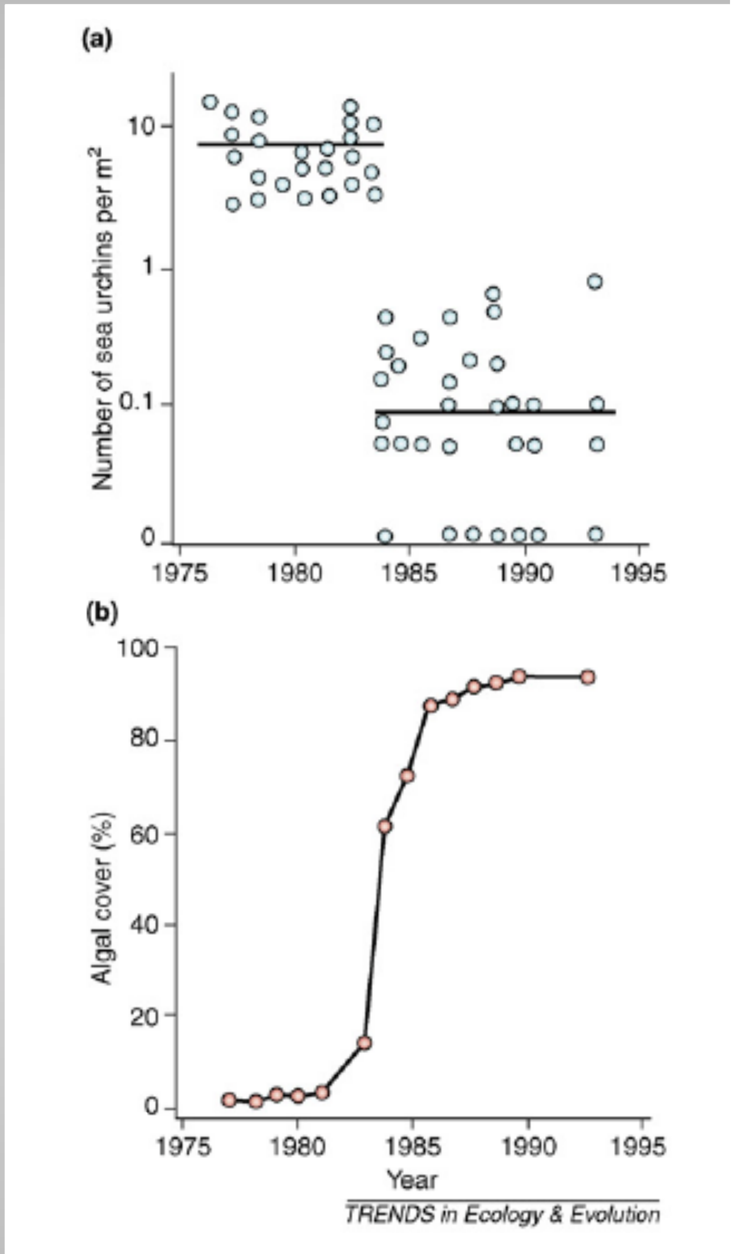
Removal of fish &
Eutrophication

Sea urchins #'s increase

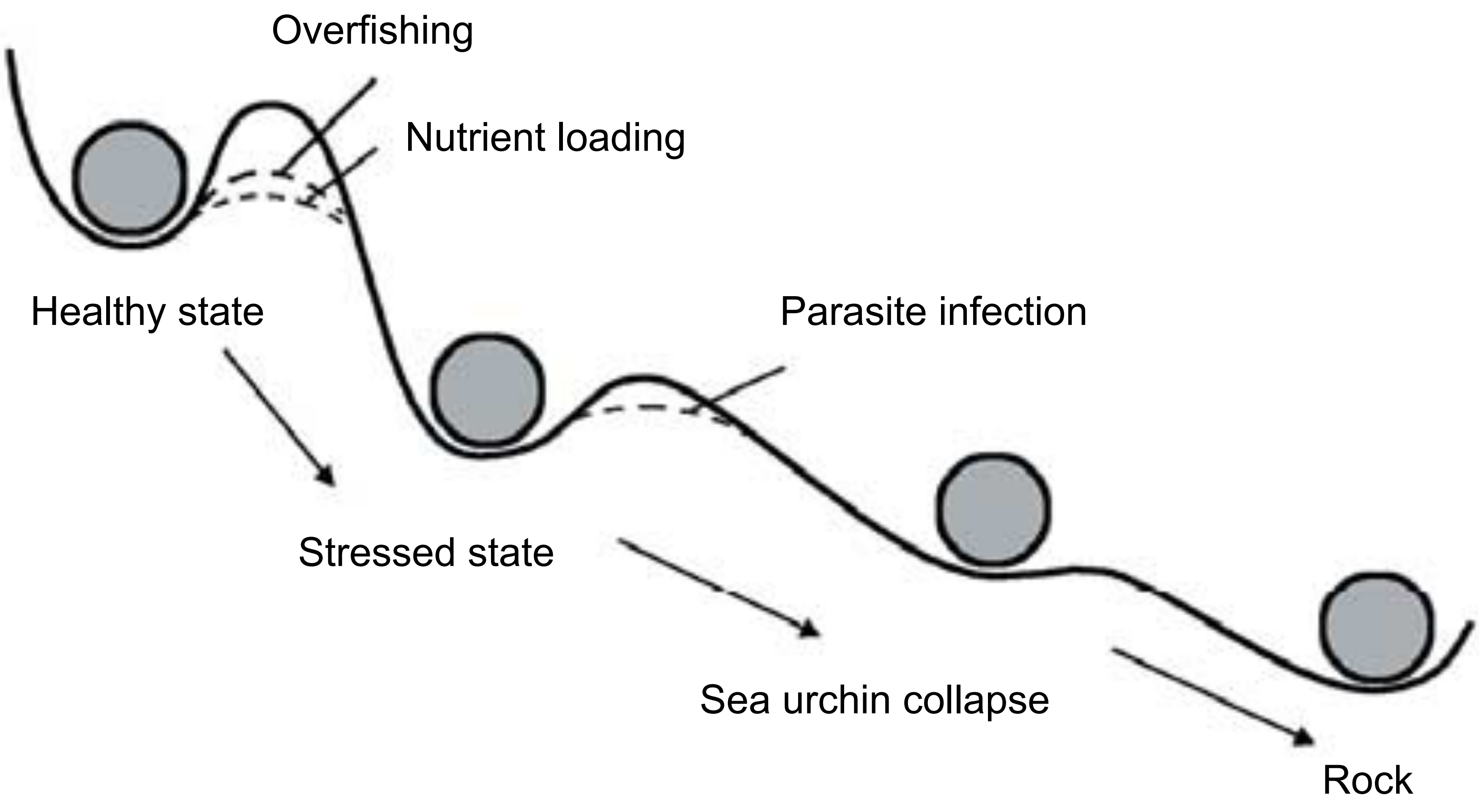
Hurricane in '81
(urchins recolonized)

