# PHASE RELATIONSHIPS AND CONTROLS OF THE UPWELLING-DOMINATED CENTRAL CALIFORNIA CURRENT ECOSYSTEM


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# Conceptual Framework

## Ecosystem Controls: Bottom-Up, Top-Down or Something Else?

- Q1: Is the central CCS ecosystem (MB to Bodega Bay, CA) controlled from the "bottom", i.e., by climate variability and climate change?
  - Hypotheses/Predictions:
    - Positive correlations between climate indices (e.g., NOI, UI) and trophic level indicators…
    - In phase (or lagged) relationships between climate indices and trophic level indicators…
    - Positive correlations between trophic level indicators, primary to secondary, etc.
      - Consideration: CAUSAL OR CO-VARIANCE?

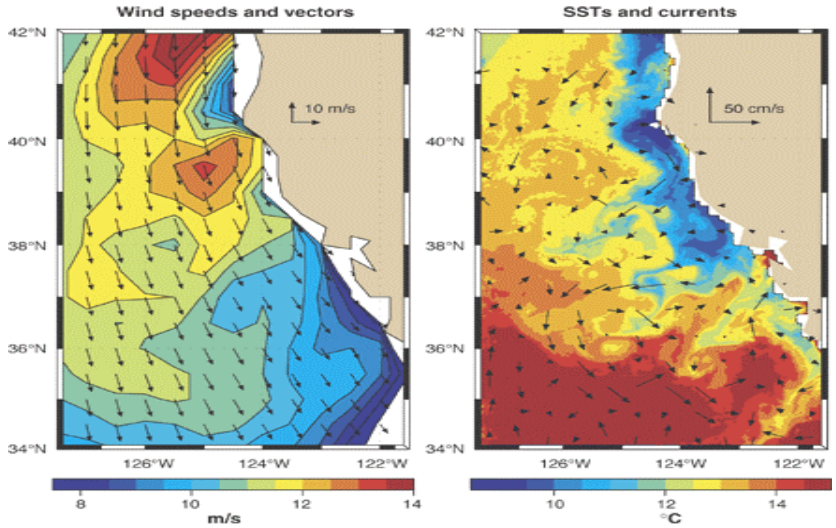
# Conceptual Framework

- Q2: Is the ecosystem controlled from the "top", i.e., by predators?
  - Hypotheses:
    - No correlations between climate indices and trophic level indicators…
    - Negative correlations between trophic level indicators…
    - Out of phase (no evidence of "phase-locking") relationships between climate indices and trophic-level indicators…

# Conceptual Framework

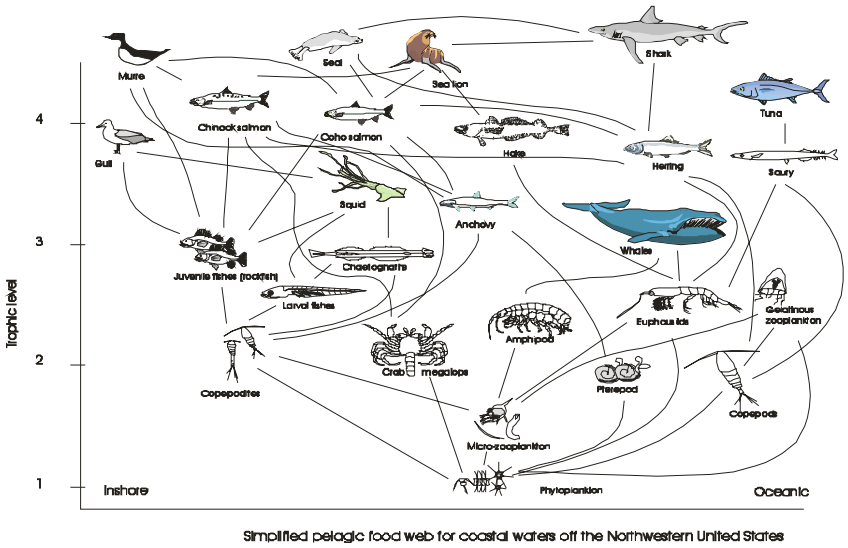
- Q3: Is the ecosystem controlled by something else?, for example a combination of bottom-up/top down?
  - Hypotheses:
    - Bottom up factors and top down factors interact; e.g., poor oceanographic conditions leads higher levels of predation
      - Prediction for both: change points evident; shifts from positive to negative correlations and visa versa
      - Intermittent in phase (and/or /lagged) relationships between climate indices and trophic-level indicators…
        - » "PREDATOR LIMITATION HYPOTHESIS"

# Overview of the System

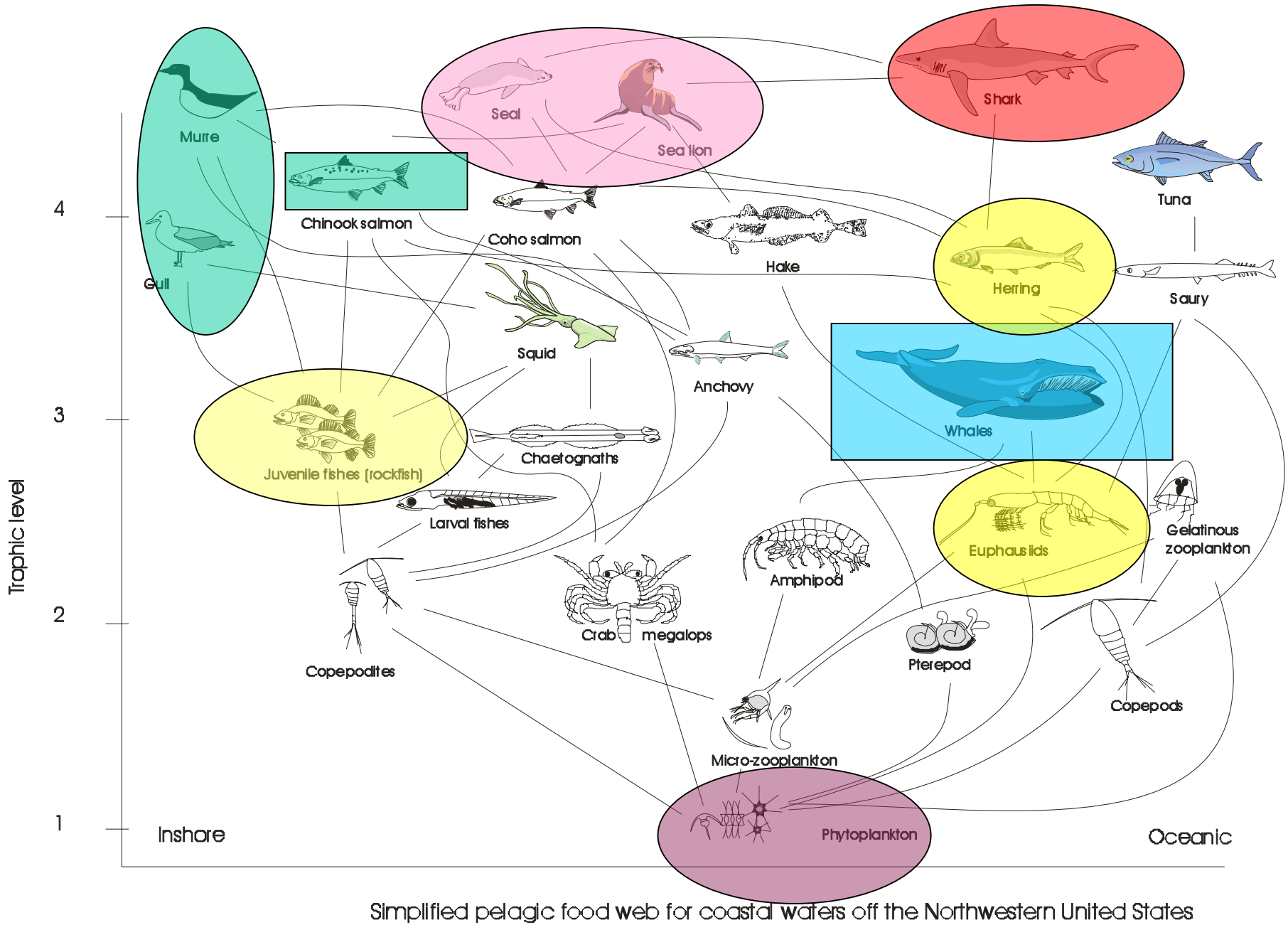



California Current System

(a) upwelling-dominated,
(b) mediated by basin-scale factors (circulation transport)

