Empirical evidence for North Pacific ecosystem regime shifts revisited

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PICES 2012 POC Topic session: Challenges in understanding Northern Hemisphere ocean climate variability and change

outline

- Empirical evidence for North Pacific ecosystem regime shifts
  – Looking back
  – Updates for the NE and NW Pacific

- Some closing thoughts about nowcasts, predictability, and developing broad-scale ecosystem indicators

Pergamon

Progress in Oceanography 47 (2000) 103–145

Progress in Oceanography

www.elsevier.com/locate/pocean

Empirical evidence for North Pacific regime shifts in 1977 and 1989

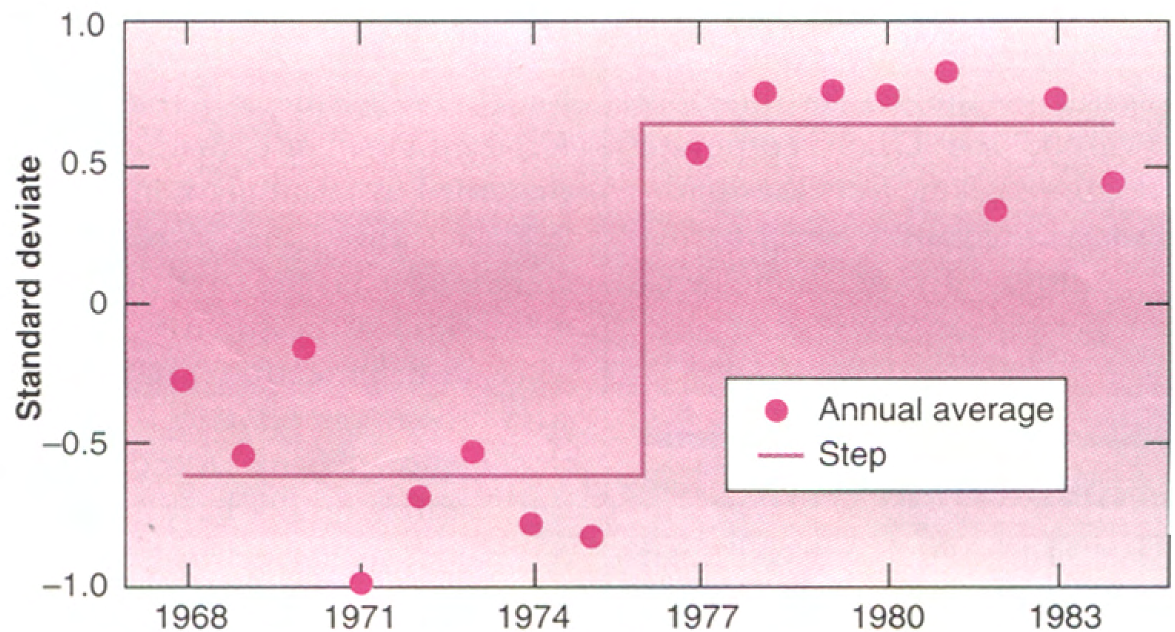
Steven R. Hare [a,*], Nathan J. Mantua [b]

- HM2000 aimed at a broad-scale assessment of North Pacific ecosystem and climate variations over the 1965-1997 period.
  - A blended analysis that included 69 biological time series (for groundfish recruitment, salmon landings, zooplankton abundance), and 31 physical indicators (local and large scale climate-related indices)

“1976 Step in Pacific Climate: 40 environmental changes …”

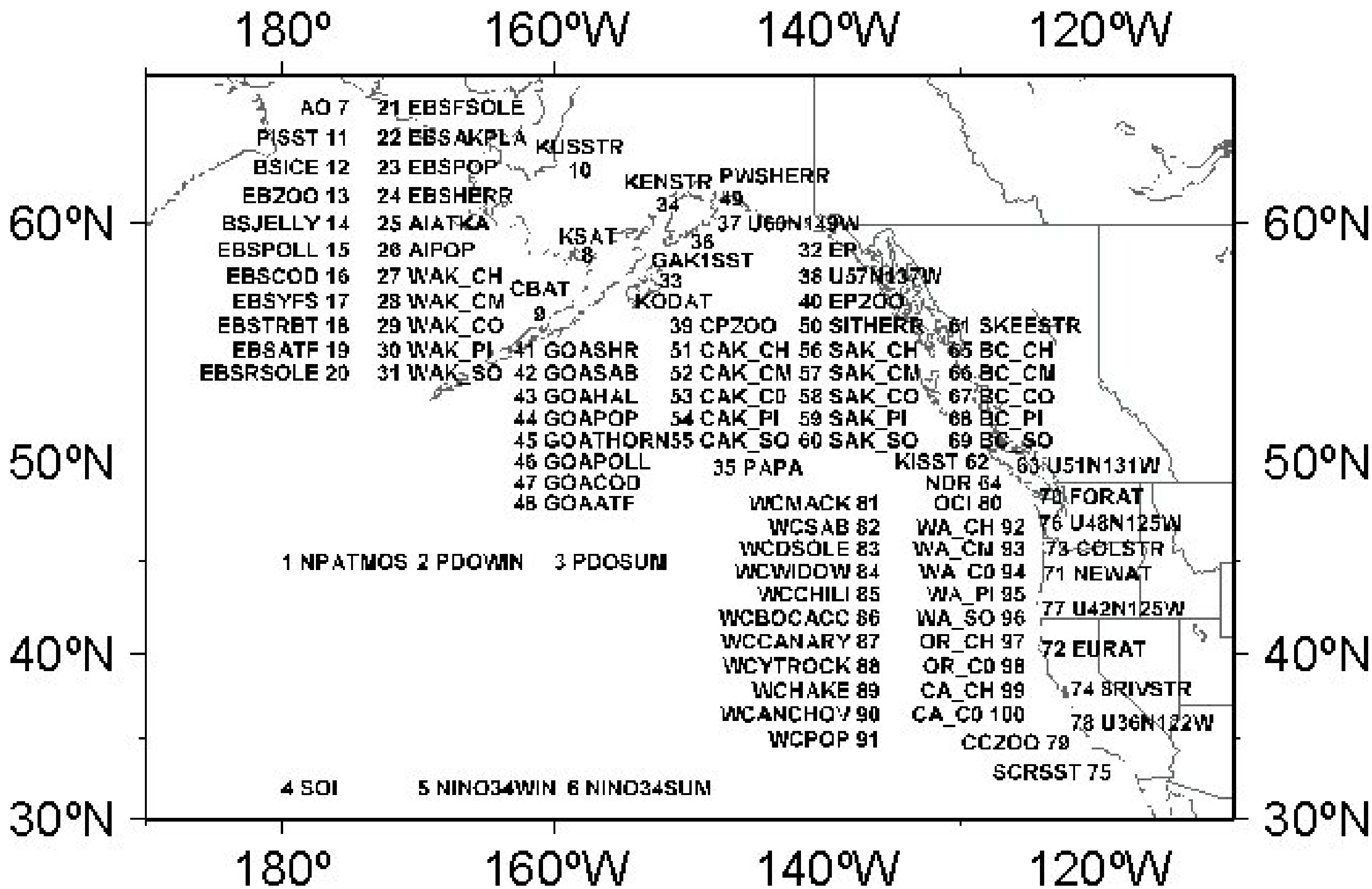
(Ebbesmeyer et al. 1991, PACLIM proceedings)