Pathogen

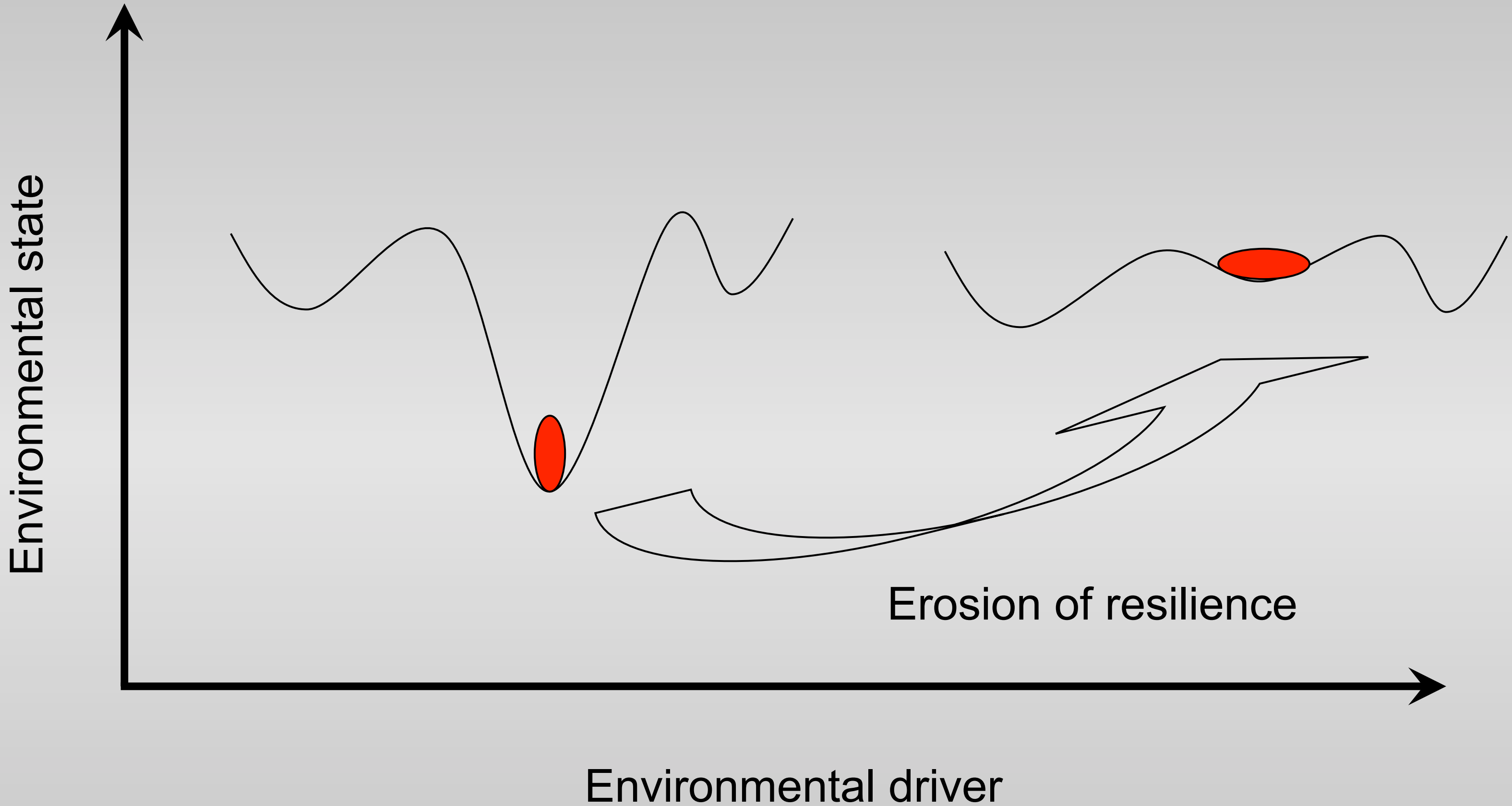
Fleshy brown algae took over



Loss of resilience



Erosion of resilience



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

Review of different oceanic examples

- **North Pacific** – complex natural state change(s)
- **Scotian Shelf** – driven primarily by fishing, cascading trophic impacts
- **North Sea** – combined drivers: natural=biogeographic shift and human=fishing

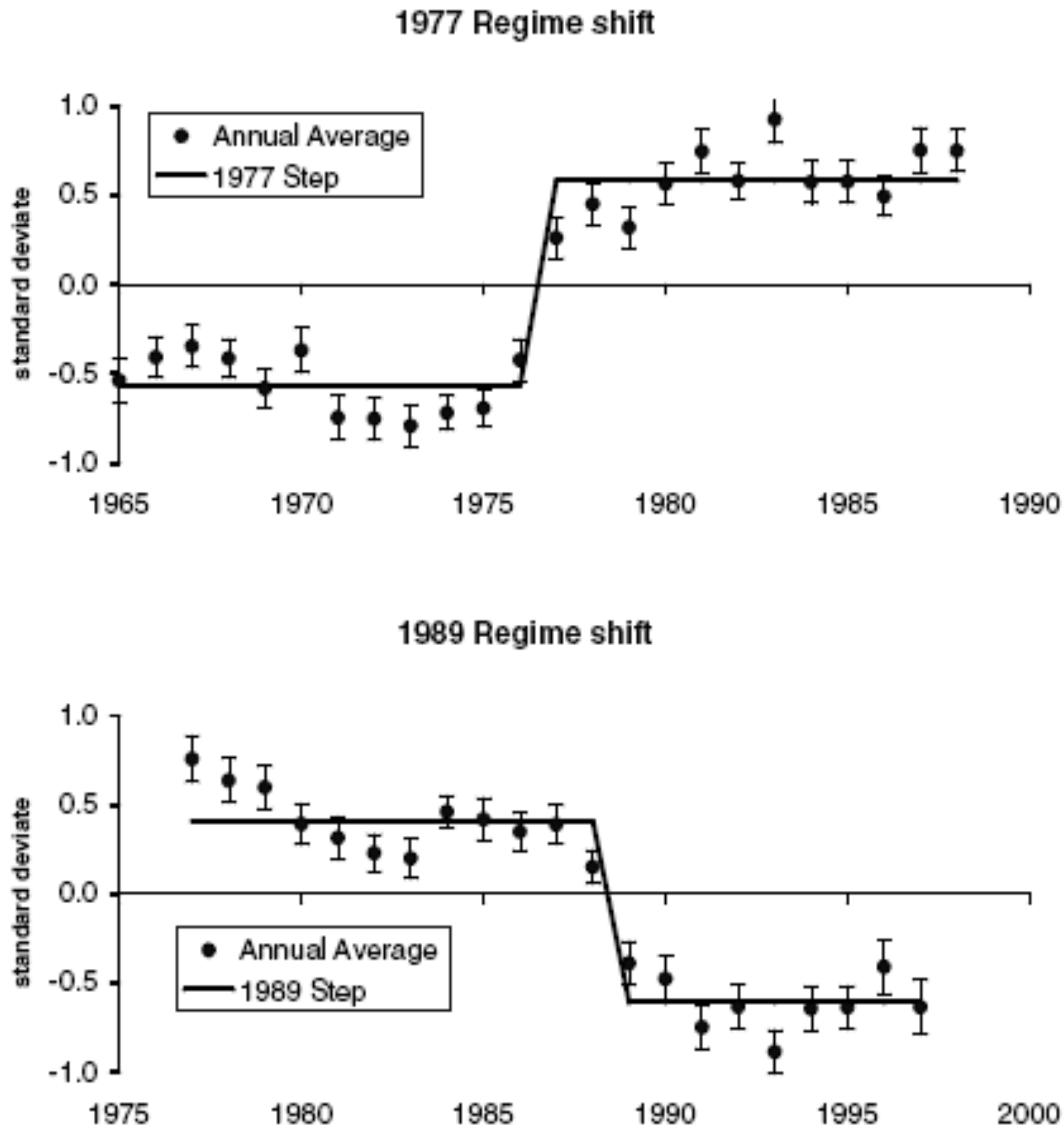


Fig. 4. Results from two regime shift analyses of a composite of the 100 environmental time series. The step passes through the mean standard deviate within each regime. The standard error of the 100 time series is illustrated for each year. After Hare and Mantua (2000).

North Pacific regime shift – Hare and Mantua (2000)

