

# What is a Regime Shift?

## Semantics and Recent Indicators

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Over 100 papers on physical/biological regimes

- *Ignoring the impacts of such climate variability on the abundance trends of commercially important species could lead to the collapse of major fisheries.*

Beamish et al. (2004)

- *So far there are no clear convincing evidence that changes in ocean climate induce bi-stable modes in marine ecosystems.*

Steele (2004)

- *Useful if relationships (predator/prey, recruit/biomass, species/physics) are different in “different” regimes*

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# Three Definitions of Regimes

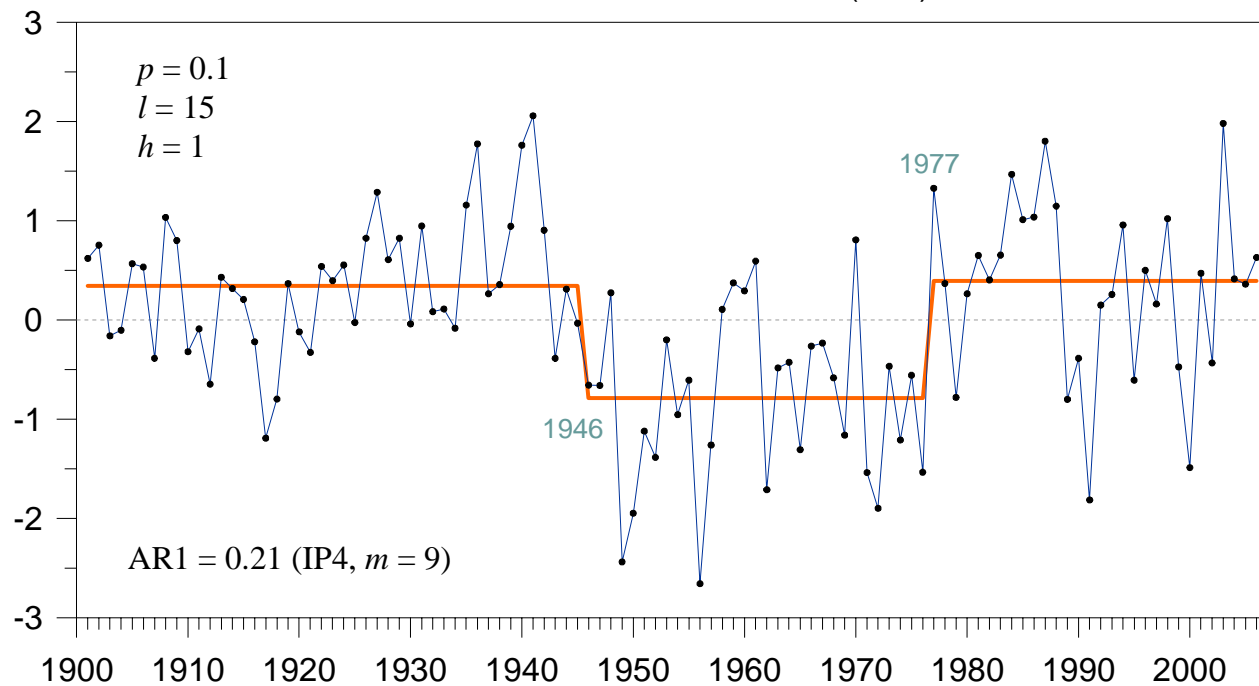
- ***Displacement:*** Statistically significant shifts in short timeseries deYoung et al. (2004)
- ***Mechanism:*** Non-linear processes with multiple maxima Rednick and Davis (2006), Hsieh et al. (2005)
- ***External:*** External forcing of marine systems (Climate, fishing). Internal changes are Phase Transitions Duffy-Anderson et al. (2005)

# Displacement

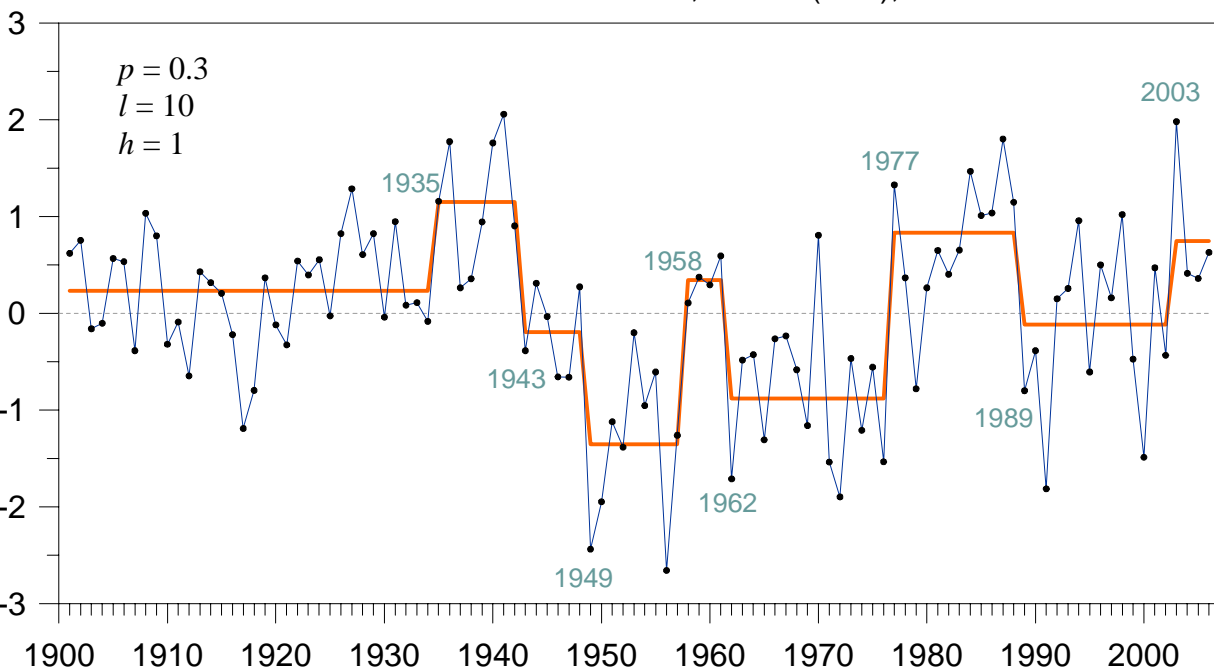
Statistically significant shifts in means relative to within-regime variance

