PDO, Domain or Regime Shifts, and long-term patterns in gyre productivity & NAO effects on Gulf of Maine Production

Class 27, Tu 9 December 2008

Slide 1 PDO, Domain or Regime Shifts, and long-term patterns in gyre productivity & NAO effects on Gulf of Maine Production

NOTES:

Remaining Lecture Schedule

- Class 27, 12/9/08
  - Gyres, PDO & NAO
  - No bacterial processes in 2008
- Class 28, 12/11/08
  - Final Class, Satellite Remote Sensing
- Final Exam, 9 am - Noon 12/15 Monday
  - 3 hour closed book, you can start at 10 if you wish
  - UMB in classroom, Amherst & Lowell: pdf will be mailed to proctors
  - Jaclyn starting at 10 am (do others want to start later too?)
- Term papers (5-10 pages double spaced) due 12/22 by email (or earlier)

Slide 2 Remaining Lecture Schedule

NOTES:

Final exam essays

- Why are there so many benthic infaunal species in the deep sea? Provide arguments in favor of one or more theories for high deep-sea diversity. Does your chosen theory explain why diversity appears to be higher at intermediate depths (e.g., outer continental slope & rise)? [Chapter 5, Jumars & Gallagher (1982)]

Slide 3 Final exam essays

NOTES:

Final exam essays

- Using Townsend & Spinrad's paper, especially the nomogram, as a guide, when should the spring bloom occur in a 35-m deep water column in Western Massachusetts Bay? Usually, the large spring bloom in MA Bay occurs in March. Is a March spring bloom consistent with Sverdrup's critical depth concept? Reconcile the disparities. [Chapter 11, Townsend & Spinrad (1986), Sverdrup (1953)]

Slide 4 Final exam essays

NOTES:

Final exam essays

- In the 1970's, the dominant paradigm for central North Pacific gyre planktonic ecosystems concluded that the gyre ecosystems were 'slow, stable and steady-state.' Describe several of the key studies that led to the rejection of that view. [Chapter 15, Peterson 1980, Platt et al. 1989]
- Describe the changes in the biological and chemical properties of a recently upwelled parcel of water as it is advected offshore from an upwelling center. Describe the location of your chosen upwelling center (e.g., Northern or Southern Hemisphere, Eastern or Western margins), the direction of upwelling favorable winds, and the movement of the parcel of water relative to the coastline. [Chapter 12, Ryther et al. 1971, Mann & Lazier]

Slide 5 Final exam essays

NOTES:

Final exam essays

- Describe the major features of Pearson & Rosenberg (1976, 1978) and the Rhoads et al. (1978) model for the effects of organic enrichment on benthic community structure. Include in your answer, the effects of organic enrichment on species diversity, benthic functional groups, population abundances, and depth to the redox potential discontinuity. [Chapter 6, Rosenbeg 2001]
- The most widely used bioturbation model, the Goldberg-Koide model, isn't appropriate to model non-local mixing. What is non-local mixing, what functional groups of feeding guilds of benthic organisms might be responsible for non-local mixing, and how might non local mixing account for subsurface maxima in chlorophyll *a* within marine sediments? [Chapter 2, Shull 2001]

Slide 6 Final exam essays

NOTES:

Final exam essays

- Phytoplankton exhibit Redfield stoichiometry only when growing at high relative growth rates. Does the ubiquity of Redfield stoichiometry in the ocean indicate that phytoplankton are never nutrient-limited? [Chapter 10, Howarth (1988)]
- Is a subsurface fluorescence maximum always a subsurface chlorophyll *a* maximum? Include justification for your answer and a description of how the depth profiles of each can be measured. [Chapter 7, Lorenzen 1966, Falkowski & Raven Chapter 9]

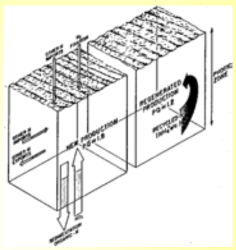
Slide 7 Final exam essays

NOTES:

The effective *annual f*-ratio may be 0.3 to 0.4, not 0.05 to 0.1!