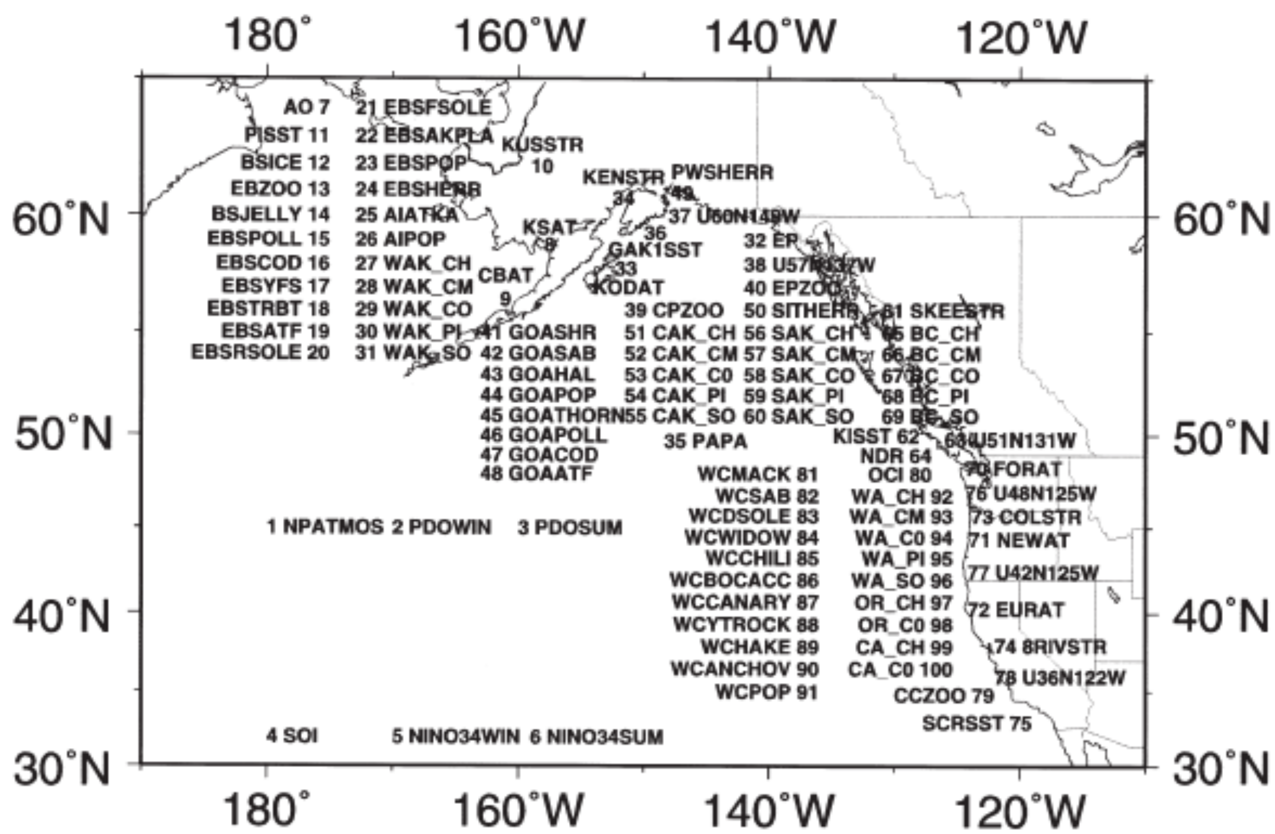
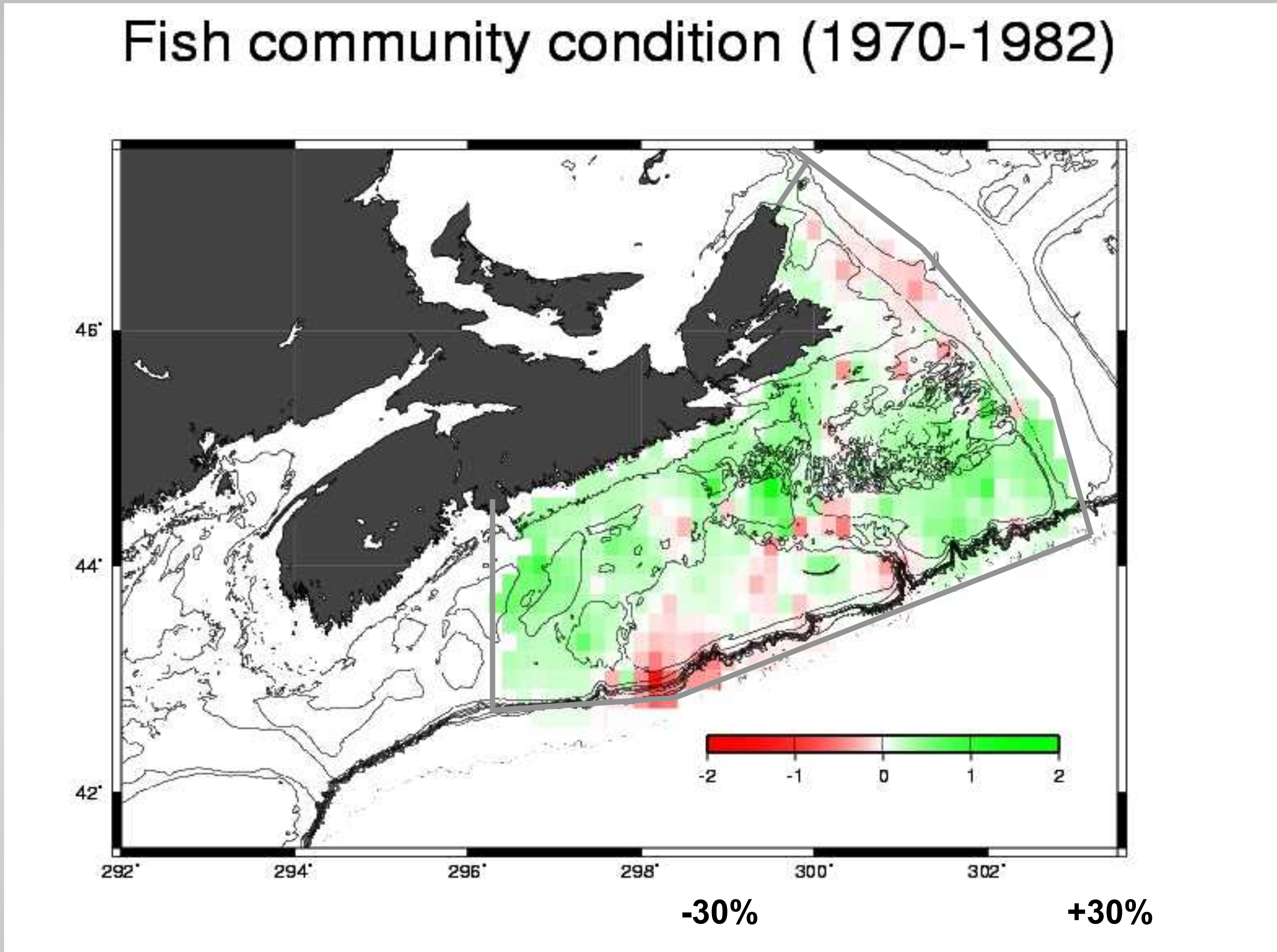


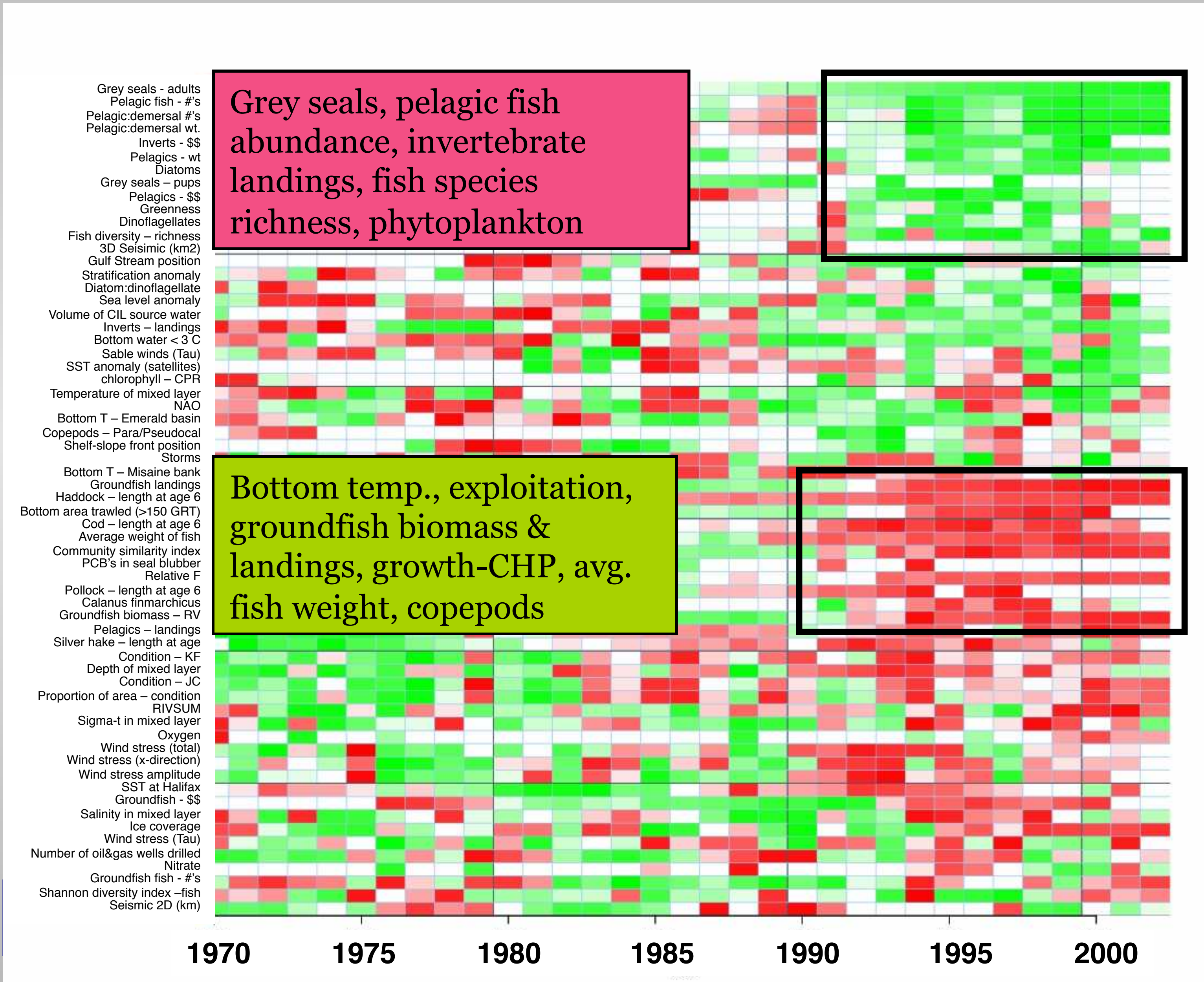
Fig. 1. Numeric and alphabetic abbreviations for the 100 time series used in this study. Geographical arrangement gives a general indication of where each variable is measured or has influence. See Table 1 for a definition of each abbreviation.