(Rodionov 2004)

Pacific Decadal Oscillation Index, Winter (DJF), 1901-2006



Pacific Decadal Oscillation Index, Winter (DJF), 1901-2006



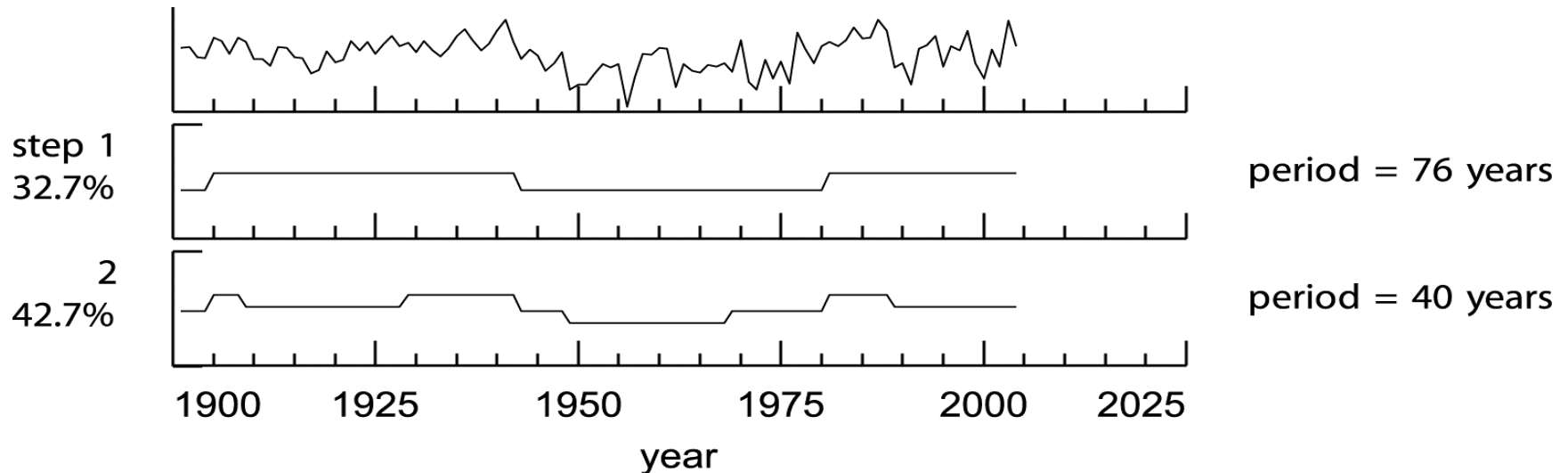
Depends on false positive parameter  $p$ , and time scale  $l$

# Mechanisms

- Nonlinear- Deterministic Process: several strongly interacting variables (few dimensions)
- Stochastic (Random) Process: Many separate processes contributing to timeseries (high number of dimensions).
- Central Limit Theorem: A process made up of many other processes will have a smooth (Gaussian) frequency distribution



# Fit square oscillator to Pacific Decadal Oscillation (PDO) timeseries: “multiple stable states”



BUT: Other simple times series models without multiple stable states also fit the PDO data equally well!