Platt *et al.* 1989 Figure 1

- **In a steady-state system**
  - Sinking rate of nitrogen is balanced by the vertical (and horizontal flux of nitrogen)
  - Oxygen utilization beneath the euphotic zone represents the horizontal sinking of primary production and should be equivalent to new production
  - New production could be measured by the vertical flux of NO_3^-
  - Total production = New production * 1/*f*
- **Problems with this 'chemostat' view**
  - Gyres may not be 'steady-state,' with mini-blooms with high f ratios
  - There can be pronounced vertical structure



Slide 8 The effective annual f-ratio may be 0.3 to 0.4, not 0.05 to 0.1!

NOTES:

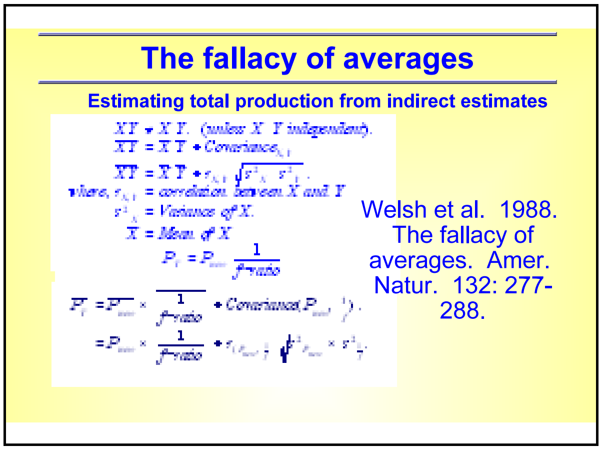
Platt *et al.*'s concensus

Reconciling high short-term rates with bulk properties

- Fallacy of the average and mismatched time scales
  - The *f* ratios in the gyre are much higher than 0.1; 30% to 40% would be more reasonable
  - **2 g C m^{-2} d^{-1} production with the low Chl *a* standing stocks in the gyres would violate the quantum requirements of photosynthesis**
- Two-layered vertical structure
  - Low *f* ratios in surface
  - High *f* ratios at nutracline
  - Vertical nitrate flux trapped at the subsurface chlorophyll maximum
- Non-steady-state
  - Blooms due to rainfall events & mesoscale eddies, hurricanes, cyclones, typhoons
  - Pacific: Long-term increases in Chl *a*, species composition, and nutrient input due to PDO
  - Temporal decoupling of autotrophy & heterotrophy

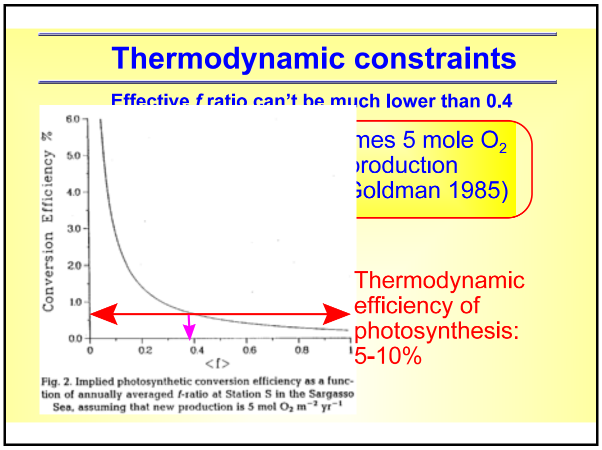
Slide 9 Platt et al.'s concensus

NOTES:



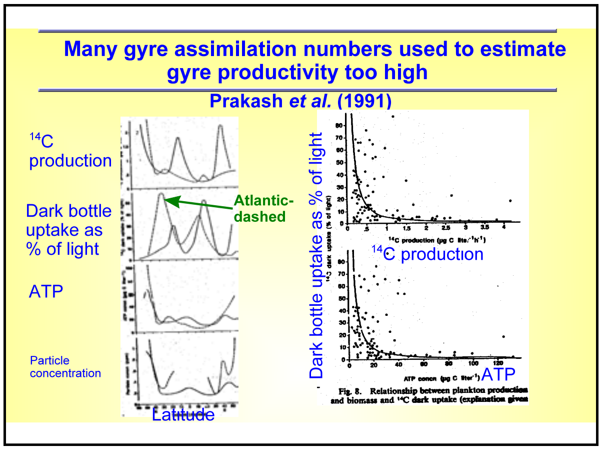
Slide 10 The fallacy of averages

NOTES:



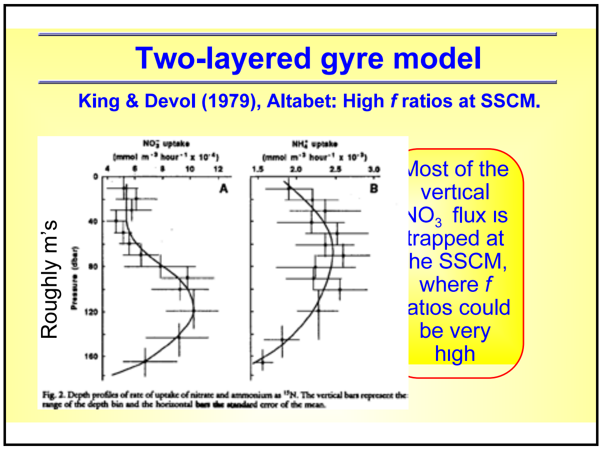
Slide 11 Thermodynamic constraints

NOTES:



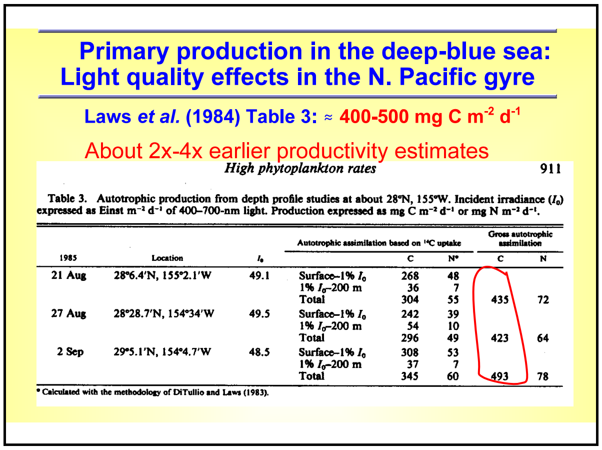
Slide 12 Many gyre assimilation numbers used to estimate gyre productivity too high

NOTES:



Slide 13 Two-layered gyre model

NOTES:



High phytoplankton rates 911

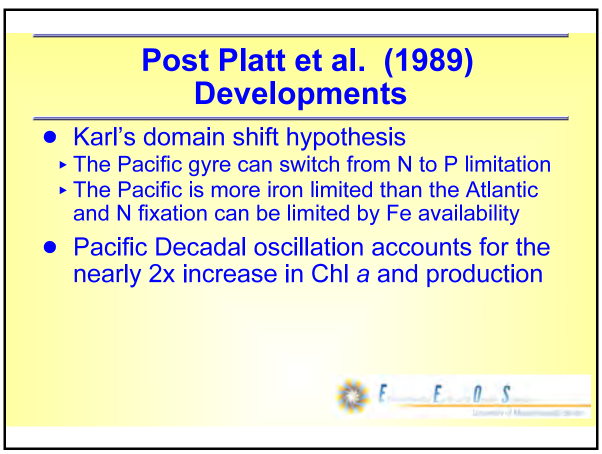
Table 3. Autotrophic production from depth profile studies at about 28°N, 155°W. Incident irradiance (I_0) expressed as Einst m^{-2} d^{-1} of 400–700-nm light. Production expressed as mg C m^{-2} d^{-1} or mg N m^{-2} d^{-1}.

			Autotrophic assimilation based on ¹⁴C uptake			Gross autotrophic assimilation	
1985	Location	I_0		C	N*	C	N
21 Aug	28°6.4'N, 155°2.1'W	49.1	Surface–1% I_0	268	48		
			1% I_0–200 m	36	7		
			Total	304	55	435	72
27 Aug	28°28.7'N, 154°34'W	49.5	Surface–1% I_0	242	39		
			1% I_0–200 m	54	10		
			Total	296	49	423	64
2 Sep	29°5.1'N, 154°4.7'W	48.5	Surface–1% I_0	308	53		
			1% I_0–200 m	37	7		
			Total	345	60	493	78

* Calculated with the methodology of DiTullio and Laws (1983).