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

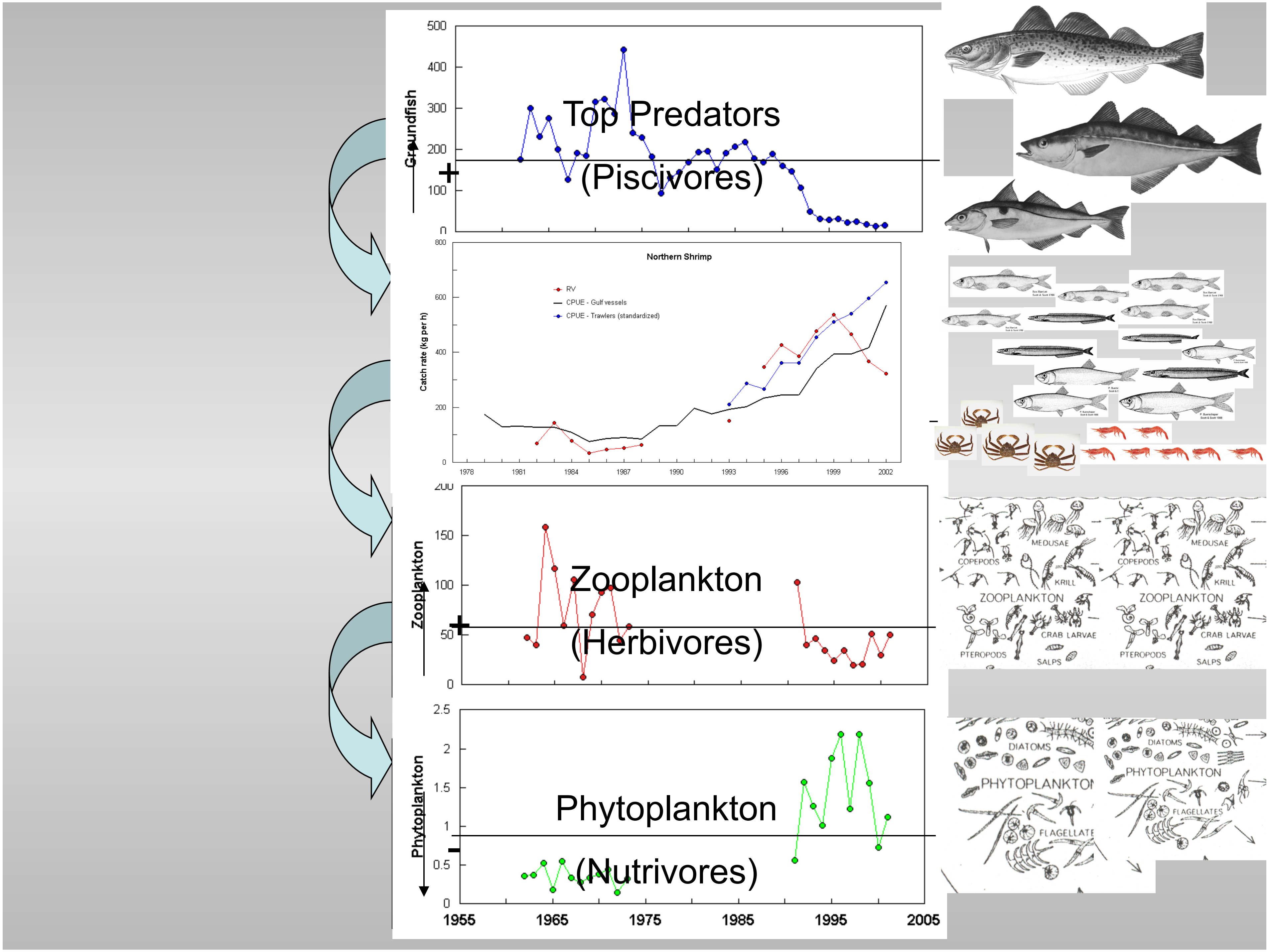
Colour display of 60+ indices

for Eastern Scotian Shelf



Red – below average

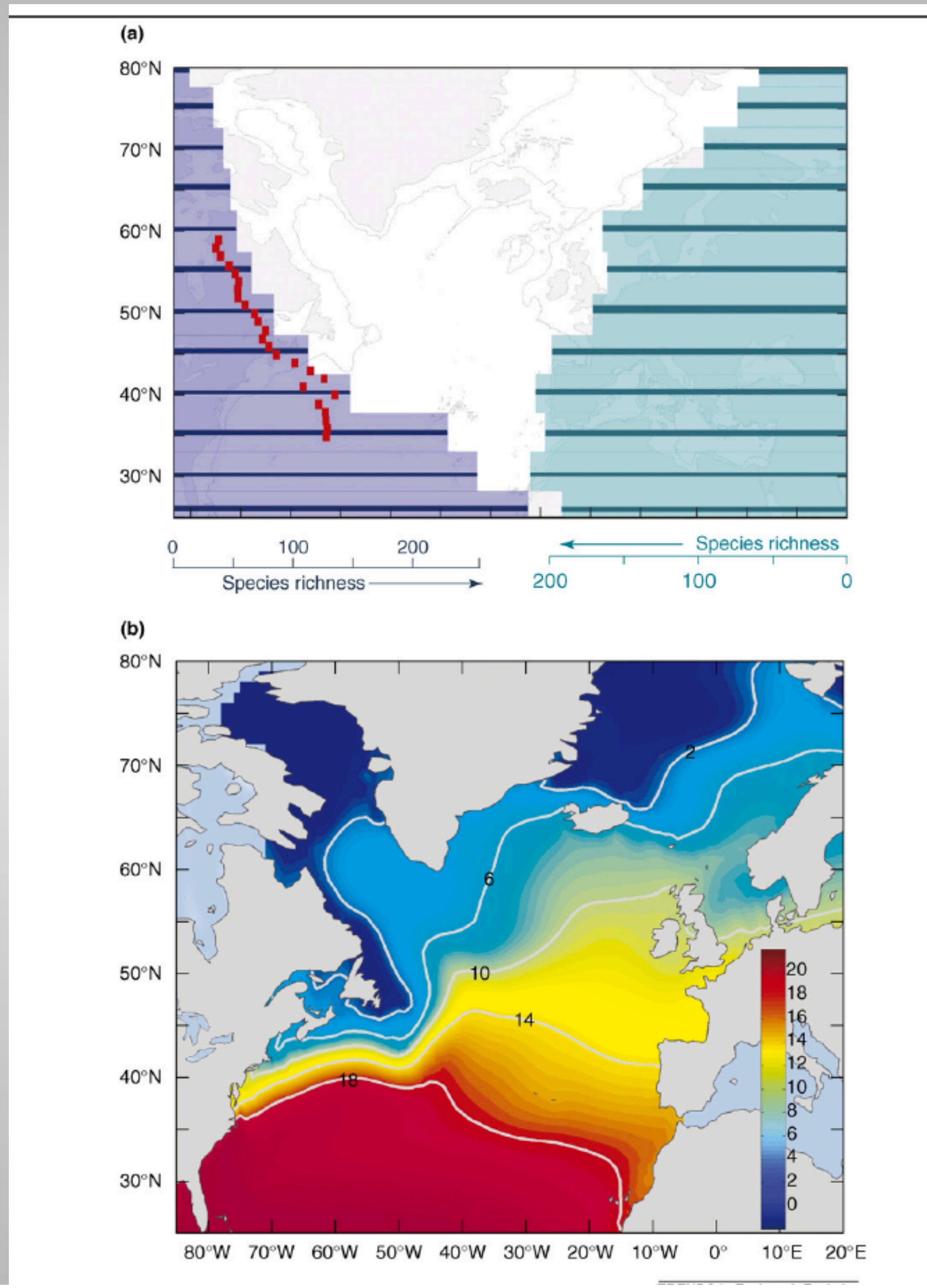
Green – above average

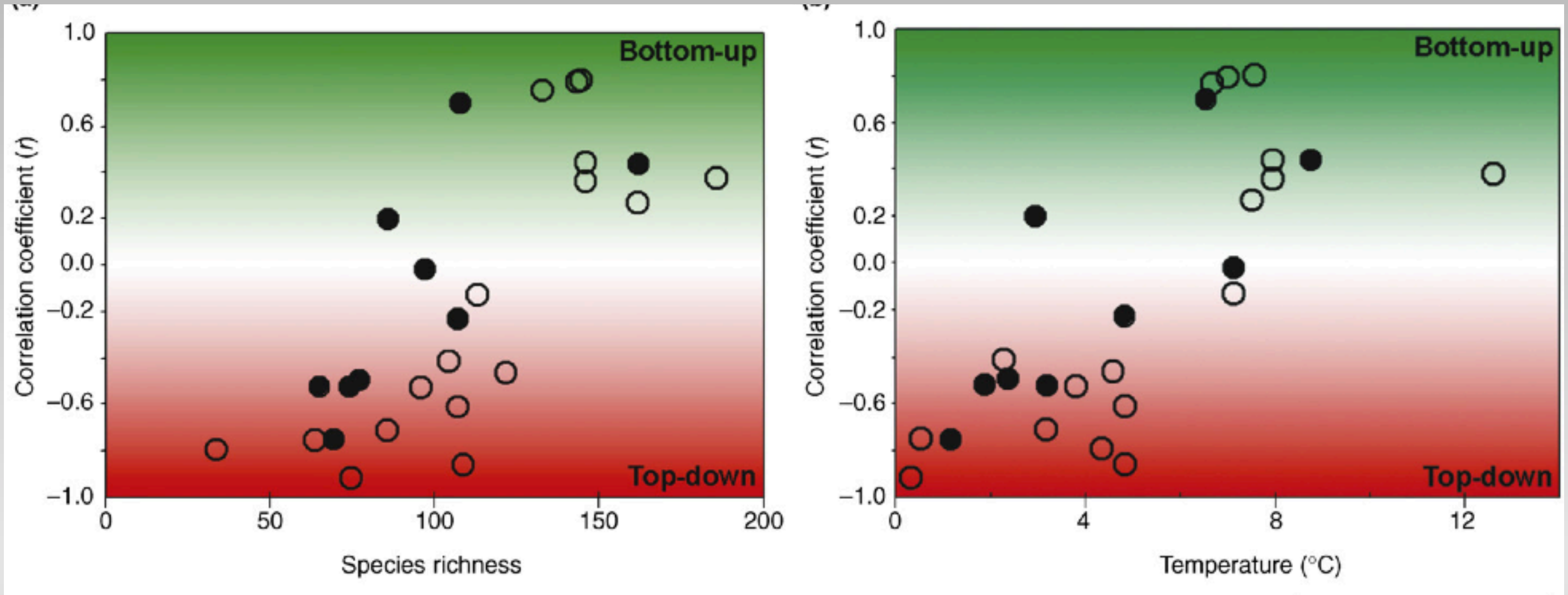

Top Predators
(Piscivores)
Groundfish
+
Northern Shrimp
RV
CPUE - Gulf vessels
CPUE - Trawlers (standardized)
Catch rate (kg per h)
Zooplankton
(Herbivores)
Zooplankton
+
Phytoplankton
(Nutrivores)
Phytoplankton
-
1955
1965
1975
1985
1995
2005
MEDUSAE
COPEPODS
KRILL
ZOOPLANKTON
CRAB LARVAE
PTEROPODS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

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?

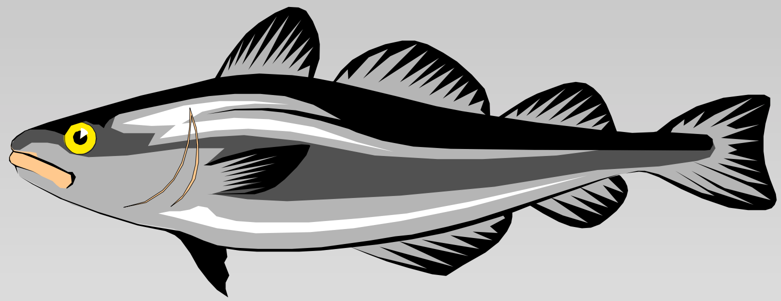
Frank *et al.* (2007 – TREE) looked at temperature and species richness, for the North Atlantic

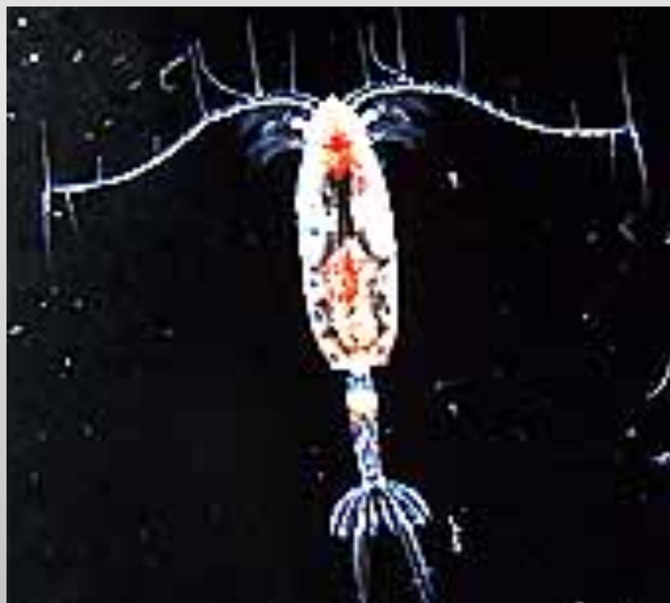


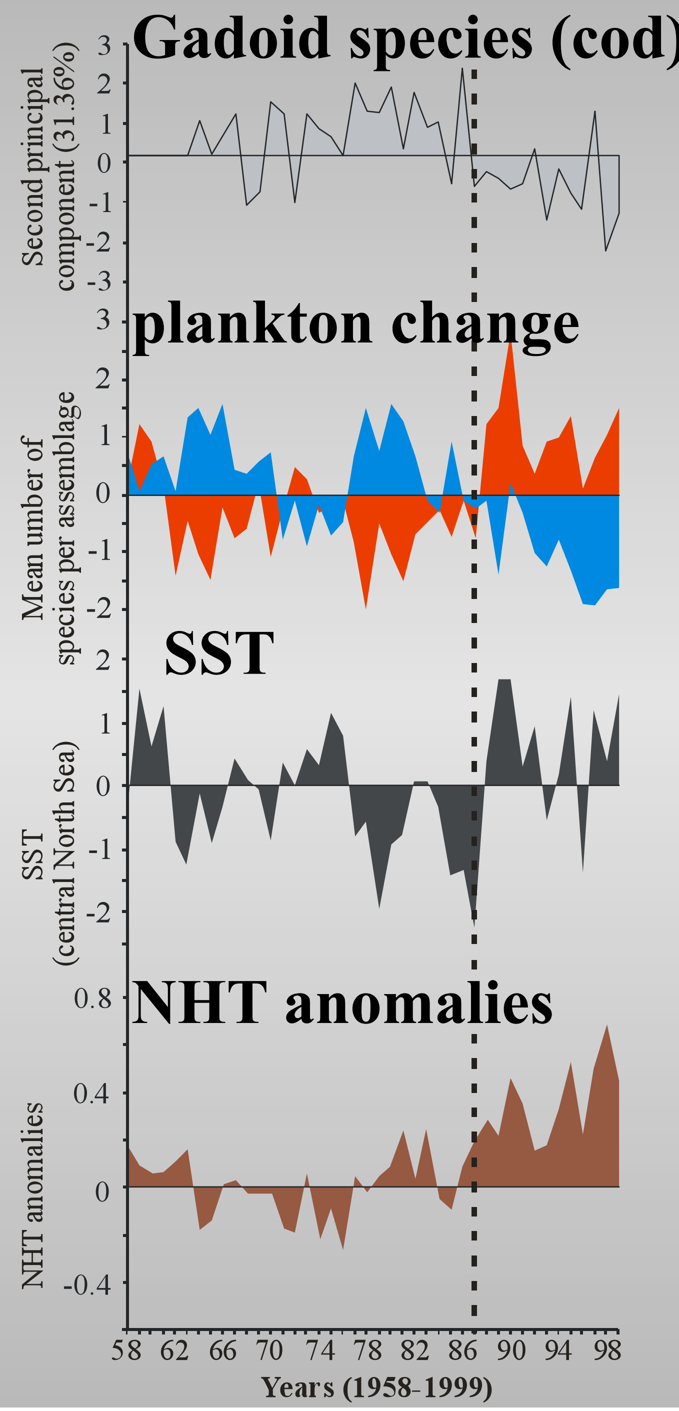


But here there is really not much difference between temperature and species richness since the two are strongly correlated.

North Sea: Long-term changes in the ecology (hydro-climate + biology)

