Regime Shifts in Marine Ecosystems: What Could Happen?

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DEFINITION OF REGIME SHIFT

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


“Simple” example
Jamaican coral reef systems

Hughes Science 1994

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

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.
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)

Scotian Shelf – Frank et al. 2005
Colour display of 60+ indices
for Eastern Scotian Shelf

Grey seals, pelagic fish abundance, invertebrate landings, fish species richness, phytoplankton

Bottom temp., exploitation, groundfish biomass & landings, growth-CHP, avg. fish weight, copepods

Red – below average
Green – above average
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

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
Moving through a regime shift, the coral reef example

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

a) Diversity
- Species interactions
- Exchange of individuals and materials

b) Connectivity
- Local community
- Species
- Genes

C) Adaptive capacity
- Range shift
- Evolution

Pulse disturbances:
- Storms, heat waves, etc.

Press disturbances:
- Rising temperatures, changes in ocean chemistry and circulation, etc.
Lots happening on the little planet earth
Lots happening on the little planet earth

Steffen et al. 2011
Key possible tipping points of the earth system

- Reduced warming of Greenland
- Cooling of northeastern tropical Pacific, thermocline shoaling, weakening of annual cycle in EEP
- Enhanced water vapour export from Atlantic
- Shift to a more persistent El Niño regime
- Tropical moisture supply changes
- Warming of Ross and Amundsen seas
- Drying over Amazonia
- Disintegration of West Antarctic ice sheet
- Melt of Greenland ice sheet
- Collapse of Atlantic thermohaline circulation
- Freshwater input
- Fast advection of salinity anomaly to North Atlantic
- Sea-level rise causing grounding line retreat
- Southward shift of intertropical convergence zone
- Heat accumulation in Southern Ocean
- Increase in meridional salinity gradient

TRENDS in Ecology & Evolution

Kriegler et al. PNAS 2009
Lenton & Williams TREE 2013
But what about Ocean Acidification? Could it push global ecosystems beyond a threshold?
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

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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