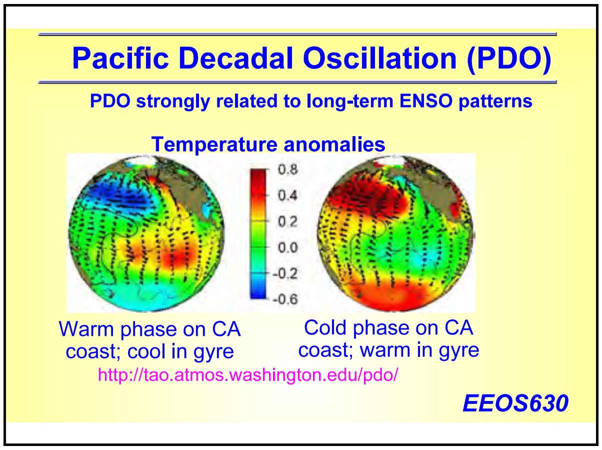
Slide 14 Primary production in the deep-blue sea: Light quality effects in the N. Pacific gyre

NOTES:



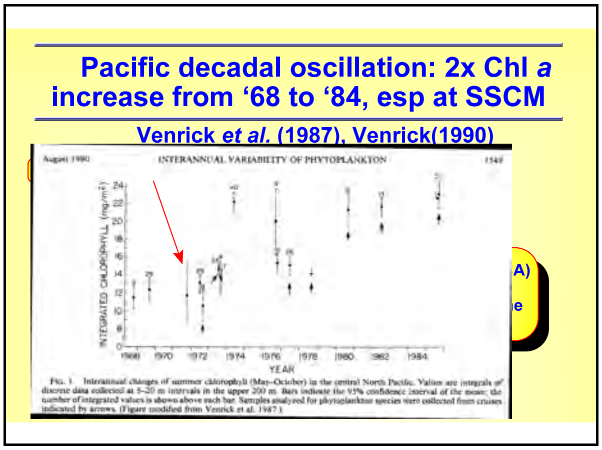
Slide 15 Post Platt et al. (1989) Developments

NOTES:



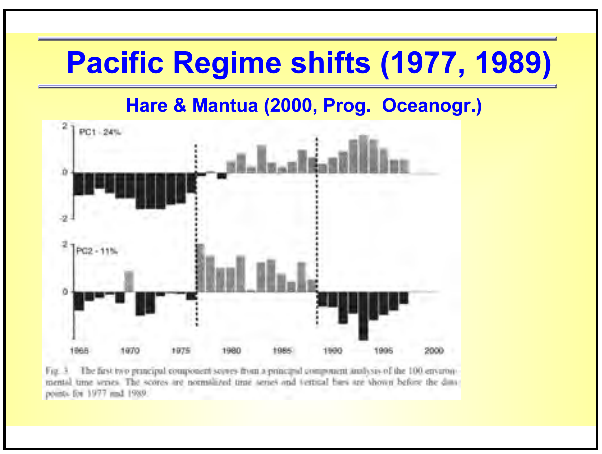
Slide 16 Pacific Decadal Oscillation (PDO)

NOTES:



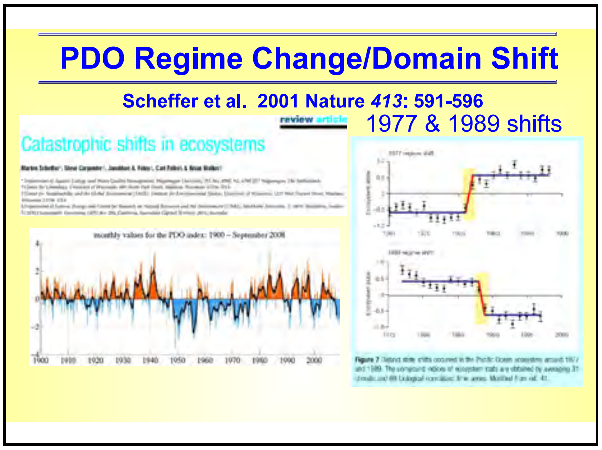
Slide 17 Pacific decadal oscillation: 2x Chl a increase from '68 to '84, esp at SSCM

NOTES:



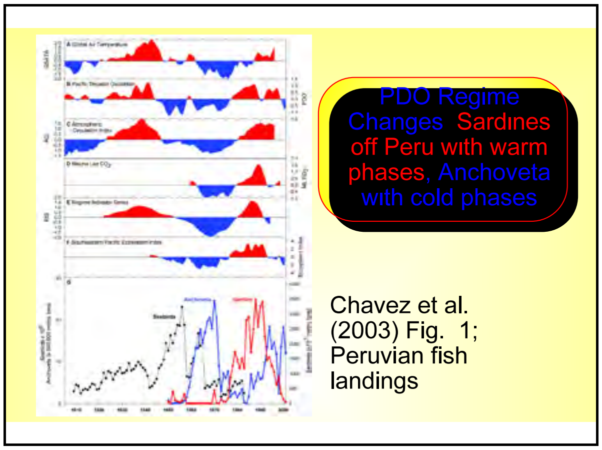
Slide 18 Pacific Regime shifts (1977, 1989)

NOTES:



Slide 19 PDO Regime Change/Domain Shift

NOTES:



Slide 20

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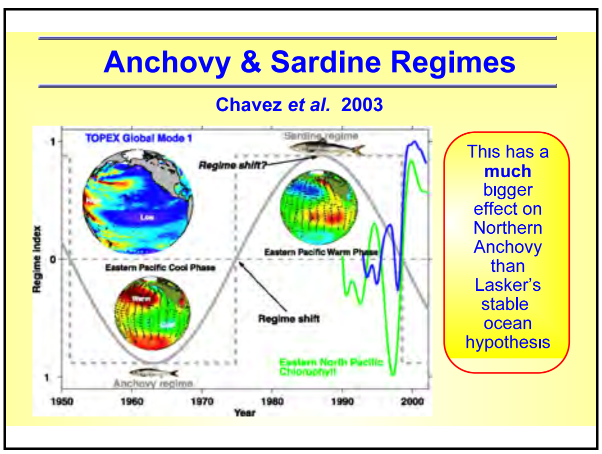


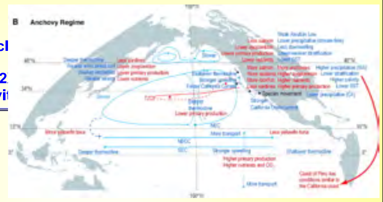
Slide 21 Anchovy & Sardine Regimes

NOTES:

1960s -> 1978 Anchovy (Cold) Regime

Chavez et al. (2003) Science

- California current
  - Higher nutrients
  - High macrozooplankton (*Calanus pacificus*) off California
  - More seabirds
  - More salmon
- Gyre
  - Deeper gyre thermocl nutracline
  - Chl *a* concentration 2
  - lower gyre productivi



Slide 22 1960s -> 1978 Anchovy (Cold) Regime

NOTES:

1930s & 1980s Sardine (Warm) Regime

Chavez et al. (2003)

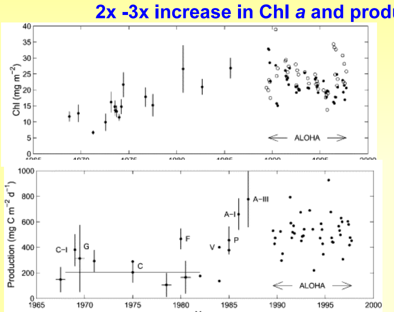
- California & Peru in 1930s & 1980s: Sardine Regime
  - Low macrozooplankton off CA
  - Deeper thermocline
  - Less salmon
  - Off Alaska & British Columbia
    - More salmon
    - Higher production
- Gyres
  - Shallower thermocline
  - Much higher production in g

Slide 23 1930s & 1980s Sardine (Warm) Regime

NOTES:

The domain-shift hypothesis

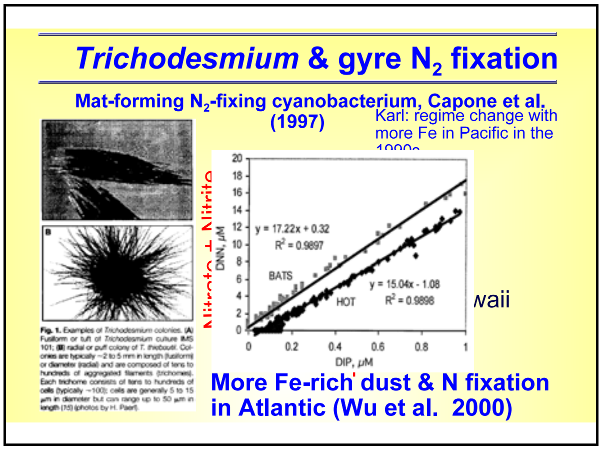
2x -3x increase in Chl *a* and production



Karl et al. (2001): No strong evidence for trace metal effects on production

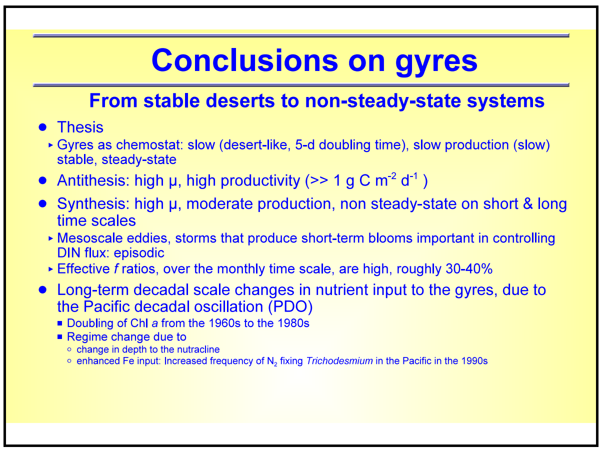
Slide 24 The domain-shift hypothesis

NOTES:



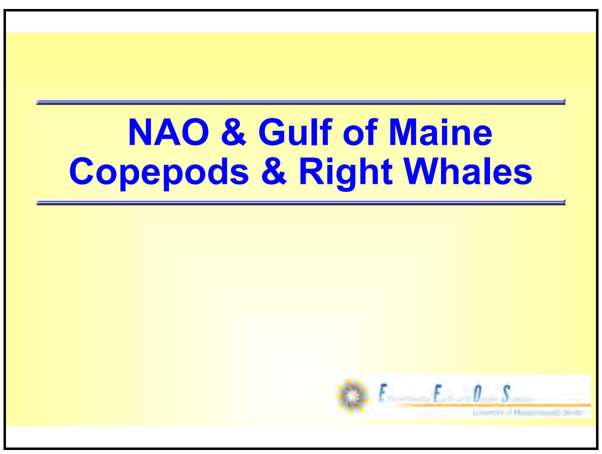
Slide 25 Trichodesmium & gyre N2 fixation

NOTES:



Slide 26 Conclusions on gyres

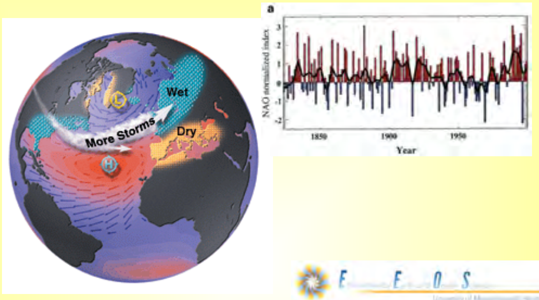
NOTES:



Slide 27 NAO & Gulf of Maine Copepods & Right Whales

NOTES:

Positive NAO

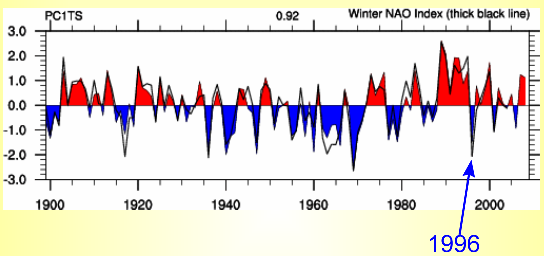


Slide 28 Positive NAO

NOTES:

NAO Index ’00 to ‘08, note 1996 Negative NAO event

http://www.cgd.ucar.edu/cas/jhurrell/indices.info.html#naopcdjfm

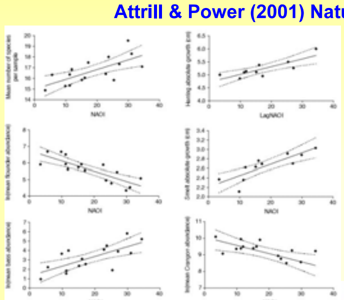


Slide 29 NAO Index ’00 to ‘08, note 1996 Negative NAO event

NOTES:

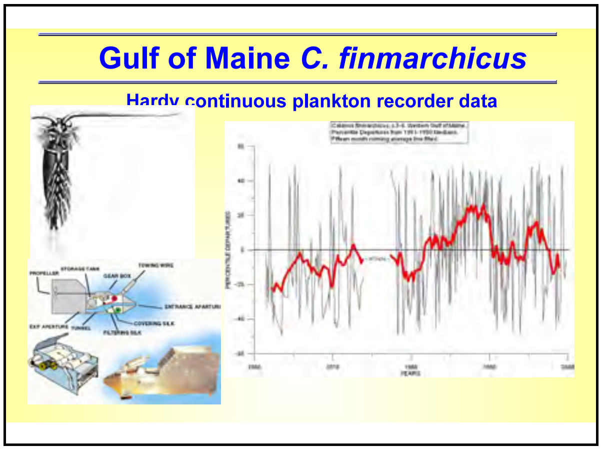
NAO on European fish stocks

Attrill & Power (2001) Nature



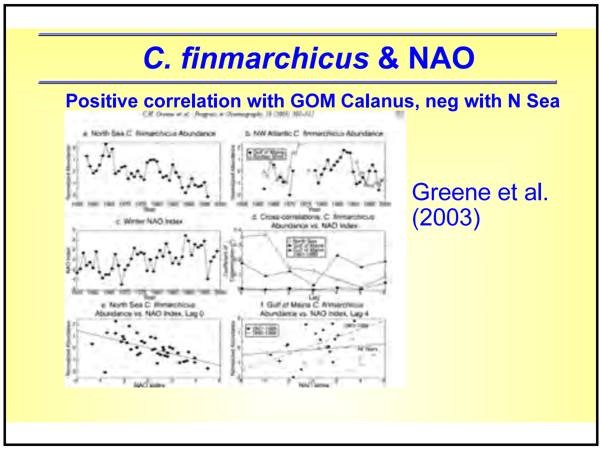
Slide 30 NAO on European fish stocks

NOTES:



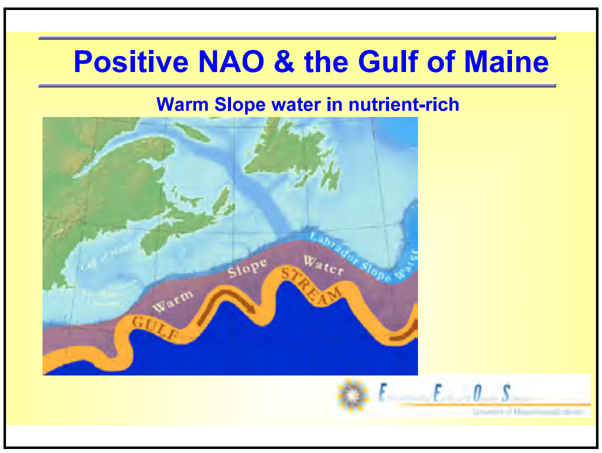
Slide 31 Gulf of Maine C. Finmarchicus

NOTES:



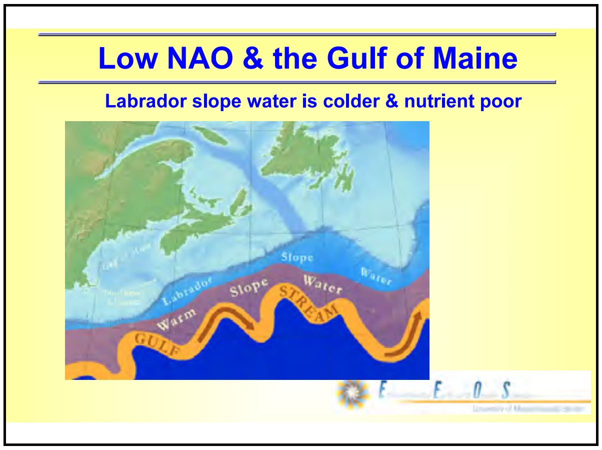
Slide 32 C. Finmarchicus & NAO

NOTES:



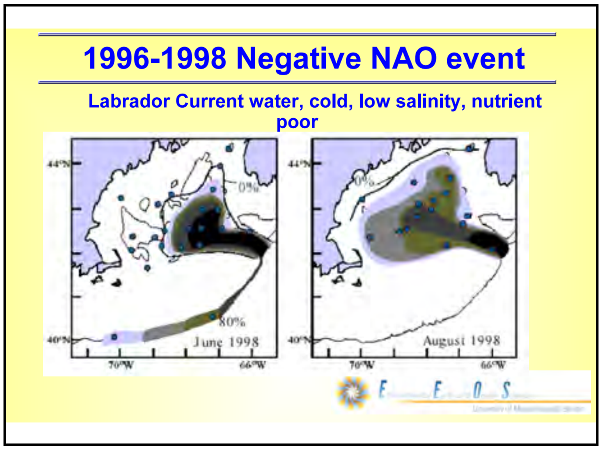
Slide 33 Positive NAO & the Gulf of Maine

NOTES:



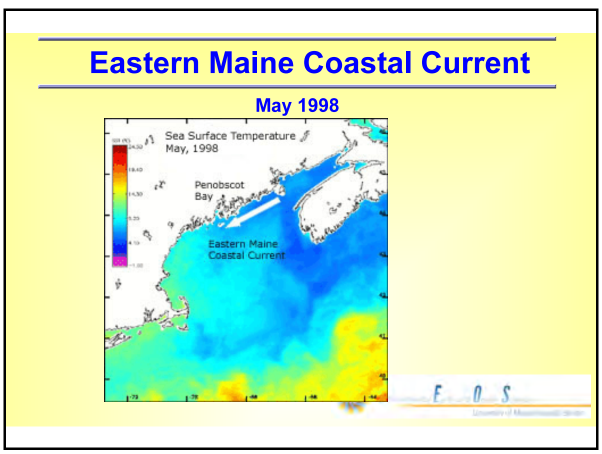
Slide 34 Low NAO & the Gulf of Maine

NOTES:



Slide 35 1996-1998 Negative NAO event

NOTES:

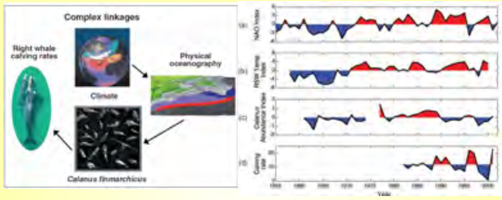


Slide 36 Eastern Maine Coastal Current

NOTES:

NAO & Right Whales

Greene & Pershing 2004 Front. Ecol. Environ. 2: 29-34



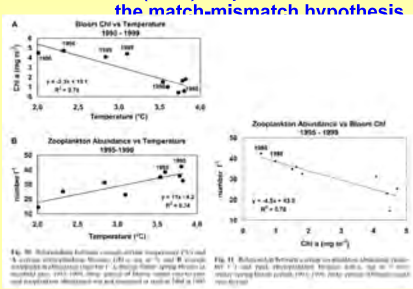
The interaction is not simple. 1996 event associated with high calving rates

Slide 37 NAO & Right Whales

NOTES:

Blooms in MA Bay

Keller et al. (2001): Explained lack of 1998 bloom with the match-mismatch hypothesis

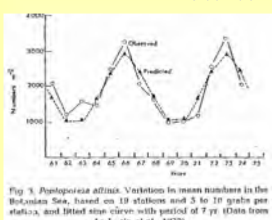


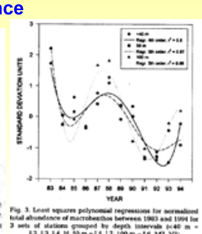
Slide 38 Blooms in MA Bay

NOTES:

Long-term cycles in N. Europe

Gray & Christie (1983) *Pontoporeia* cycles; Tunberg & Nelson (1998) Swedish NAO cycles in infaunal abundance





Slide 39 Long-term cycles in N. Europe

NOTES: