Zooplankton of the eastern & western subarctic Pacific:

Similarities in the face of strong decadal variability & contrasting mean environments

David L. Mackas
Fisheries & Oceans Canada
Institute of Ocean Sciences

Kazuaki Tadokoro
Institute of Oceanic Research & Development
Tokai University

Goal: updated overview of subarctic Pacific zooplankton ecology

- What we knew at the start of CCCC
- What we've learned during CCCC (especially from between-region and between-year comparisons)
- Some future directions

What we knew at the start of CCCC (1995-97)

<u>"Average"Zooplankton:</u>

- **Basin-scale distribution of biomass**
- **Dominant species and their distributions**
- **Seasonal life history (in a few places)**
- **Diet and predators (in a few places)**

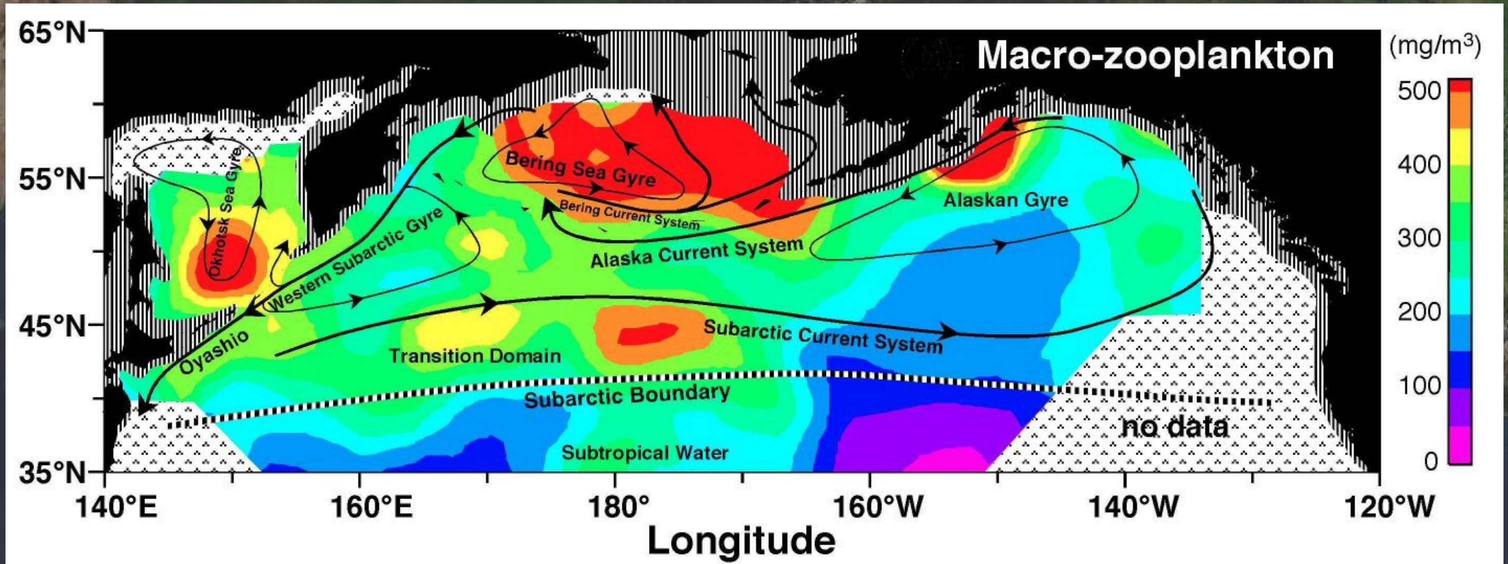
<u>"Average" environment:</u>

- **Water properties**
- **Mean circulation**
- **Seasonal cycles**
- **Contrasts East vs. West**

<u>Increasing awareness of:</u>

- **HNLC regions and Fe**
- **Climate variability (Regimes and ENSO)**
- **Climate trends and CO2**

Basin-scale distribution of total zooplankton biomass



Mean horizontal distribution of summer zooplankton biomass, 1956-1994

(Mackas & Tsuda 1999, original figure by K. Tadokoro)

- **Margins > Gyres; West > East**
- **~Follows distribution of primary productivity & chlorophyll**
- **North - South gradient changes with season (above is a summer picture)**

Lists of dominant zooplankton: "Short & Similar" in all deepwater areas

Always abundant:

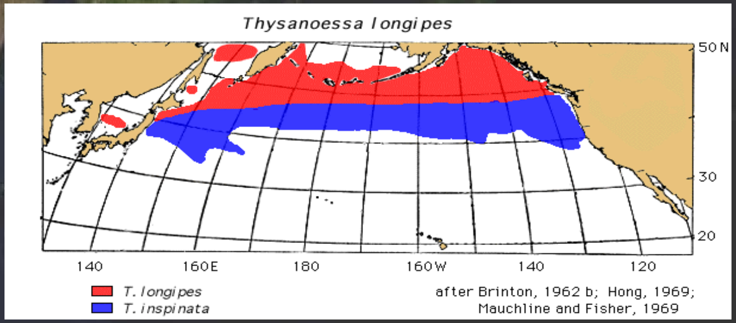
- "Interzonal" copepods
  (4 spp., 4-10mm)
- Smaller copepods
  (~6 spp., 0.5-3 mm)
- Euphausiids
  (1-3 spp., 1-3 cm)
- Chaetognaths
  (2 spp., 1-3 cm)

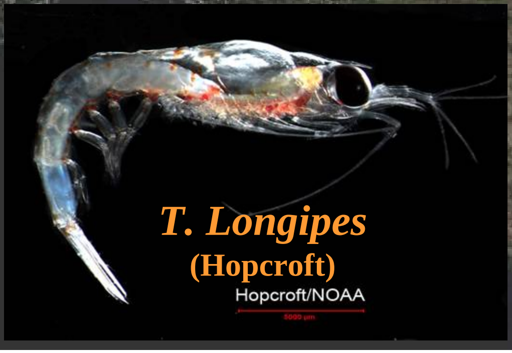
"Boom & Bust":

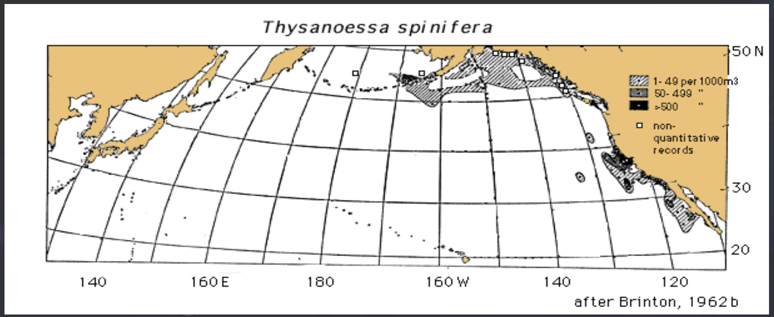
- Pteropods
  (2-3 spp.)
- Salps
  (2 spp.)
- Hyperiid Amphipods
  (1-3 spp.)
- Medusae & siphonophores
  (1-4 spp.)

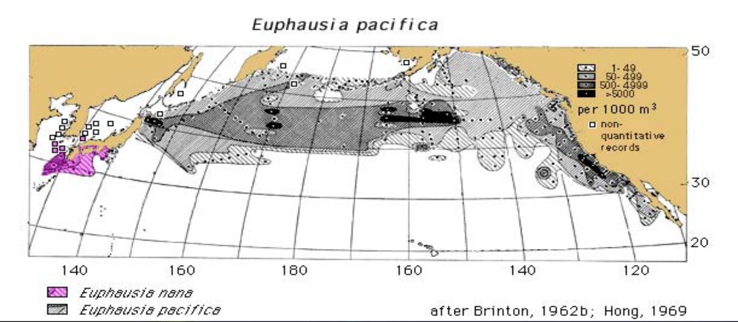
Dominant ‘oceanic’ species are trans-Pacific
Some ‘nearshore’ species restricted to E or W

Example: Euphausiids (Brinton, Nemoto, Mauchline)