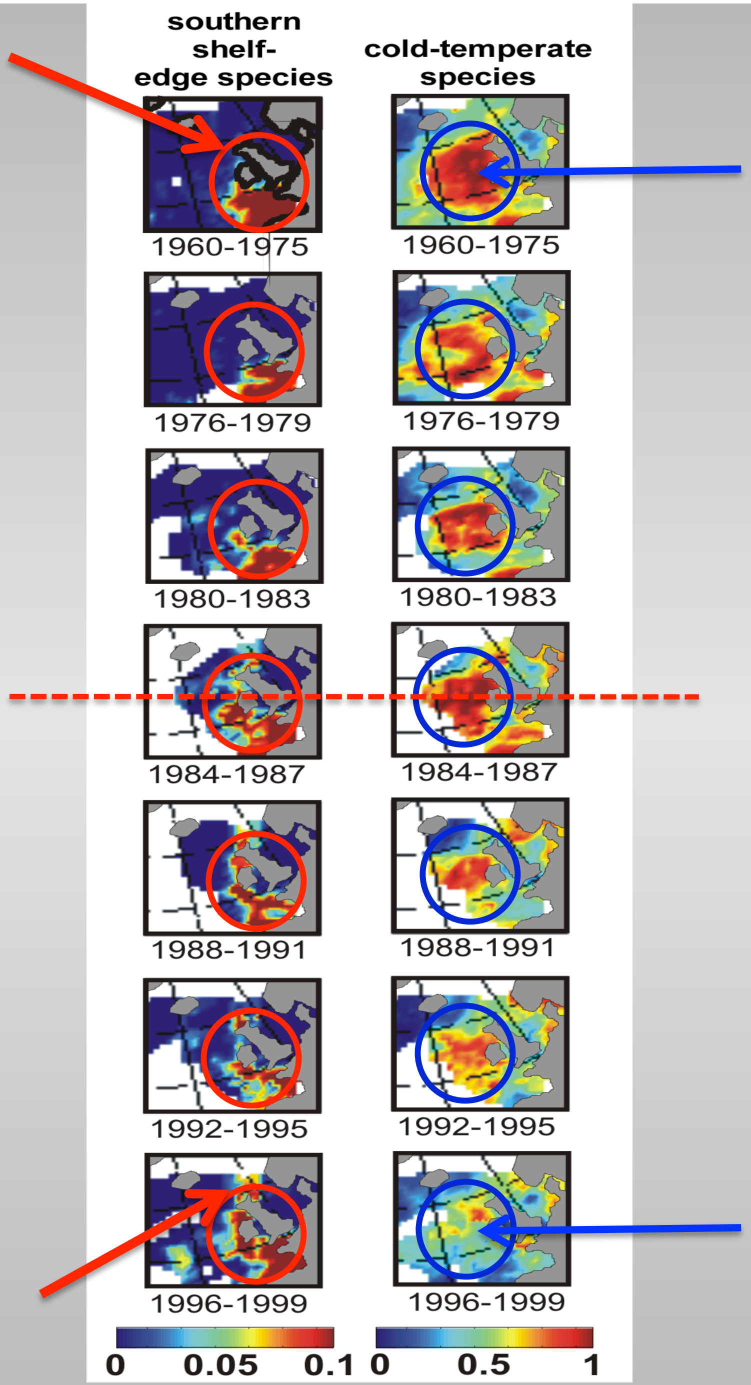






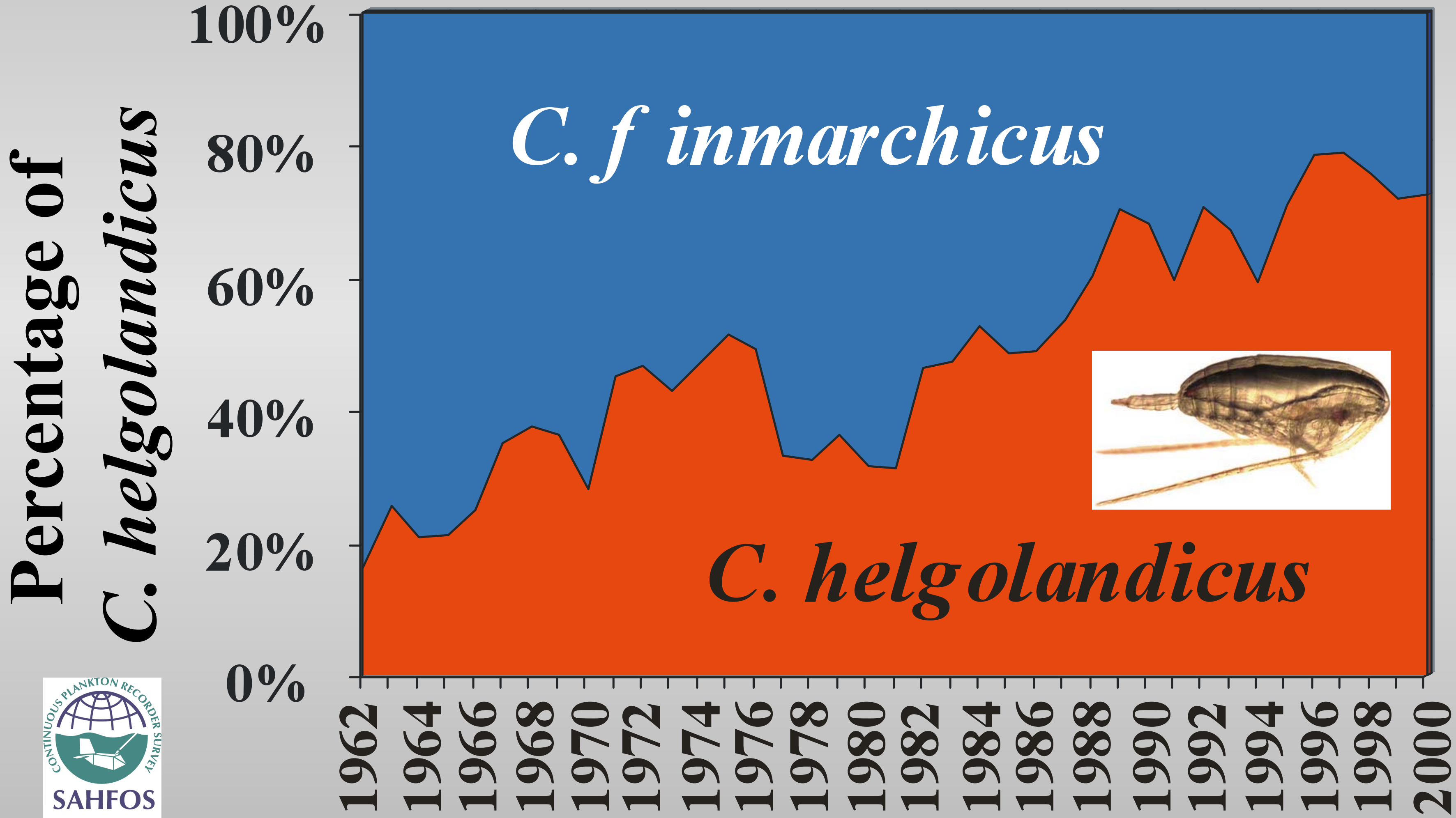
Shifts in copepod distributions in the North Atlantic:

Warm-water species have extended their distribution northward by more than 10° of latitude, while cold-water species have decreased in number and extension.



(Beaugrand et al., Science, 2002)

Long-term changes in the abundance of two key species in the North Sea



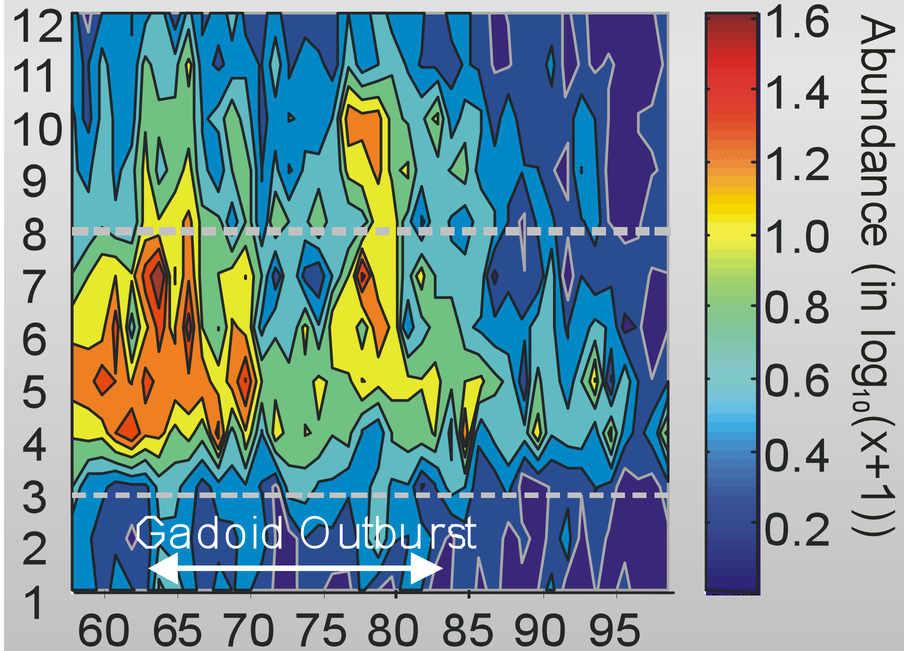
Reid et al. (2003)

CONTINUOUS PLANKTON RECORDER SURVEY
SAHFOS

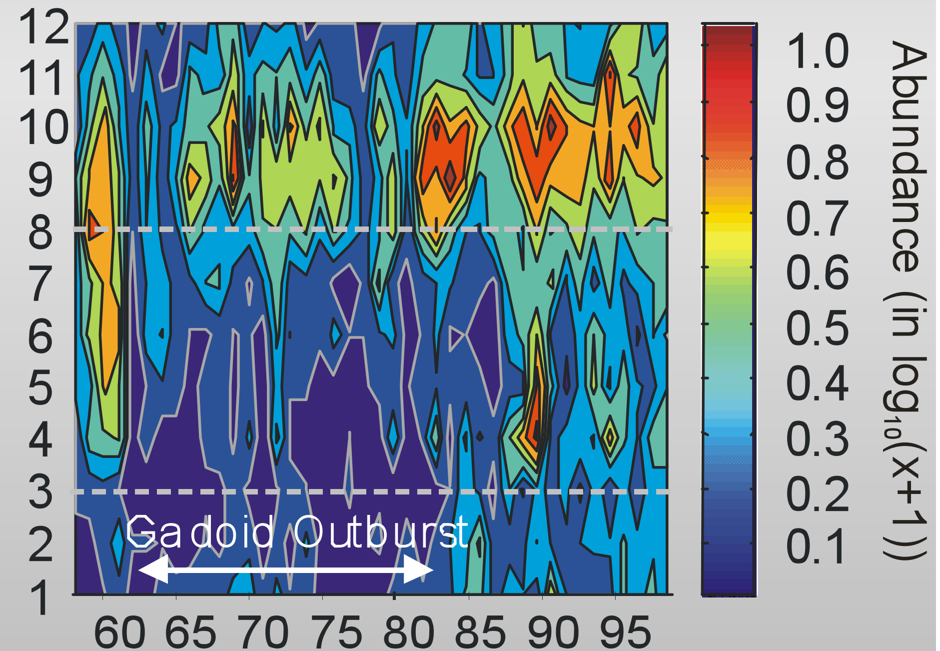
Consequences of plankton changes on higher trophic level