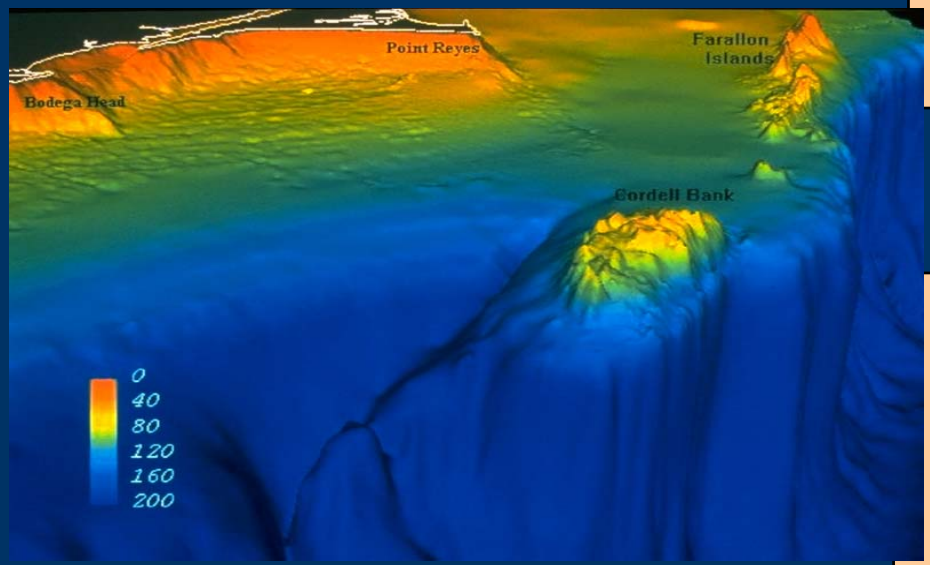



(c)“wasp-waist” trophic structure




Simplified pelagic food web for coastal waters off the Northwestern United States

# Time Series – Climate Indices and Physical Measurements




## Climate Indices

(a) SOI, **(b) NOI**, (c) ALPI,
**(d) UI @ 36° & 39° N**

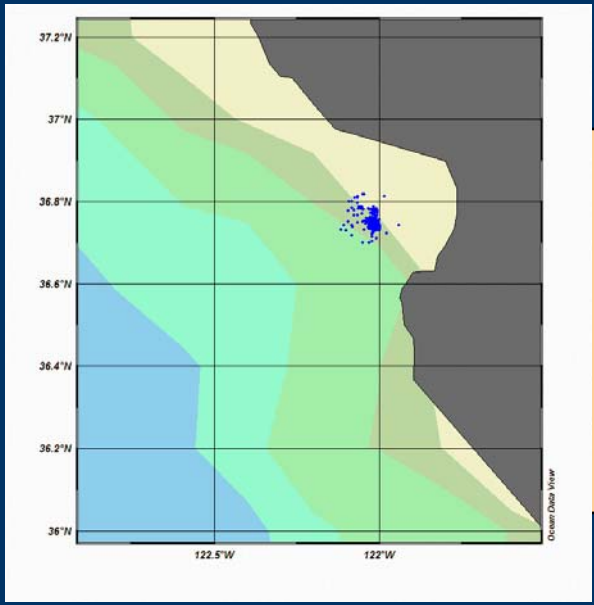
(Schwing et al. 2002, Bakun 1975)

## Temperature/Salinity

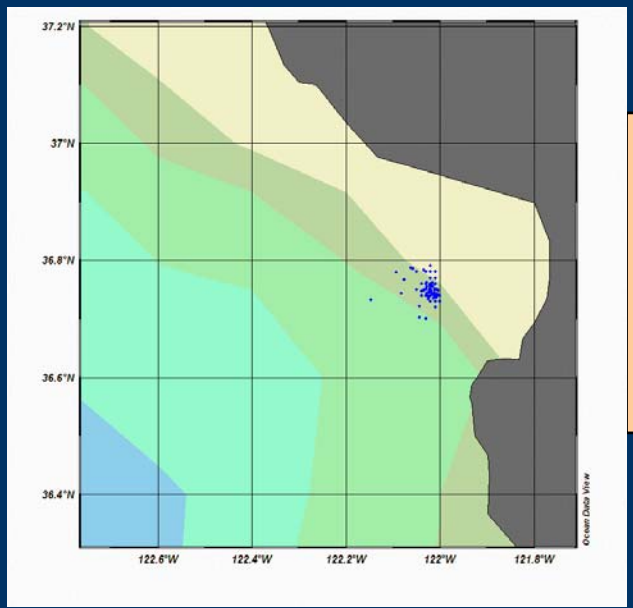
(a) CTD casts, Monterey Bay monthly samples, 1989-2003

**(b) Daily surface water samples, SE Farallon Island, 1971-2003**

# Time Series – NUTS and Lower Trophic Level (from Monterey Bay)



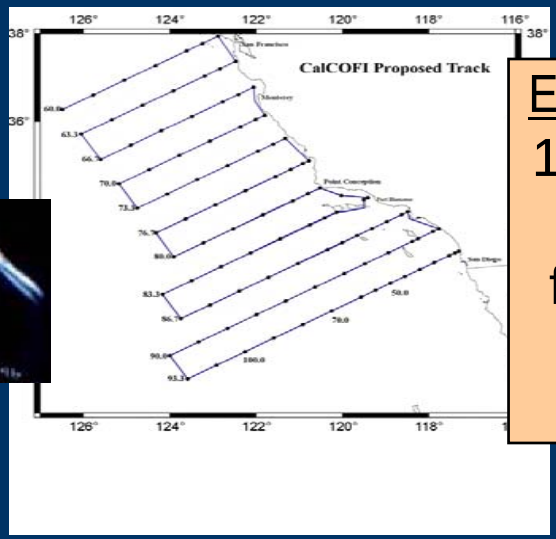

NUTS (nitrate, phosphate)
CTD bottle samples in the vicinity
Of MBARI's "M1" mooring;
monthly samples, 1989-2003



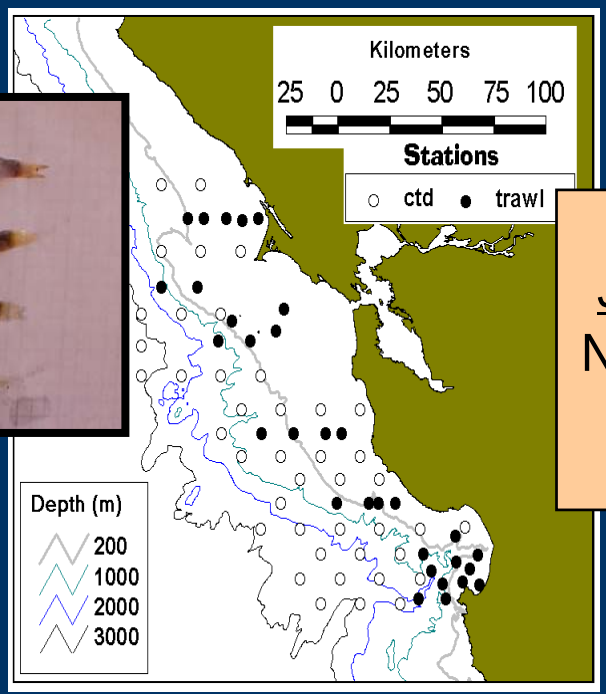

Chlorophyll/Phytoplankton –
Surface samples from CTD rosette;
1989-2001

prbo

# Time Series – Mid Trophic Level




Euphausiids (*T. spinifera; E. pacifica*)
1971-1984: CalCOFI bongo samples;
1985-2003: estimated abundance from southern CCS sampling, (after Abraham and Sydeman 2004)




Juvenile Rockfish (S*ebastes spp.*)
NMFS Santa Cruz midwater trawls, 1983-2002 (NMFS, unpublished)

prbo

# Time Series – “Upper Trophs”

(1) Pinnipeds: 4 spp; **Abundance**; counts of animals at haul-outs, rookeries; “population level” analyses.

(2) Humpback Whale; **Abundance**; photogrammetry, 1991-2003; mark/recapture estimates.



(3) Marine Birds: 6 spp.; **Phenology** (timing of egg-laying) and **Productivity** (0-age class recruitment) at colonies; “sub-population” level analyses.

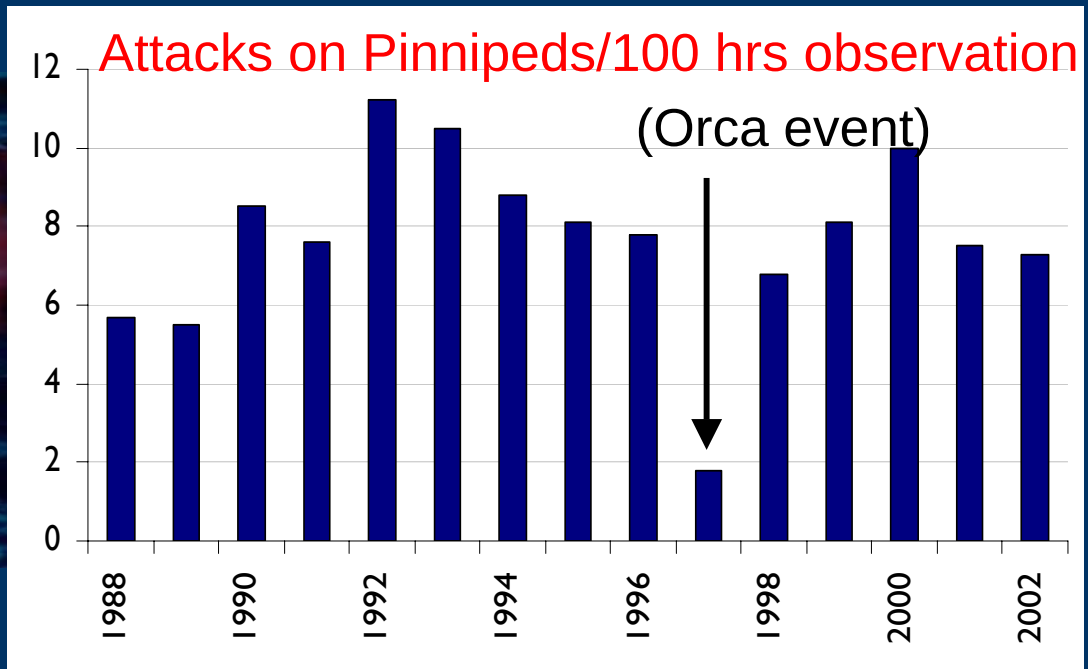
# Time Series Used in Study – Mid/Upper Level

San Francisco Bay Herring (Biomass)
CA DFG spawn/acoustic surveys;
1979-2003

Chinook Salmon (No. Fish)
PFMC, 1983-2002

prbo

# Apex: White Sharks



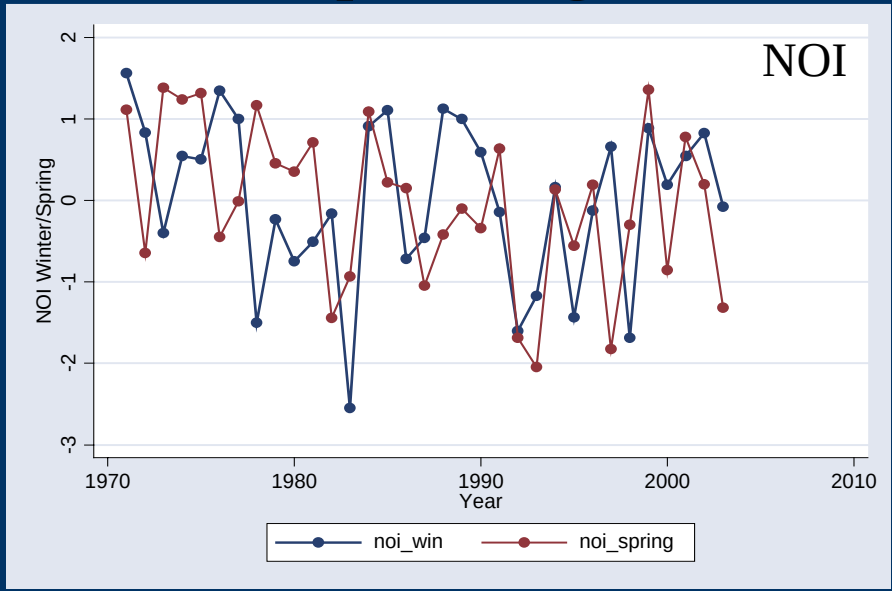
# Overview of Results

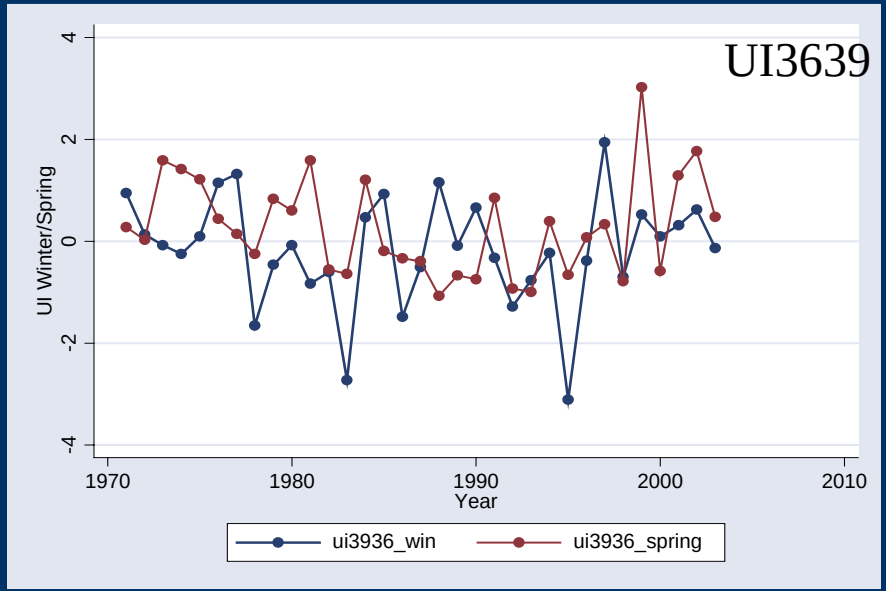
- (1) Describe some time series – synchronous multi-trophic level responses to environmental variability (e.g., El Nino/La Nina)

- (2) Data simplification – EOFs on top predators (seabirds and pinnipeds)

- (3) Time series analysis (focus on variance)
  - Seasonal decomposition using LOWESS (Ekman transport)
  - Wavelet Analysis – "what is the time/frequency power in the series"? (main advantage: allows for non-stationarity in statistics; "window" of observation can change in time)
  - Cross-wavelet power spectrum: asks "do time series show similar fluctuations in variance/power in time/frequency?"