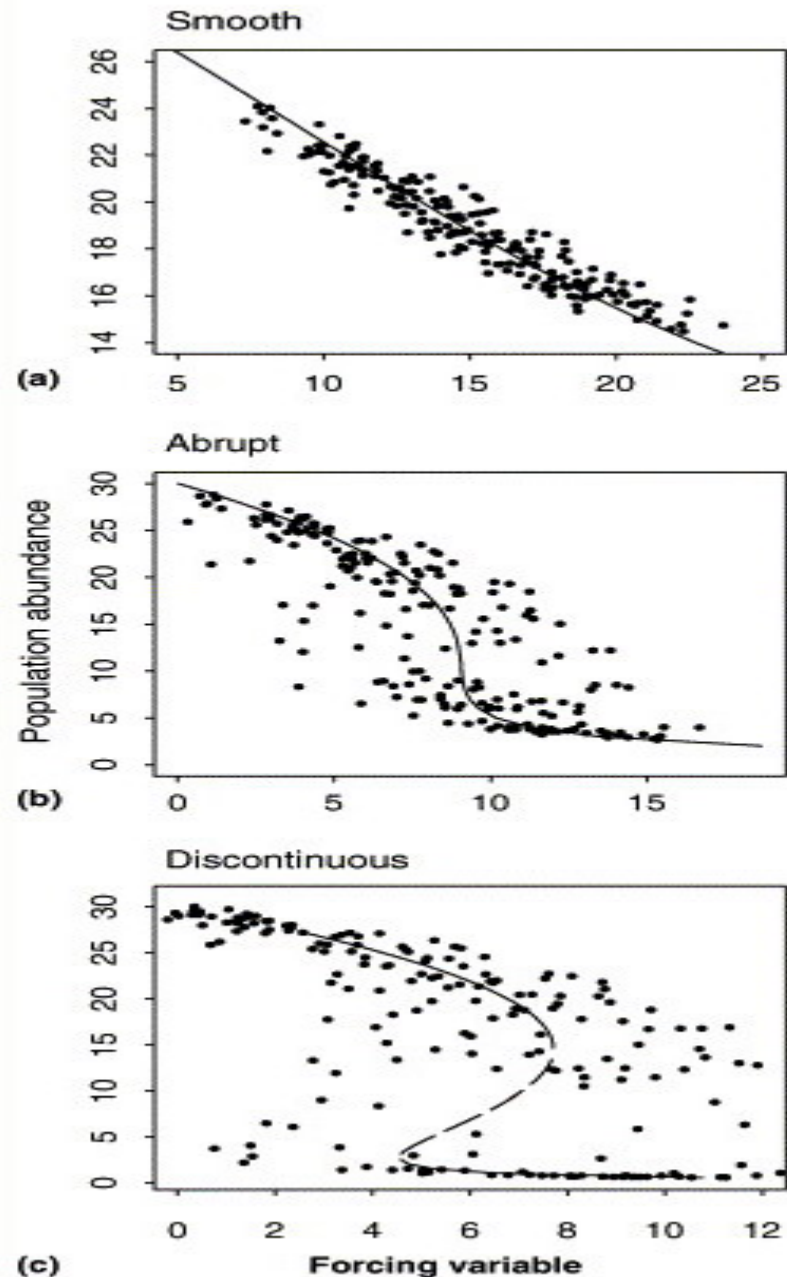
CONCLUSION: *Cannot determine underlying process model from data alone for records shorter than 200 years*

Can “simple” biological models help?

Several predator prey equations

Different ranges of parameters in models give qualitatively different responses

(Collie et al. 2004)



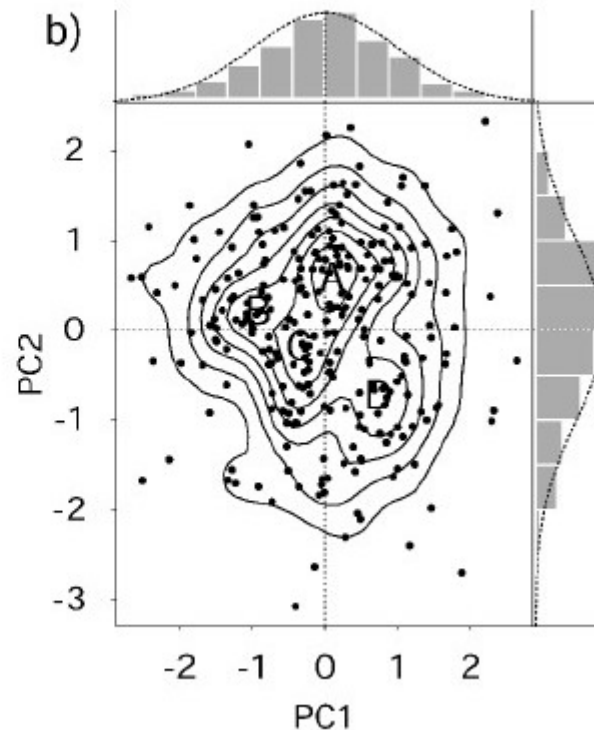
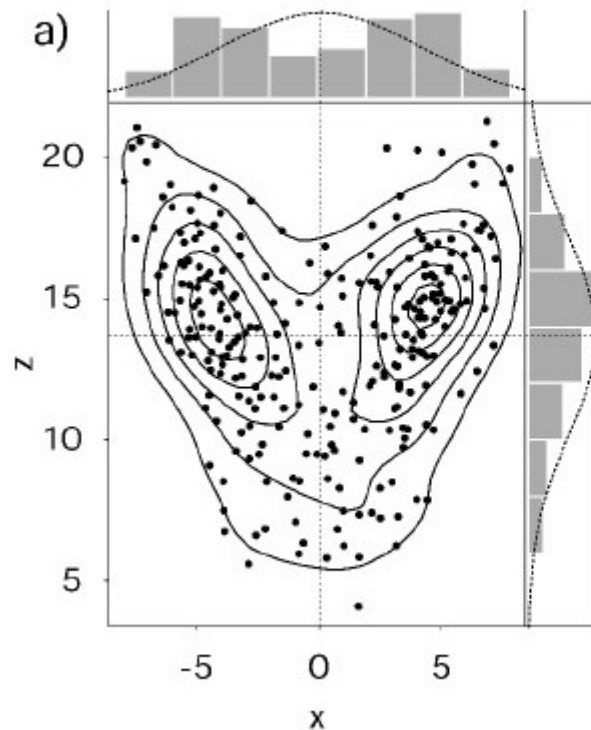
Lorenz model: three equations,  
three variables (dimensions)  
(Phase space plots)

What if you could observe only  
one timeseries, x or z?

