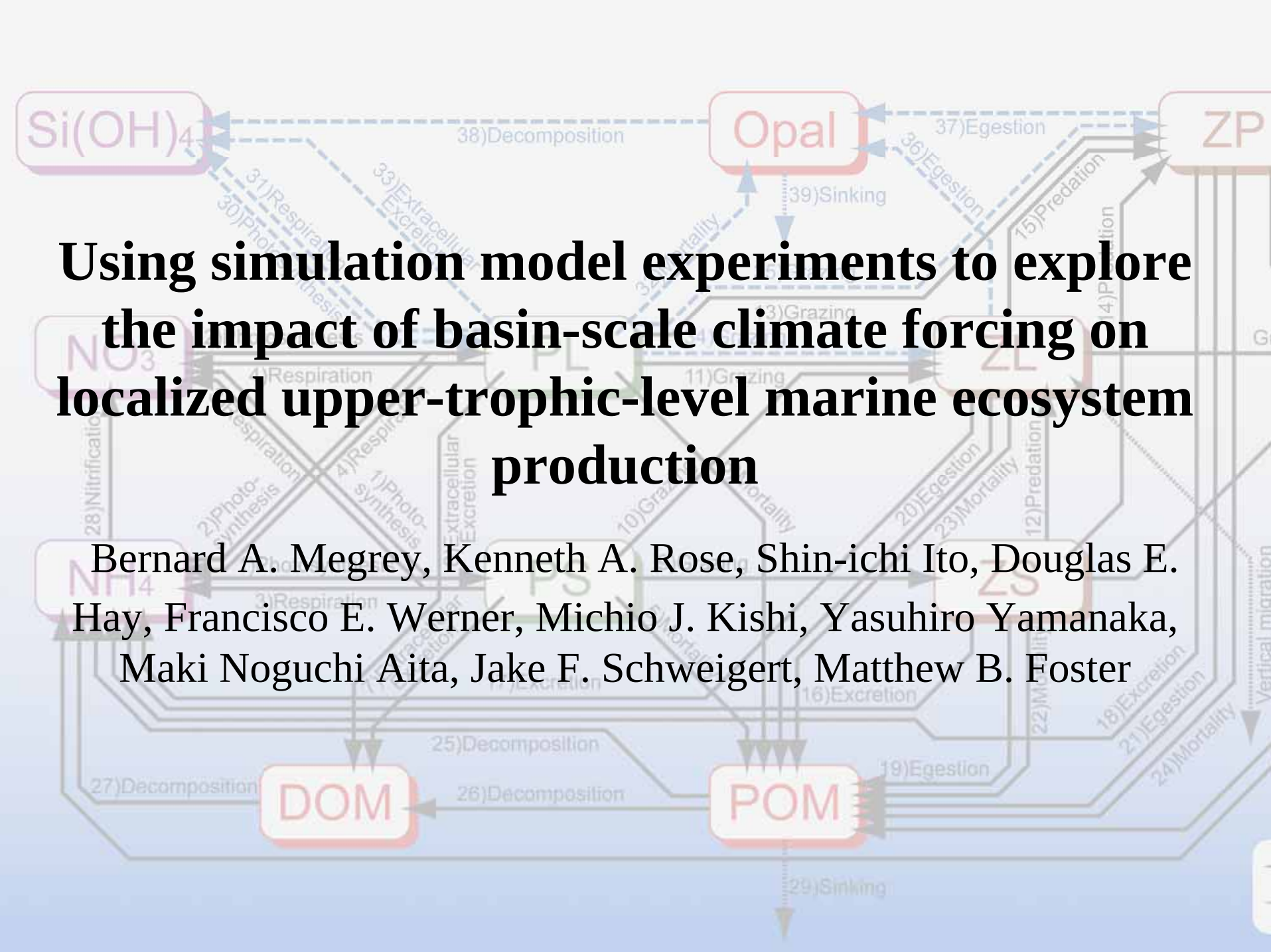


Using simulation model experiments to explore the impact of basin-scale climate forcing on localized upper-trophic-level marine ecosystem production

Bernard A. Megrey, Kenneth A. Rose, Shin-ichi Ito, Douglas E. Hay, Francisco E. Werner, Michio J. Kishi, Yasuhiro Yamanaka, Maki Noguchi Aita, Jake F. Schweigert, Matthew B. Foster

Presentation Overview

- Brief model introduction
- Review model experimental procedure
- Present results of three applications showing impacts of climate change on marine ecosystems

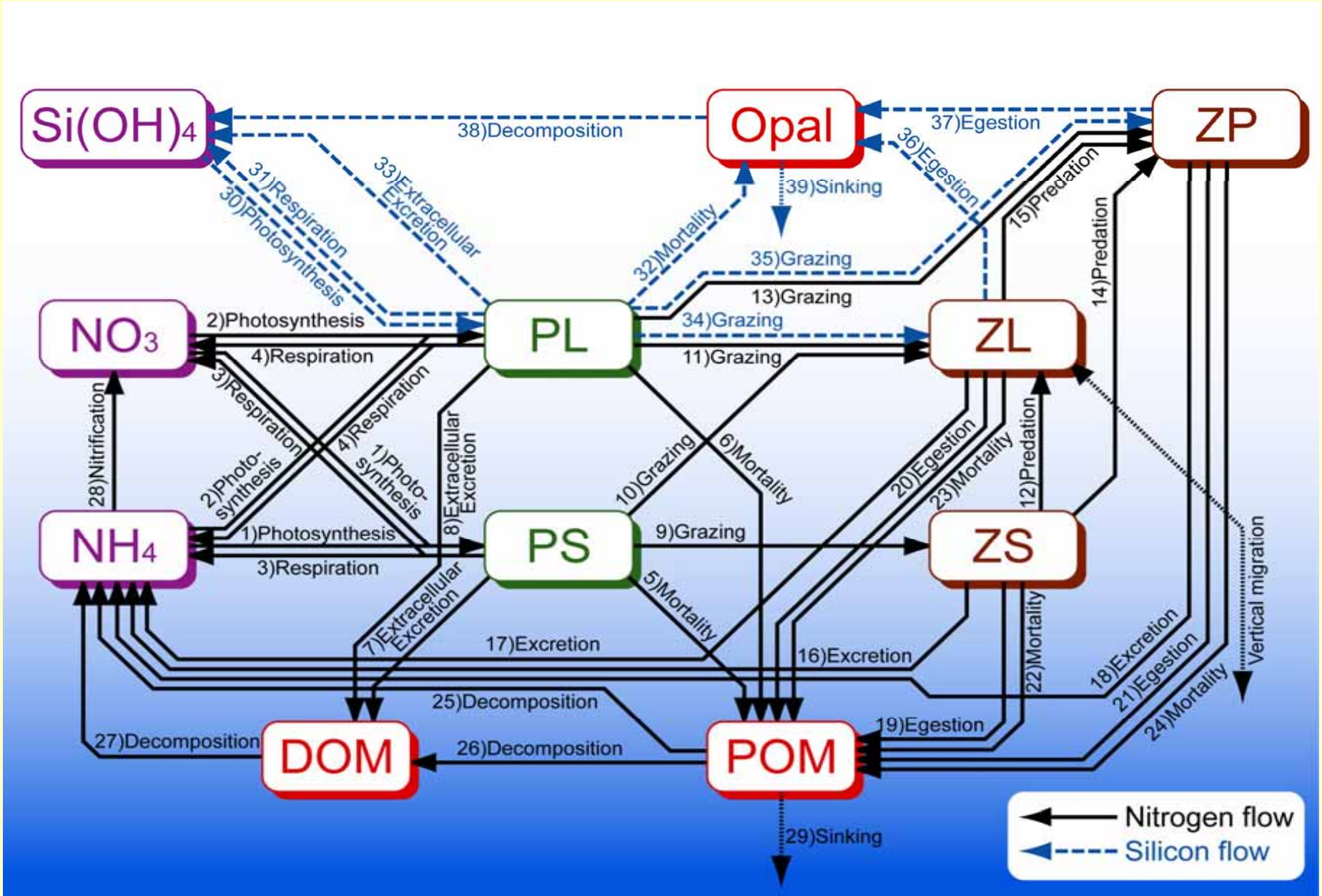
NEMURO

North Pacific Ecosystem Model for Understanding Regional Oceanography

"A conceptual model representing the minimum trophic structure and biological relationships between and among all the marine ecosystem components thought to be essential to describe ecosystem dynamics in the North Pacific"