Mismatch between the timing of calanus prey and larval cod

Abundance of *C. finmarchicus*

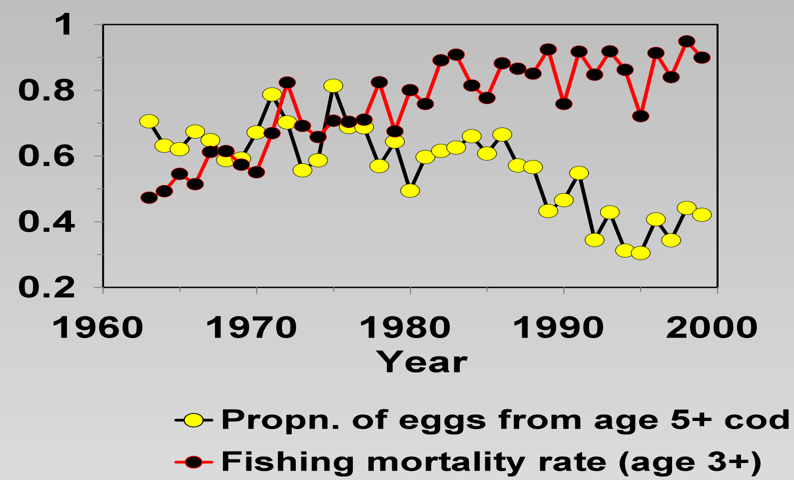


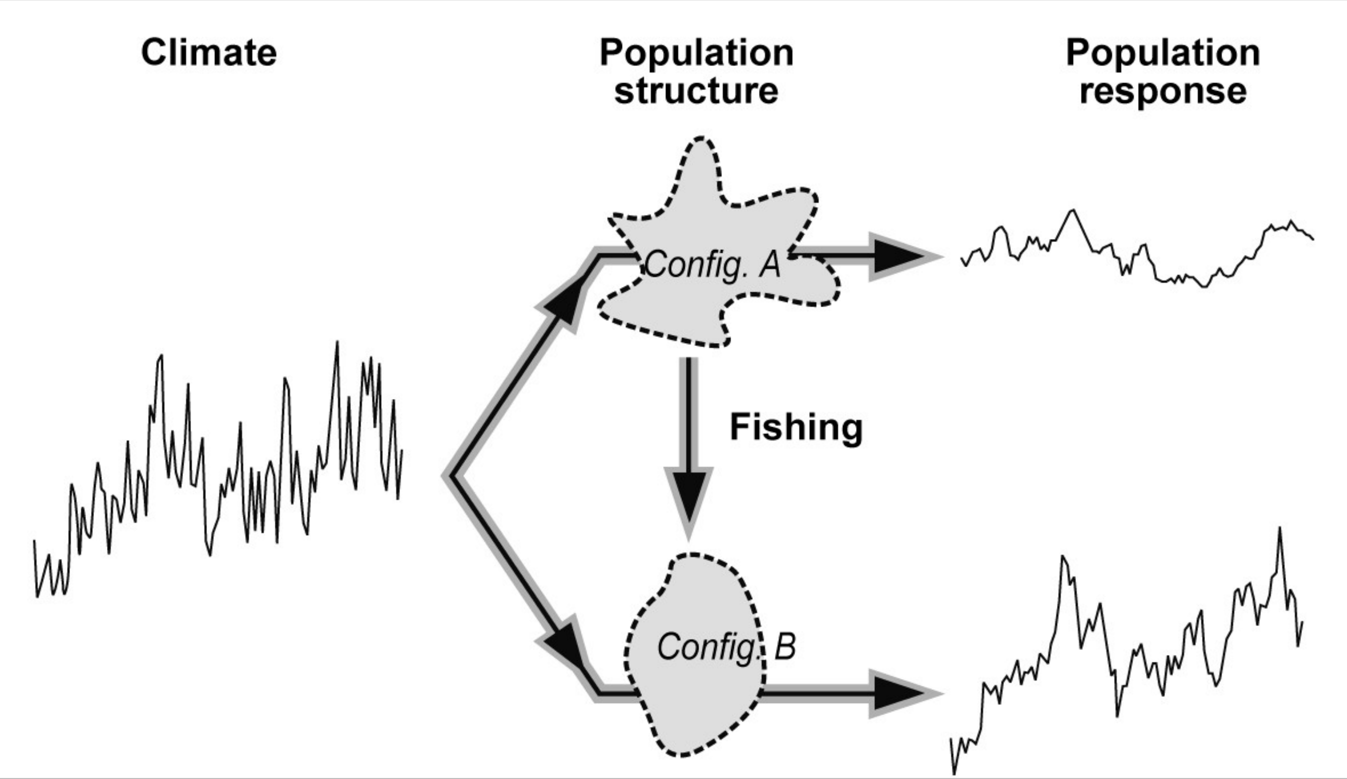
Abundance of *C. helgolandicus*



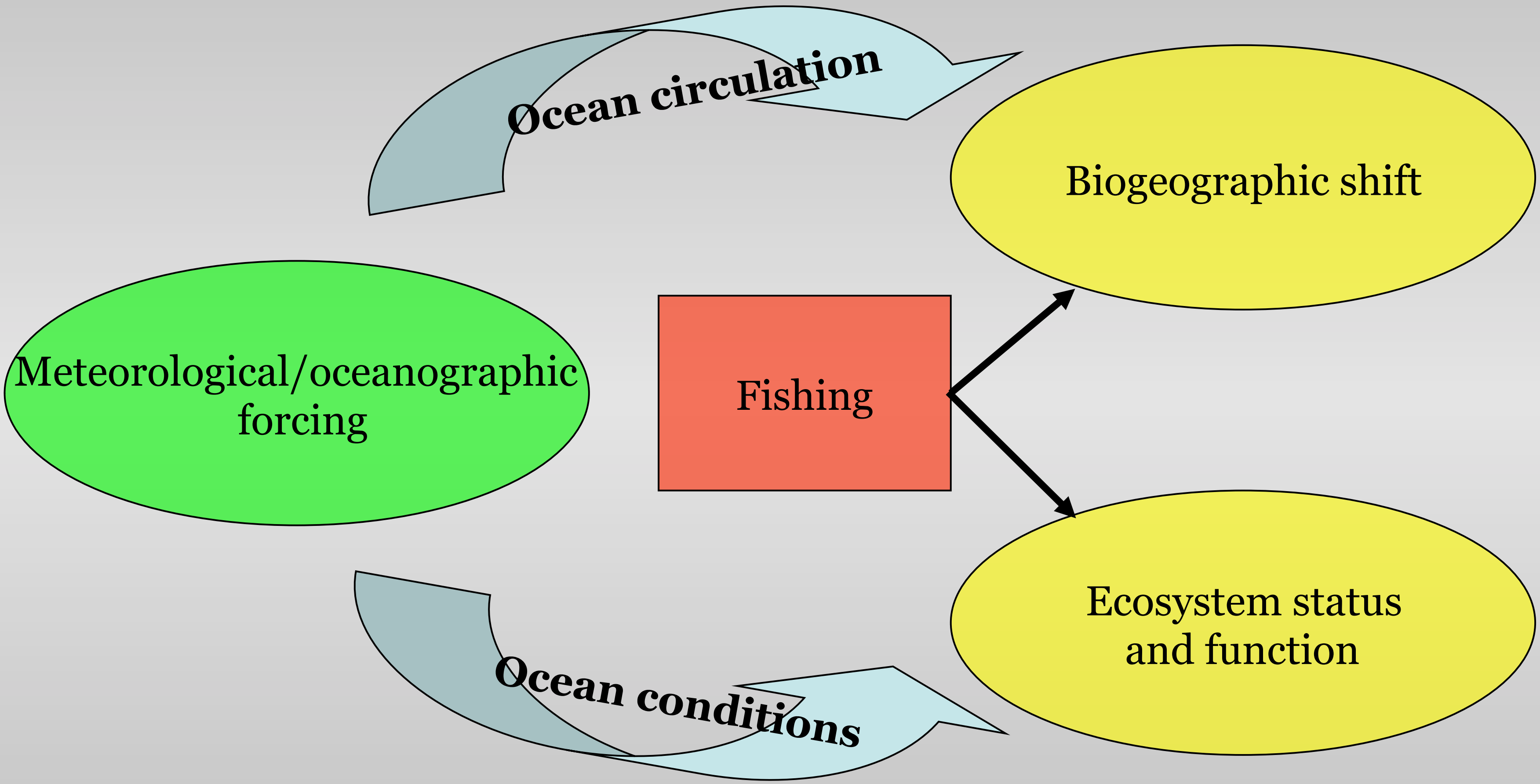
Beaugrand, et al. (2003) Nature. Vol. 426. 661-664.

But there is also an influence from fishing – how much?





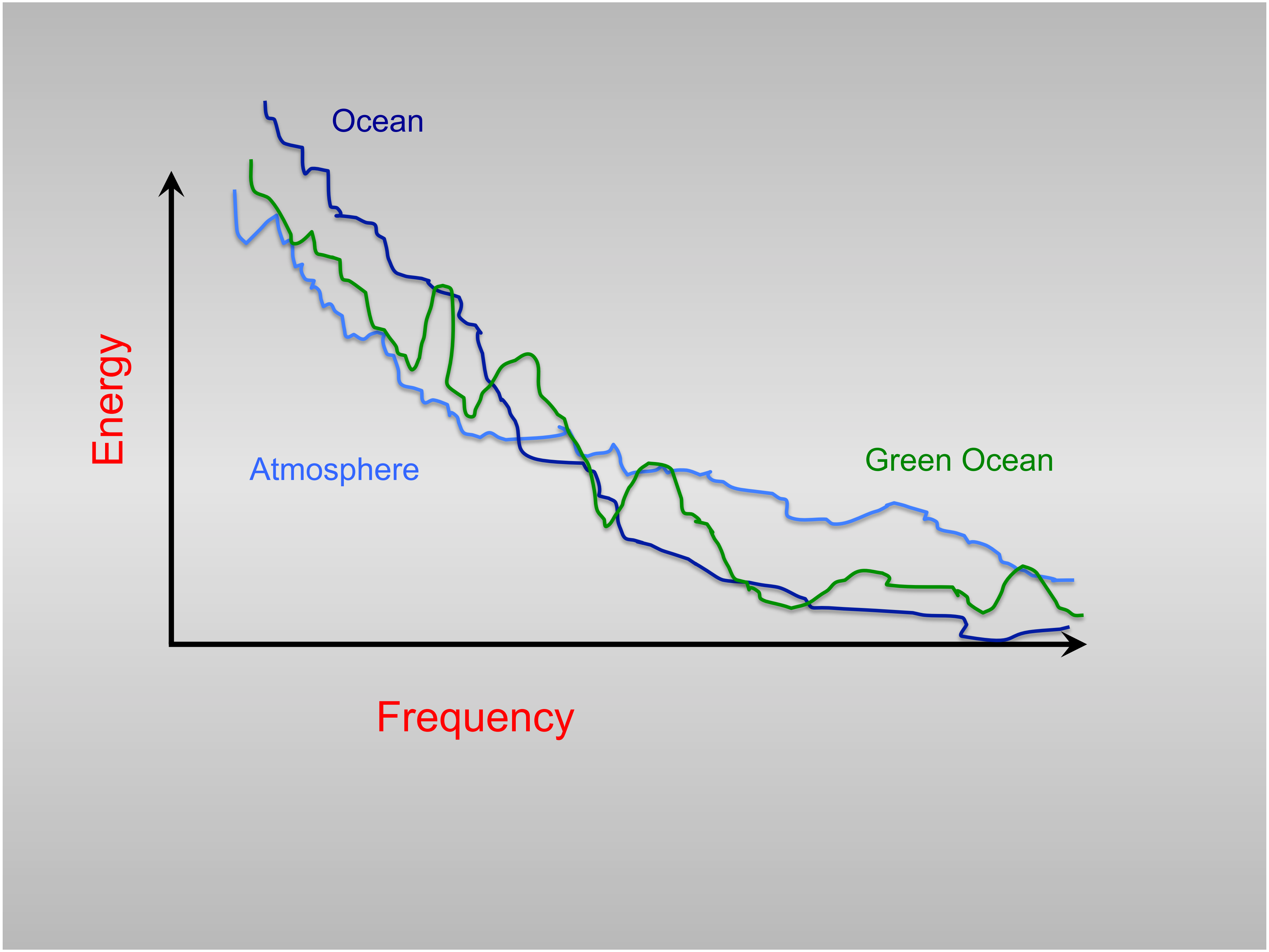
North Sea - dynamics



How does the driver generate a response ?

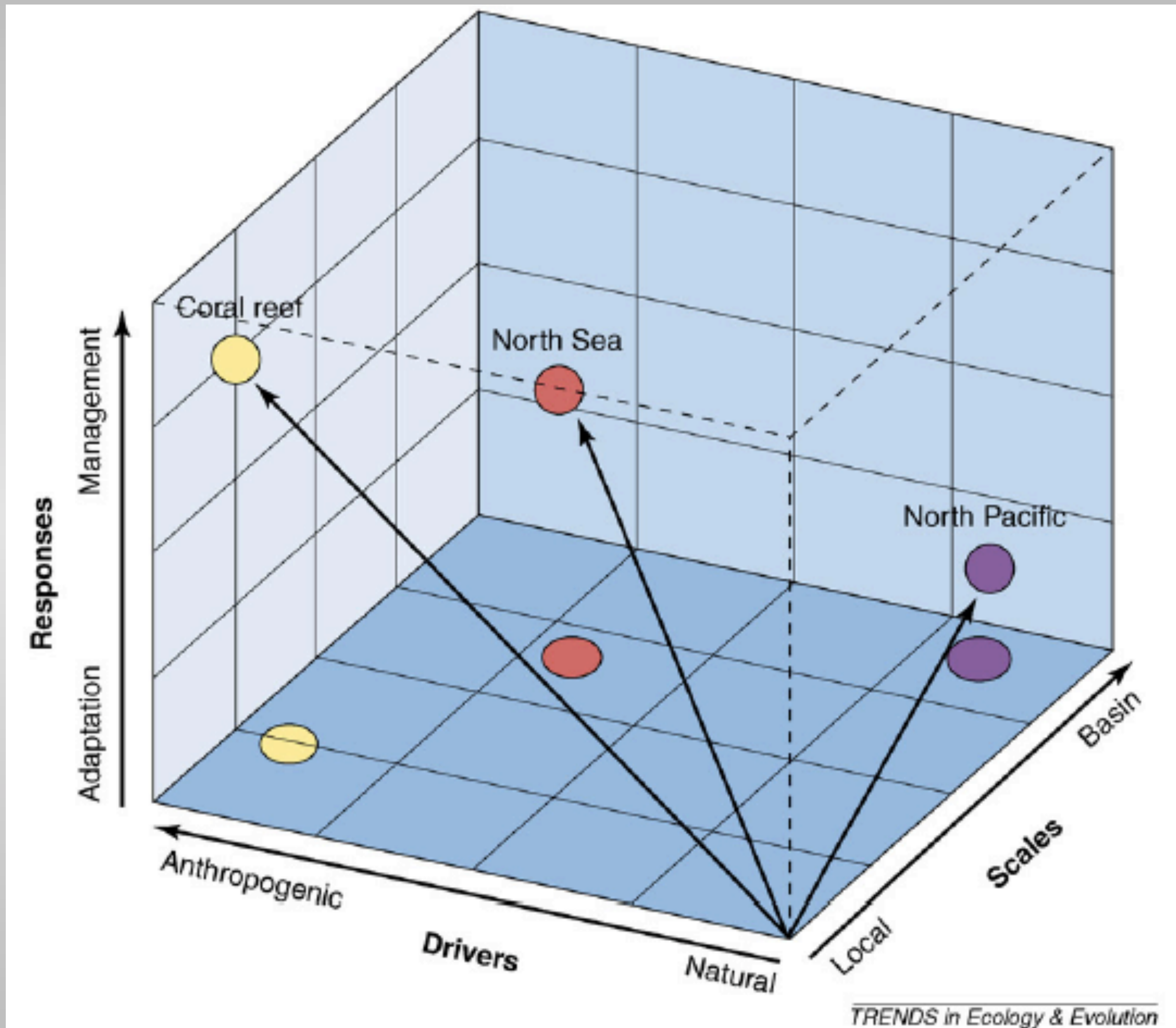
Hsieh, Sugihara *et al.* (2005) showed that physical drivers tend to be stochastic but linear, while biological variables are quite non-linear

Hasselman (1976) described the ocean as a linear red-noise integrator of the atmosphere


Ocean
Energy
Atmosphere
Green Ocean
Frequency

How predictable are regime shifts?

- Coral reefs (the “simplest” case)
  - We understand the causal links
  - We can’t predict disease outbreaks
- Fishing-dominated systems
  - Although fishing can be the dominant driver, its consequences are not predictable without understanding the foodweb dynamics
  - Shifts may not be easily reversible
- North Pacific
  - We have not been able to separate drivers or where different states are occurring
  - Accurate prediction not currently possible



deYoung et al. (2007)

Summary

- Lots of evidence for regime shifts in the ocean – but it can be confusing and hard to develop a clear picture

- More regime shifts are likely – decreased resilience

- Limited data, systemic complexity, range of different structures, underlying dynamics rarely very clear, shifting structures

- Need sustained monitoring, experimental work, models, etc., understanding any one system may not serve as a guide elsewhere