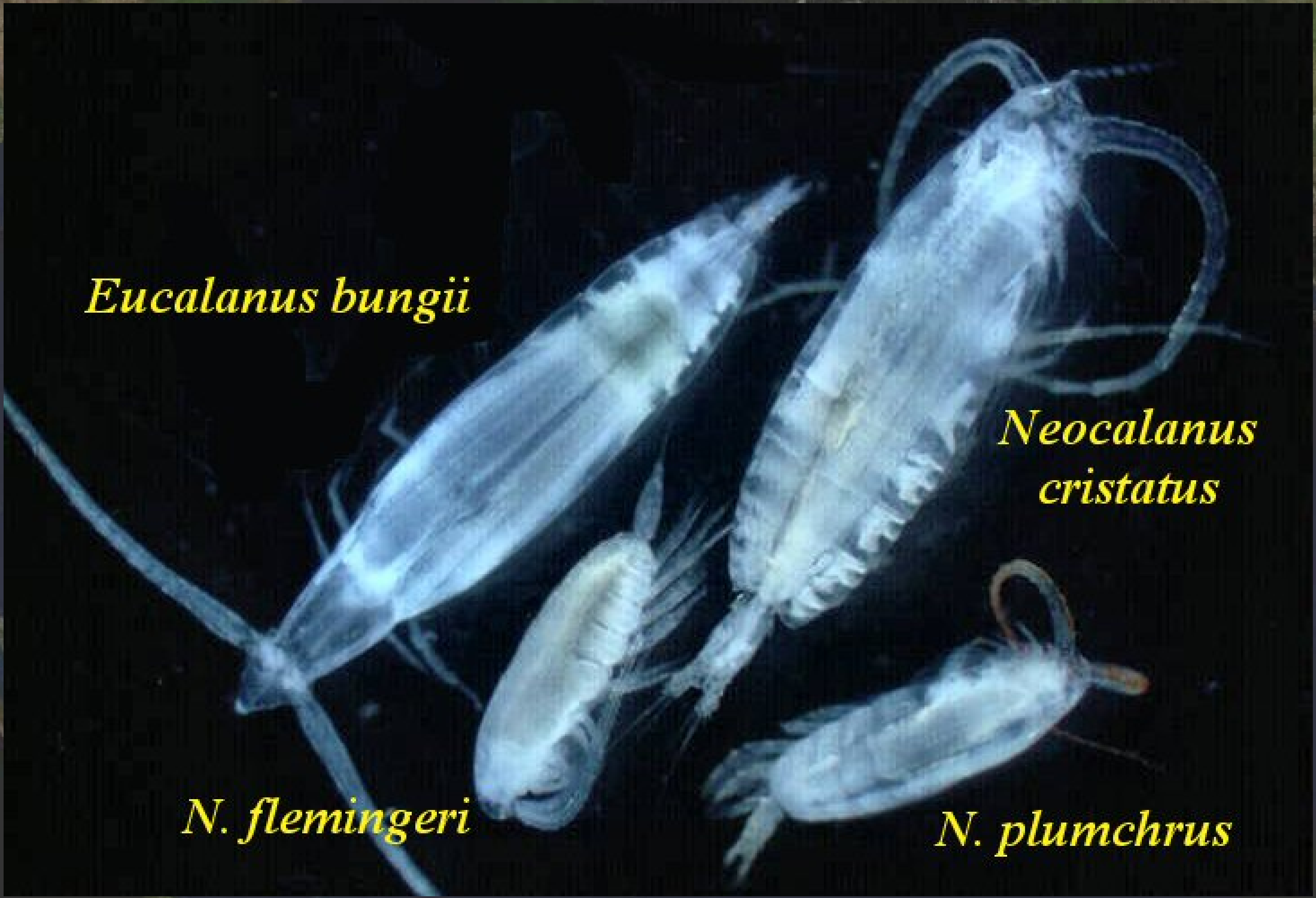






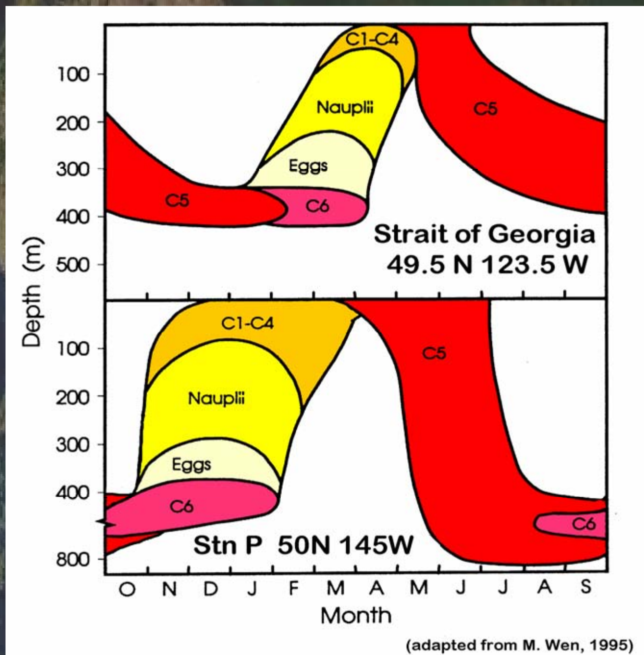


Interzonal migrant copepods: Dominate total biomass at all deep water locations in spring-summer

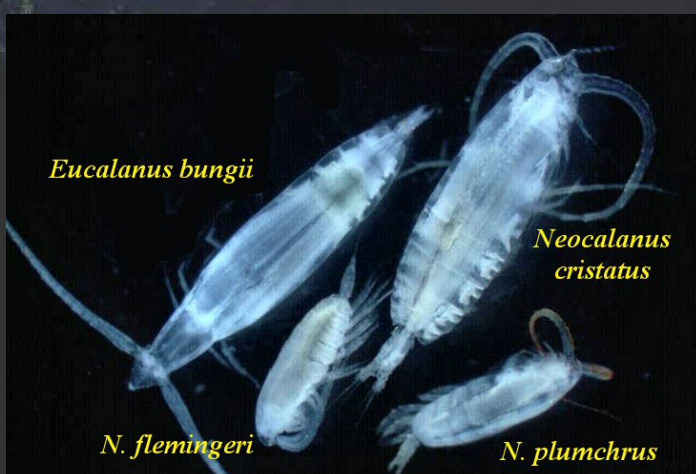


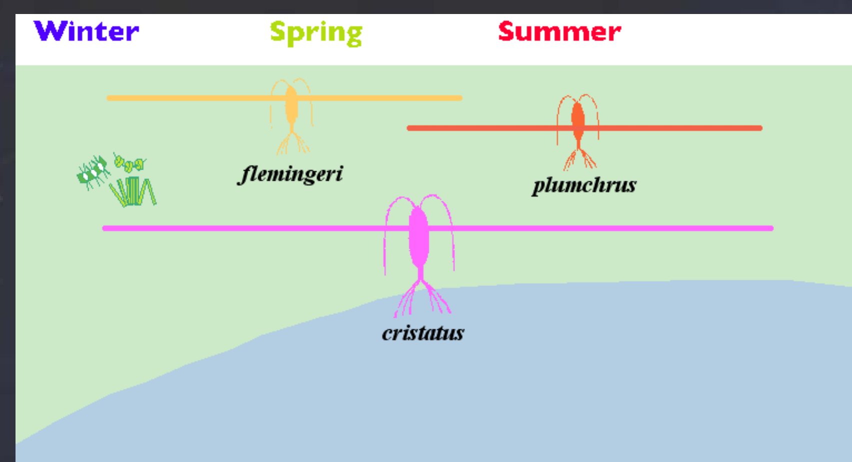
Interzonal copepods: distinctive life history

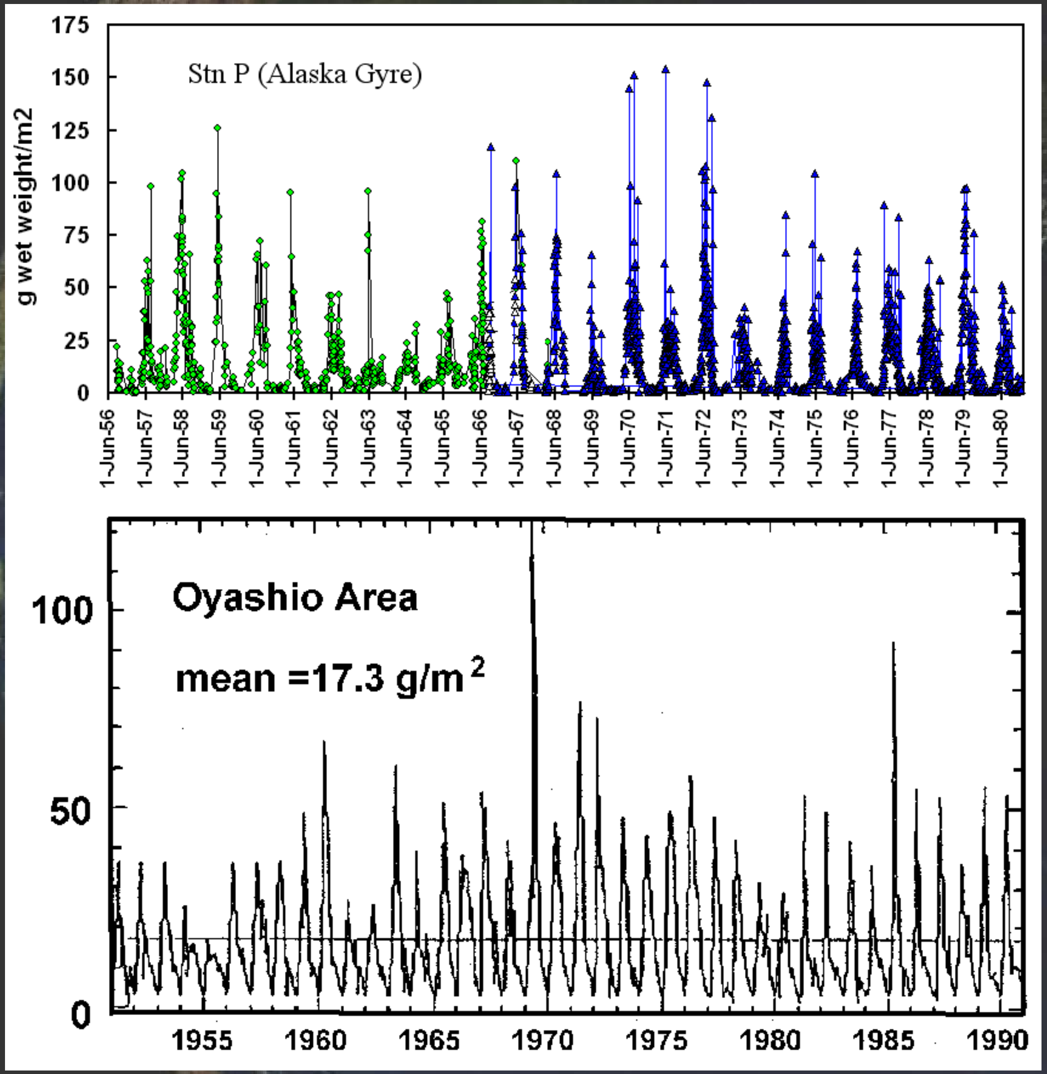
(C. Miller, J. Fulton, A.K. Geynrich)



- **Annual life cycle (usually)**
- **Prolonged & deep dormancy from summer-winter (timing & life-stage vary)**
- **Depth & time partition the upper ocean during growing season**







The life cycle of the interzonal copepods is a main driver of the strong seasonality of upper ocean zooplankton biomass