Source: Kishi et al. 2007. Ecological Modeling

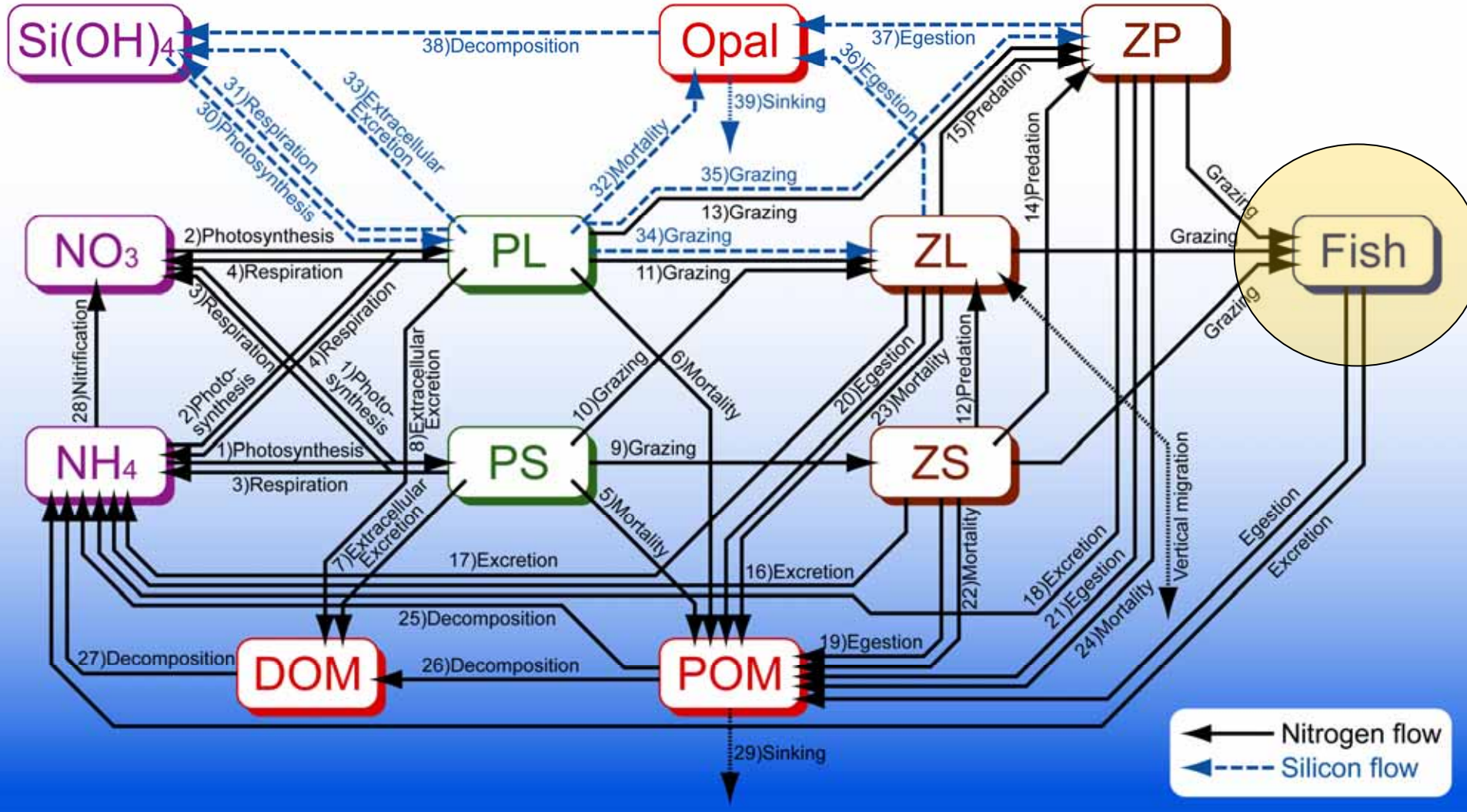
NEMURO


Si(OH)4
Opal
ZP
38)Decomposition
37)Egestion
36)Egestion
39)Sinking
31)Respiration
30)Photosynthesis
33)Extracellular Excretion
32)Mortality
35)Grazing
15)Predation
14)Predation
13)Grazing
NO3
2)Photosynthesis
PL
34)Grazing
ZL
4)Respiration
11)Grazing
3)Respiration
4)Respiration
28)Nitrification
2)Photo-synthesis
1)Photo-synthesis
8)Extracellular Excretion
10)Grazing
6)Mortality
20)Egestion
23)Mortality
12)Predation
NH4
1)Photosynthesis
3)Respiration
PS
9)Grazing
ZS
5)Mortality
7)Extracellular Excretion
17)Excretion
16)Excretion
22)Mortality
18)Excretion
21)Egestion
24)Mortality
Vertical migration
25)Decomposition
27)Decomposition
DOM
26)Decomposition
POM
19)Egestion
29)Sinking
Nitrogen flow
Silicon flow

NEMURO.FISH
NEMURO
For Including Herring and Saury

- Explicitly include higher trophic level (fish) dynamics in the simulation of marine ecosystems

NEMURO.FISH


Si(OH)4
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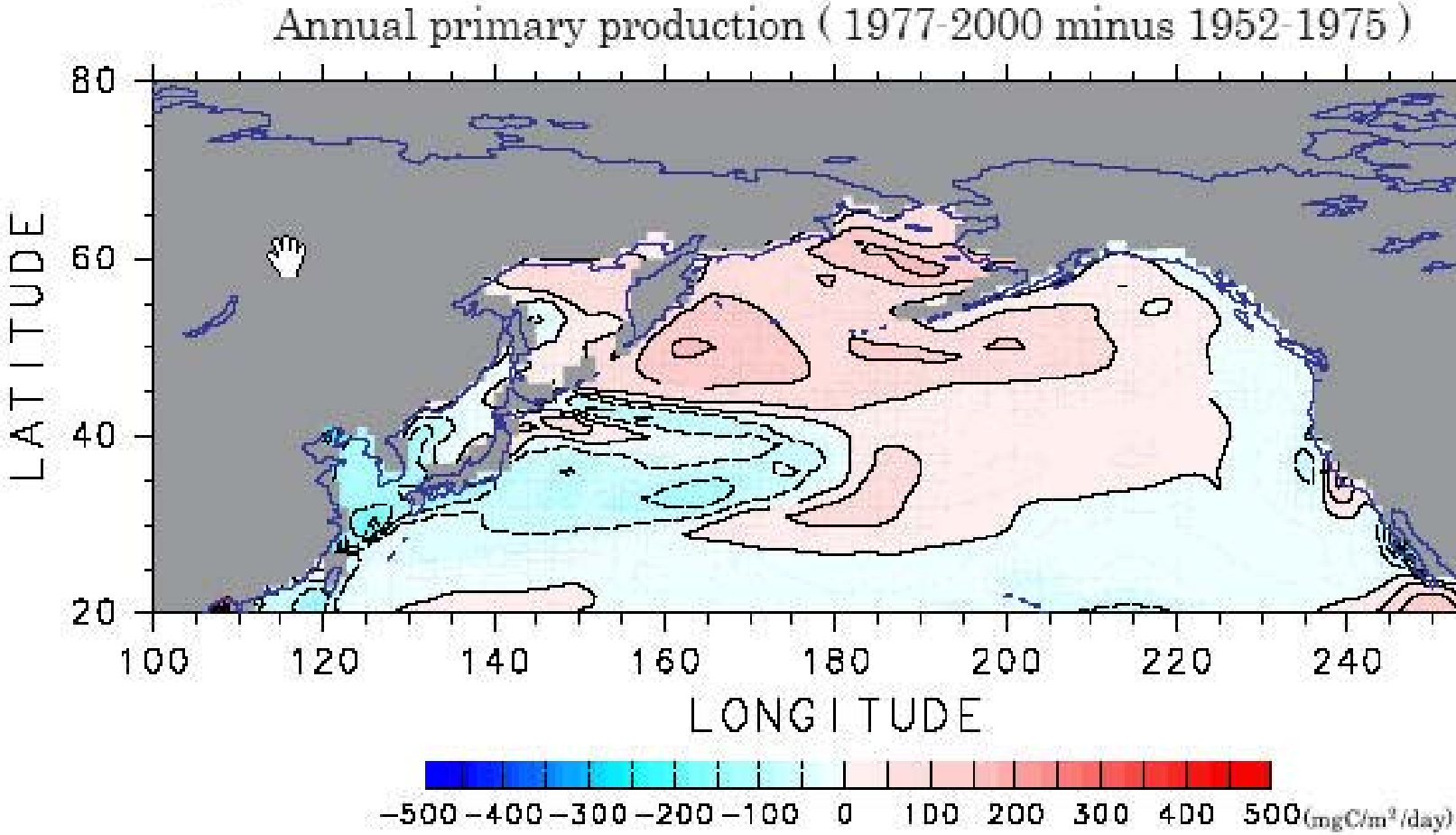
24)Mortality
Vertical migration
Egestion
Excretion
25)Decomposition
27)Decomposition
26)Decomposition
19)Egestion
29)Sinking
Nitrogen flow
Silicon flow