***Hidden dimensions***

First two principal components  
of winter atmospheric circulation  
(Dots are monthly data)

Data seems to cluster, but  
rather Gaussian distributions  
Weakly connected processes?

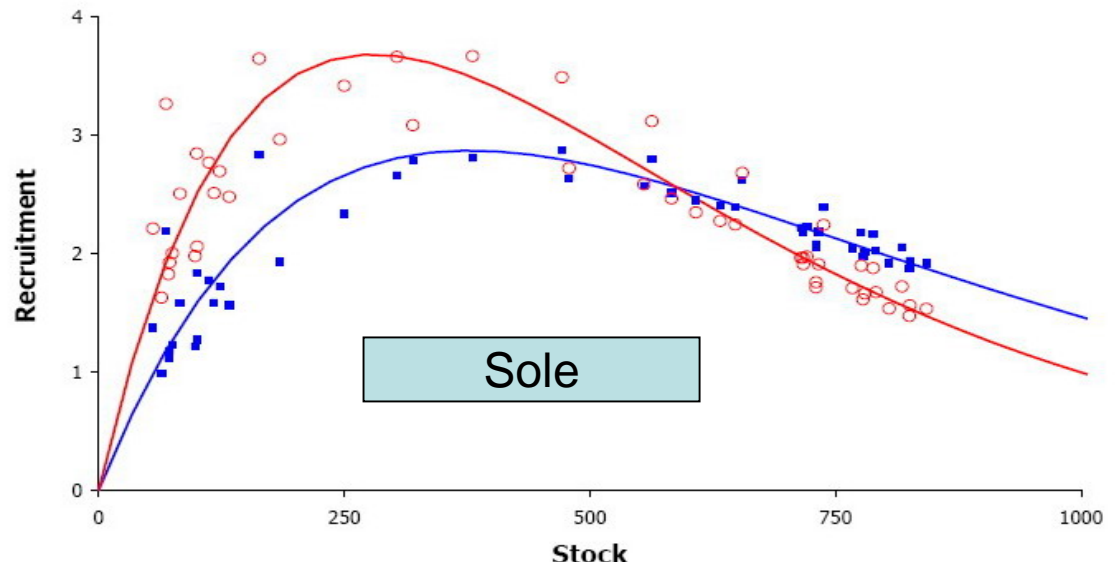


Stephenson et al. (2004)

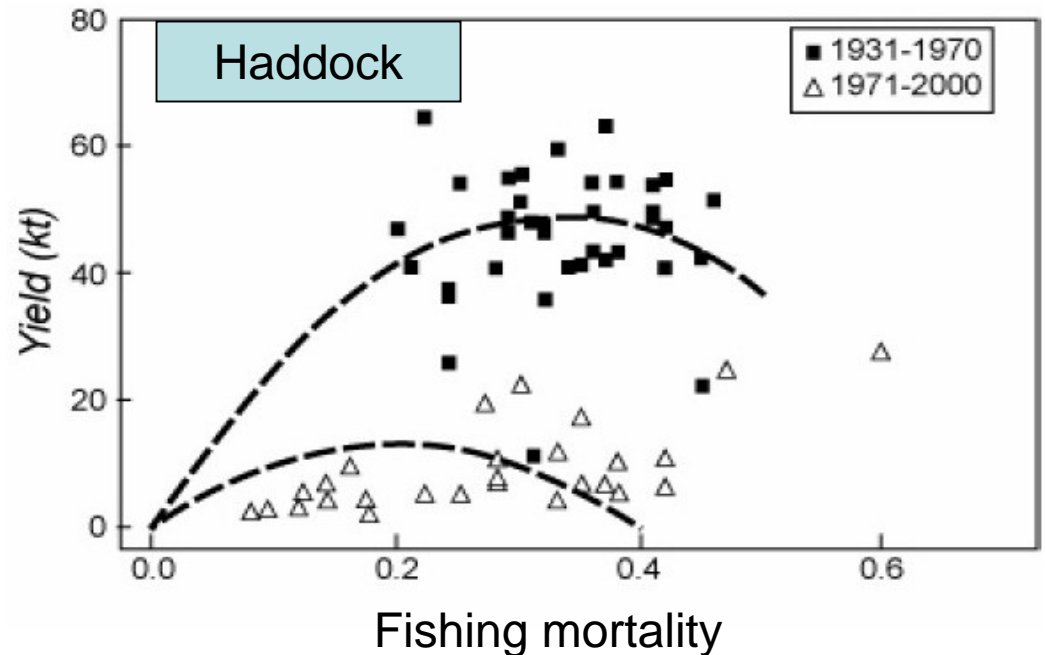


## Examples from Nature

a) Bering Sea sole: Different R/S curves for different wind conditions  
(Wilderbuer et al. 2002)

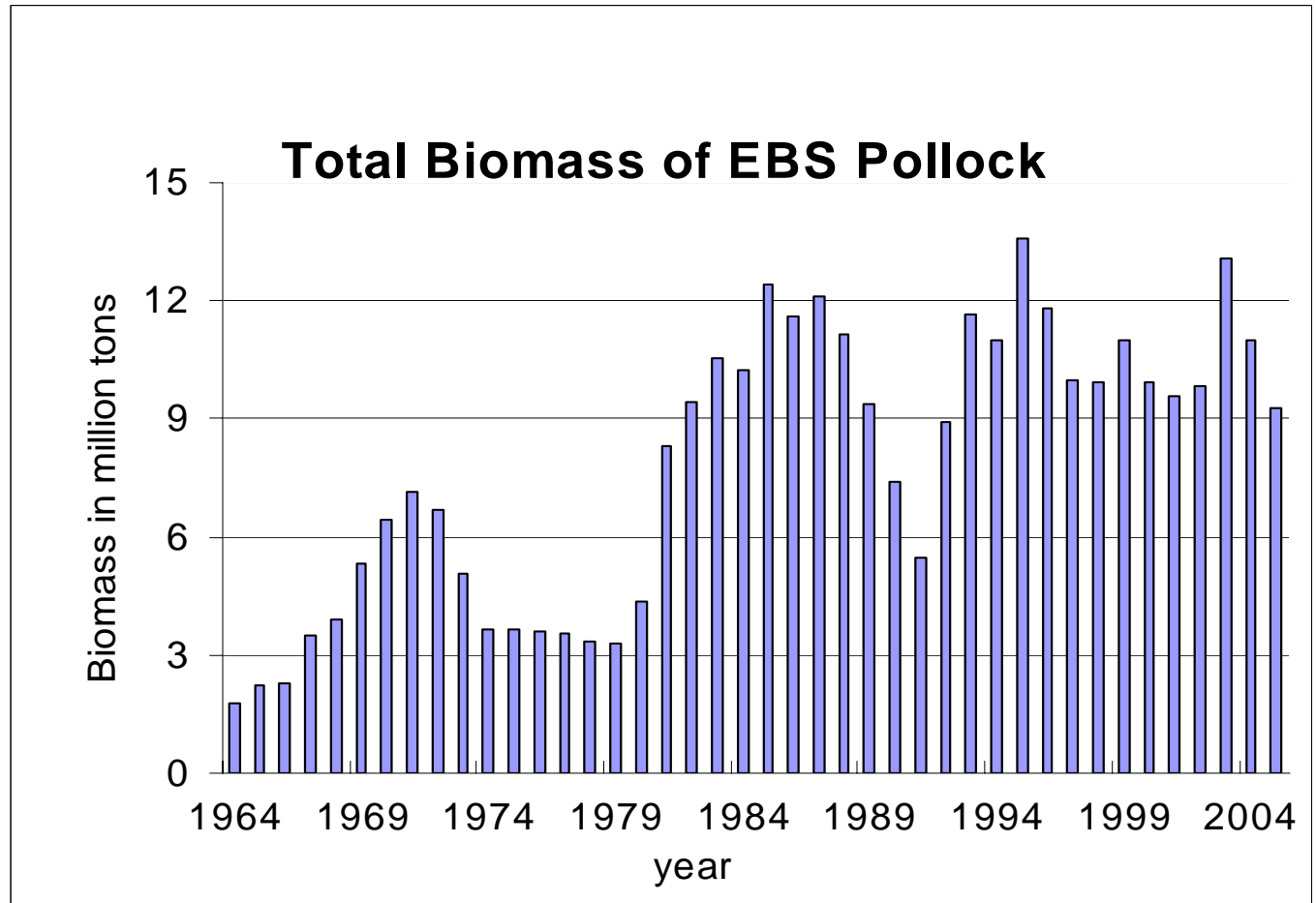


b) Georges Bank haddock: No return to high yields when fishing decreases  
(Steele et al. 2004)



Paradox: A simple model of BS Pollock (cannibalistic) would be unstable, but there is a continued observed high biomass (spatial influence?)