Large and local scale climate indices, Canadian geese, NW salmon, dungeness crab, Pacific sea birds numbers, Washington Oyster growth … all folded into a 40-member composite variable.
(see Kerr, *Science* Vol 255, 1992)



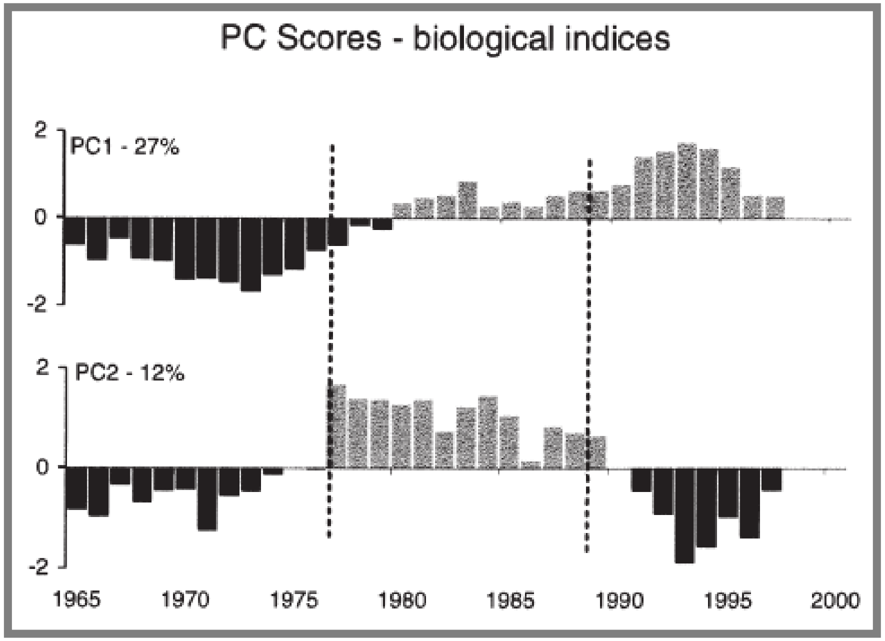
Something sudden in the Pacific. *A composite of 40 environmental variables jumped to a new state after 1976.*

Treat fishery and fishery-independent survey data like climate data; use PCA to identify coherent patterns in marine ecosystems

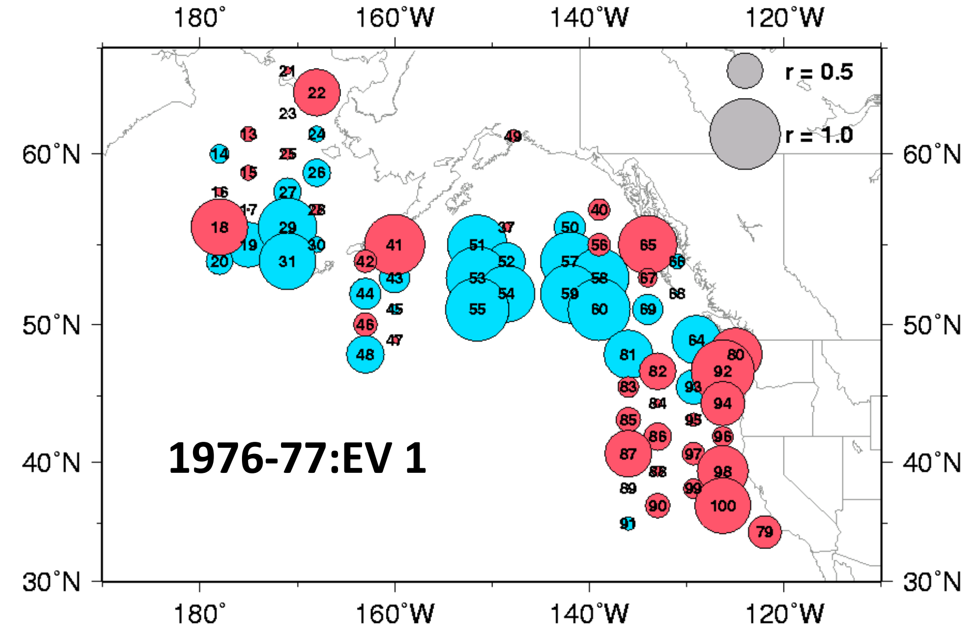


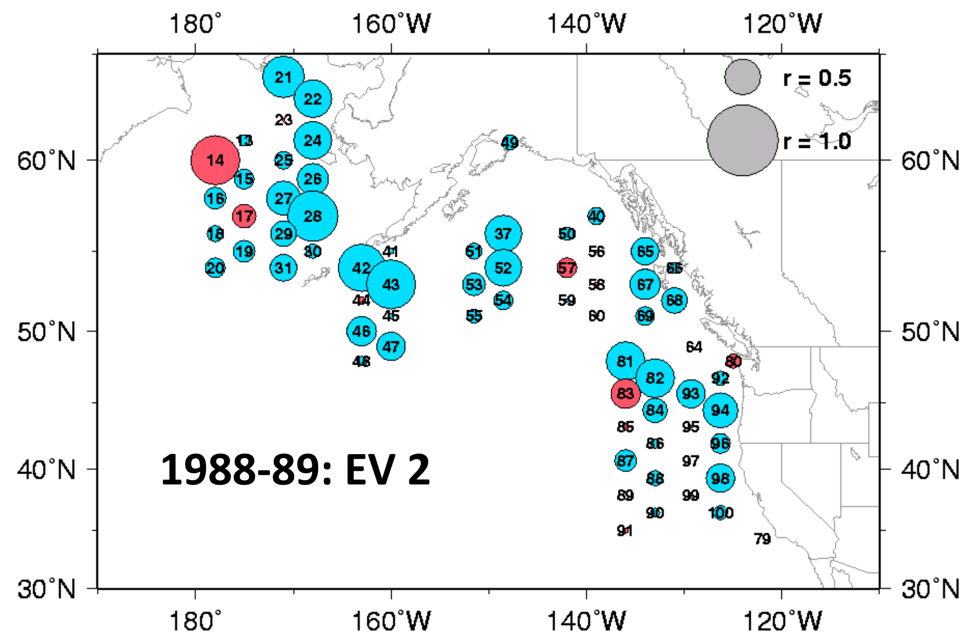
Hare and Mantua, Progress in Oceanogr. 2000

Main results from HM2000



Ecosystem indicators appear to exhibit more "regime-like" behavior than climate indicators





Hare and Mantua, Progress in Oceanogr. 2000

conclusions, speculation, and a question from HM2000

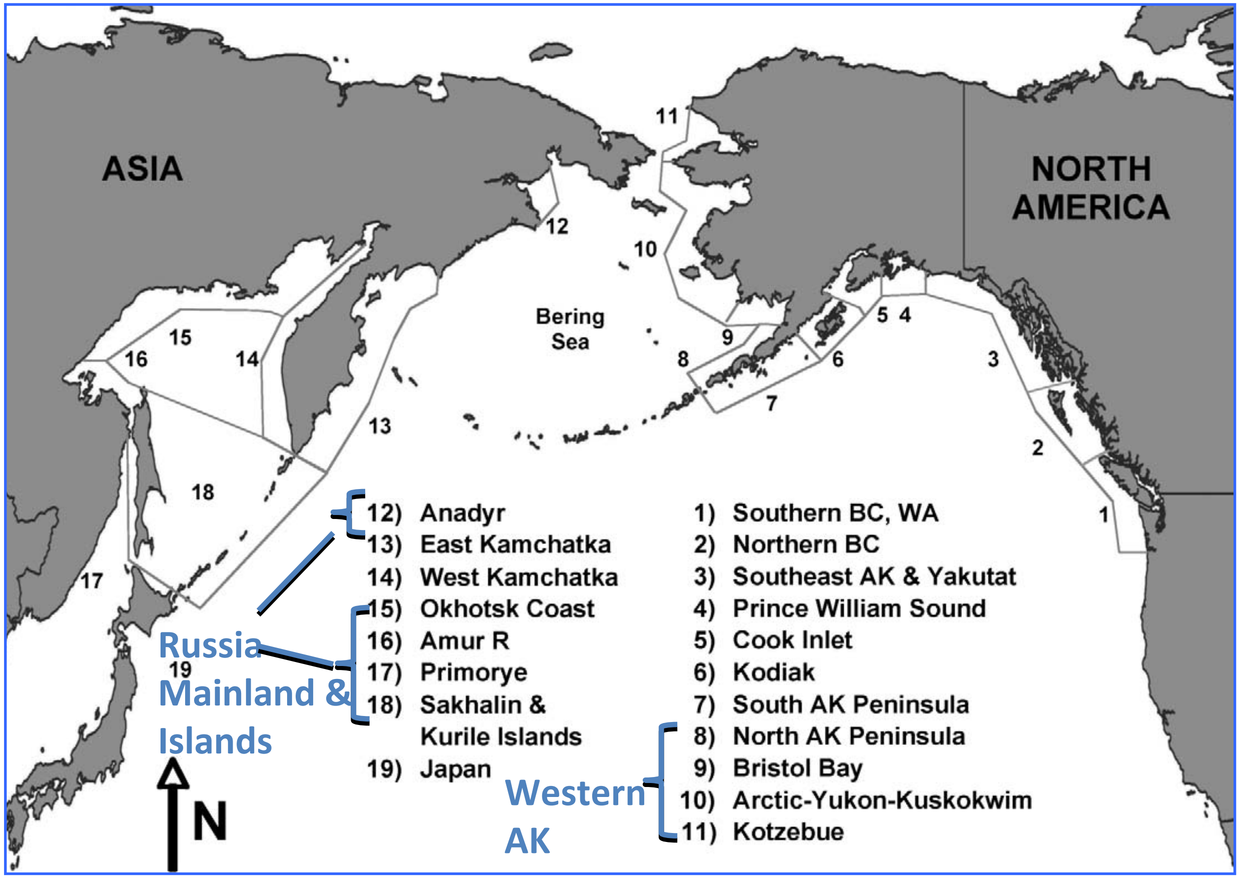
- Evidence for ecosystem shifts in 1977 and 1989
  - Climate is "noisy", not necessarily regime-like in its low-frequency variability
- Large-marine ecosystems filter environmental forcing and respond non-linearly with regime shifts
  - Ecosystem monitoring may allow for an earlier identification of regime shifts than climate monitoring alone
- <u>And a question</u>: *Would the abrupt shift to La Niña in 1998 and associated change to cool phase PDO conditions in the North Pacific trigger another ecosystem shift?*

RESULTS FROM SOME NEW ANALYSES

Salmon Run-size Data

(from Ruggerone et al. 2010: Mar. and Coastal Fish.)

- Wild and hatchery pink, chum, and sockeye salmon catch+escapement estimates from 12 regions in North America and Asia for 1952-2005
- Lagged to year of ocean entry and log-normalized



Japanese Fishery Data

- http://abchan.job.affrc.go.jp/digests23/
- Translations provided by Minobe, Ito, and Tadokoro
- Recruitment time series for 17 stocks of 11 species, and Oyashio zooplankton and Russian Saffron cod recruitment time series from 1972-2009

Resource evaluation system by groups FY 2011 fish species (84 fish species based group 52)

S) Note machi, East China Sea bottom fish species are treated as a group of 4 and 6 each system

Basic rules for the calculation of fiscal 2011 ABC

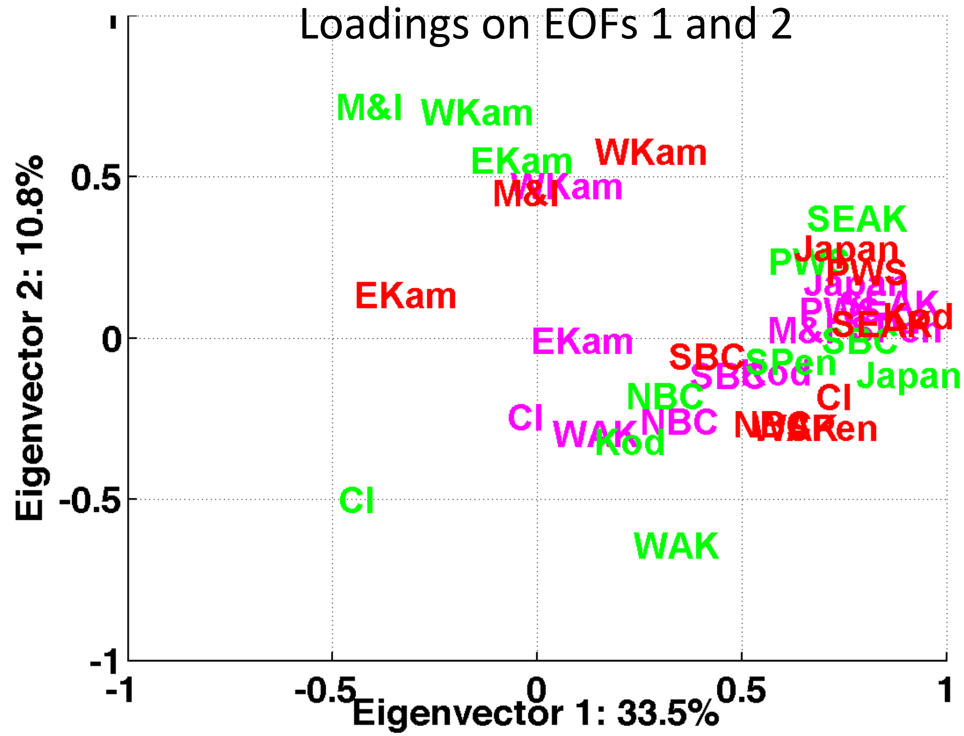
Trends Increase unchanged: Decrease

divided into species and non-target species TAC, the order of fish species are listed in order of each classification.

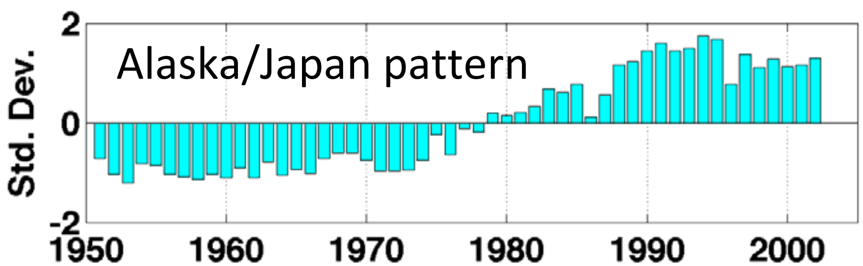
Fish species	System group	Digest October 28, 31, 2011 Public	Detailed version	Trend	Level
Pilchard	Pacific Ocean system group	○	5.74MB		Low order
	Tsushima Current system group	○	1.85MB		Low order
Jack mackerel	Pacific Ocean system group	○	2.08MB		Medium
	Tsushima Current system group	○	1.66MB		Medium
Chub mackerel	Pacific Ocean system group	○	1.74MB		Low order
	Tsushima Current system group	○	1.75MB		Medium
Southern mackerel	Pacific Ocean system group	○	1.59MB		Higher order
	East China Sea based group	○	1.66MB		Medium
Saury	Northwest Pacific Ocean system group	○	2.81KB		Medium

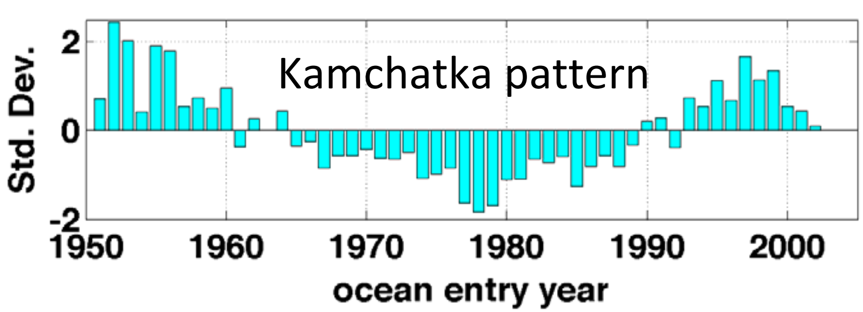
PCA of Pacific Rim sockeye, pink, and chum salmon run-sizes, 1952-2005

- Leading pattern has covarying abundance for Alaska and Japanese stocks (wild and hatchery-reared)
- 2nd pattern has covariation among Kamchatka and Russian mainland and island stocks



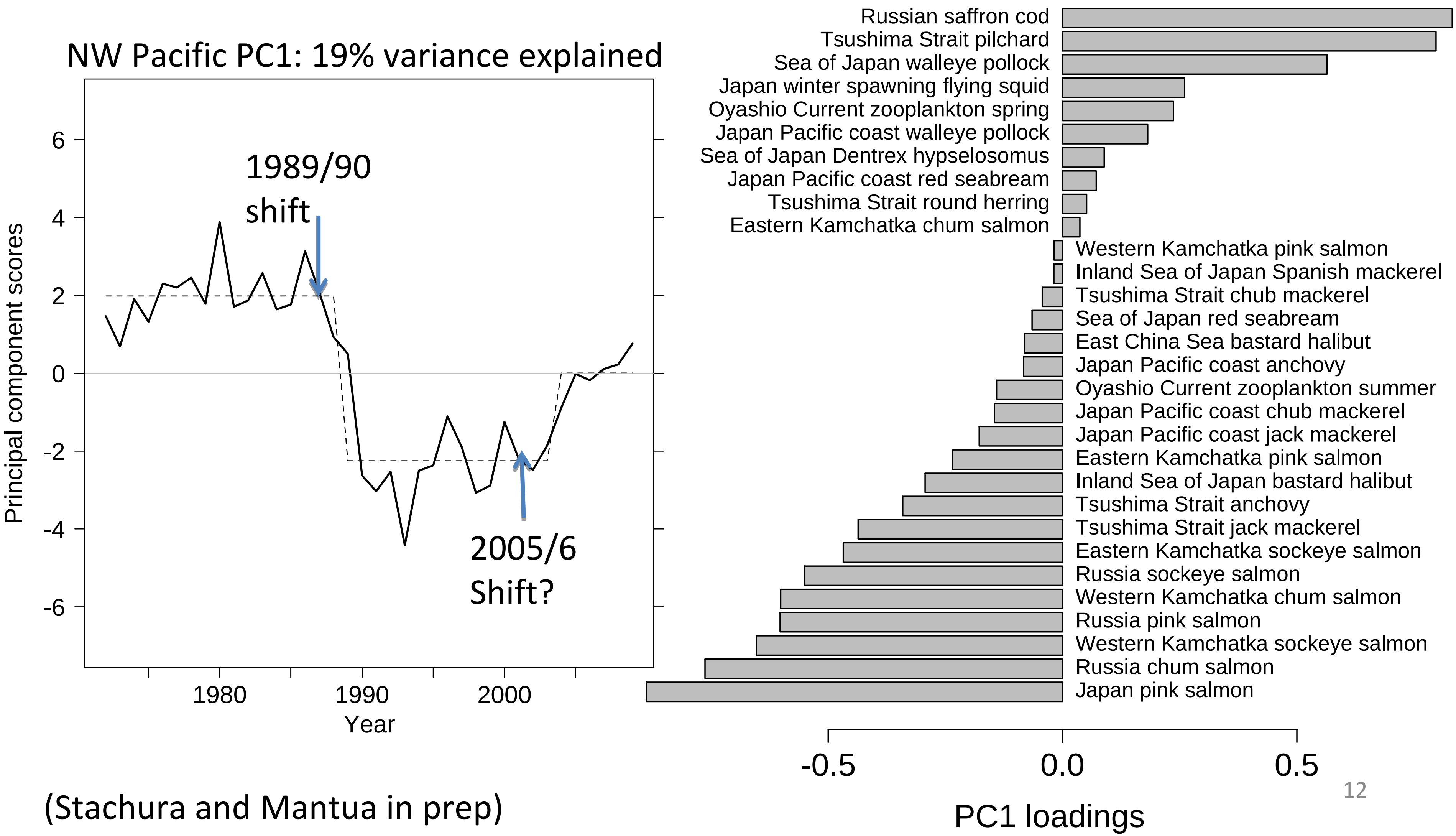
- The Alaska/Japan pattern has low abundance in the 50s-70s, especially high abundance in 90s-2000s
- Kamchatka pattern has peak abundance in 50s and 90s, lowest values in the 70s





(Stachura, Scheuerell and Mantua in prep)

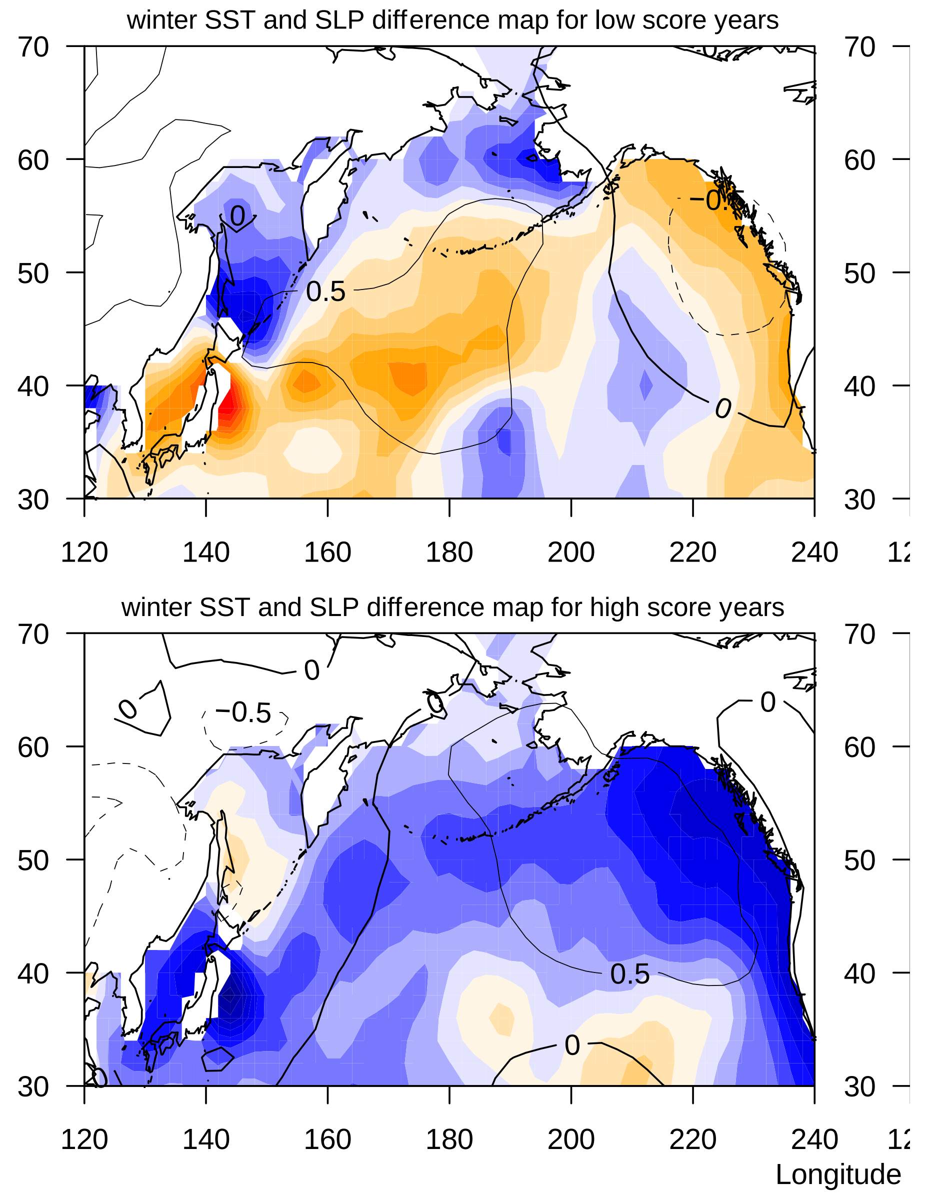
Combined PCA of Asian salmon run-sizes and Japanese recruitment data, 1972-2009

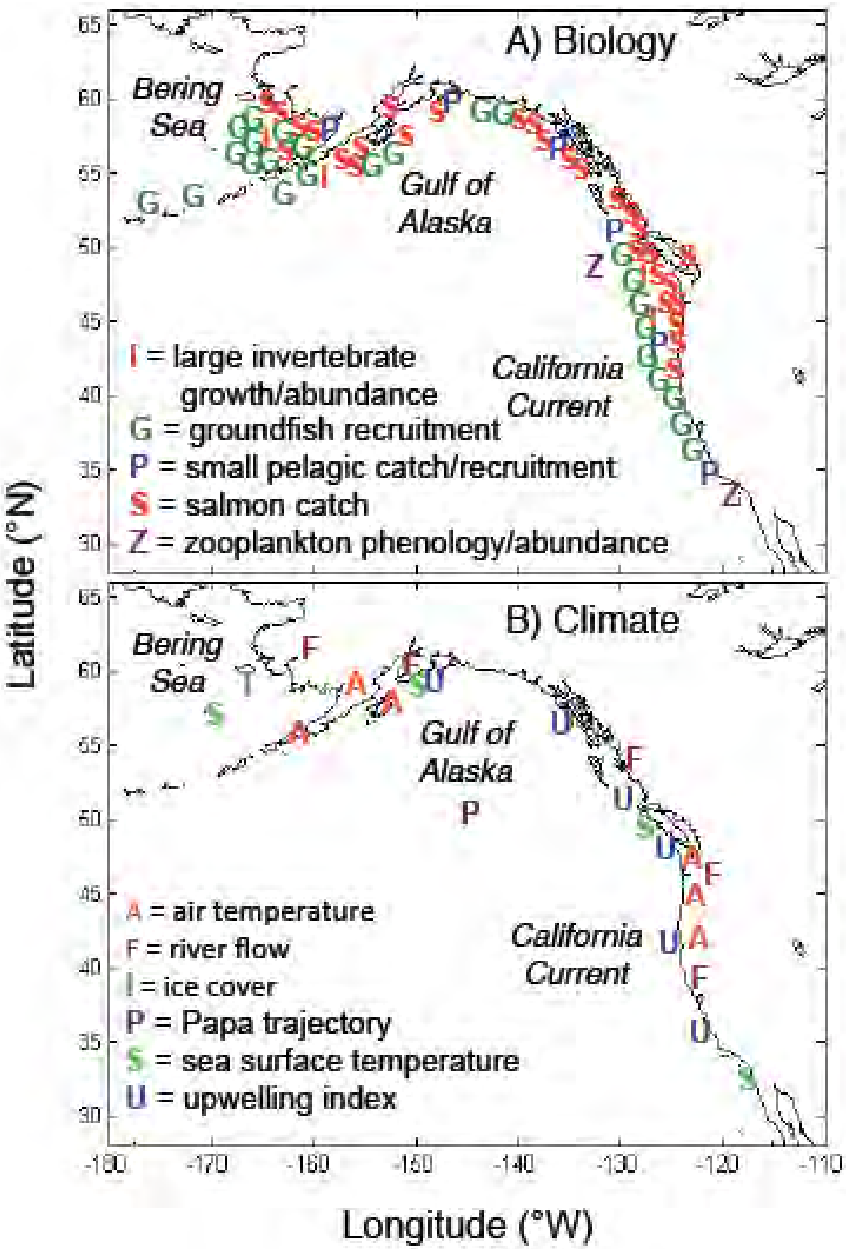


(Stachura and Mantua in prep)

SST and SLP anomalies associated with NW Pacific pattern

- Low values of PC1 (1990-2005) associated with warmer than average SST around around Japan
- High values of PC1 (1972-89) associated with colder than average SST around Japan

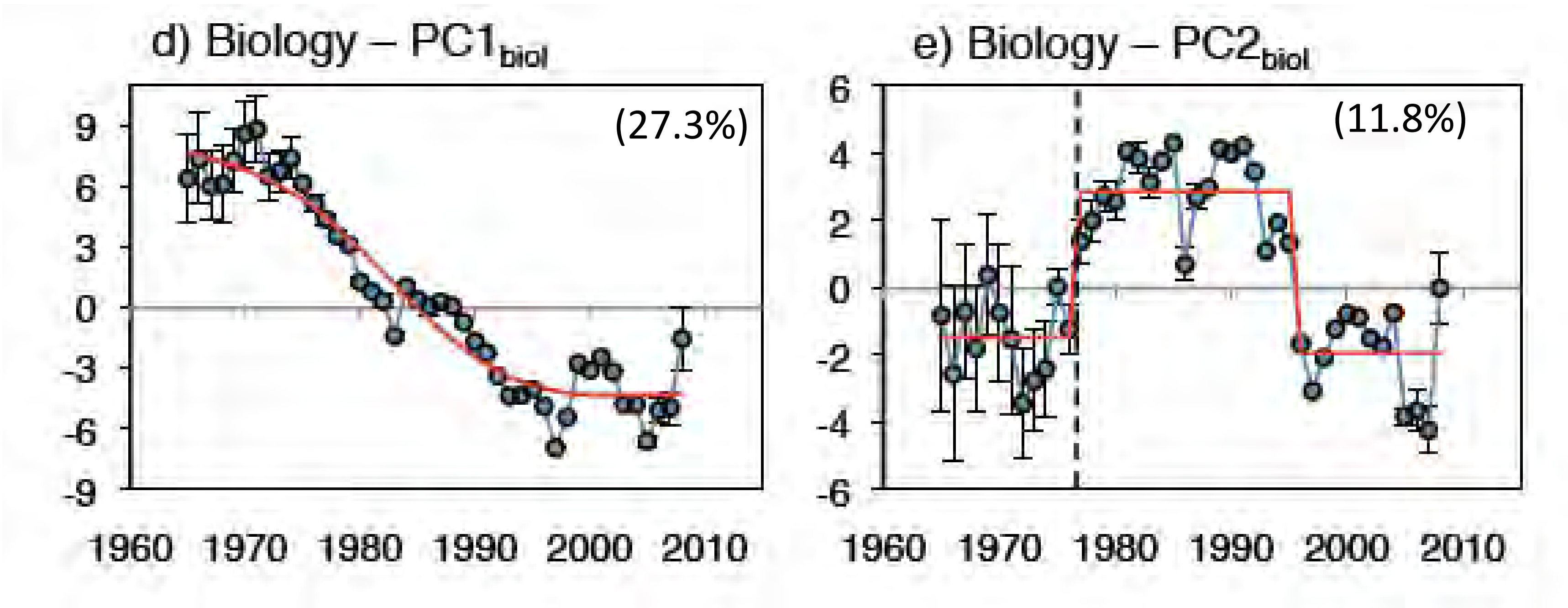




Litzow, Mueter, and Hobday (LMH2012) 2012 update of HM2000

- Updated 95 of the 100 indices and re-did the PCA
  - to 2008 for biology, 2011 for climate
- Address a number of questions, including:
  - Evidence for more ecosystem shifts since the late 1990s?
  - Gradual or abrupt ecological changes?

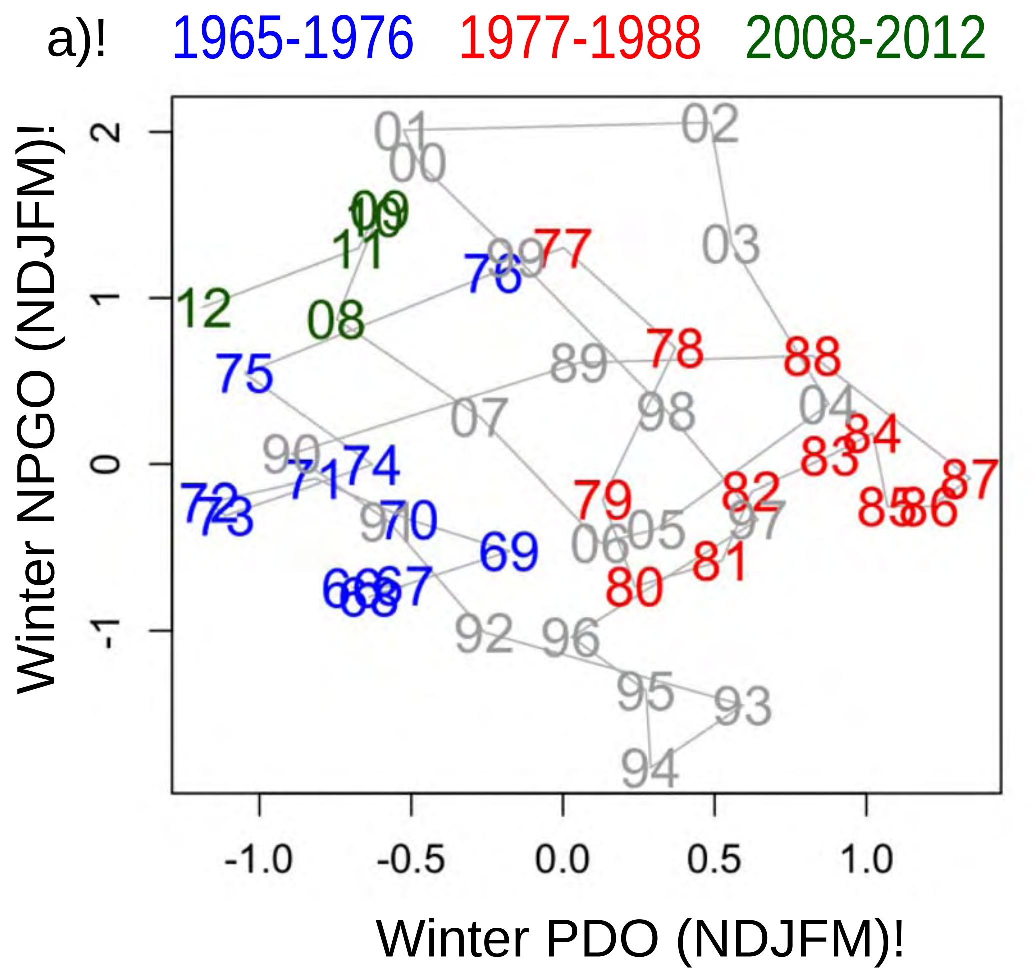
LMH2012 Biology only PCs 1 and 2



- PC1 captures "inverse production regimes" in west coast salmon, best fits a gradual change model
- PC2 similar to HM2000 with 77 and 89 shifts, best fits an abrupt change model
- They find no evidence for a sustained 1998 PDO-related shift
- Large changes in biology PC 1 and 2 phase space in 2008 – the first indication of a new ecosystem regime?

Low-frequency variability of the PDO and NPGO

- the 2008-2012 period marks a recent change in NPGO/PDO phase space
- How long might this era last?
  - "Red noise" models for PDO and NPGO suggests that predictability for North Pacific climate is limited to 1 or 2 years into the future



(figure from LMH2012)

Challenges in developing ecosystem indicators

- does it make sense to mix local and large-scale climate variables?
  - NPGO and PDO indices can be modeled as integrals of atmospheric forcing
  - Integrated ocean processes influence SST, mixed layer depth, upper ocean heat content, and large-scale current systems
  - Shorter term ocean processes include wind-driven Ekman transports and turbulent mixing

- Does it make sense to mix recruitment time series with abundance/biomass time series?
  - Recruitment events typically episodic, while abundance/biomass integrates recruitment over time

- For "filtered" ecosystem indicators, it seems that large-scale ocean indices and abundance/biomass time series should provide the best metrics for tracking ecosystem states

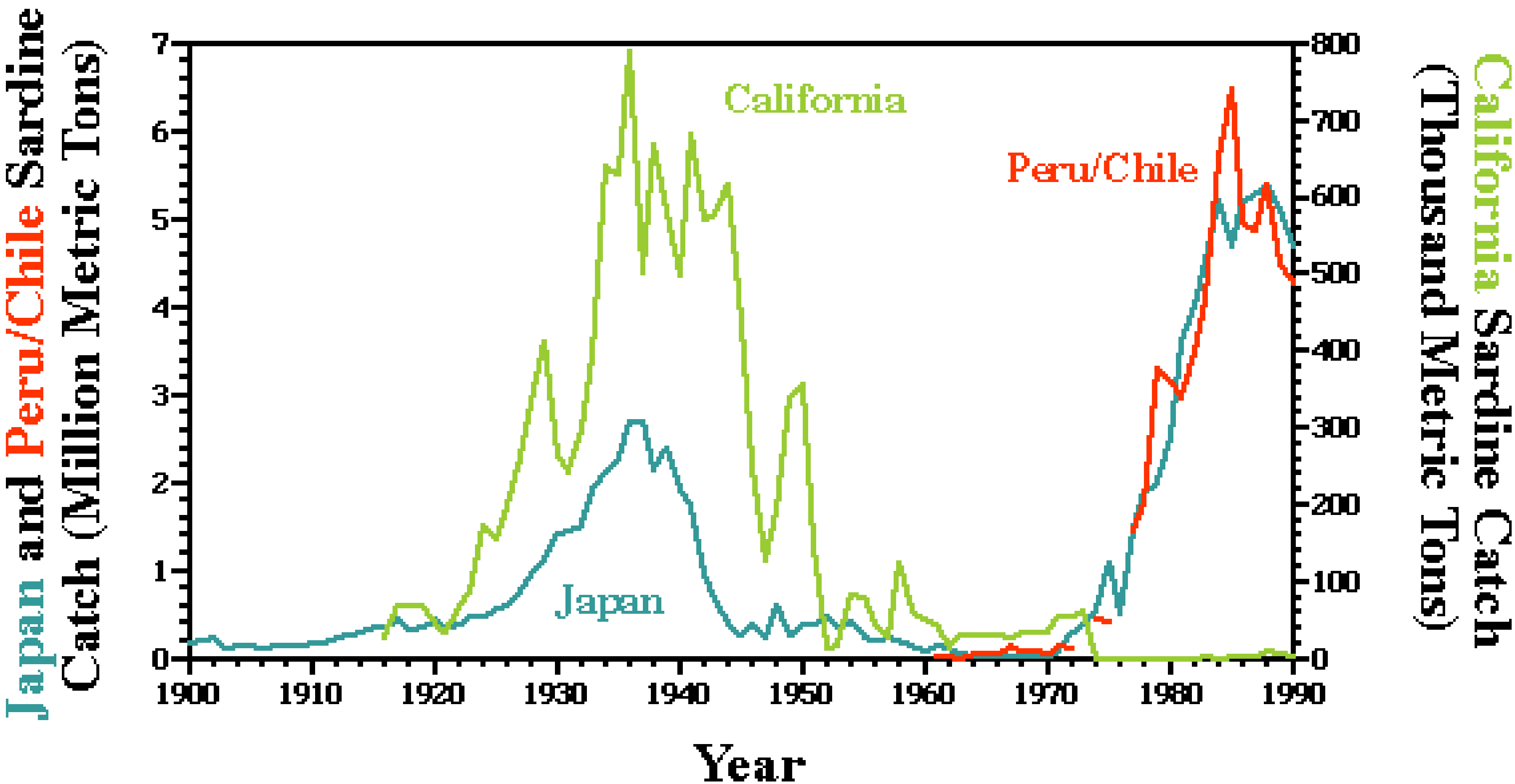
Challenges in detecting and predicting ecosystem shifts

- Ecosystem indicators are not typically available in real-time
  - Recruitment time series often estimated with a few years lag-time; abundance/biomass estimates lagged back to recruitment year also come with lags
- Climate variables are generally available in real-time
  - However, predictability is limited to 1 or 2 years if red-noise processes are primary drivers of low-frequency climate variations in the North Pacific

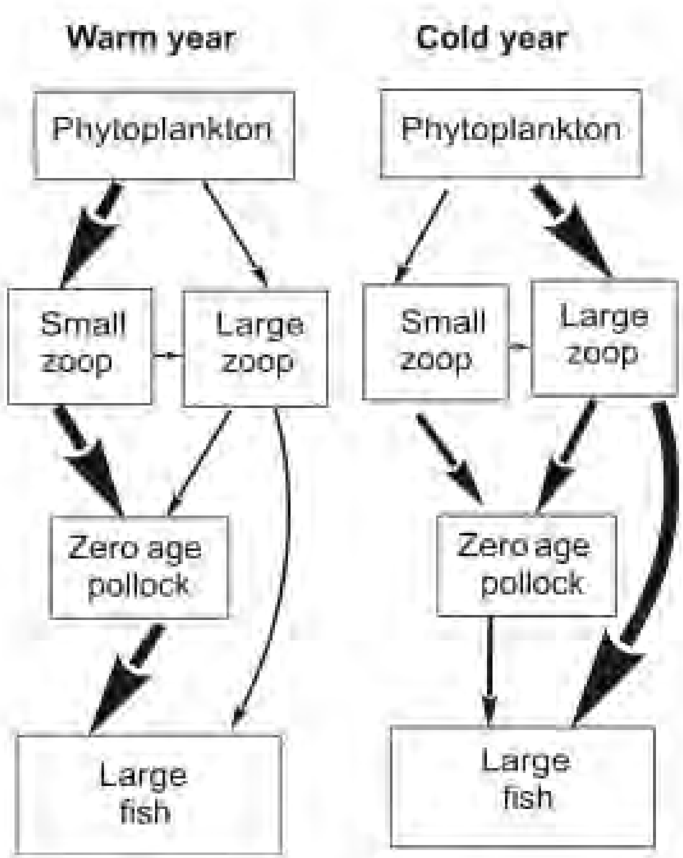
- One outcome: even if you detect an ecosystem shift, predictability will be highly limited if red-noise climate forcing is a key driver

Pacific Sardines: a history of synchronous 20th Century boom and bust cycles

(Kawasaki 1983, Kawasaki and Omori 1988, Lluch-Belda et al. 1989)



Bottom-up control seems to be a key factor in these large-scale and regional-scale patterns of climate impacts on marine ecosystems



From Coyle et al. 2011: Fish. Oceanogr.

- In at least a few regions with adequate time series for zooplankton (E. Bering Sea, NE Pacific, California Current), see compelling evidence for changing energy flows in food-webs
  - Cold water typically favoring larger, more lipid rich taxa, which in turn favor shorter and more efficient food-webs

Fisheries/Ecosystem Considerations

- many management schemes promote specialization and a goal of “sustained yield” …
  - but expectations for long-term stability of a target fish stock appear to be at odds with nature … “red noise” in the ocean contributes to naturally occurring “shifting baselines” in marine ecosystems , sometimes gradual, sometimes abrupt, that can play out over a typical human lifetime
  - the table is set for ***fishery*** collapses -- *fish stock collapse + economic collapse + community disruptions*

A few key studies that advanced this line of research

- Rudnick and Davis (2003): “red noise and regime shifts”
  - need to be careful when combining multiple auto-correlated time series
- Bond et al. (2003): Victoria pattern prominence in the 1990-2002 period
- Di Lorenzo et al. (2008): the NPGO and its impacts
  - 2^{nd} EOF of NE Pacific sea level captures another prominent low-frequency mode of ocean variability linked to marine ecosystems
- Newman et al (2003) and Newman (2007)
  - the PDO can be reconstructed from 3 different red noise processes (none has a preferred period of oscillation), predictability for these dynamics is limited to 1 or 2 years