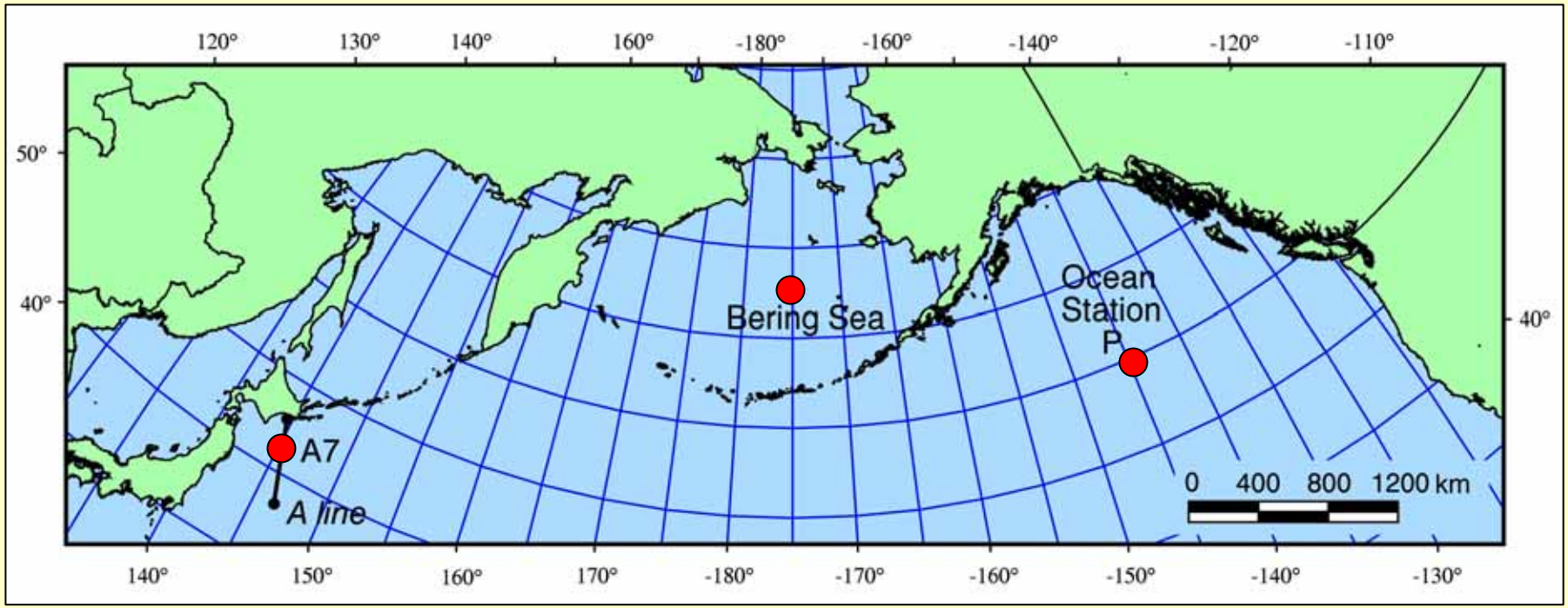
NEMURO-3D

Basin scale predictions of the state of the LTL ecosystem
NEMURO embedded in a GCM grid of the North Pacific



Source: Noguchi et al. 2007. Ecological Modeling.

The Research Plan



Apply the same model structure (i.e. equations and parameters) and climate scenarios to three different ecosystems – any observed differences in dynamic response will be due to local characteristics and forcing

Experimental Procedure

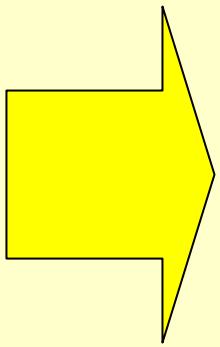
- Used predictions of temperature and zooplankton from 3D-NEMURO (NEMURO embedded in a 3-D circulation model)
  - Aita-Noguchi, Yamanaka, and Kishi (2007) Ecological Modelling
- ***Uncoupled***: used stored output from NEMURO as input to herring growth model
- Can we see regime shifts effects cascading up the food web?

Static Linking Fish Bioenergetics/Biomass to NEMURO

Fish Model

$$\frac{1}{W}\frac{dW}{dt} = \left[C - (R + S + F + E)\right]$$

Run NEMURO, save output file of Small, Lg and Pred Zoop and use to drive fish model