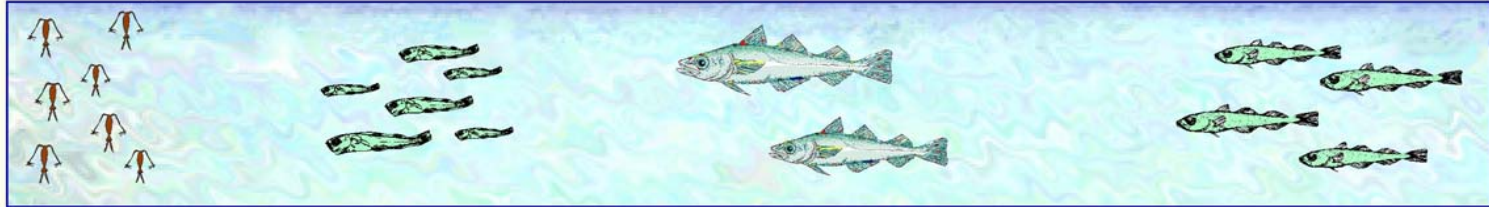
Climate and ecosystems are more complex (and stable?) than low dimensional models



# Oscillating Control Hypothesis

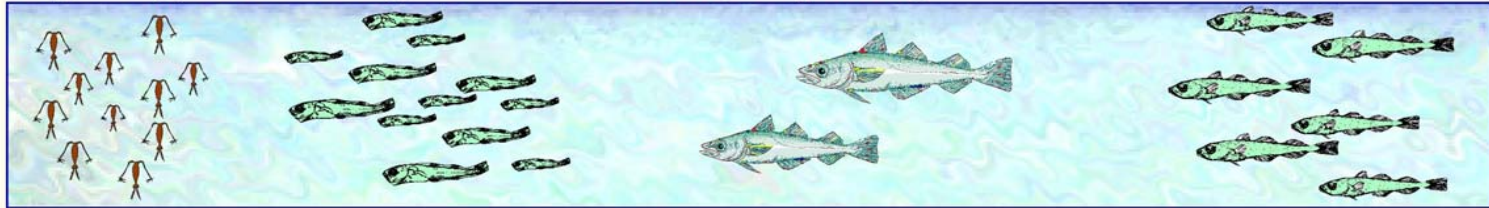
**Cold Regime**

**(Bottom-Up Regulation)**



**Beginning of Warm Regime**

**(Bottom-Up Regulation)**



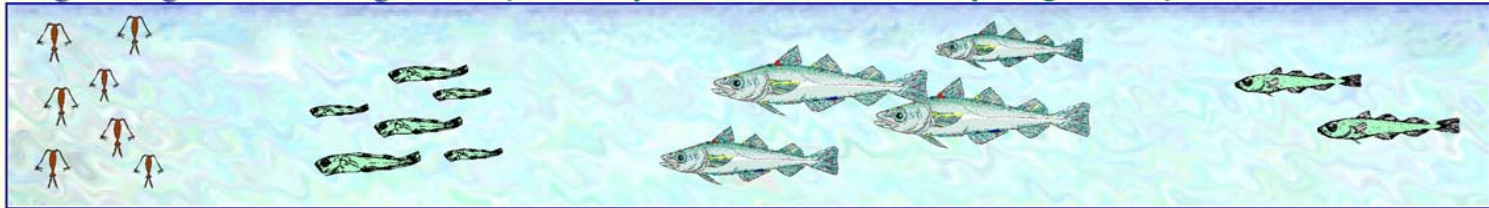
**Warm Regime**

**(Top-Down Regulation)**



**Beginning of Cold Regime**

**(Both Top-Down and Bottom-Up Regulation)**



Zooplankton

Larval Survival

Abundance of Cannibalistic Adults

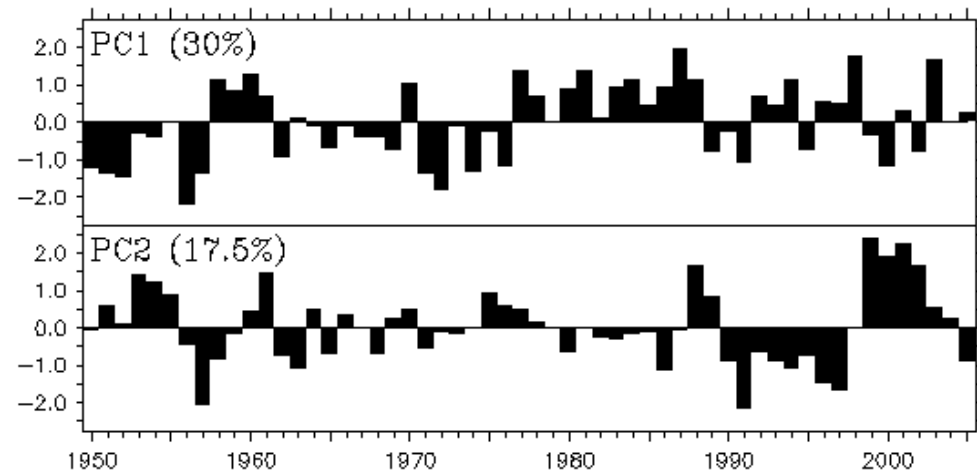
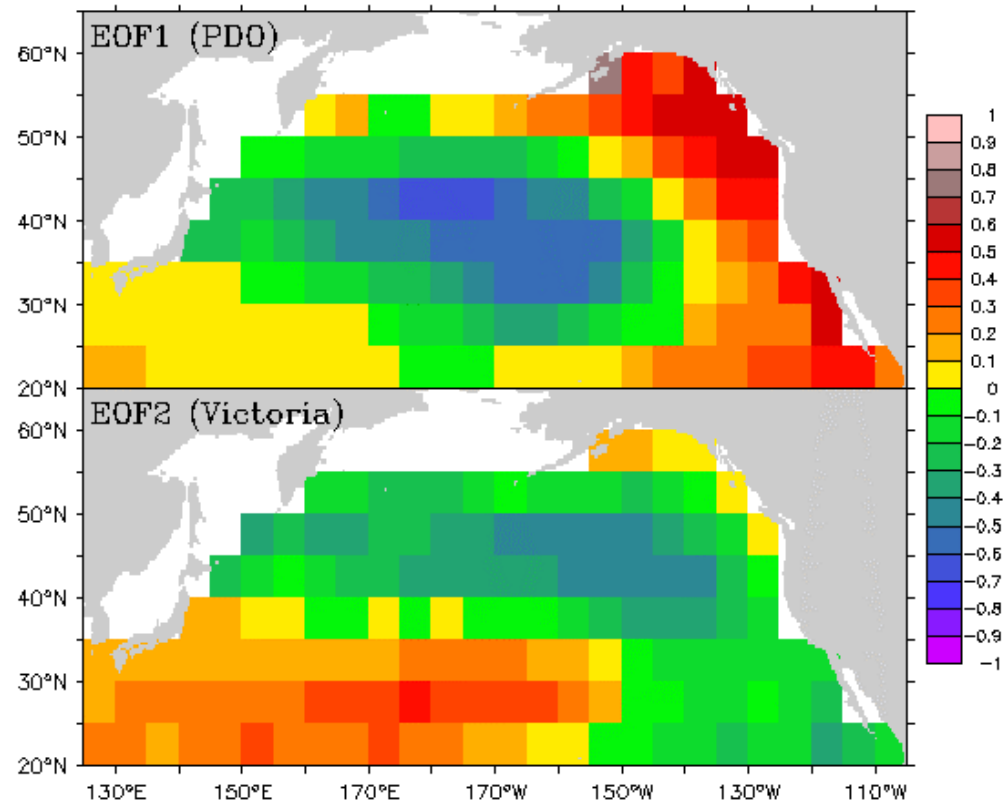
Juvenile Recruits

# Hsieh et al. (2005) Nature

- **10 northeast Pacific biotic timeseries:** *All but one salmon stock had a low dimensional behavior of 3-4, and CalCOFI timeseries ranged from 4-8.*
- **6 abiotic timeseries:** 3 California SST, PDO, Aleutian low, and southern oscillation. *The physical series were consistent with a signal made up of a large number of contributing factors (dimensions).*
- *How can be sure from short timeseries?* Ghil et al. (2002)

What is Happening Now?

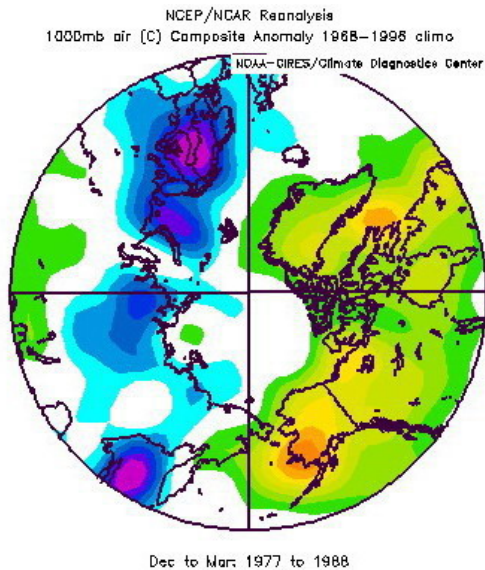
# North Pacific Winter SST Anomalies 1950–2005



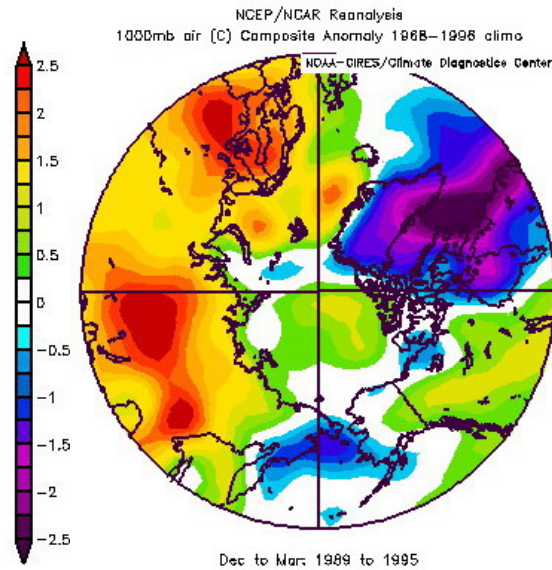


# Three Climate Patterns

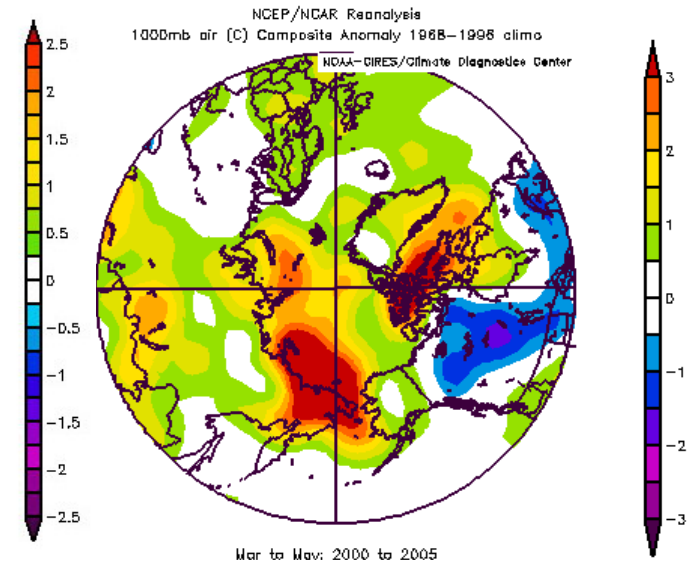
## Surface Air Temperature Anomalies



1977-1988 (PNA+)  
Pacific North American  
Related to PDO



1989-1995 (AO+)  
Arctic Oscillation

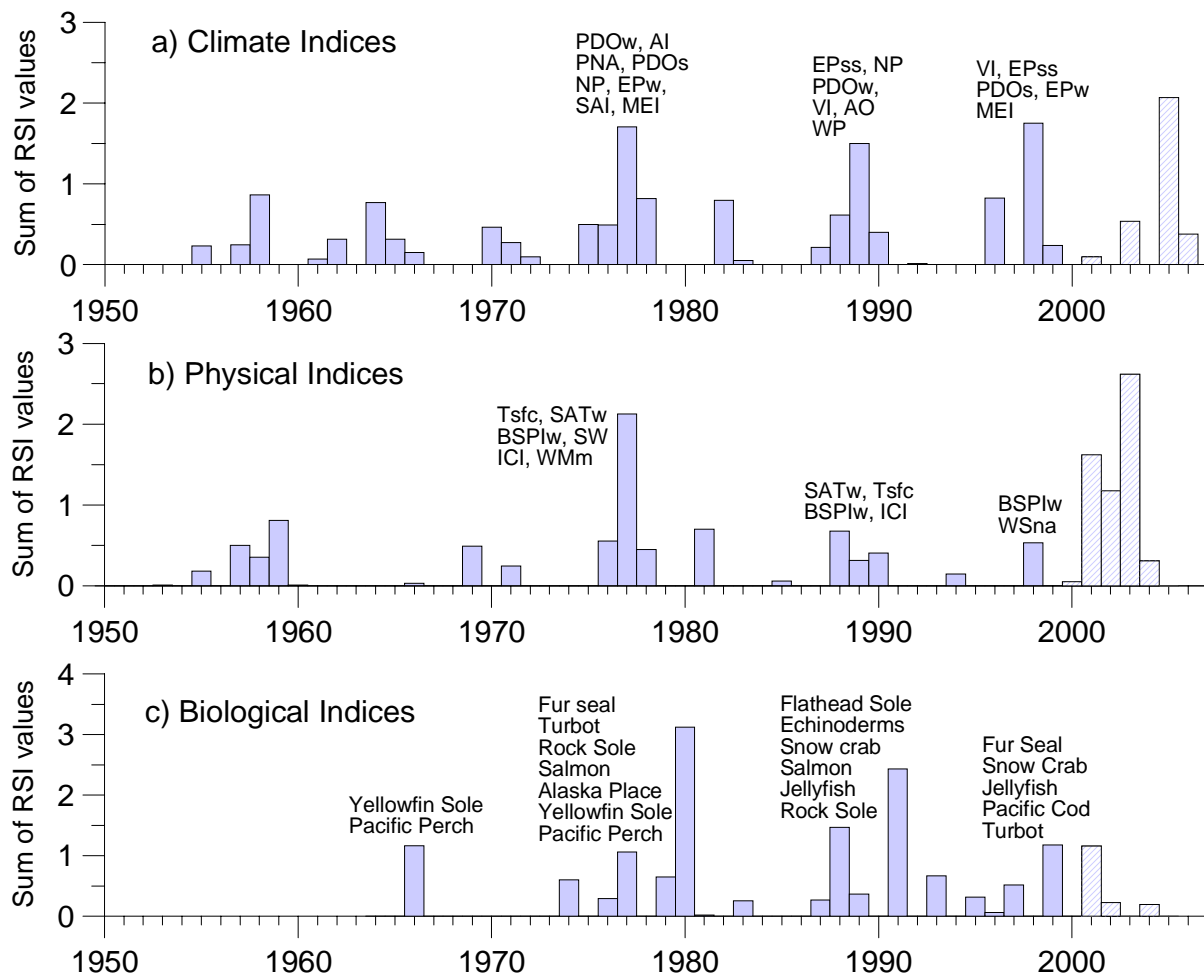


2000-2005 (Arctic Warm)

Overland and Wang (2005)



# Multivariate look at indicators



# Conclusions

- Multiple Definition of Regimes
- Time series too short to determine underlying model: non-linear/deterministic from random/Gaussian (maybe not?)
- Understand the physical-biological links, especially biological lags and trends
- Climate looks Gaussian to first order (central limit theorem), but some weak linkages
- Current state uncertain, no strong historical signals