# Time Series of Barometric Pressure, Upwelling, and SST Indices, 1971-2003



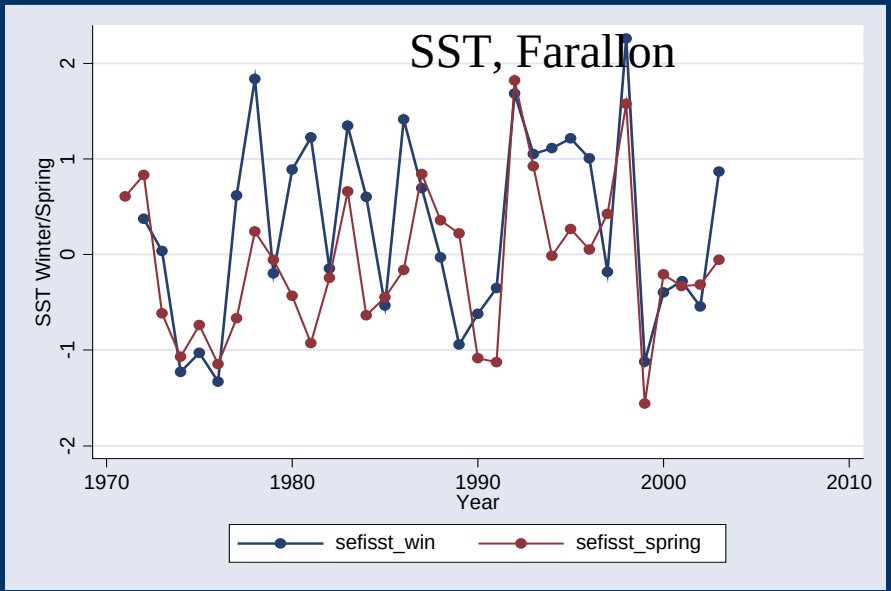



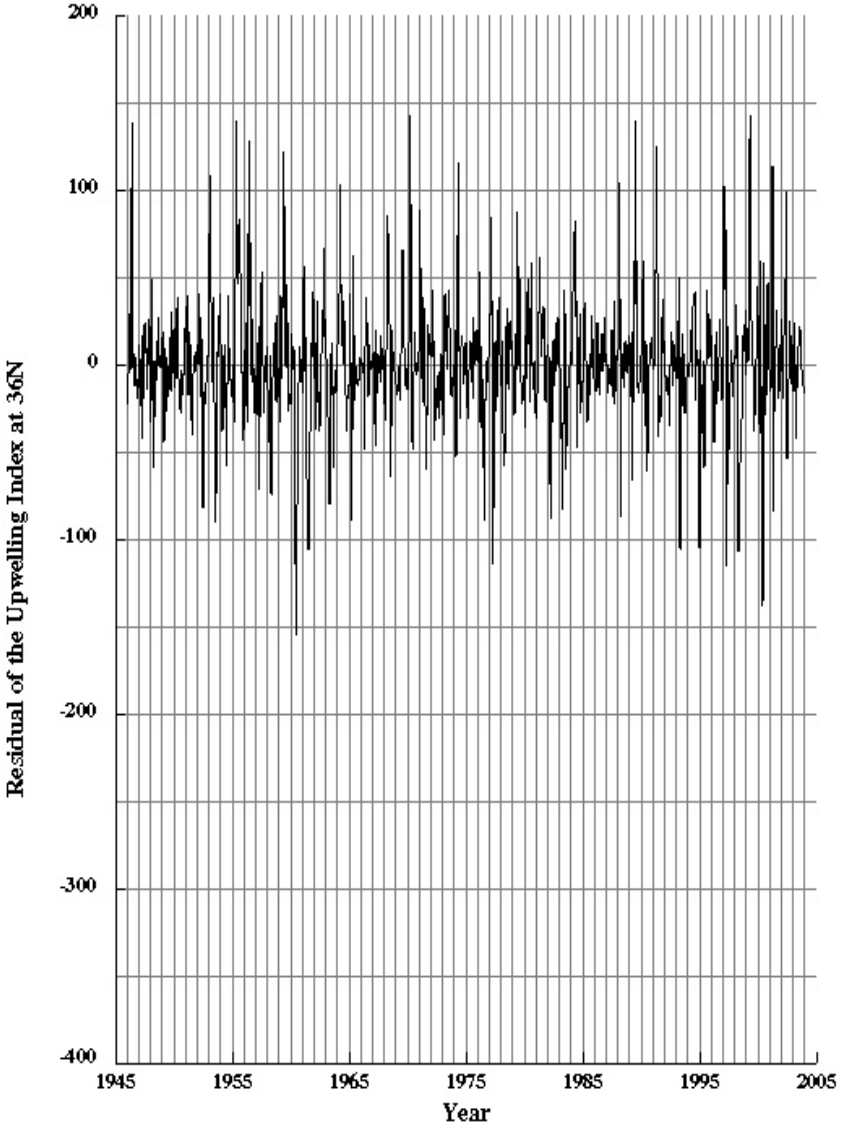

## NOI/UI are correlated

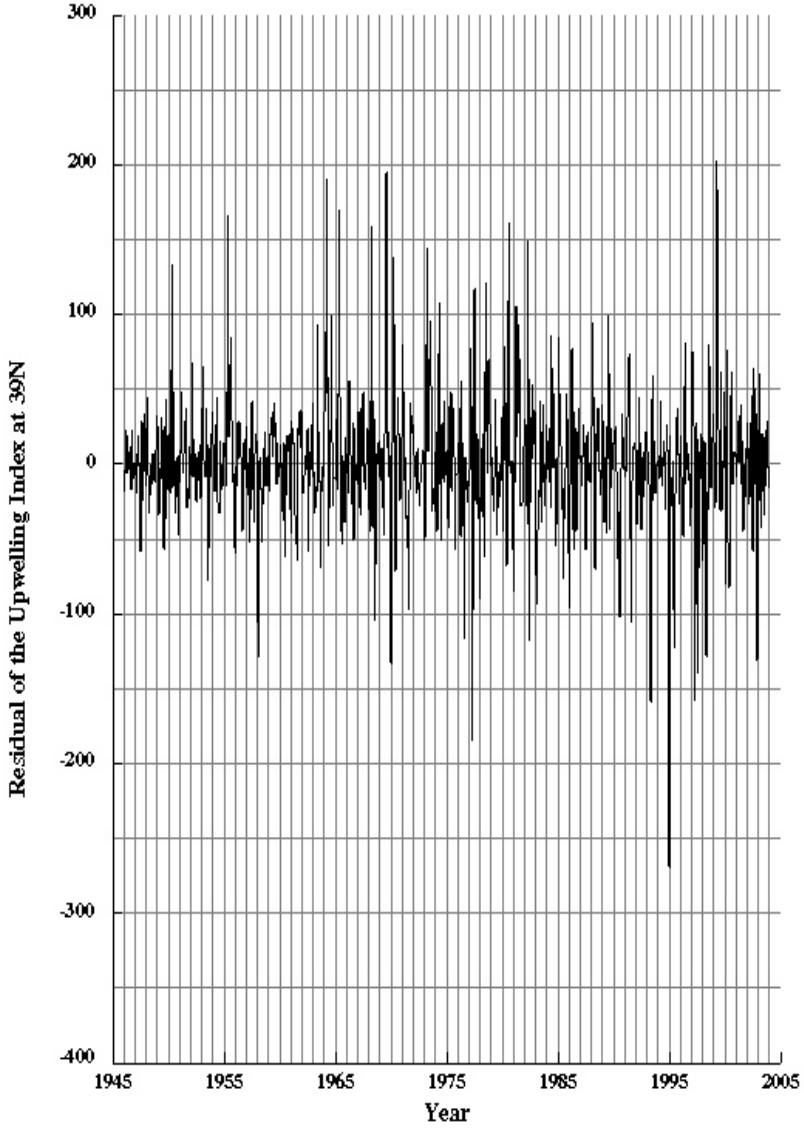
$r_{w,w}$ =.85, P<0.0001

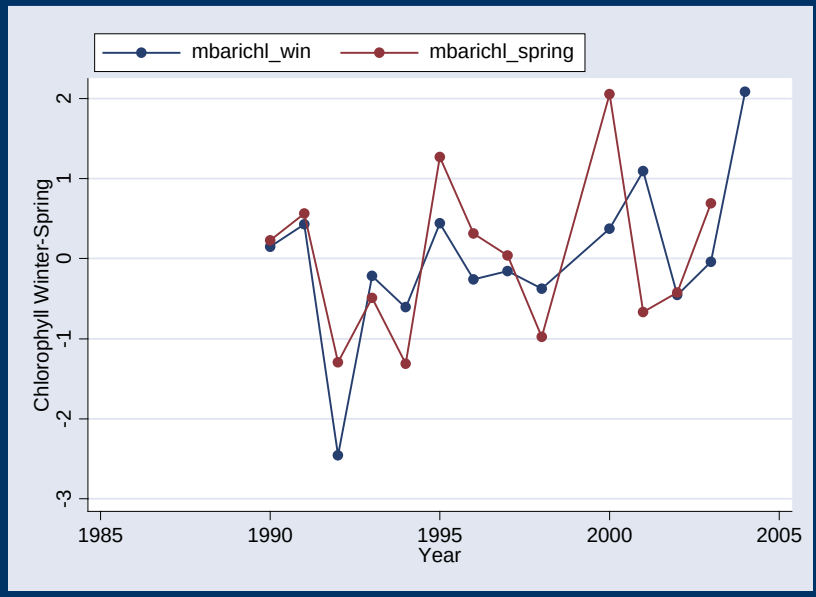
$_{w,s}$=.38, P=0.025

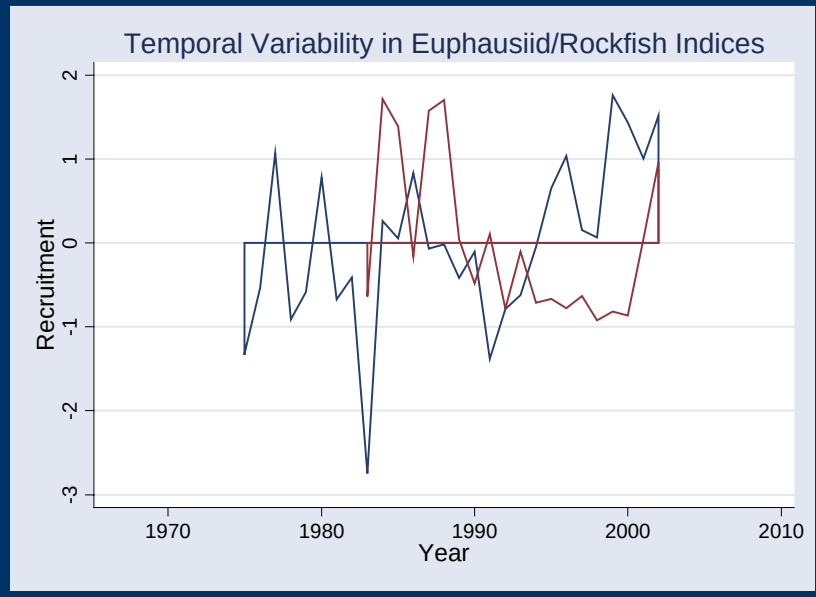
$_{s,s}$=.74, P<0.0001

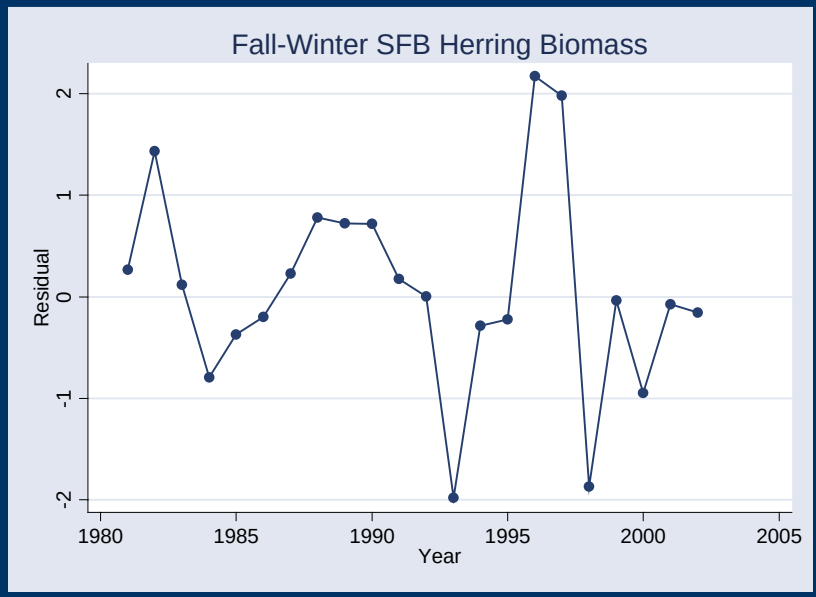



Residual of the Upwelling Index at 36N
200
100
0
-100
-200
-300
-400
1945
1955
1965
1975
1985
1995
2005
Year

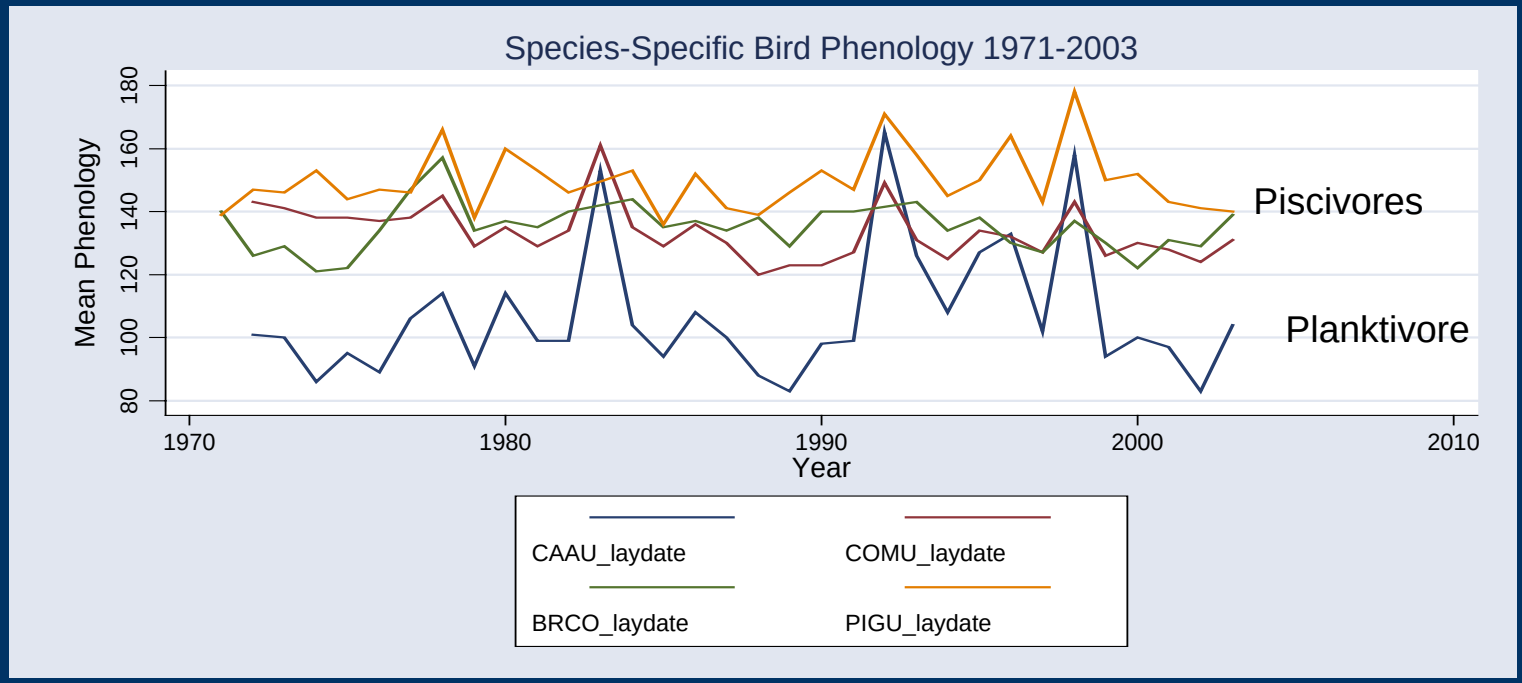

Residual of the Upwelling Index at 39N
300
200
100
0
-100
-200
-300
-400
1945
1955
1965
1975
1985
1995
2005
Year

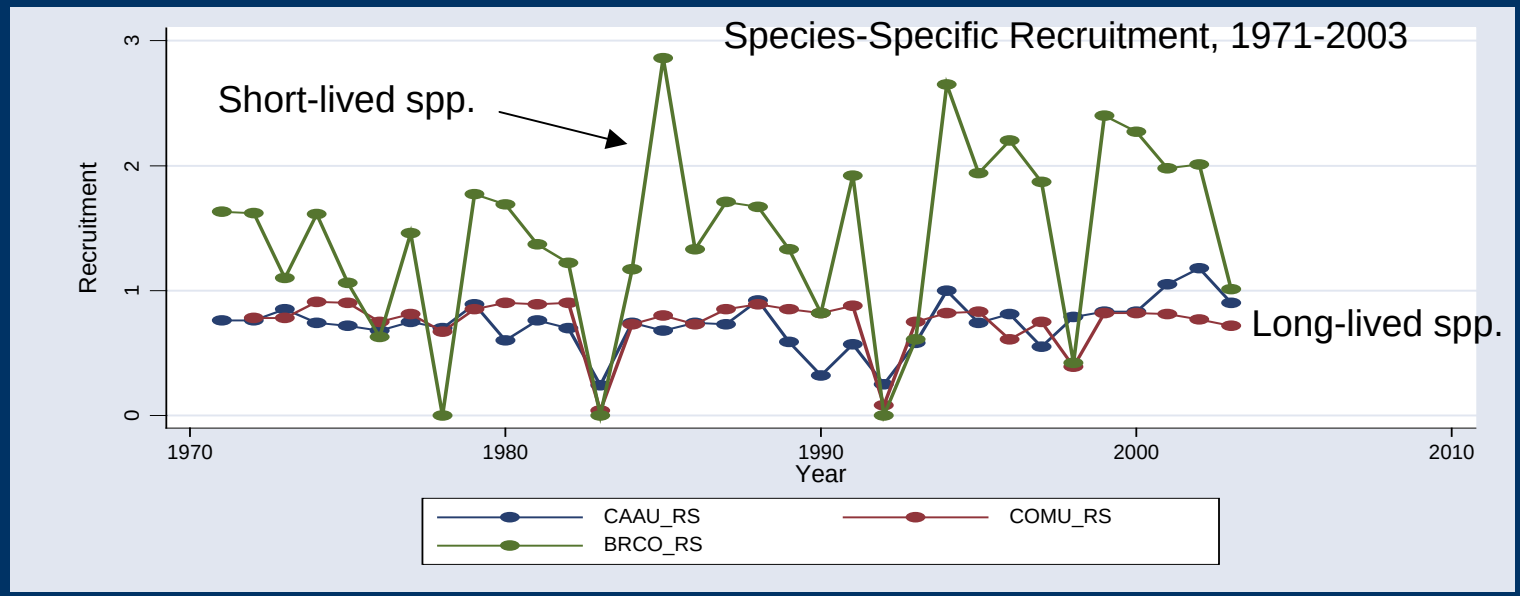

mbarichl_win
mbarichl_spring
Chlorophyll Winter-Spring
2
1
0
-1
-2
-3
1985
1990
1995
2000
2005
Year


Temporal Variability in Euphausiid/Rockfish Indices
Recruitment
2
1
0
-1
-2
-3
1970
1980
1990
2000
2010
Year


Fall-Winter SFB Herring Biomass
Residual
2
1
0
-1
-2
1980
1985
1990
1995
2000
2005
Year

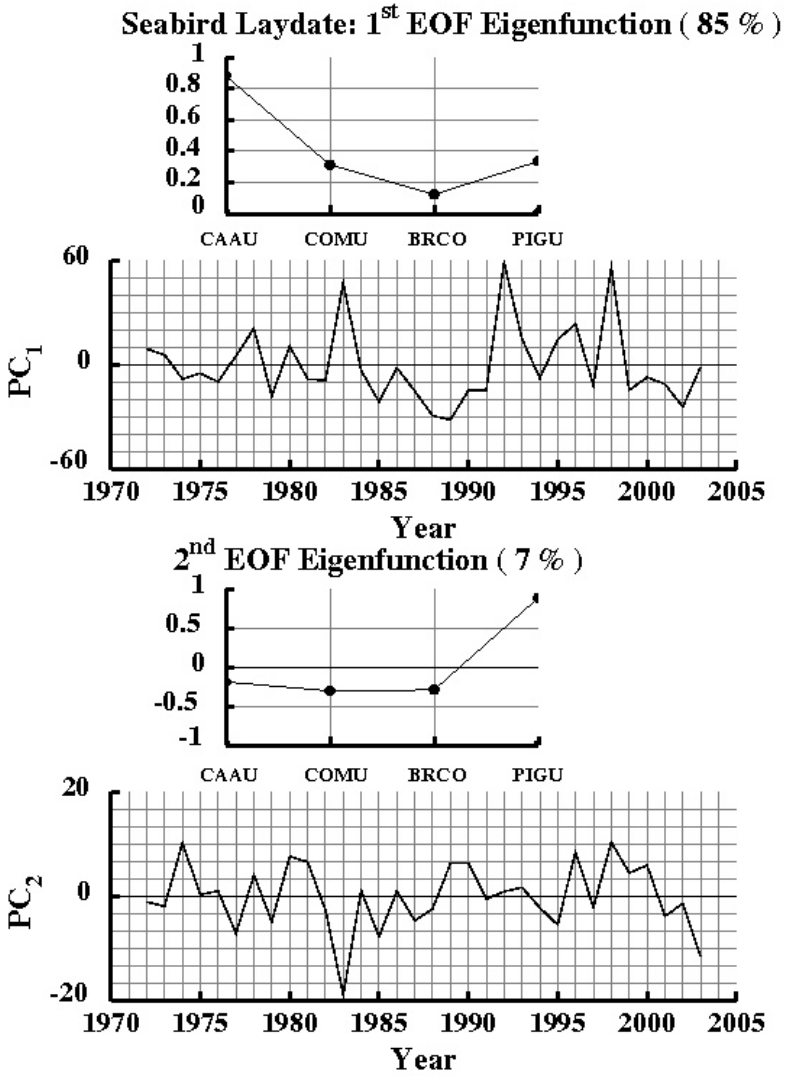

Humpback Abundance
7.2
7
6.8
6.6
6.4
1990
1995
2000
2005
Year

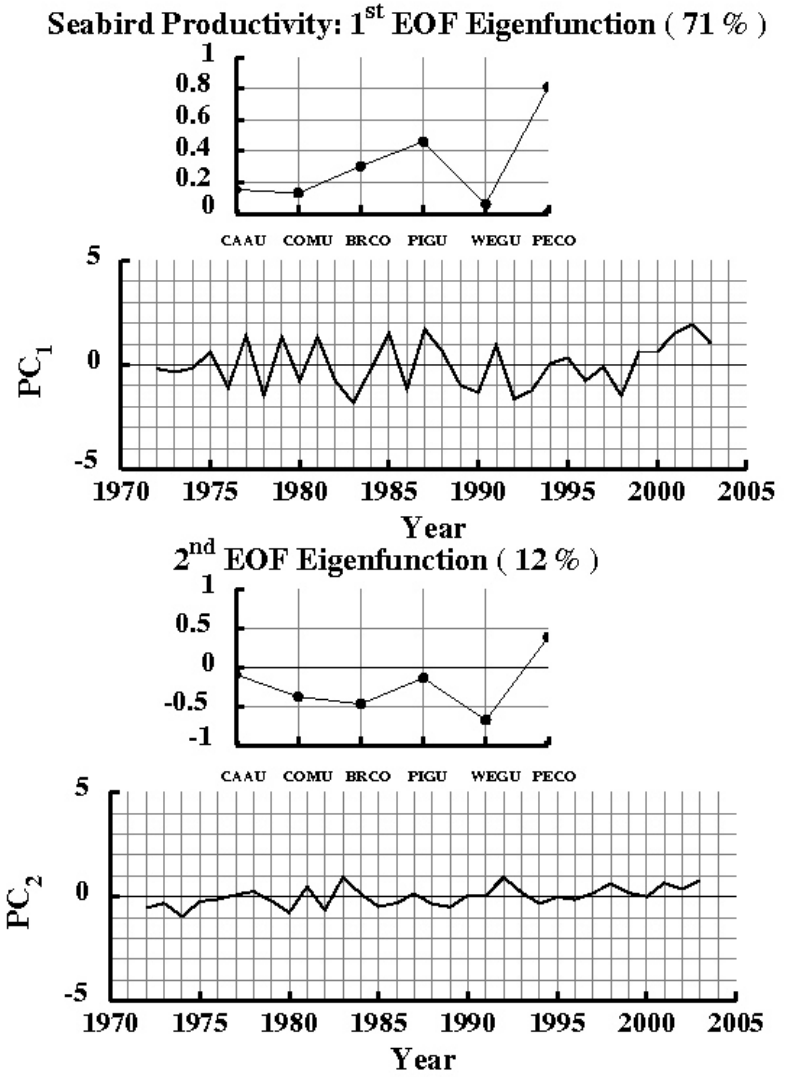

Species-Specific Bird Phenology 1971-2003
Mean Phenology
80
100
120
140
160
180
1970
1980
1990
2000
2010
Year
Piscivores
Planktivore
CAAU_laydate
COMU_laydate
BRCO_laydate
PIGU_laydate


Species-Specific Recruitment, 1971-2003
Short-lived spp.
Recruitment
0
1
2
3
1970
1980
1990
2000
2010
Year
Long-lived spp.
CAAU_RS
COMU_RS
BRCO_RS

Seabird Phenology (egg laying dates) = an integrated measurement of foraging conditions for marine birds, during the later winter/early spring each year.

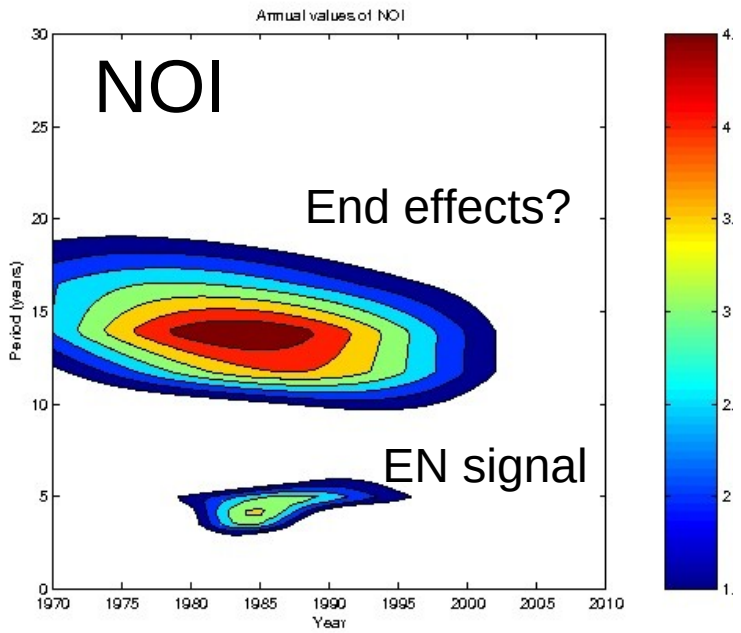
Seabird Productivity (0-age class recruitment) = an integrated measurement of foraging conditions for marine birds, from egg-laying through offspring rearing in spring/summer each year.

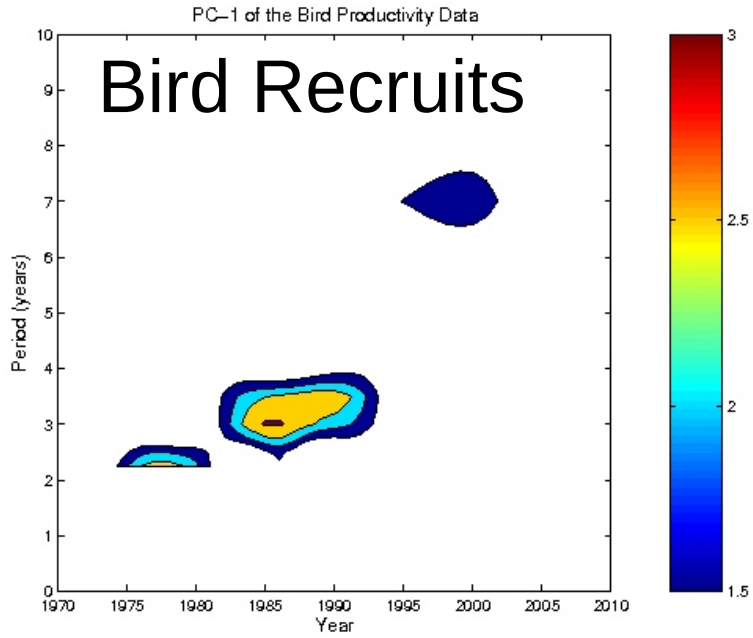


# Wavelets – Annual NOI & Bird Productivity Index.

Question: Where in time/frequency space is the Variance/Power concentrated ?

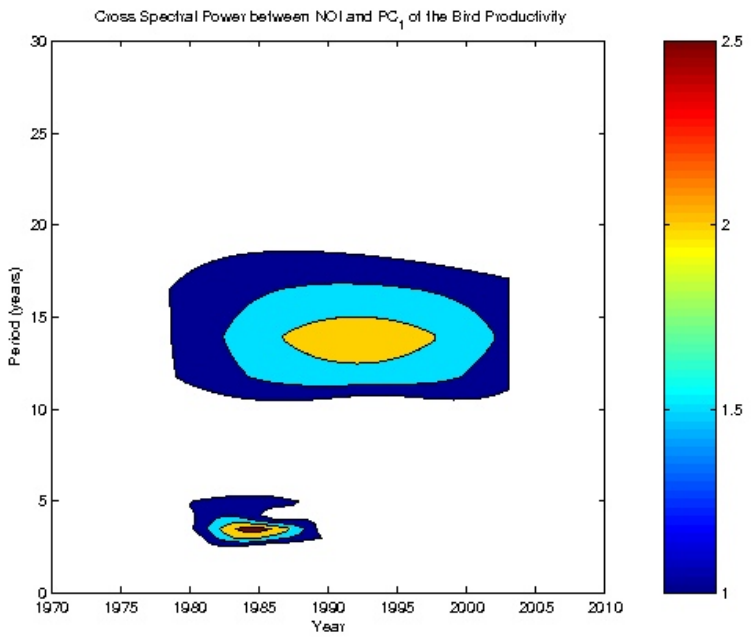


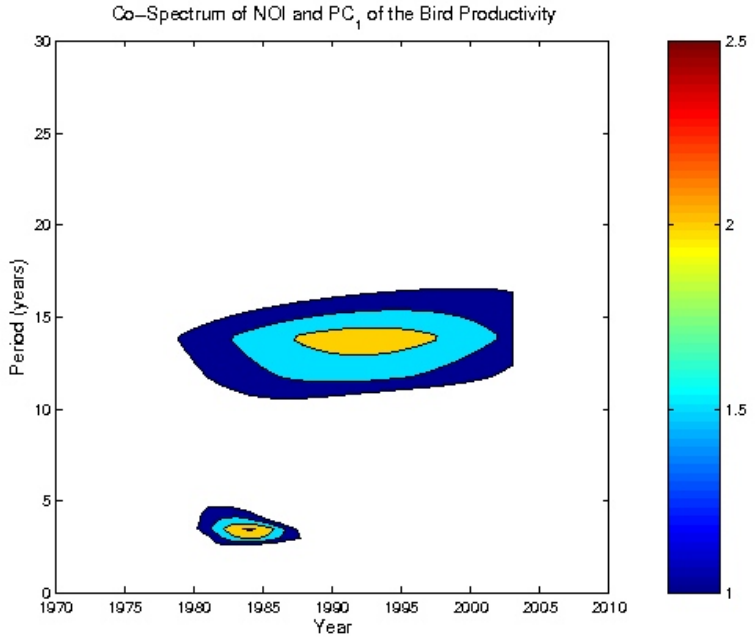




Note: on wavelets -basis is Fourier transformation; Morelet wavelet window we focus on location in “frequency” domain; scaled by variance

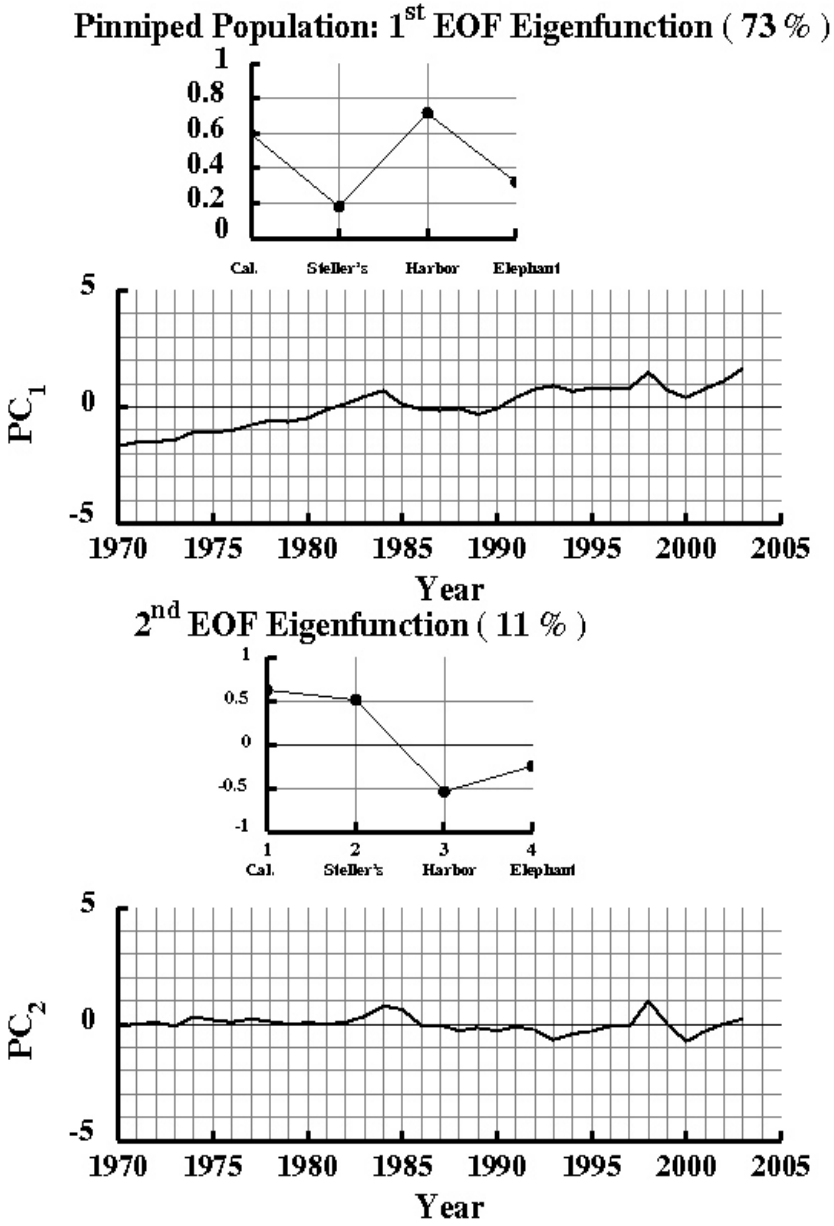
Question:
Where in time/freq. domain do they *both* have power?

Co-spectrum:
measures “in-phase” component?

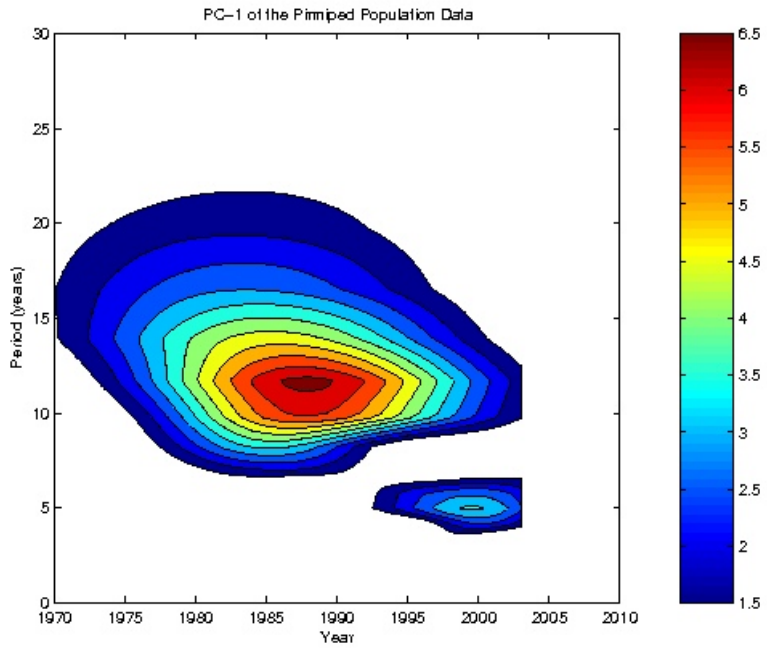



**Conclusion: NOI and bird recruitment are almost completely in phase; NOI is good indicator**



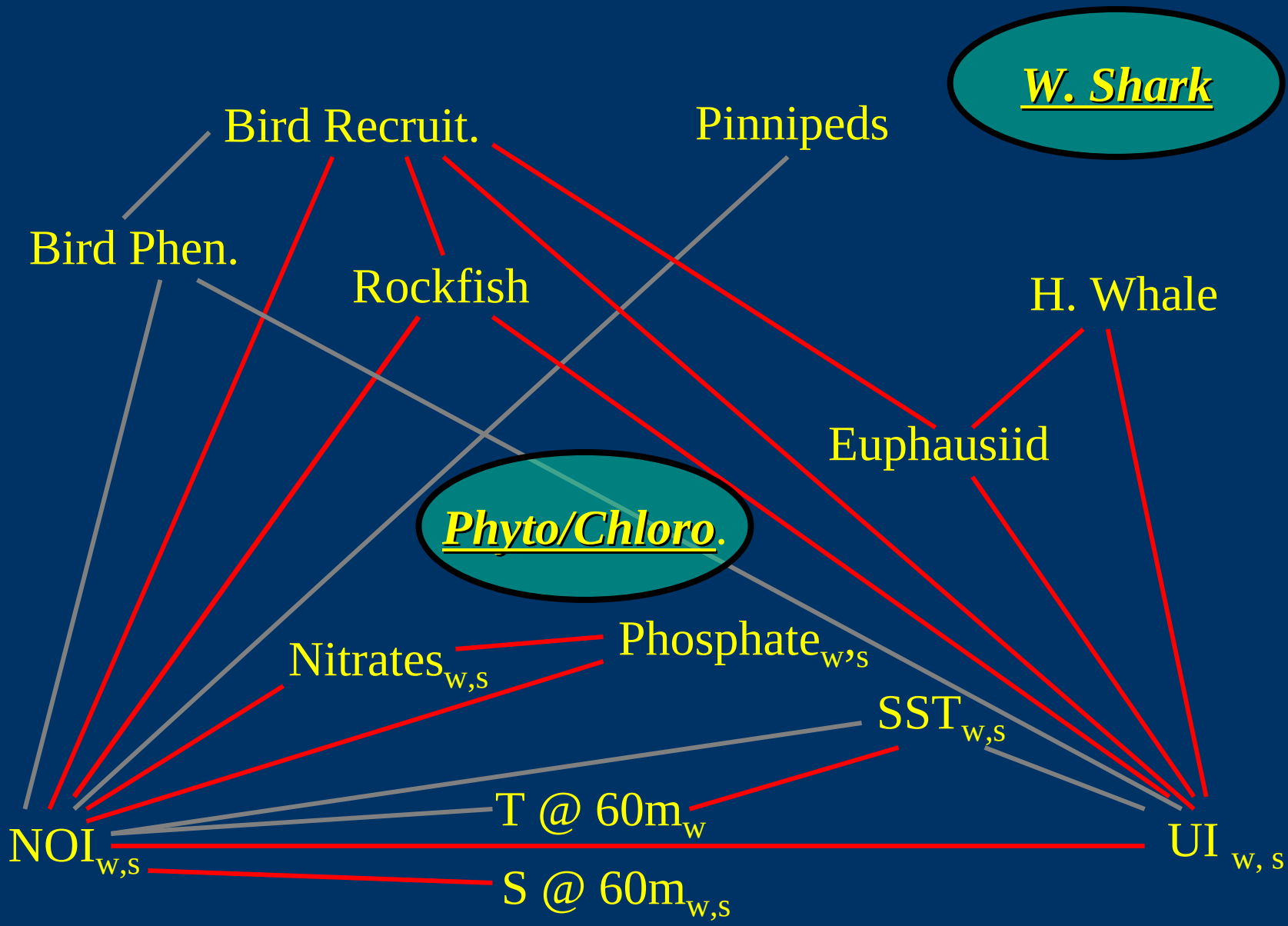

# Wavelet Power – Pinnipeds




Conclusion: Pinnipeds increase in system during/after EN events; lags of 6-18 months evident

# Spearman Rank Correlation Analysis

**(all P<0.05; red = + correlation, gray = -)**



# Summary and Conclusion

(1) Compiled multi trophic-level time series, some 30+ years, for central CCS ecosystem

(2) Foci on marine birds and pinnipeds (animals come to investigators, nice samplers)

(3) Substantial evidence for bottom-up controls through mid trophic levels; positive correlations and “phase-locked” relationships

(4) Insufficient data to fully evaluate top-down effects; however:

(5) Pinnipeds increase in abundance during periods of poor productivity, and have potential to exert top down effects in these years (may consume >25% of mid TL biomass)

(6) “Sub-population” parameters most responsive, with limited lags

(7) Major analysis; EOFs and wavelets are appropriate tools