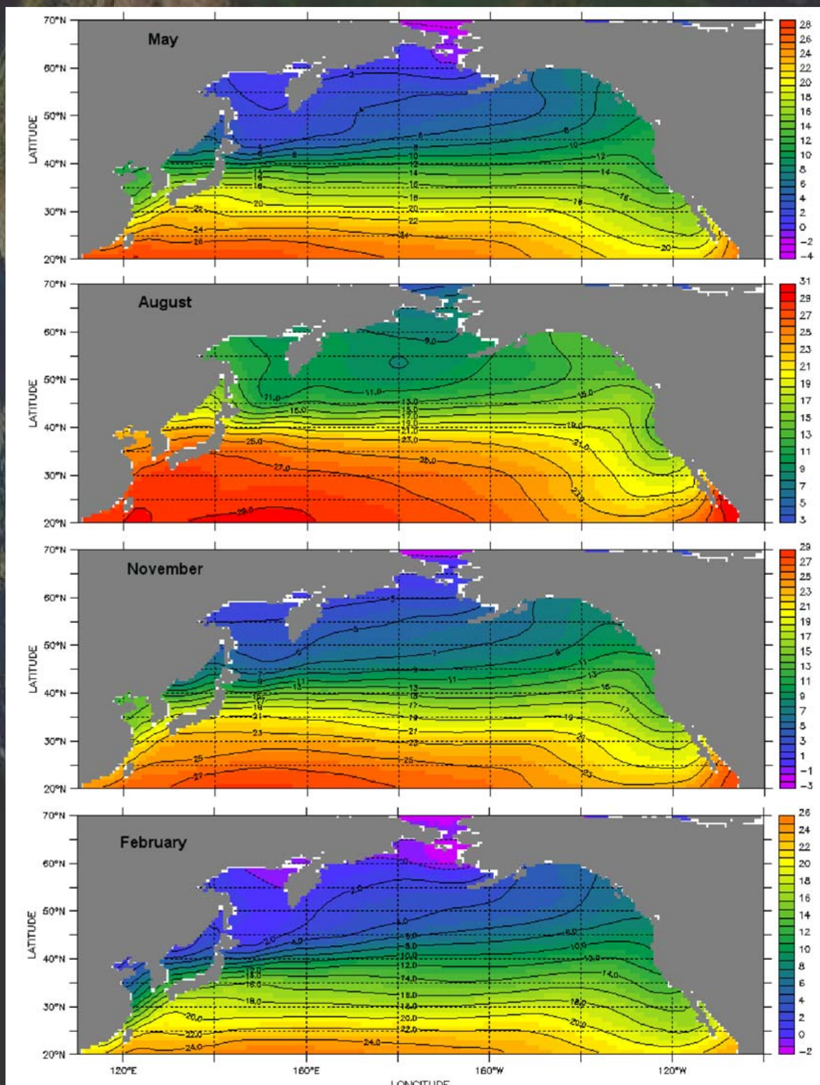
Diet & predators (vary with life stage, location & season)

Eat:
- Large phytoplankton (often unavailable)
- Microzooplankton
- Smaller mesozooplankton

(Dagg, Gifford, Nemoto, Brinton, others)

Eaten by:
- Other zooplankton
- Micronekton
- "Small" pelagic fish (including juvenile pink, chum & sockeye salmon)
- Whales & seabirds

Environment has strong E-W contrasts, despite E-W homogeneity of zooplankton

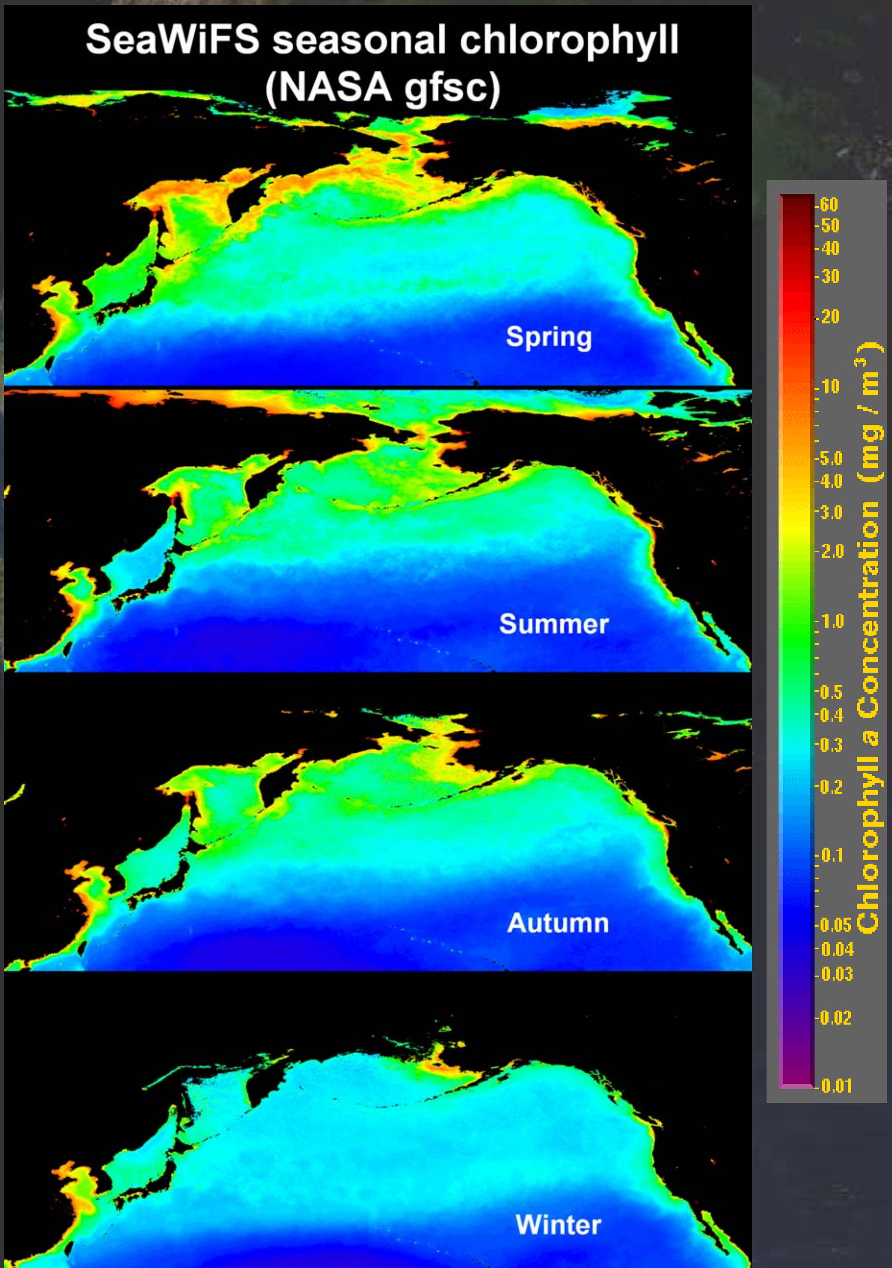


9. Climatological SST (deg C) (NOAA PFEL Live Action Server)

Western Subarctic Pacific surface ocean has:

- Colder T°C in winter
- Bigger seasonal range
- Much tighter N-S gradients, and
- Convergence of warm and cold currents

Strong environmental contrasts (continued)



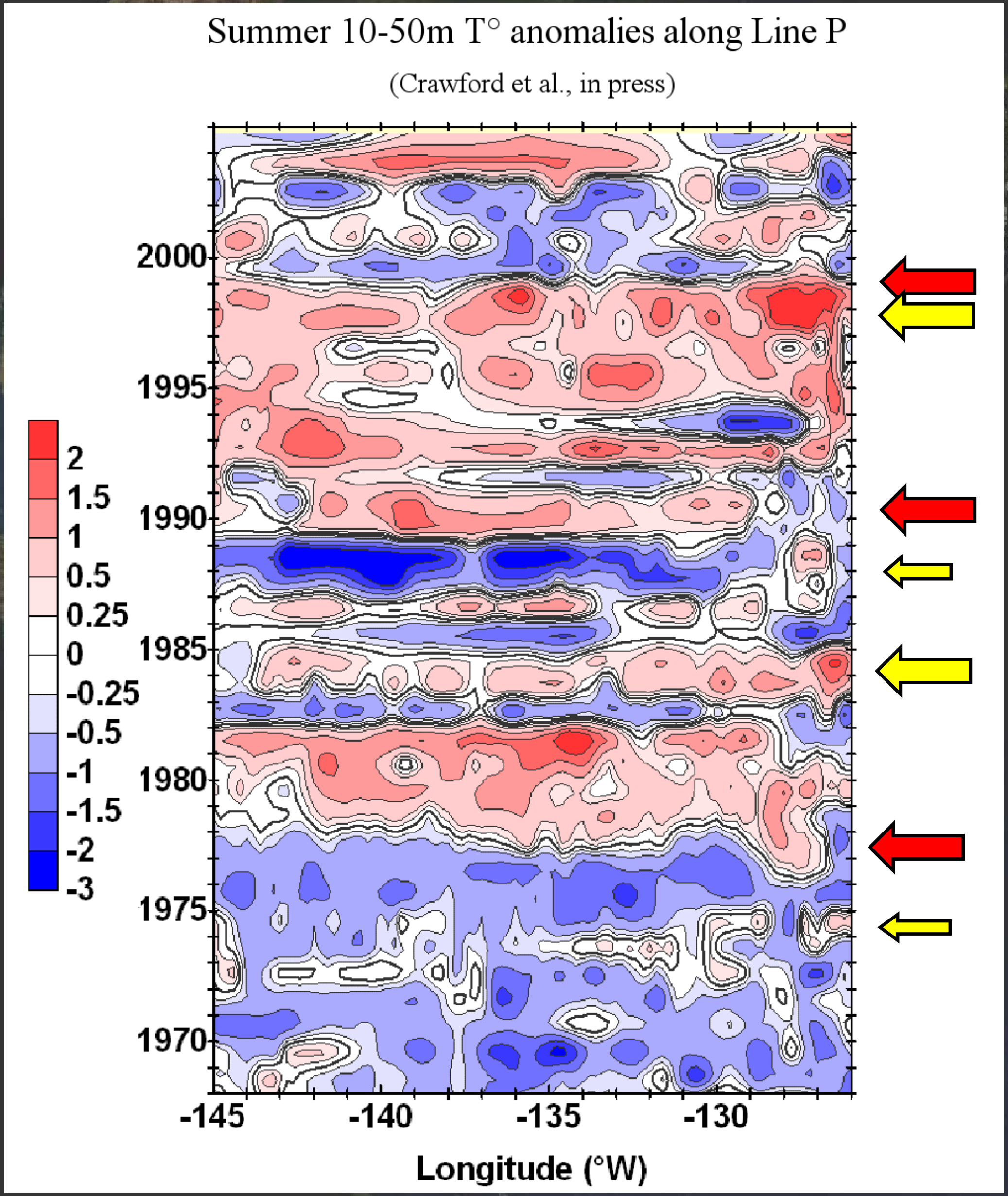
Chlorophyll & primary productivity are:

- Highest (by far) along margins
- Higher in subarctic than subtropics
- Higher in western than eastern subarctic

Causes:

- Proximity to land sources of Fe and Si
- Depth of winter mixing
- Timing of spring stratification
- Eddies & upwelling

Strong interannual variability



Three dominant time scales:

- **1-2 year ENSO**
- **Shifts between more prolonged warm/cool 'regimes'**
- **Overall warming trend**

Questions and motivations:

Q. How is spatial homogeneity and interannual-to-decadal stability of the subarctic Pacific zooplankton maintained?

A1. It isn't, entirely:

- Large interannual variability of total biomass & ranking among dominant species
- Life cycles, growth patterns & distributions are more plastic than previously realized

A2. Important clues about resilience and its limits

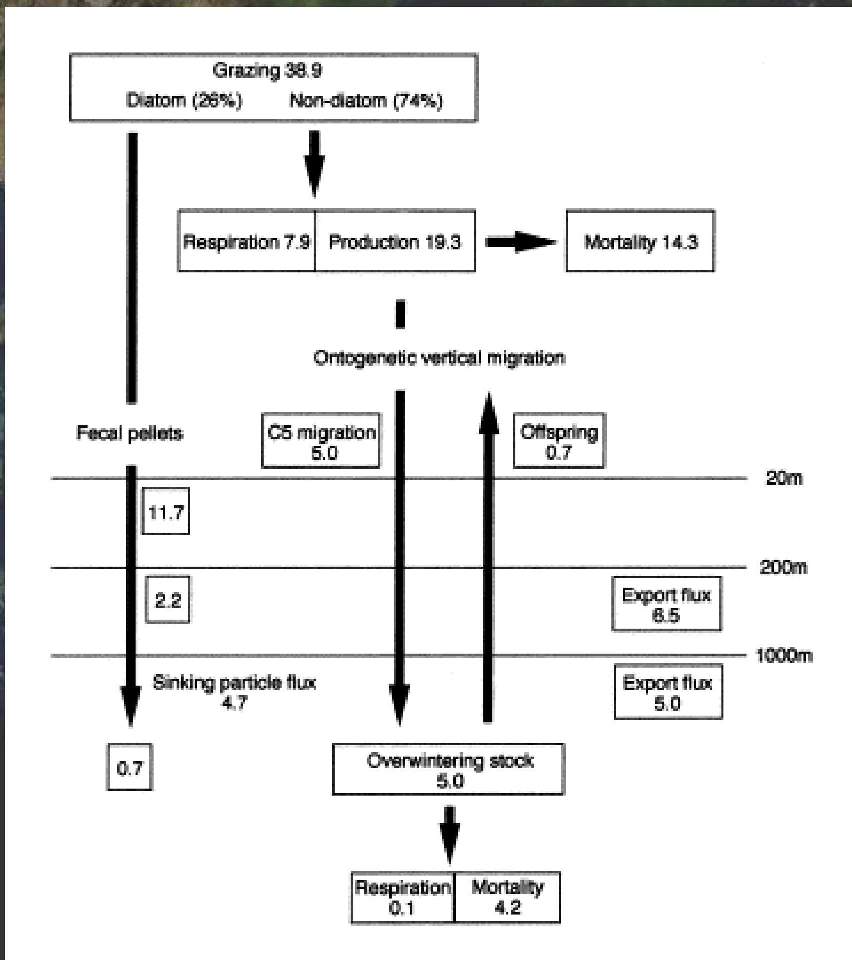
What have we learned about zooplankton during CCCC??

- Role in biogeochemical cycles & food webs of HNLC and coastal regions
- Low-frequency variability of biomass (“how much”)
- Natural history of many more taxa.
- Within-species variability of body size
- Within-species variability of phenology (“when”?)
- Changes in community composition (“who”?)
- A start on between-region comparisons of time series

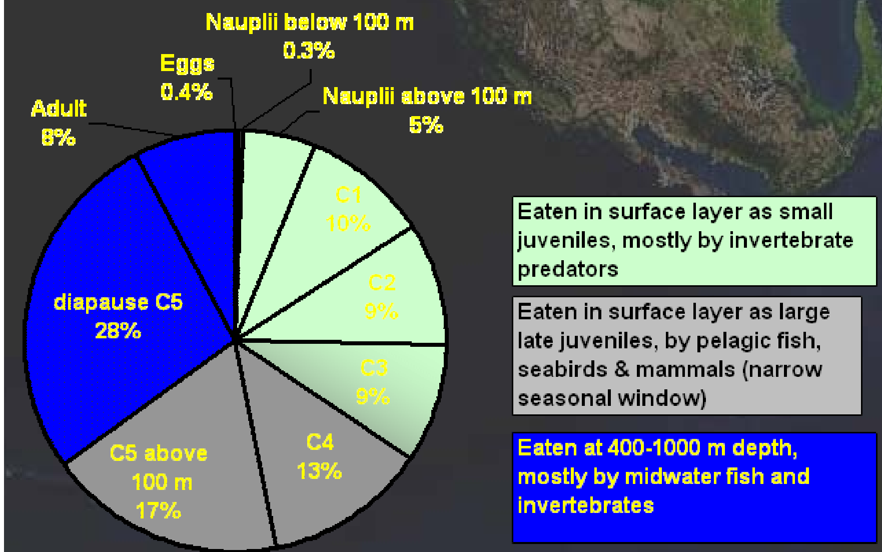
Biogeochemistry and “export” of zooplankton biomass

- 2 major iron enrichment experiments in HNLC subarctic (SEEDS, SOLAS/SERIES)
- Studies of exchange between margins and deep basins (JGOFS, GLOBEC, Eddies)

Interzonal copepods are large contributors to Carbon Pump & to nutrition of mesopelagic zone



Kobari et al. (2003)



Mackas & Tsuda (1999)

Variability of total biomass

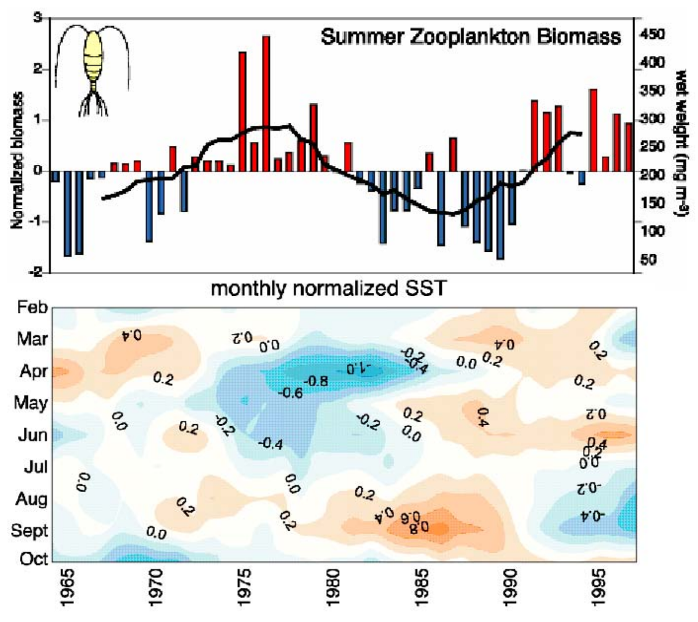
- Research started before CCCC (Brodeur & Ware 1992, Roemmich & McGowan 1995, Sugimoto & Tadokoro 1998)
- But <u>much</u> more has been published recently
- Time series from ocean margins tend to be more interpretable, because more frequent sampling reduces aliasing of seasonal cycle.

Zooplankton biomass variability:

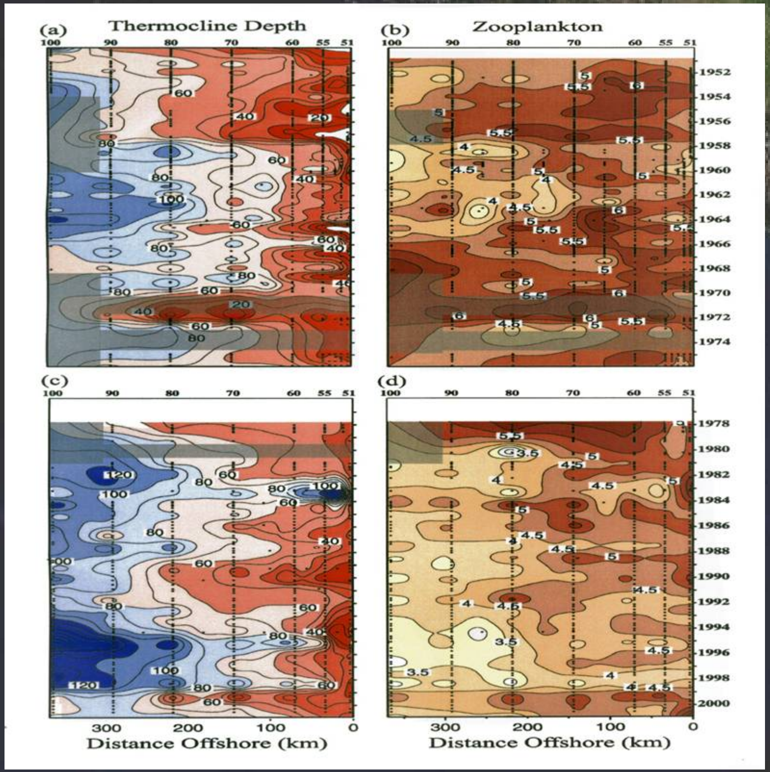
Amplitude - 3 to 5 fold range

Important time scales: interannual, ‘regimes’, ‘climate trend’

Covariance with physics/climate (& ‘*fish*’)



Oyashio region, Chiba 2005



California Current
McGowan et al 2003

Does more detailed zooplankton biology provide additional insights?? Yes!!

Elements:

Body size variation

- development rate and nutrition

Life cycle timing

- match-mismatch with changing seasonality
- match-mismatch with prey & predators

Community composition & distribution shifts

- valuable tracer of movement and origin
- what works & what doesn’t under differing environmental regimes

Now know the life history (distribution, diet & timing) of many more taxa.

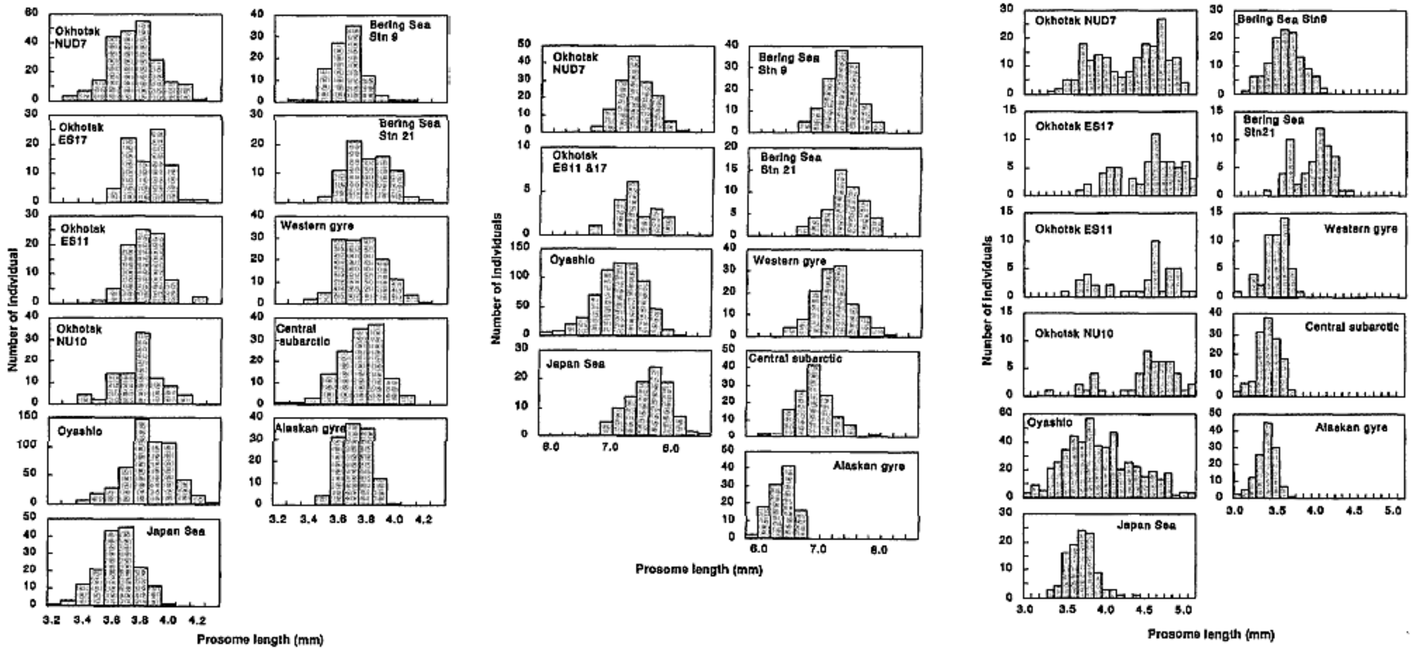
Praise our Japanese colleagues (especially Hokkaido University!!):

- Ikeda, Kobari, Tsuda, Saito, Yamada, Kaeriyama, Ozaki, Yamaguchi, Padmavati, Iguchi, Terazaki, Kotori, …..

North Pacific regions developing ‘rich’ time series

Body size, temperature, nutrition and development rate

Variation of body size



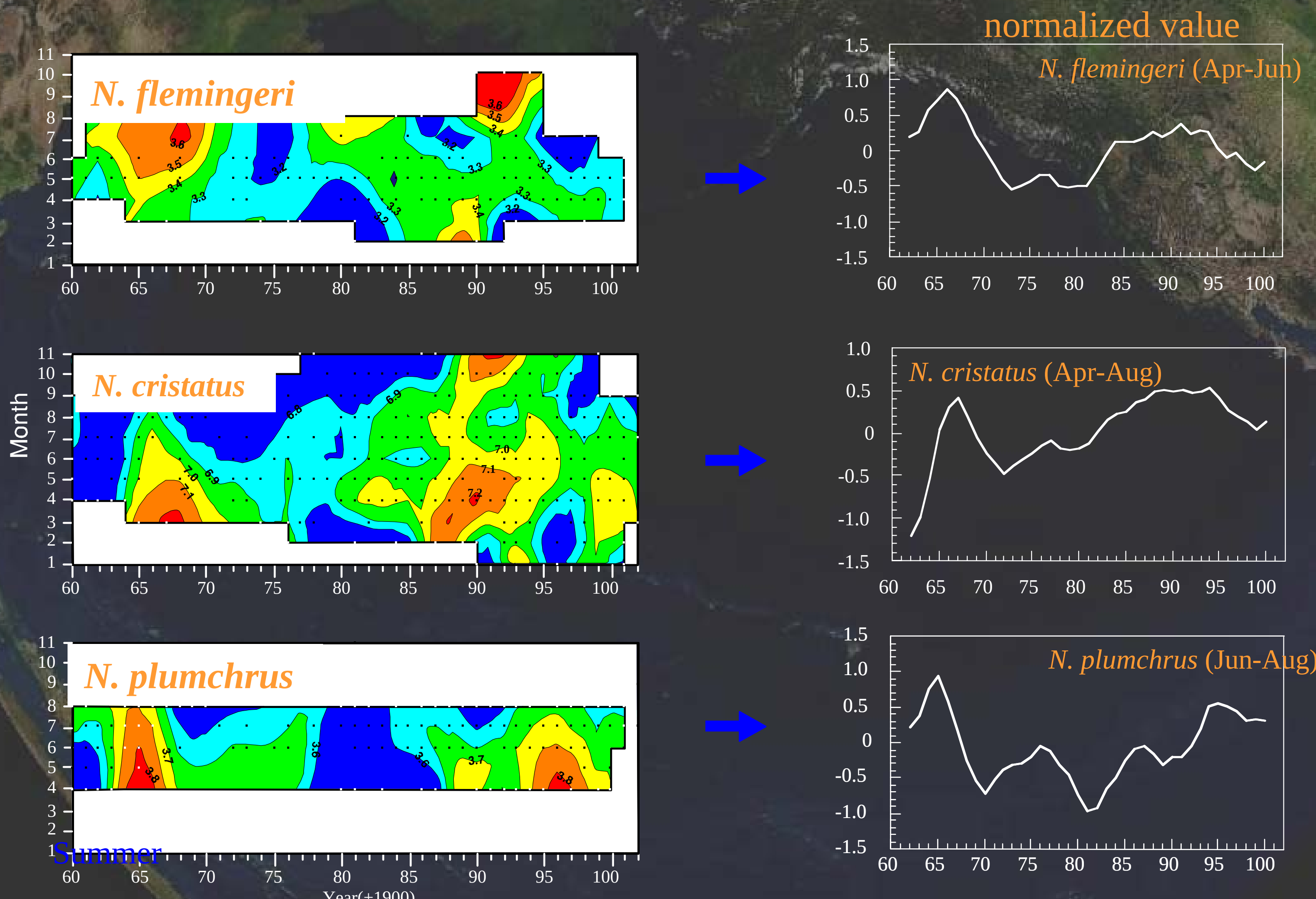
N. plumchrus *N. cristatus* *N. flemingeri*

(Tsuda, Saito & Kasai, 2001)

- Size mostly unimodal within species & region, but *N. flemingeri* is bi-modal in west and north
- Larger *N. flemingeri* size is associated with a biennial life cycle and two dormant periods
- Genetic? Controlled by within-year environment?

Interannual variation of body size

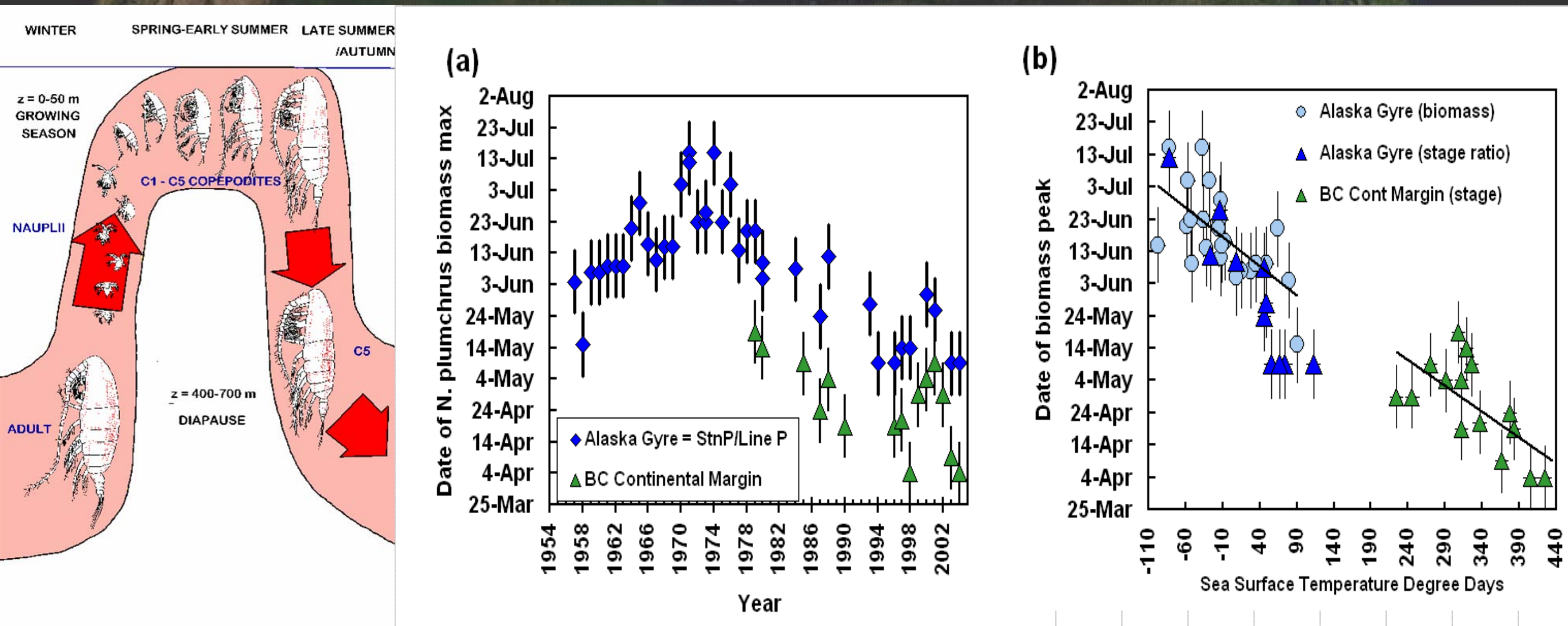
(since pioneering work by Miller et al., Kobari & Ikeda)



Tadokoro et al. (2005)

Phenology (seasonal phasing of development)

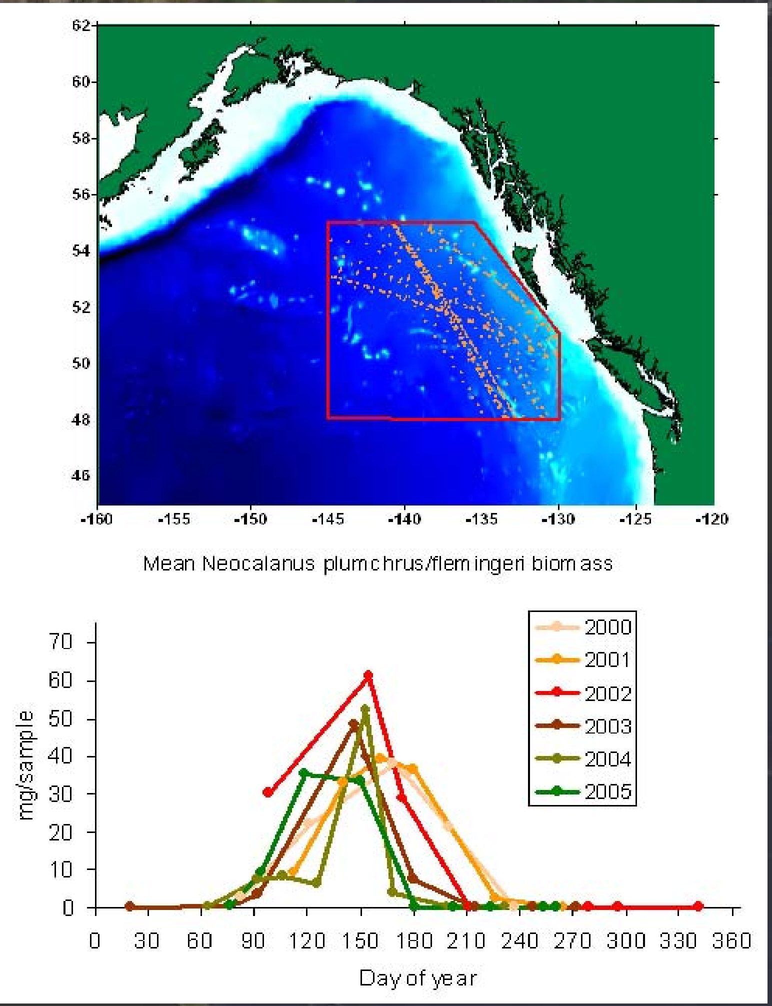
Variation of life cycle timing: 1-2 month variation in seasonal peak biomass in eastern subarctic



- **Narrow annual biomass peak in the subarctic Pacific coincides with peak abundance of C4-C5 *Neocalanus plumchrus***
- **Earlier in years with earlier & stronger thermal stratification**
- **Match-mismatch implications for seasonal planktivores**

Mackas Batten & Trudel (2006)

Timing anomalies are correlated over much of the Alaska Gyre



- **N Pacific Continuous Plankton Recorder surveys began in 1997**
- **CPR data show a S⇒N progression of *Neocalanus* development (Batten et al 2003)**
- **Interannual anomalies are superimposed on the spatial trend, and are coherent over a large area**

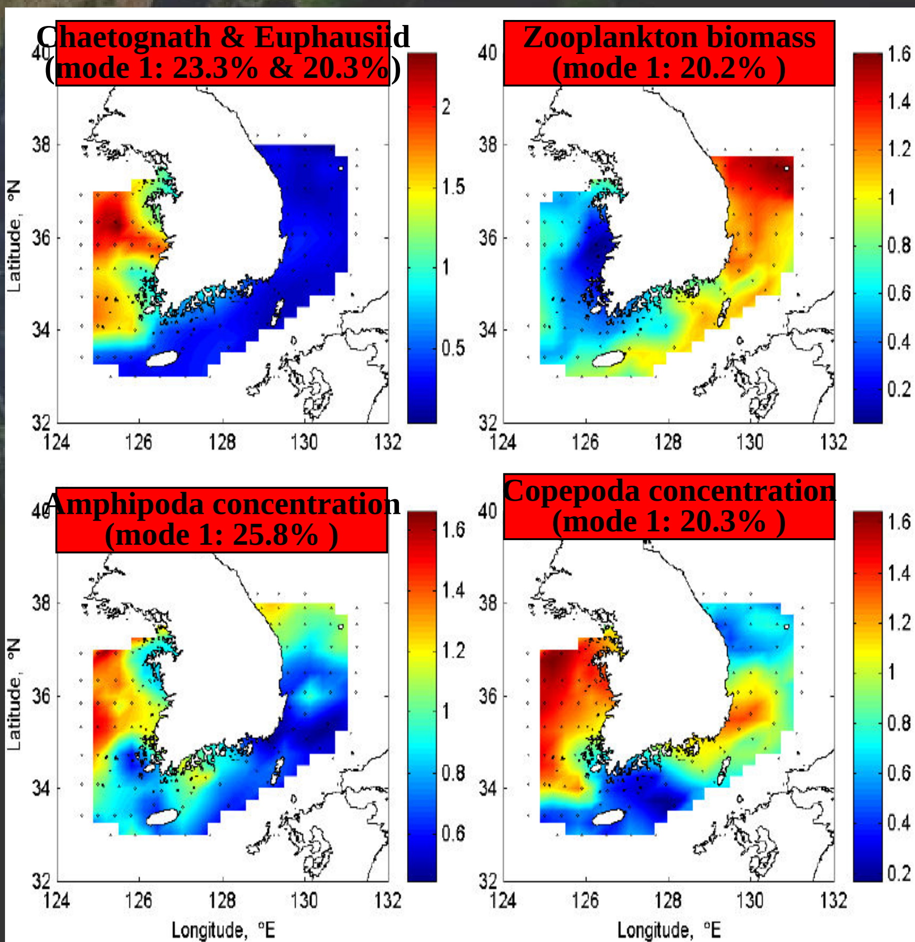
Batten et al. 2003; Mackas Batten & Trudel 2006

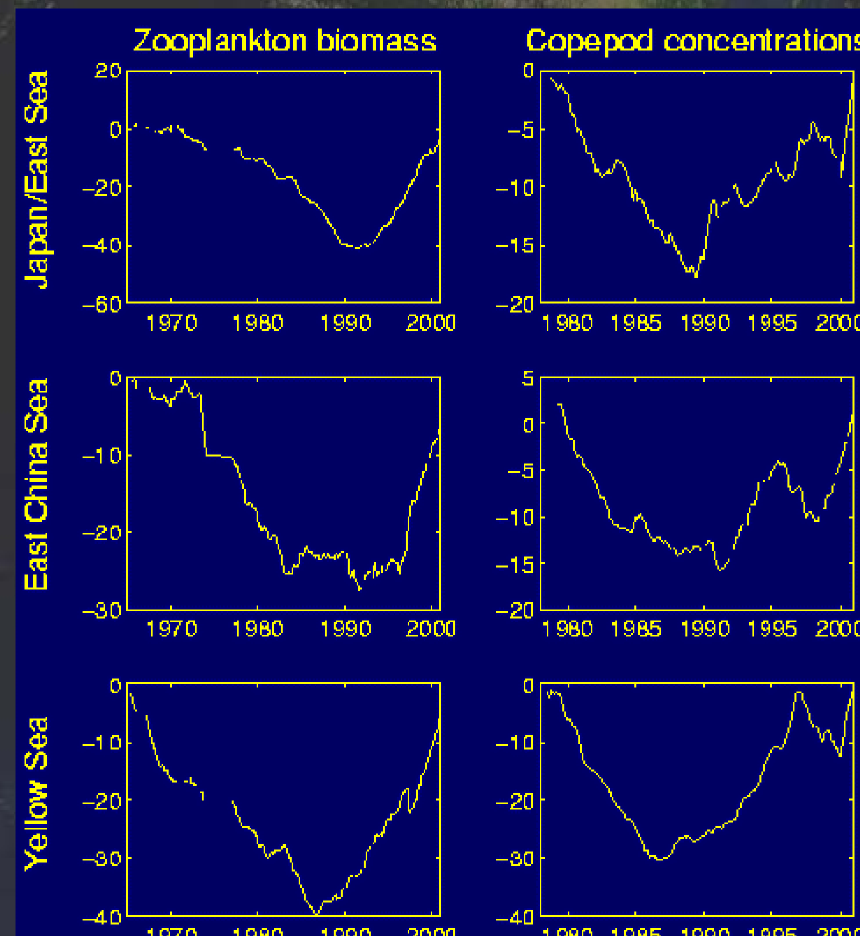
Changes in species composition & LME-scale spatial comparisons

1. Korean coastal regions (3 seas)

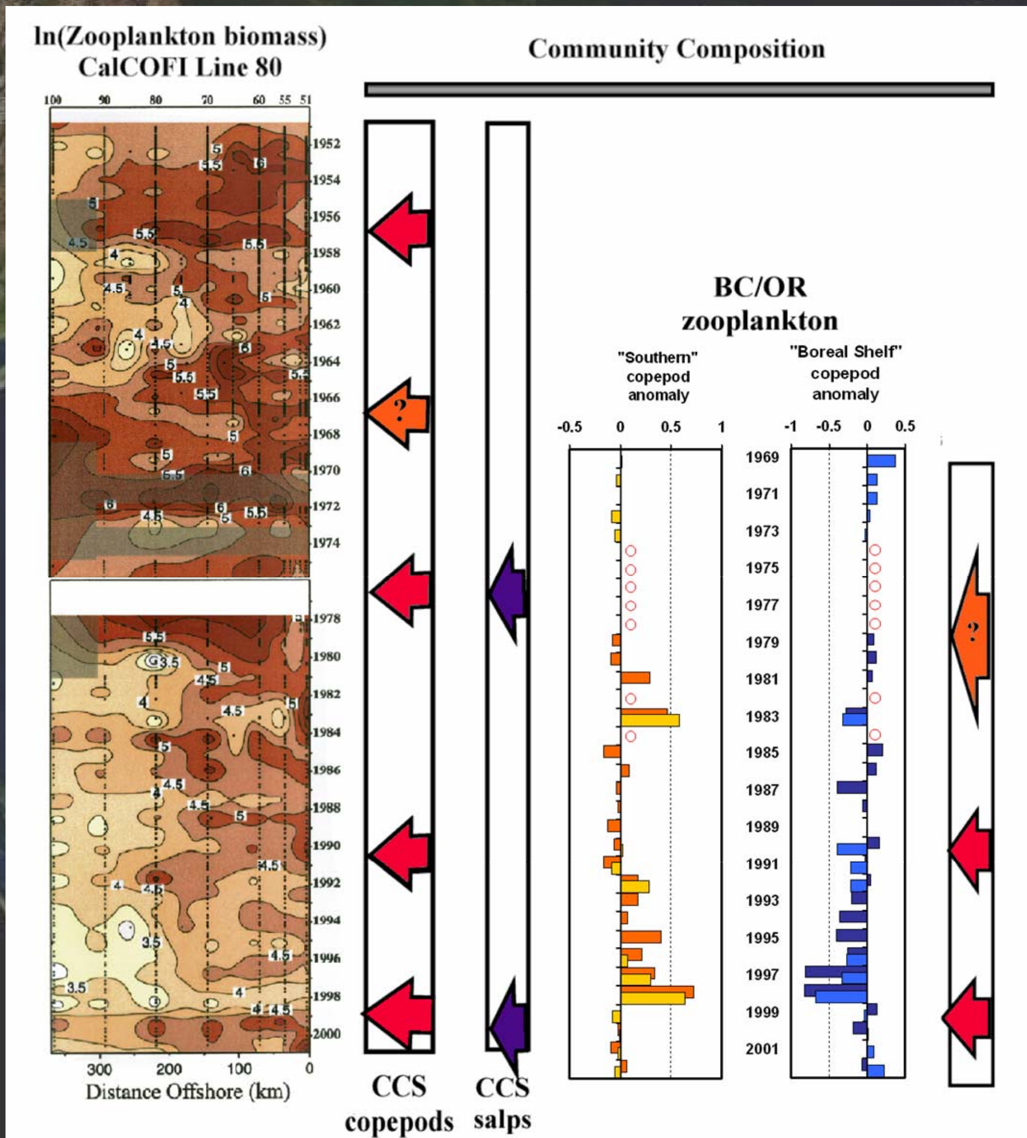
(from Rebstock & Kang 2005)

At decadal time scale, all 3 regions and several taxa share similar timing of highs and lows





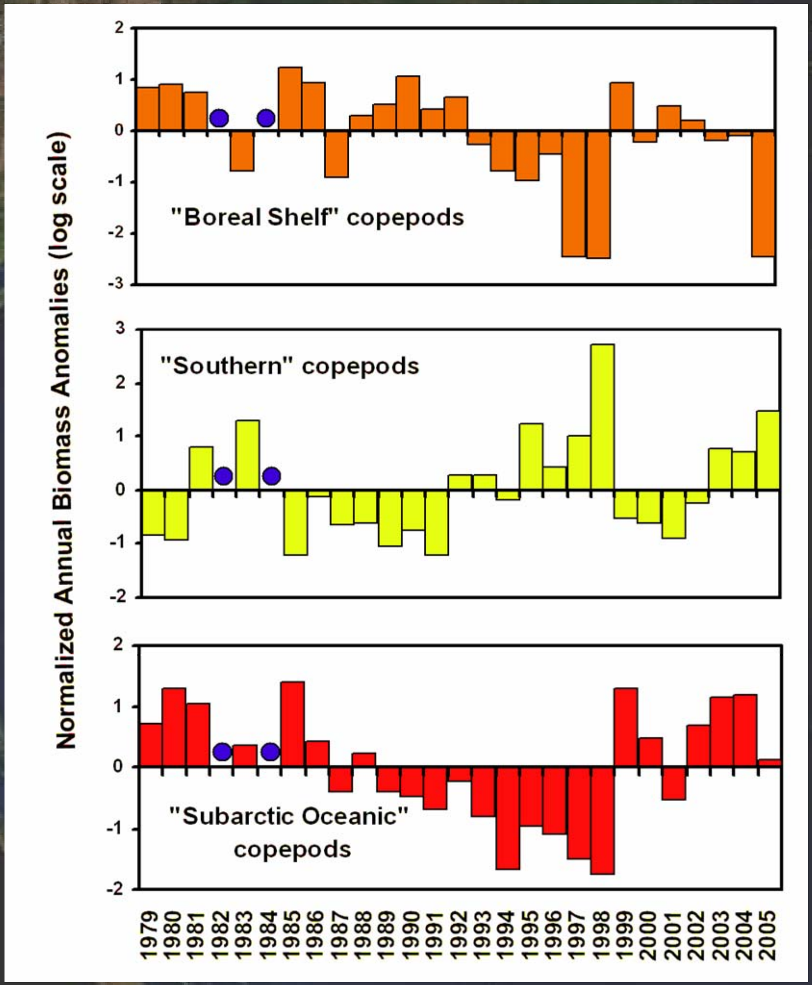
2. California Current System



- Δs in total biomass (left) often coincide with Δs in species mix (right)
- Both data types suggest strong Δs ~ 1958, 1976, 1990, 1999
- Alongshore correlation scale for species mix is ~600-800 km (Oregon to Vancouver Island)

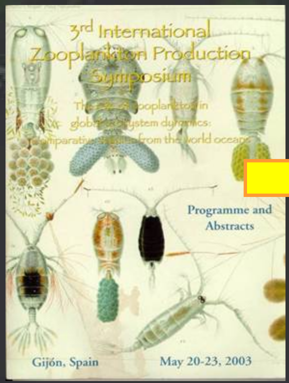
King et al 2005 (PICES Regime Shift AP); Mackas 2006

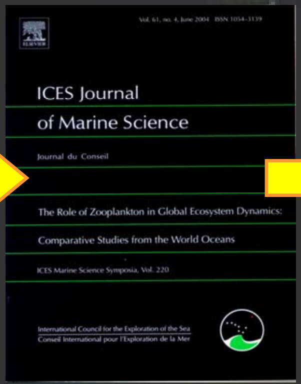
Update on Northern Calif. Current (BC & OR)



- The post-1999 “cool regime” began to decay in 2003
- By 2005, water properties and zooplankton look much like 1997-1998 (but without major ENSO forcing)

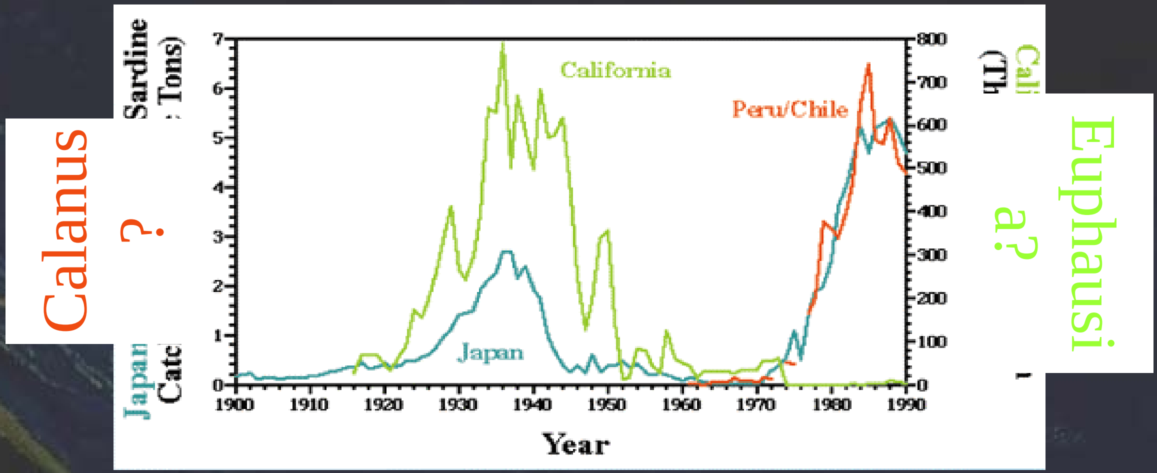
Correlation & synchrony at larger scales?? Do zooplankton mimic sardines & anchovies (or vice versa)?



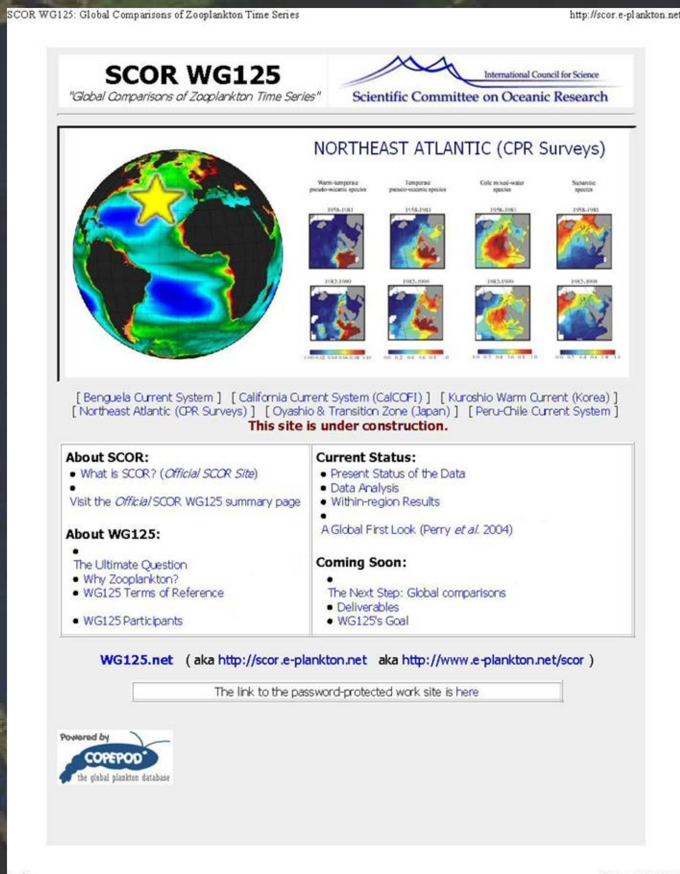



Identifying global synchronies in marine zooplankton populations: issues and opportunities

(Perry, Batchelder et al. 2004)



⇒ New SCOR Working Group
"Global comparison of zooplankton time series"


SCOR WG125: Global Comparisons of Zooplankton Time Series http://scor.e-plankton.net/

SCOR WG125
"Global Comparisons of Zooplankton Time Series"

International Council for Science
Scientific Committee on Oceanic Research

NORTHEAST ATLANTIC (CPR Surveys)

[Benguela Current System] [California Current System (CalCOFI)] [Kuroshio Warm Current (Korea)]
[Northeast Atlantic (CPR Surveys)] [Oyashio & Transition Zone (Japan)] [Peru-Chile Current System]
This site is under construction.

About SCOR:
- What is SCOR? (*Official SCOR Site*)
- Visit the *Official* SCOR WG125 summary page

About WG125:
- The Ultimate Question
- Why Zooplankton?
- WG125 Terms of Reference
- WG125 Participants

Current Status:
- Present Status of the Data
- Data Analysis
- Within-region Results
- A Global First Look (Perry *et al.* 2004)

Coming Soon:
- The Next Step: Global comparisons
- Deliverables
- WG125's Goal

WG125.net (aka http://scor.e-plankton.net aka http://www.e-plankton.net/scor)

The link to the password-protected work site is here

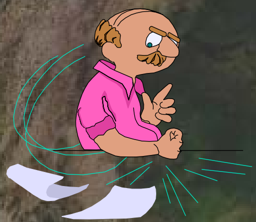
Powered by COPEPOD the global plankton database

1 of 1 31 Mar 2006 15:26

Formed early 2005

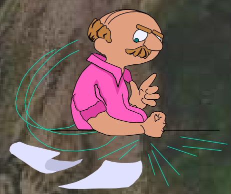
Members from PICES :

- H. Batchelder
- D. Checkley
- S. Chiba
- Y-S. Kang
- D. Mackas (co-chair)
- M. Ohman



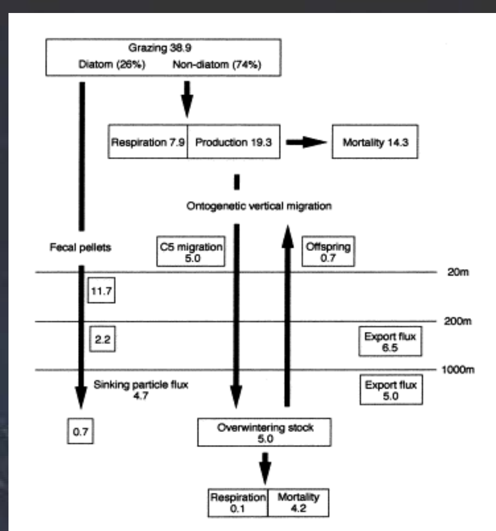
My own very preliminary "synthesis" of WG125 (will evolve):

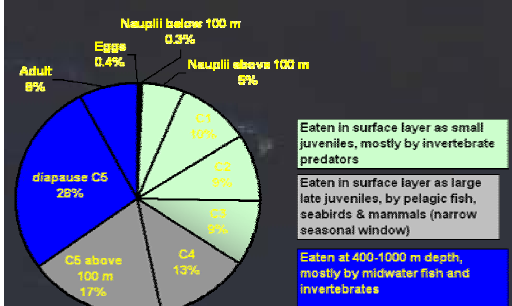
1. Scale of zooplankton spatial correlation (distance over which a similar 'change' occurs at a similar time) is proportional to event duration
2. For 5-20 year time scale the correlation length is ~1000 km
3. 'Synchrony' scale ('change' of differing variables, but similar duration and onset timing) may be trans Pacific, but probably not global

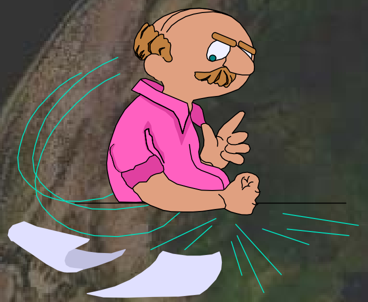


Other FUTURE directions??

The mesopelagic zone as over-winter food store: Links between interzonal zooplankton, mesopelagic micronekton, and pelagic predators

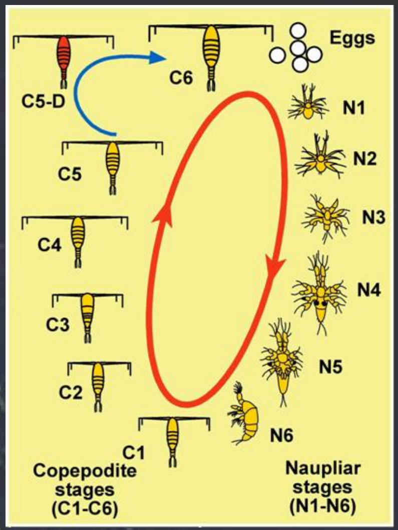




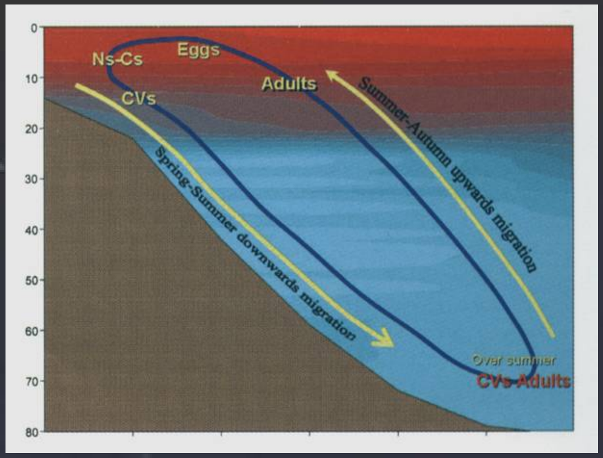


Other FUTURE directions??

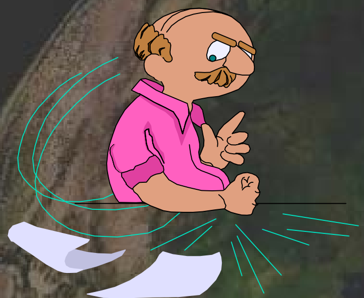
Constraints and plasticity of a multi-stage life cycle, in which each stage has different opportunities and risks



deYoung et al 2005



S.Song 2005



Other FUTURE directions??

Broader application in zooplankton research of ‘Bakun Triad’ concepts (Bakun 1996)

Finis