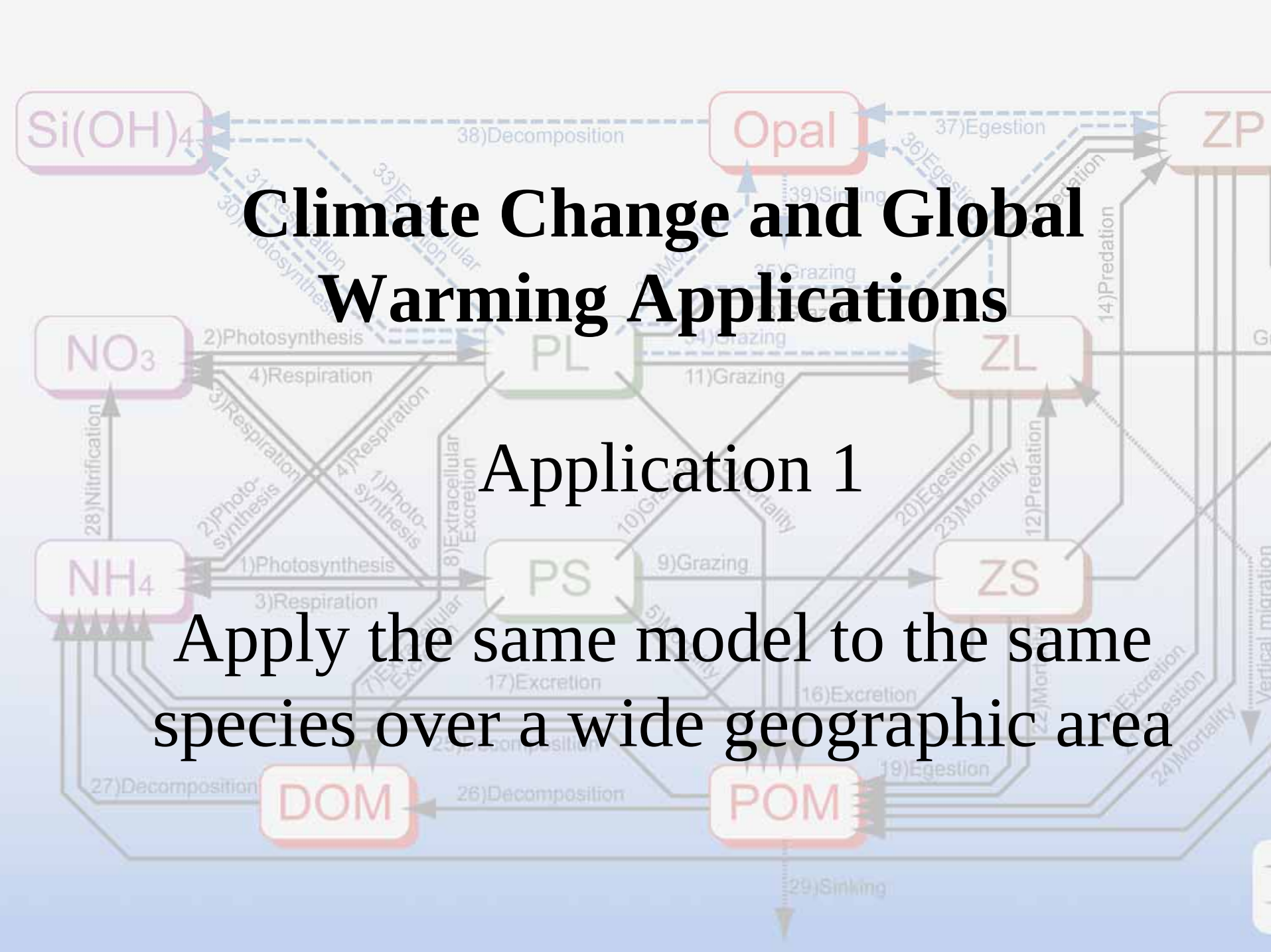


NEMURO Small Zooplankton

NEMURO Large Zooplankton

NEMURO Predatory Zooplankton

Model equations solved sequentially

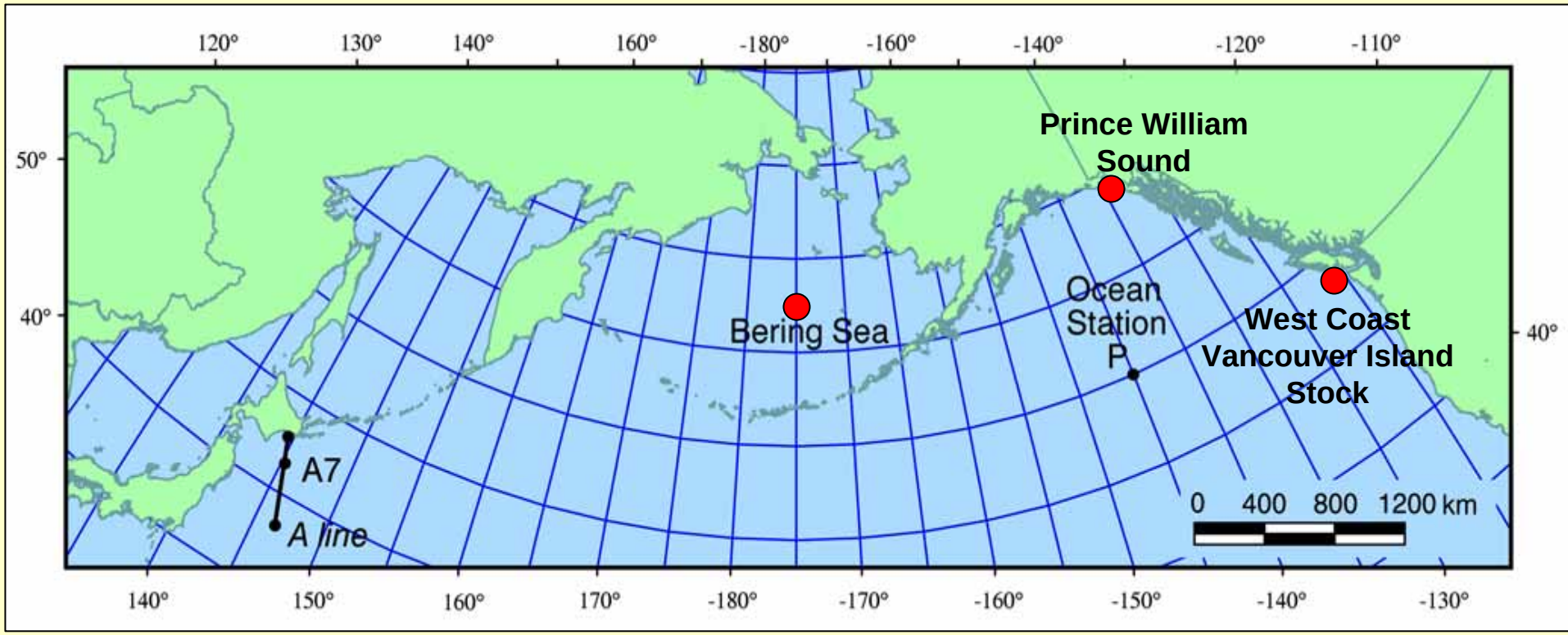


Climate Change and Global Warming Applications

Application 1

Apply the same model to the same species over a wide geographic area

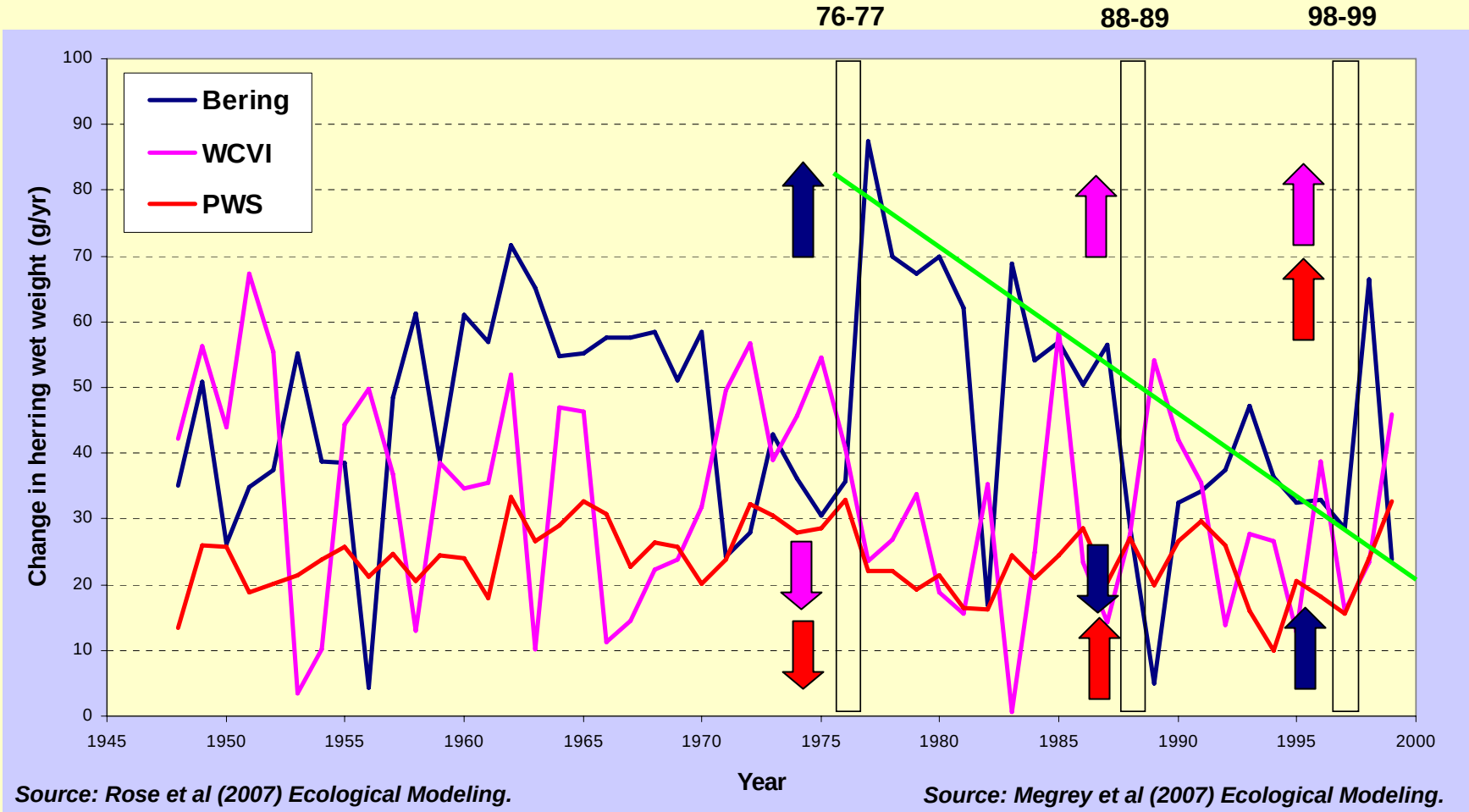
Apply the same model to Pacific herring, for three areas of the North Pacific, using the same 50 year climate forcing scenario



Impact of Regime Shifts on Herring Growth

Responses were synchronous in time but different between regions

Bering Sea responded differently from WCVI and PWS;
WCVI and PWS responded the same



Source: Rose et al (2007) Ecological Modeling.

Source: Megrey et al (2007) Ecological Modeling.

Climate Change and Global Warming Applications

Application 2

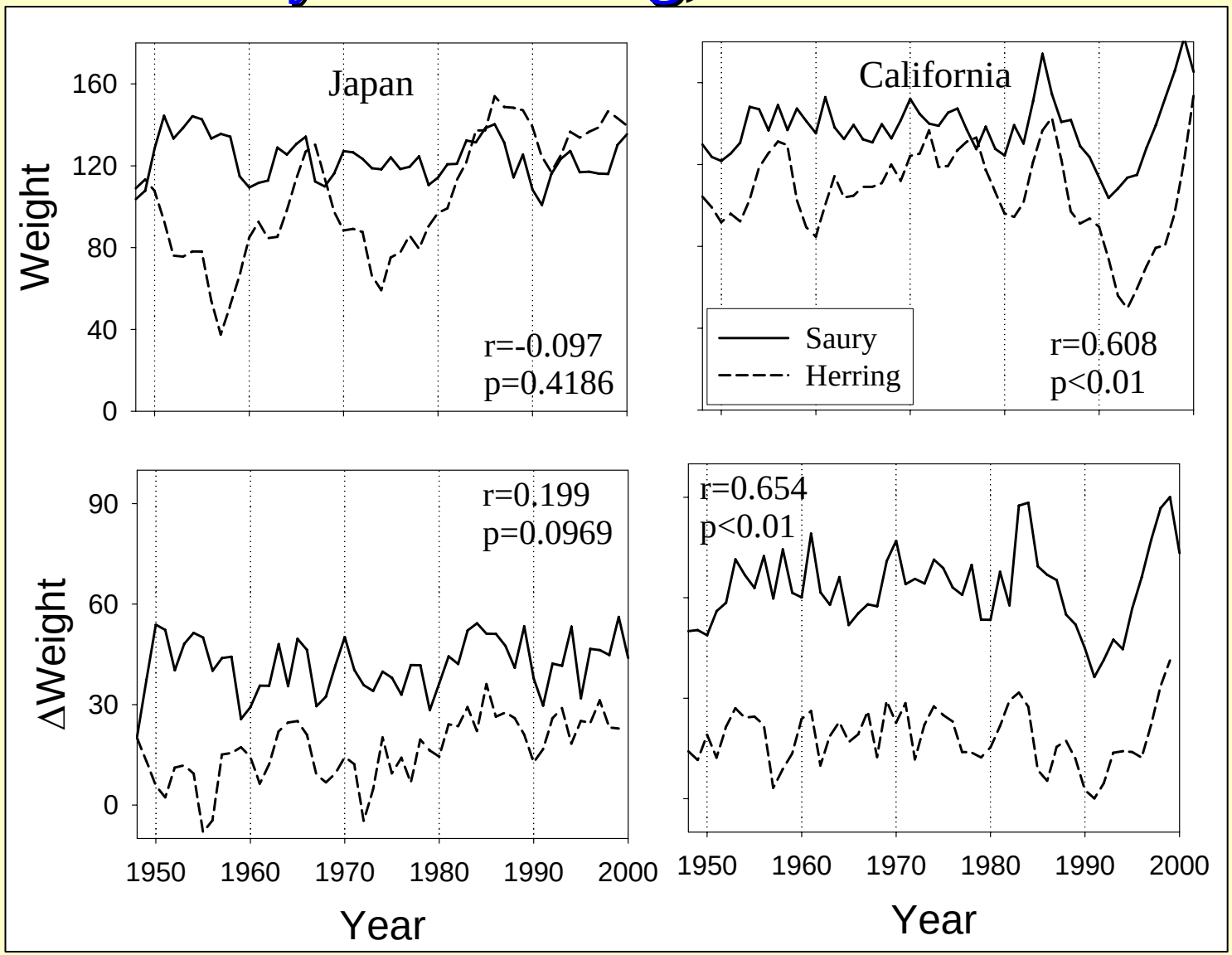
Apply the same model to two different species, in two widely separated geographic areas, within one ocean basin, using the same climate forcing

Species comparison between saury and herring

Simulate herring and saury growth in response to common climatology at each of the 6 stations which span the North Pacific basin. Within each side of the Pacific a slight latitudinal gradient was introduced.

Megrey et al. (2007); Ito et al. (2007)

Saury vs. Herring, West vs. East



Saury and herring show out of phase synchronicity in the east

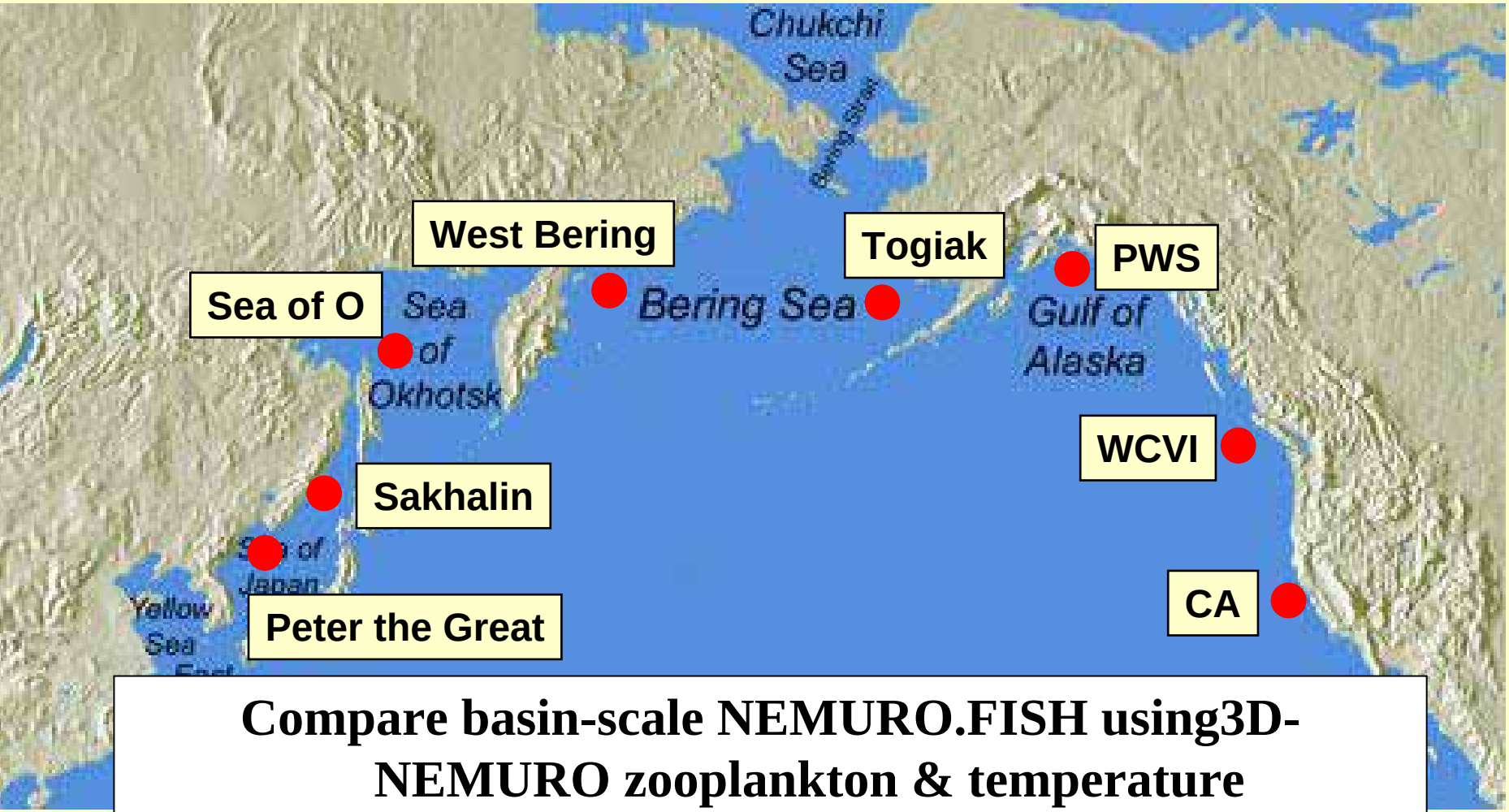
Source: Megrey et al. (2007)

Climate Change and Global Warming Applications

Application 3

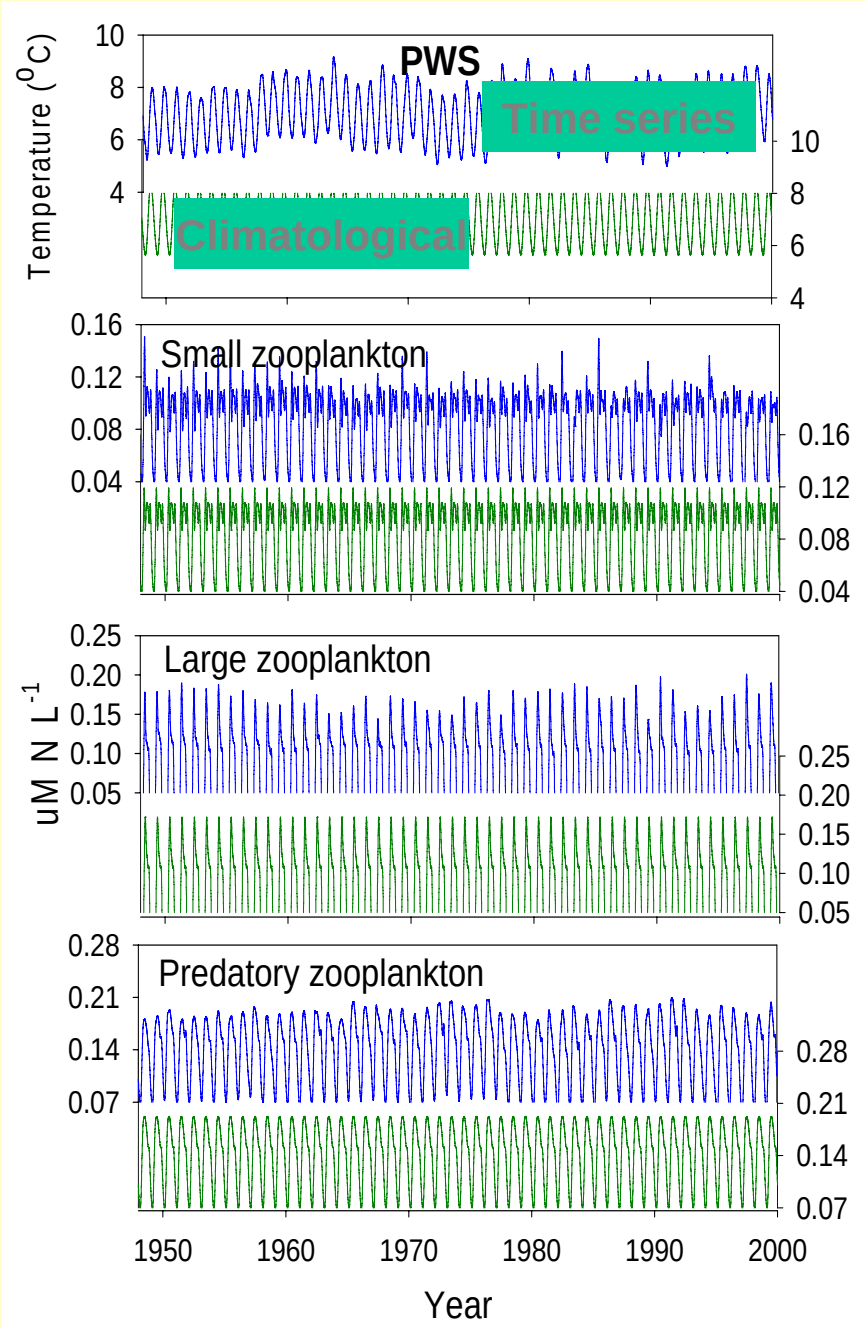
Apply the same model to the same species within one ocean basin, using the same climate forcing

Basin-Scale Geographical Herring Comparison

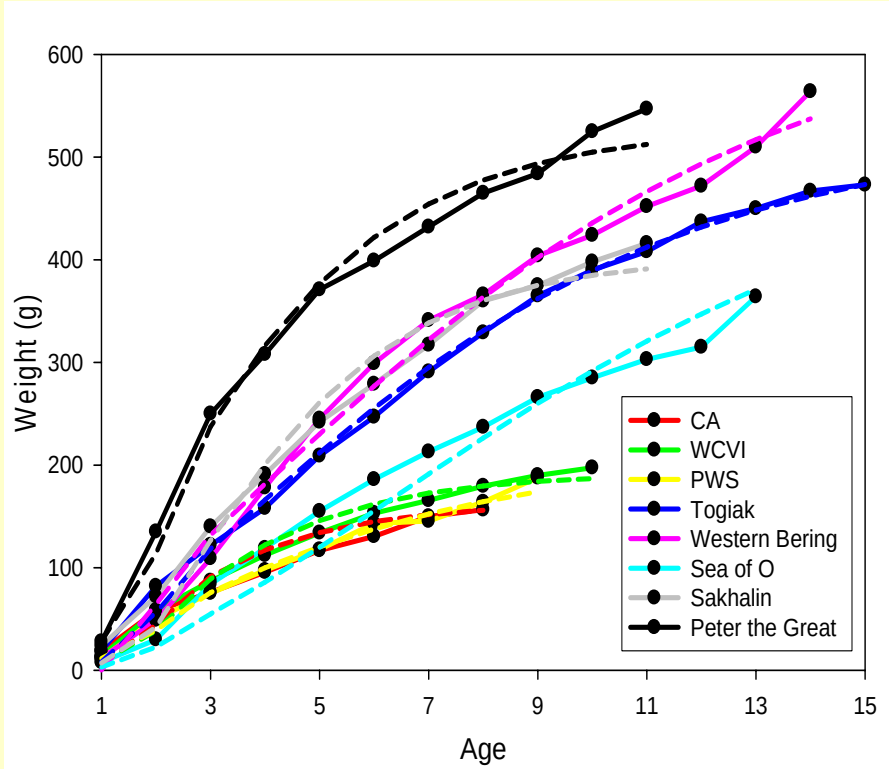


Compare basin-scale NEMURO.FISH using3D-NEMURO zooplankton & temperature (one-way static linkage).

Partly reported in Rose et al. (2007)



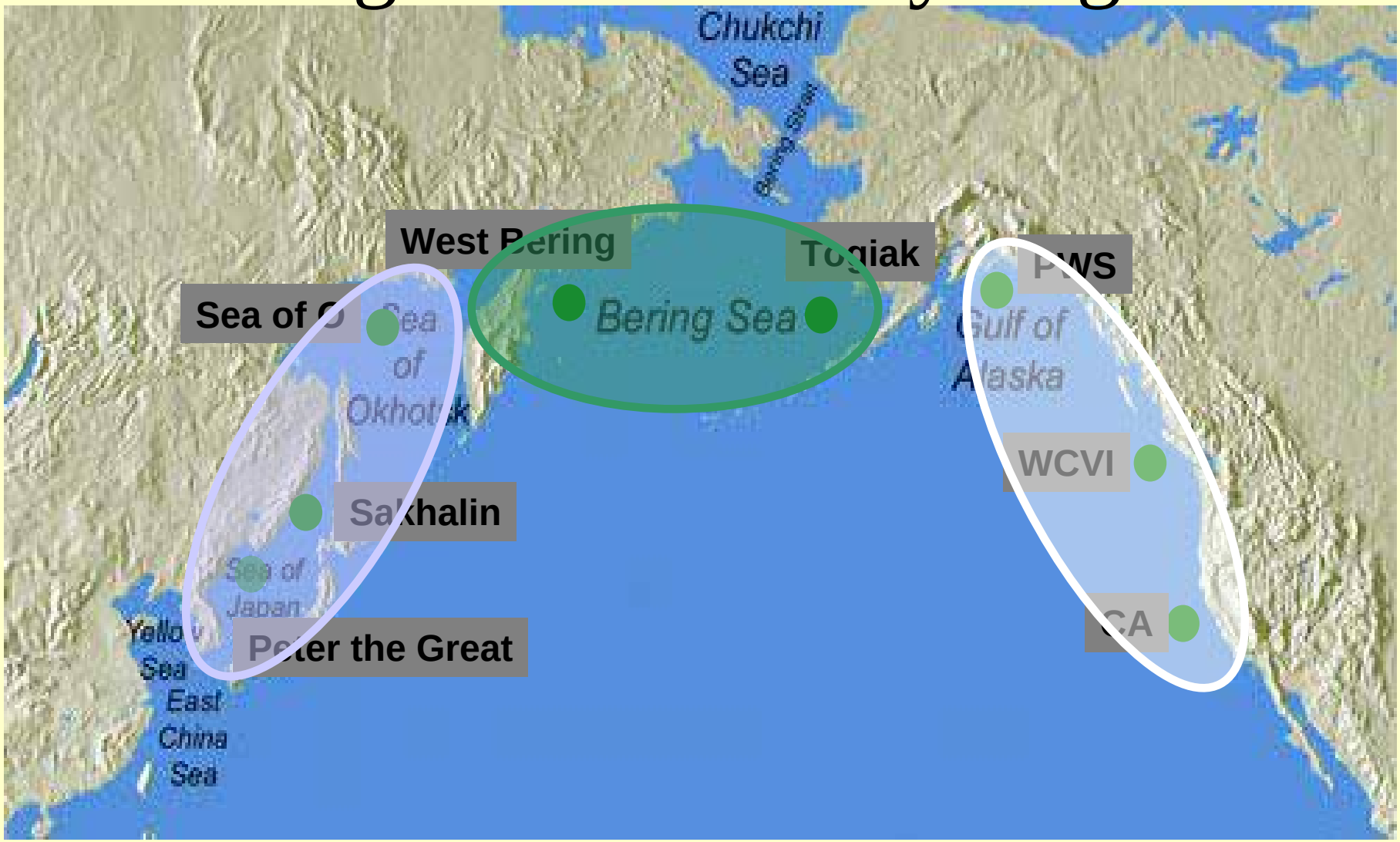
Calibration with PEST using Climatological Steady-state weights-at-age



Weights-at-age from:

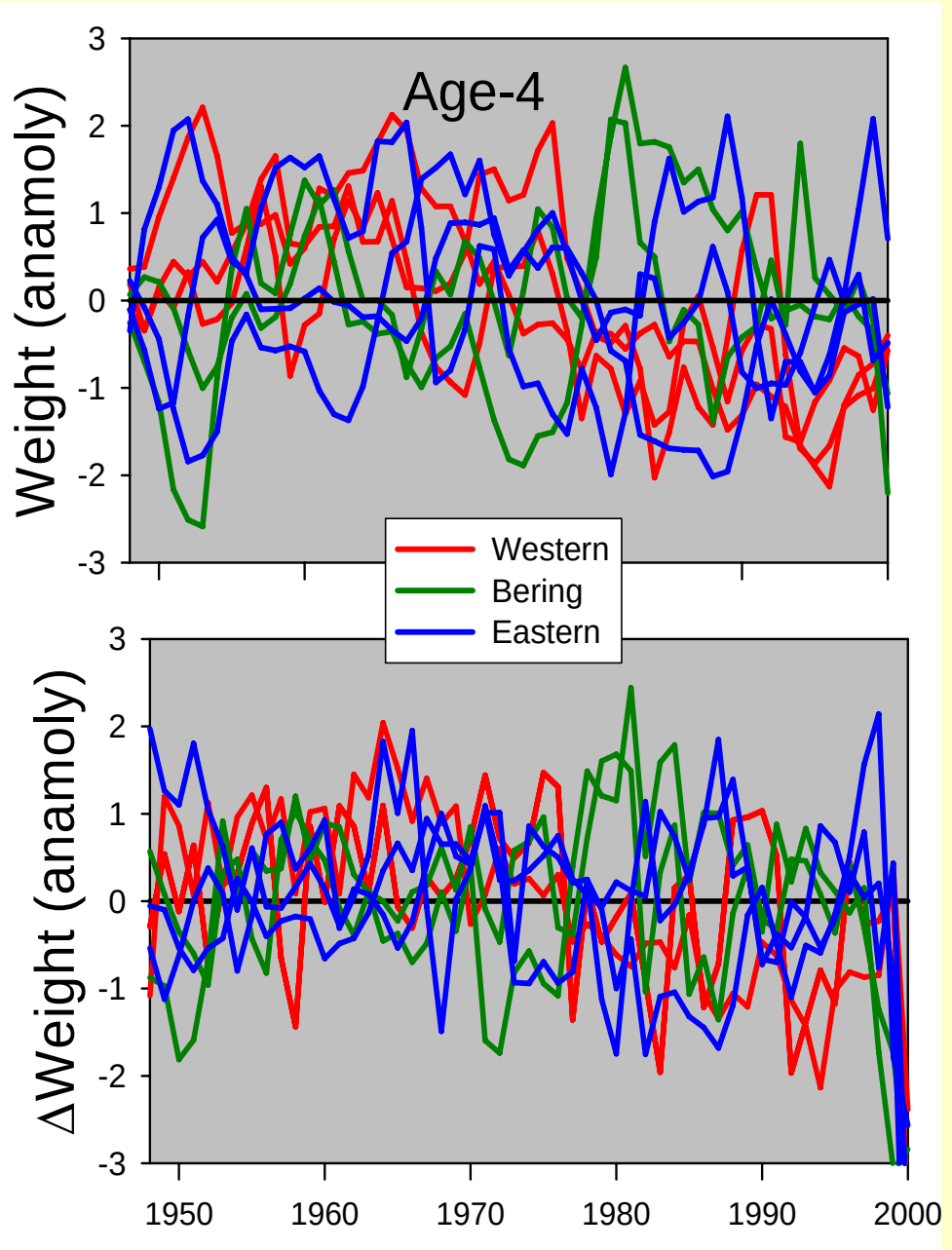
- Naumenko (2002) Report 20
- ADFG stock assessments
- Schweigert et al. (2004)
- Lassuy (1980)

Looking for Patterns by Region?

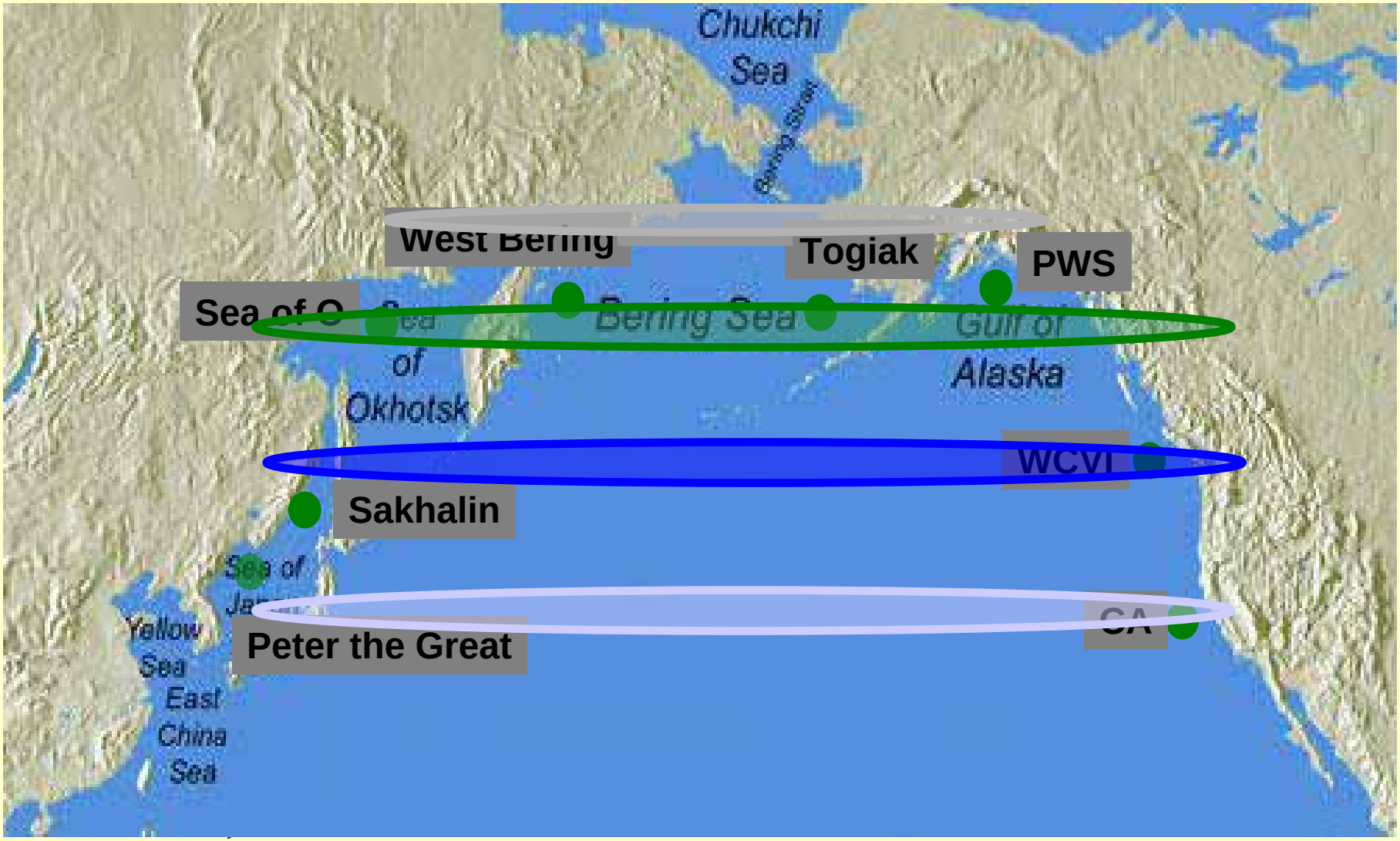


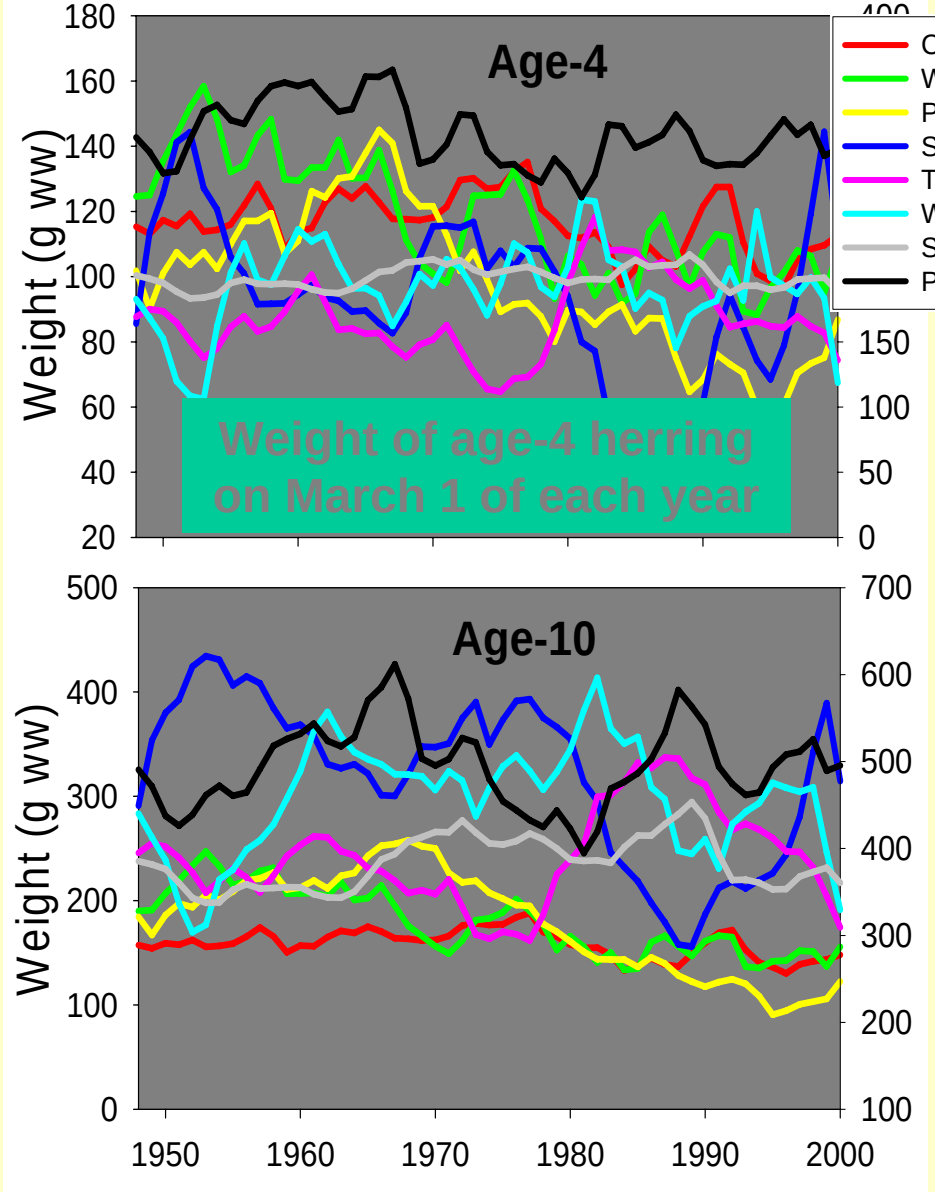
Geographic Differences?

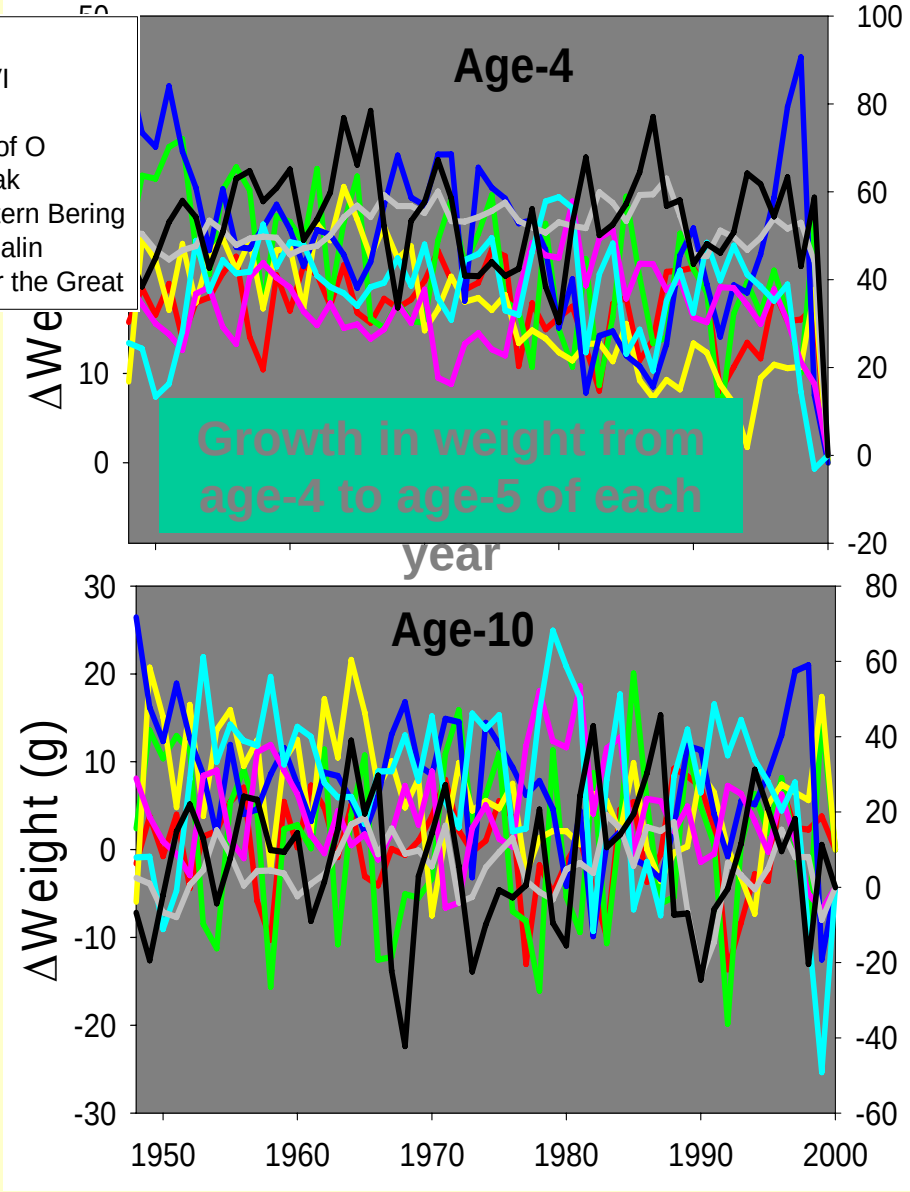
Nothing apparent in terms of trends or associations



Looking for Patterns by Latitude?

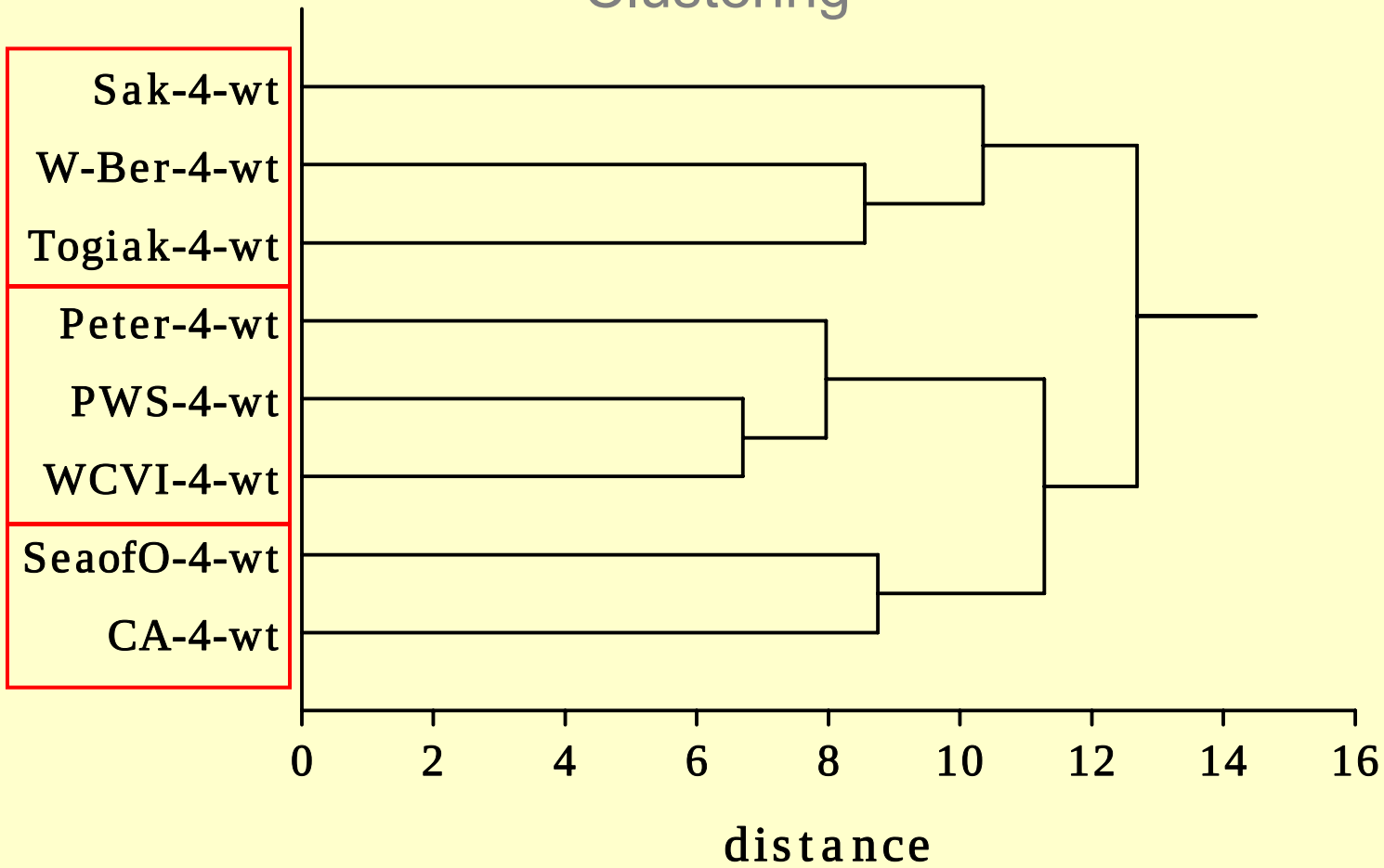






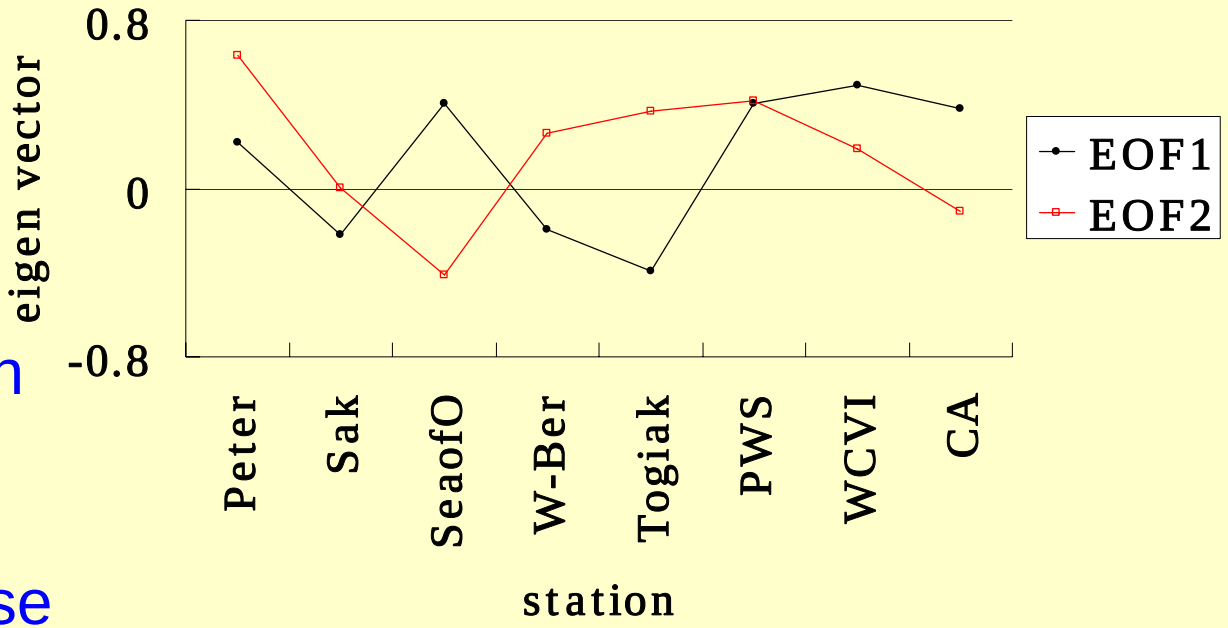
Quite messy and nothing apparent here as well

Desperately looking for patterns - Clustering

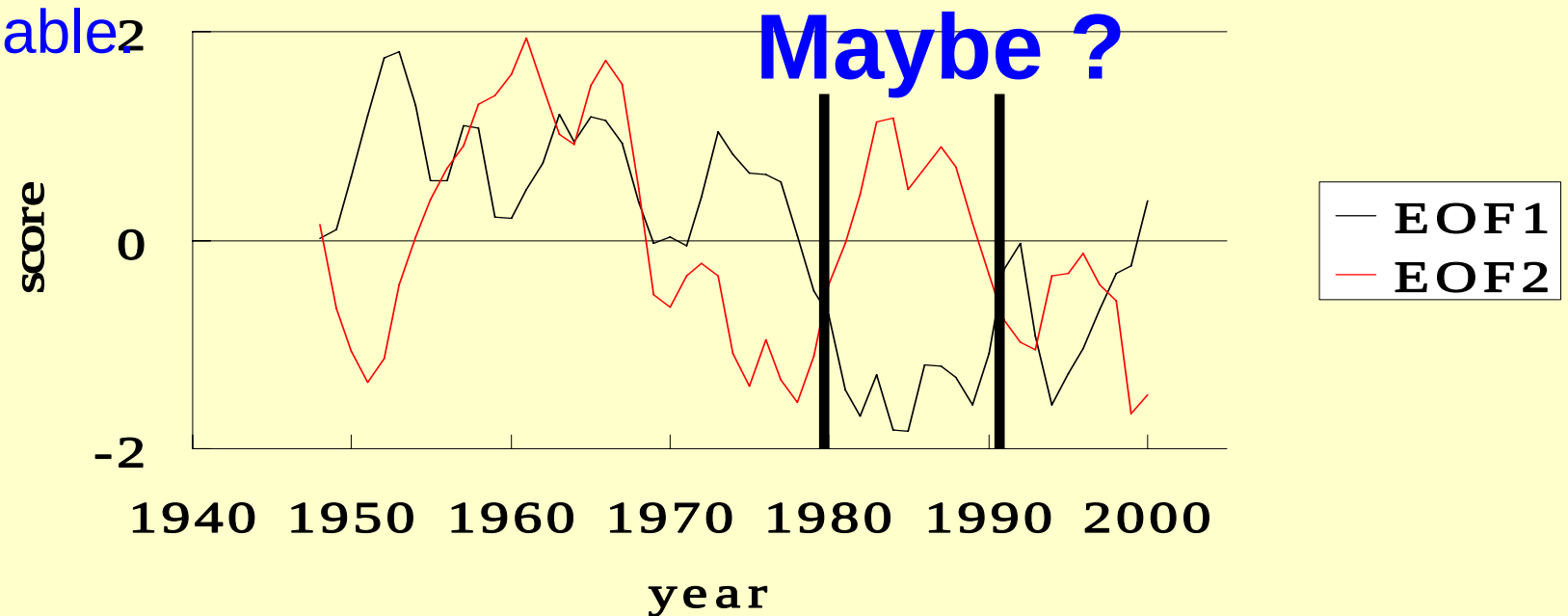


Use complete connection method with standardized Euclidian distance

Eigenvector
for wet weight
EOF1 38.1%
EOF2 19.4%



PCA analysis again showed opposing associations in the wet weight response variable



Climate Effects
Are they Top-Down, Bottom-up or Both?

- Climate affects the ecosystem from the bottom of the food web through climate signals passed through the LTL up to the HTL (i.e. changes in SST, MLD, nutrient flux, LTL productivity), or
- Top-down through climate influences on the UTL or the environment-dependent spawner recruit model that closes the life cycle.

Summary

- Within basin synchronies were detected but opposing associations were localized.
- Local associations were not always consistent
- Evidence of bottom-up ecosystem forcing
- Models like NEMURO.FISH are useful, especially when their predictions differ from known patterns and data
- Investigate additional climate change scenarios and perhaps global warming scenarios?