Fluctuations vs. Trend: What is driving changing zooplankton biomass, zoogeography, and community dominance?

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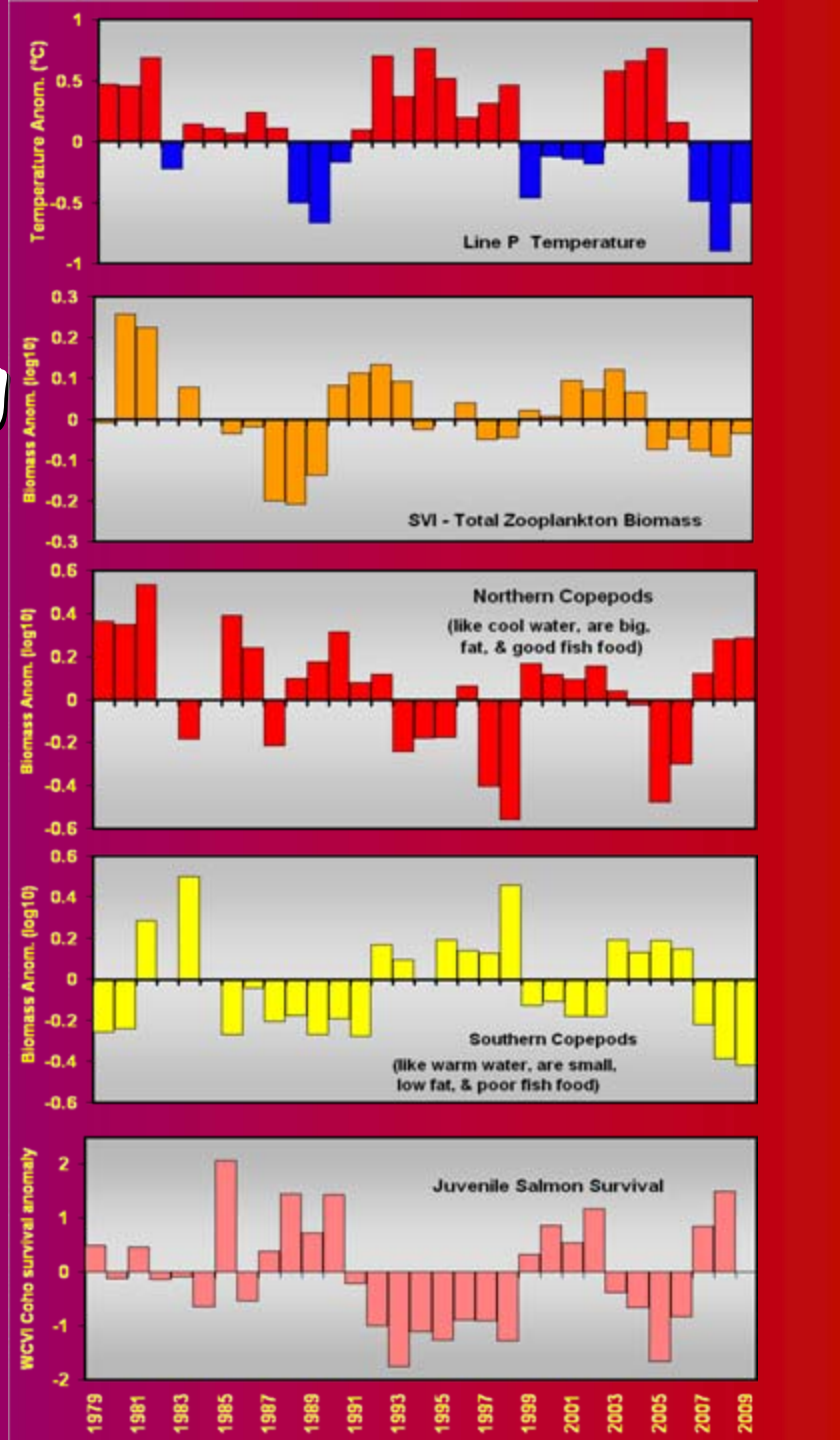


Main points for today:

- Existing zooplankton time series clearly show climate-linked 'regime' fluctuations
- BUT cumulative 'global warming' is nearing the observed range of 'regime' fluctuations
- AND many climate indices filter out 'trend' component of environmental variability
- AND (at least in NE Pacific) zooplankton community composition anomalies link strongly to fish growth & survival
- Relative amplitudes of fluctuation vs trend differ among taxa (and also among regions)

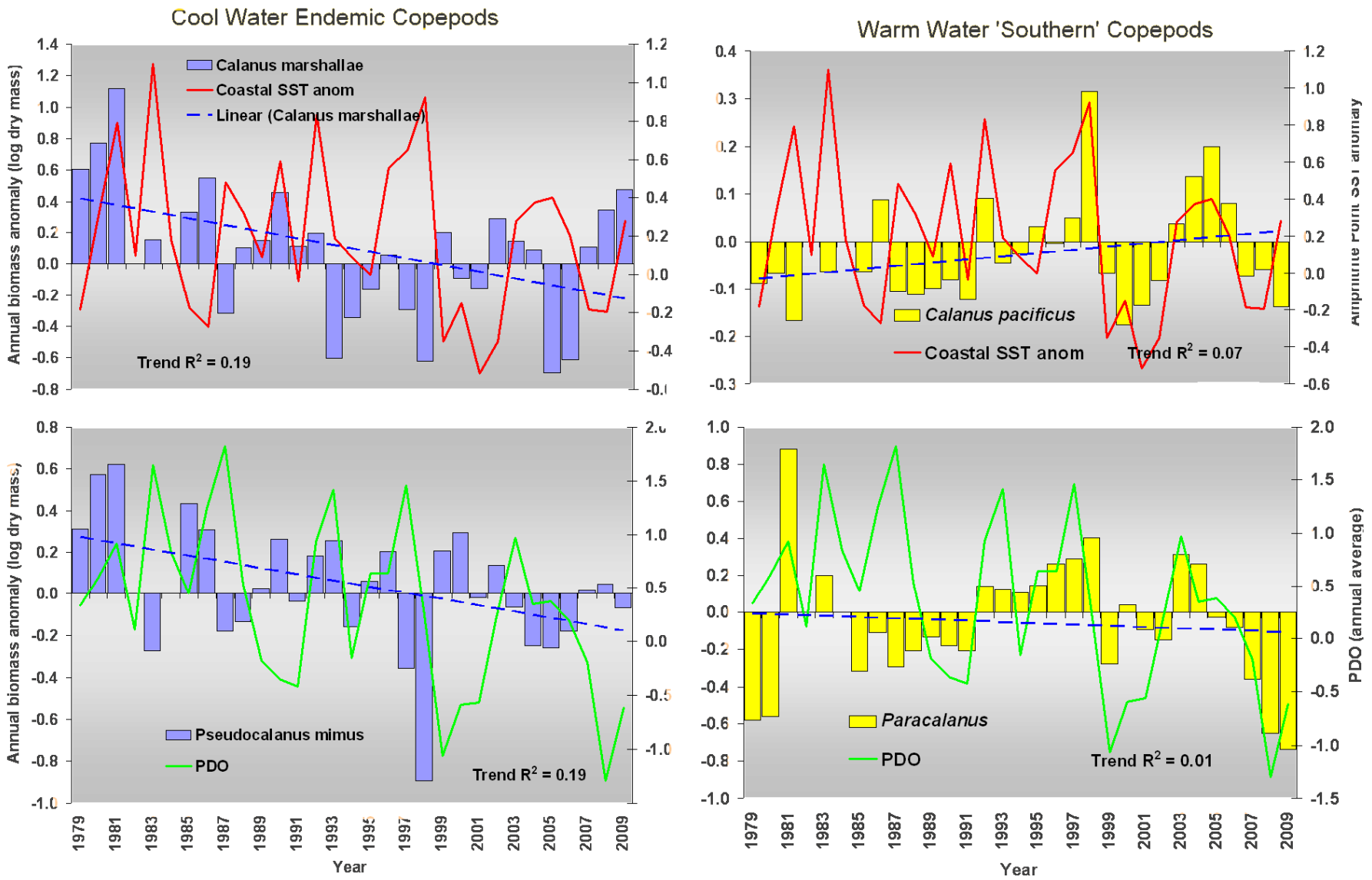
Questions for you to think about:

- What time scale(s) of change are likely to be most important for plankton and fish communities? For human society?
- Do the coupling mechanisms between climate forcing and zooplankton response differ as a function of time scale?
- What are the implications for detection and prediction of future ecosystem changes?

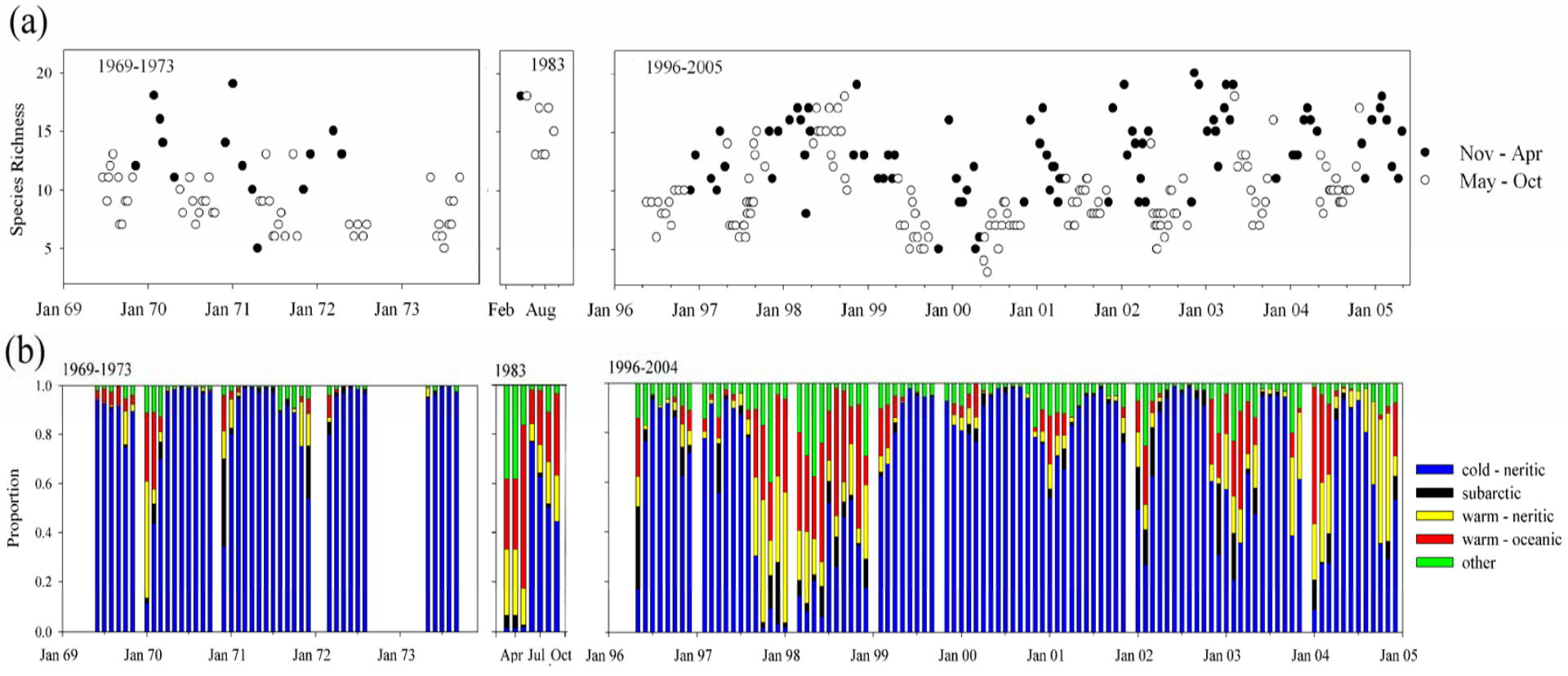
Recipe for analysis of zooplankton time series: (short message, same as NOAA & CalCOFI & SCOR WG125)

- Calculate within-region, within-time-period average biomass for each species (we use geometric mean)
- Estimate the average seasonal cycle for each region ("climatology")
- For each observation period, calculate log scale anomaly = log(Data) – log(Climatology)
- Average anomalies within year to get the annual anomaly
- Repeat for many years

Examples of NEPac zooplankton time series dominated by fluctuations (+ long-term trend):



Internannual N vs S fluctuations in NE Pac are almost certainly associated with interannual anomalies of meridional advection (= prolongation vs. shortening of the normal winter reversal of equatorward transport)



Hooff & Peterson 2006

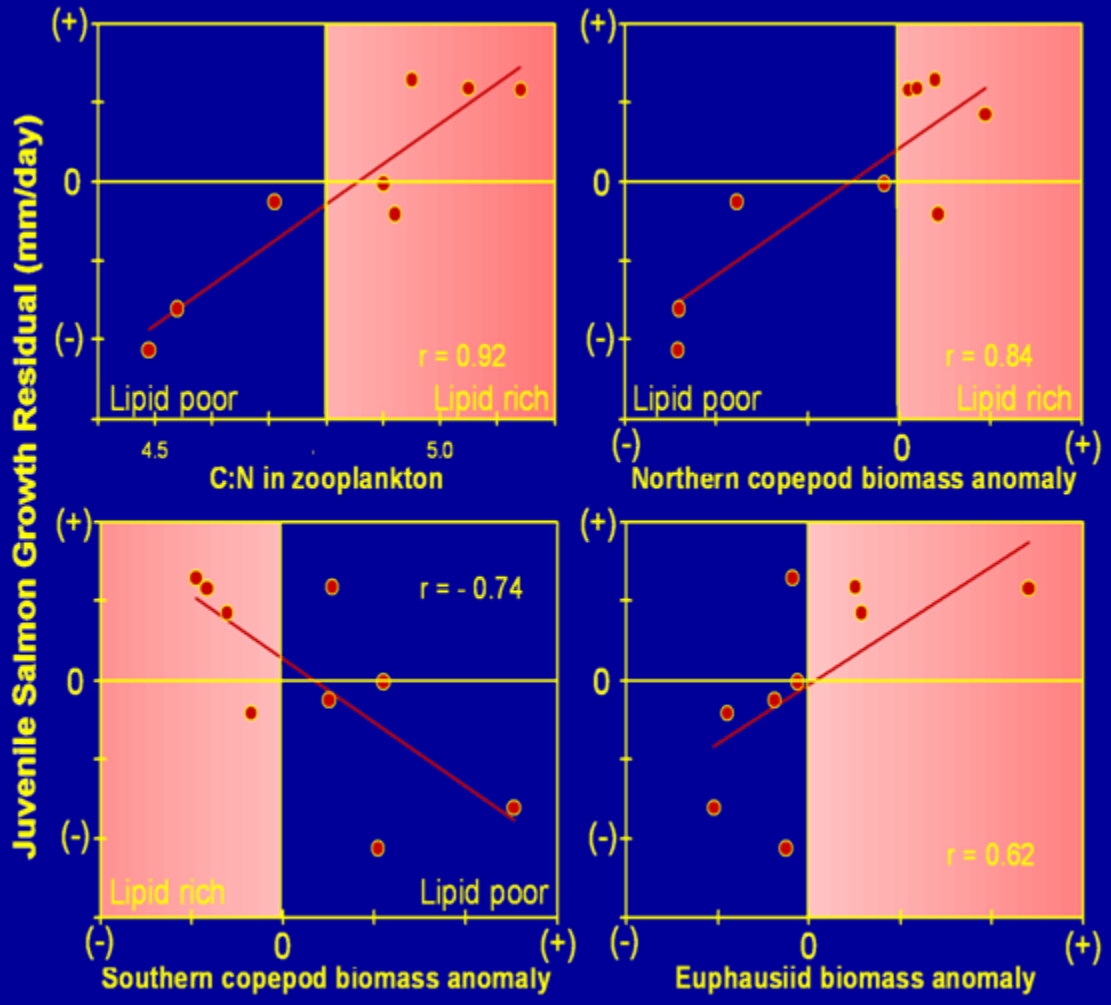
"Lean Cuisine" and salmon: Zooplankton community composition can be VERY important to fish

Young fish must grow fast to survive

Young fish must eat well to grow

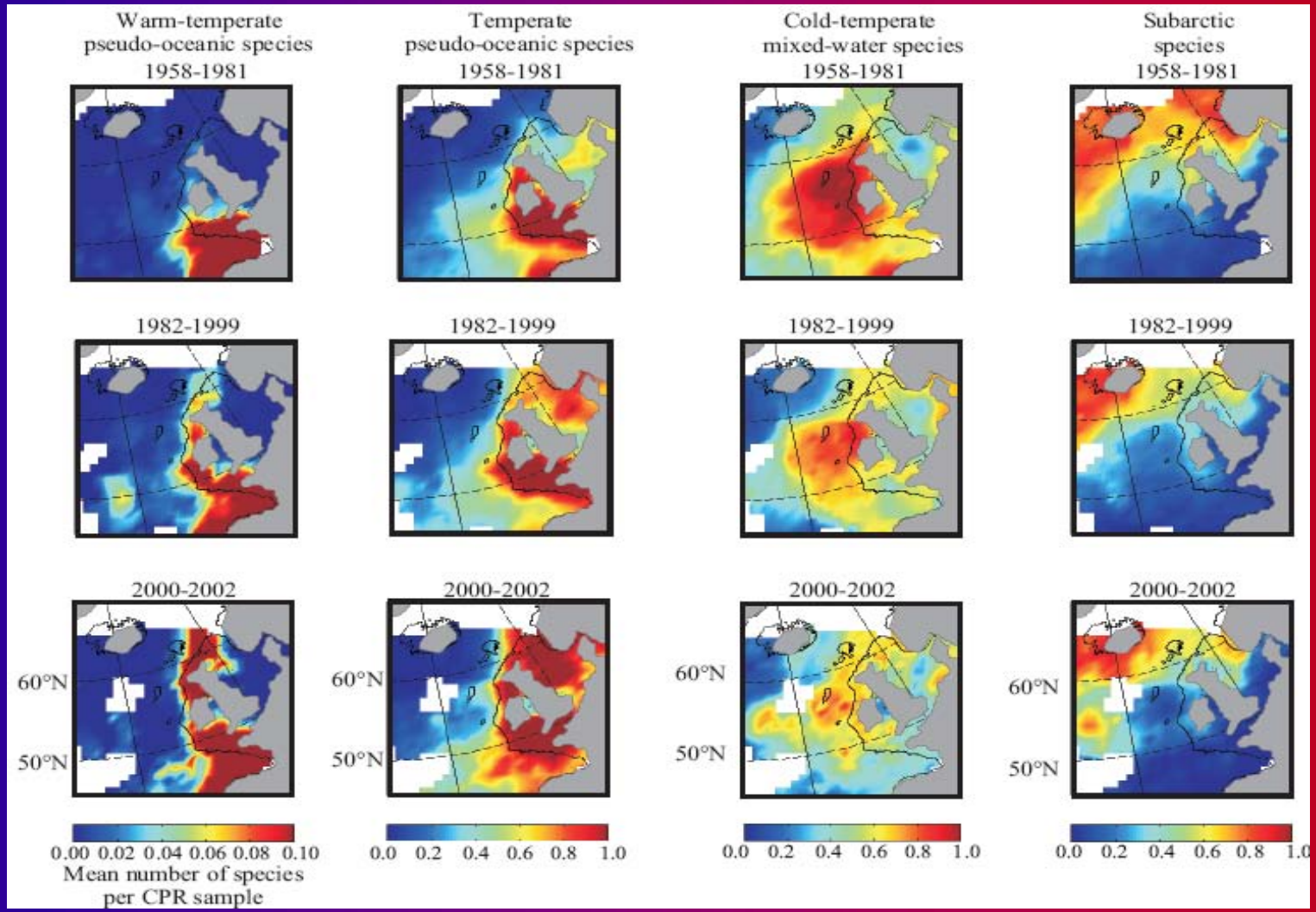
Large fat zooplankton are energy rich food

'Quality' transmits quickly to higher trophic levels



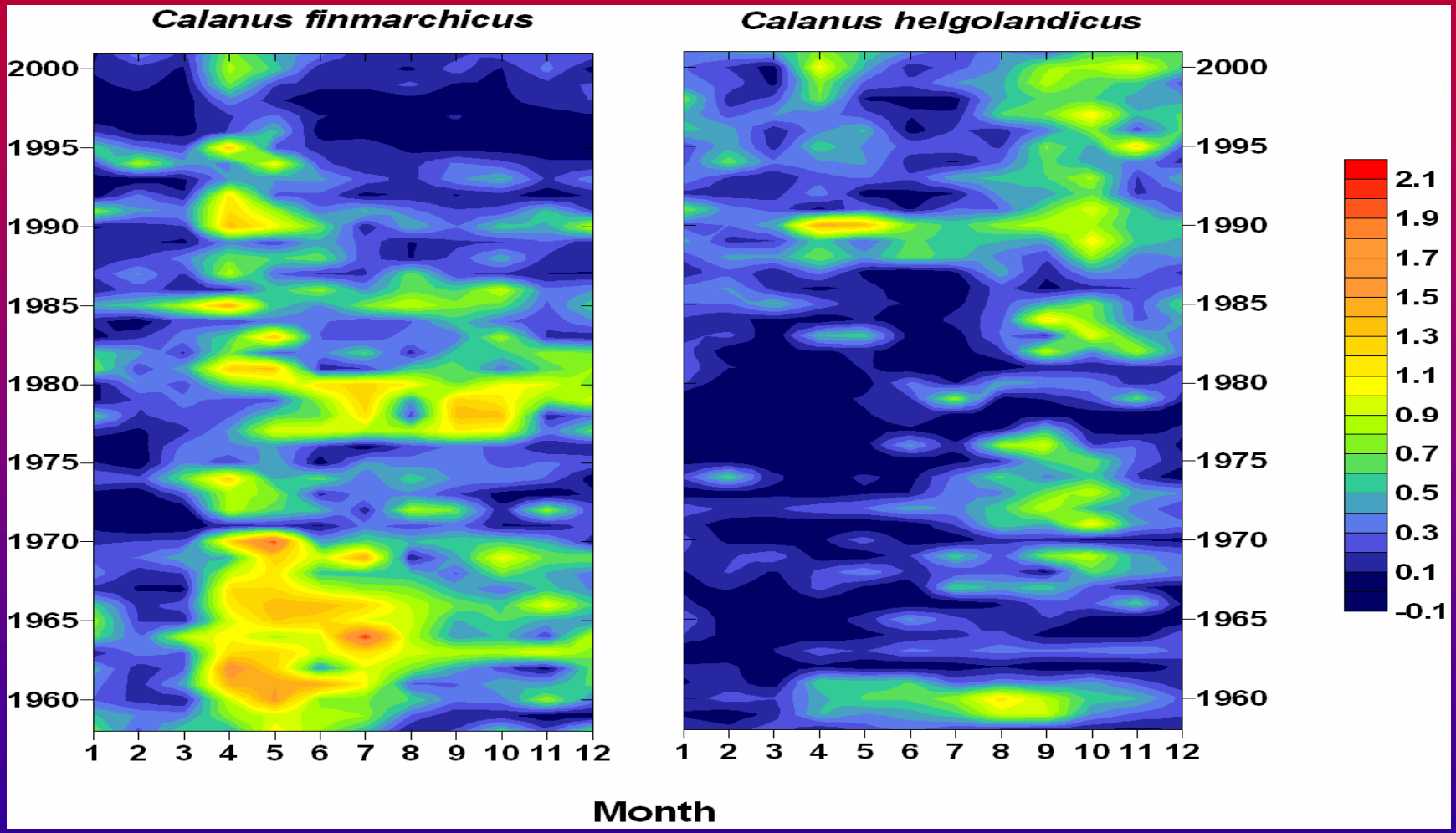
(Trudel, Mackas & Mazumder, 2008 & in prep.)

Examples of zooplankton time series dominated by long-term trend (NE Atl.):



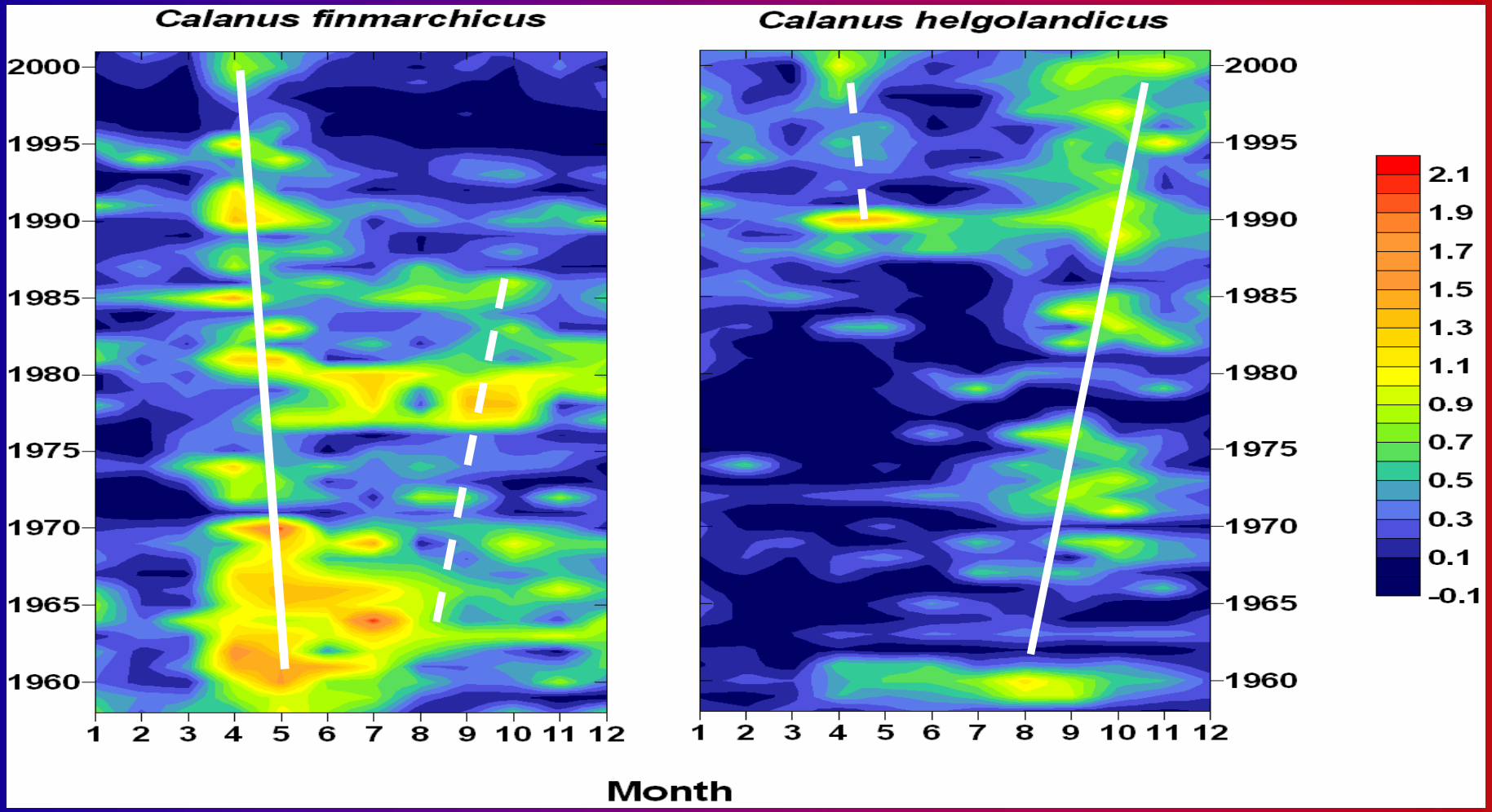
Beaugrand 2005

Another example of a zooplankton time series dominated by long-term trend (North Sea):



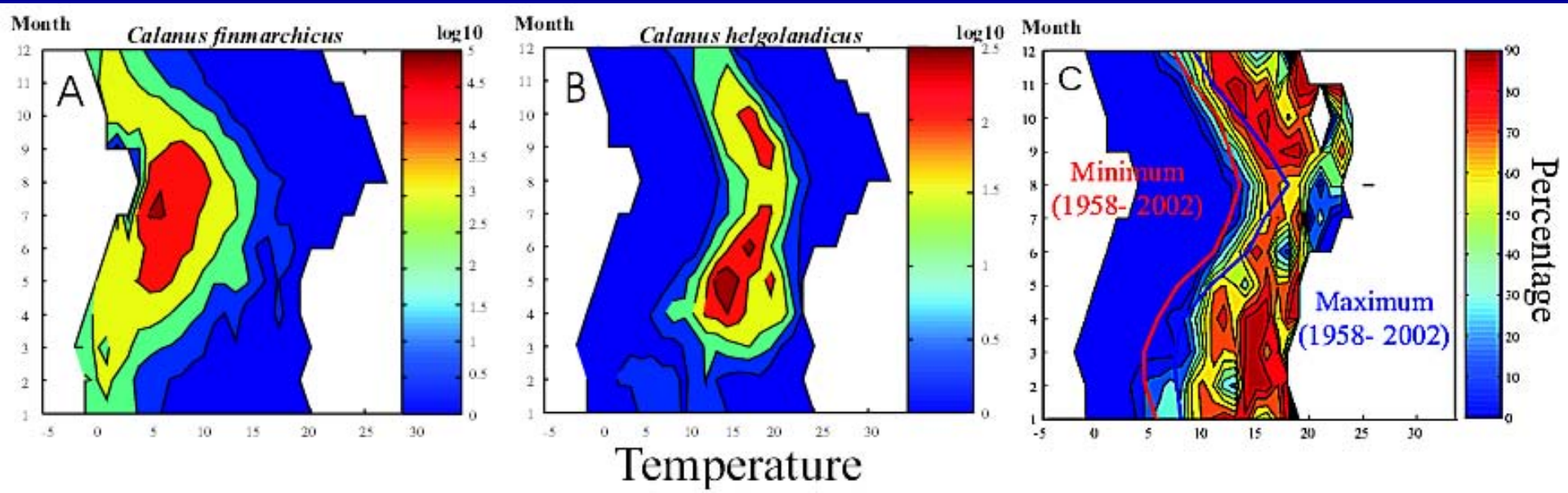
Central North Sea (win CPR v1)

The Cfin -> Chelg shift in the North Sea includes trends in phenology (complicated by appearance/disappearance of 2° cohort)



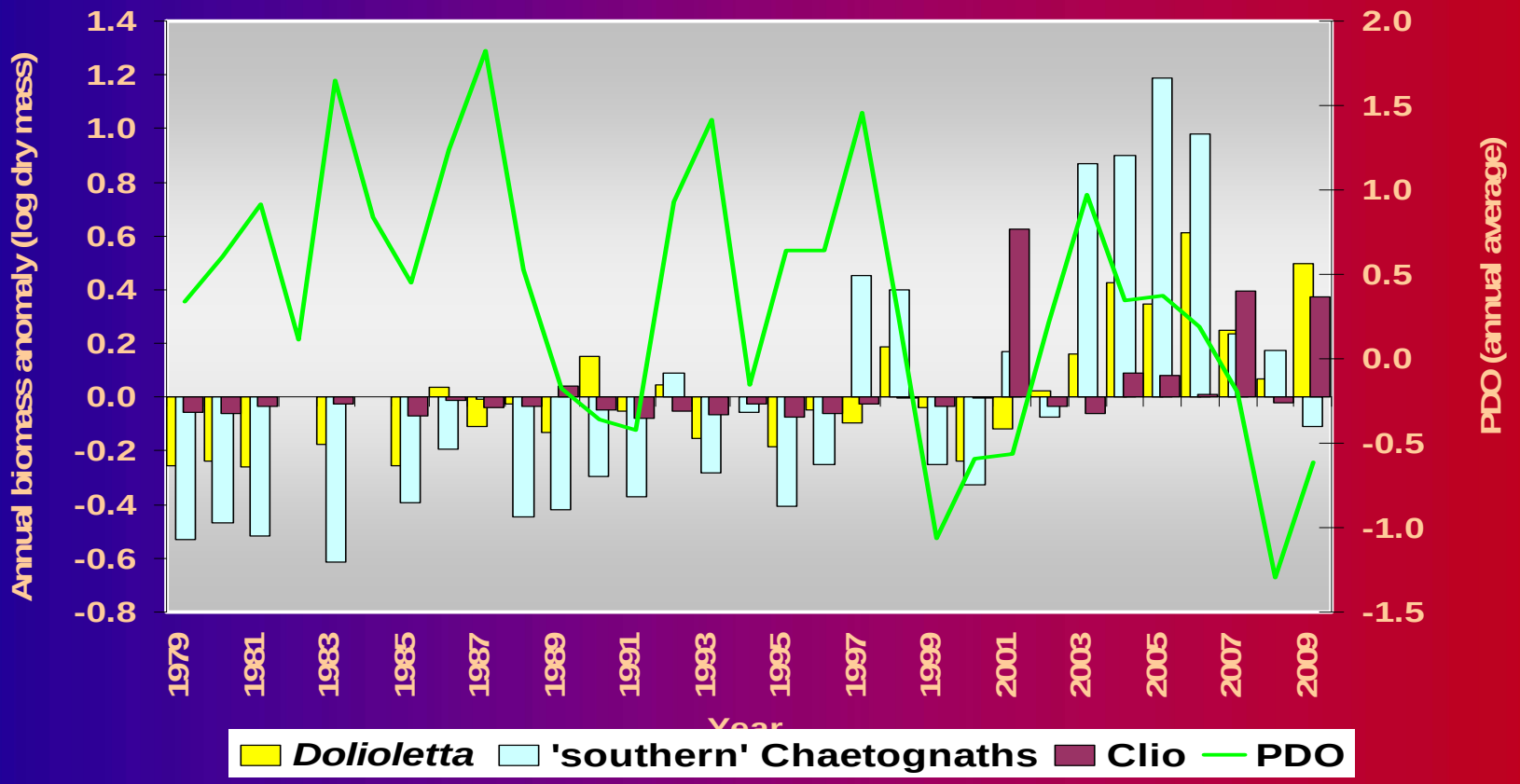
Central North Sea (data from win CPR v1)

Replacement of *Calanus finmarchicus* by *C. helgolandicus* caused by environmental cross-over between their respective seasonal temperature niches



Helaouët & Beaugrand (2007)

Examples of step/trend zooplankton time series from the NE Pacific

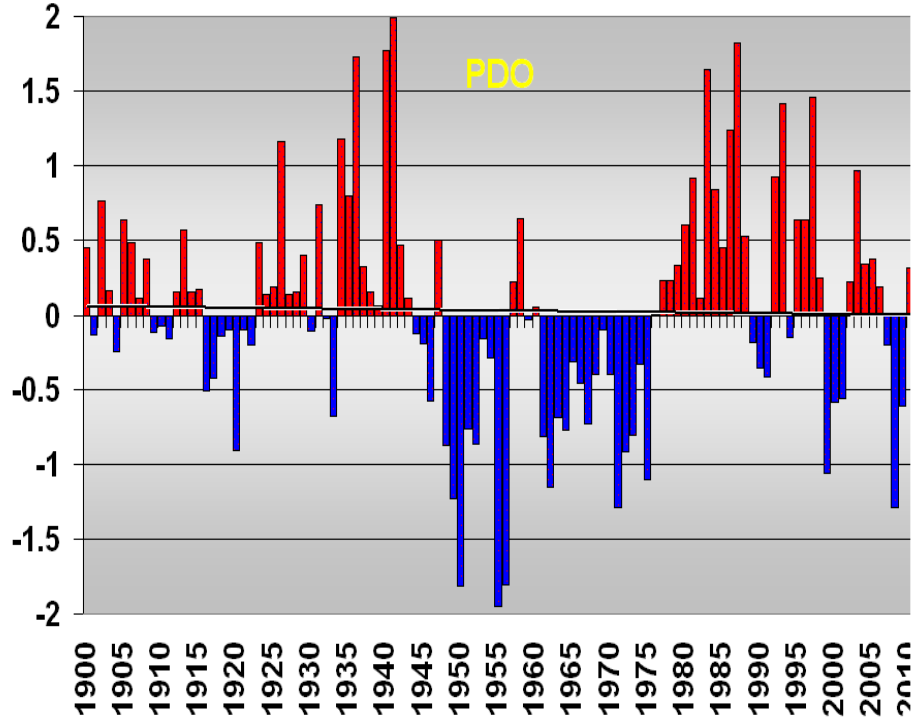


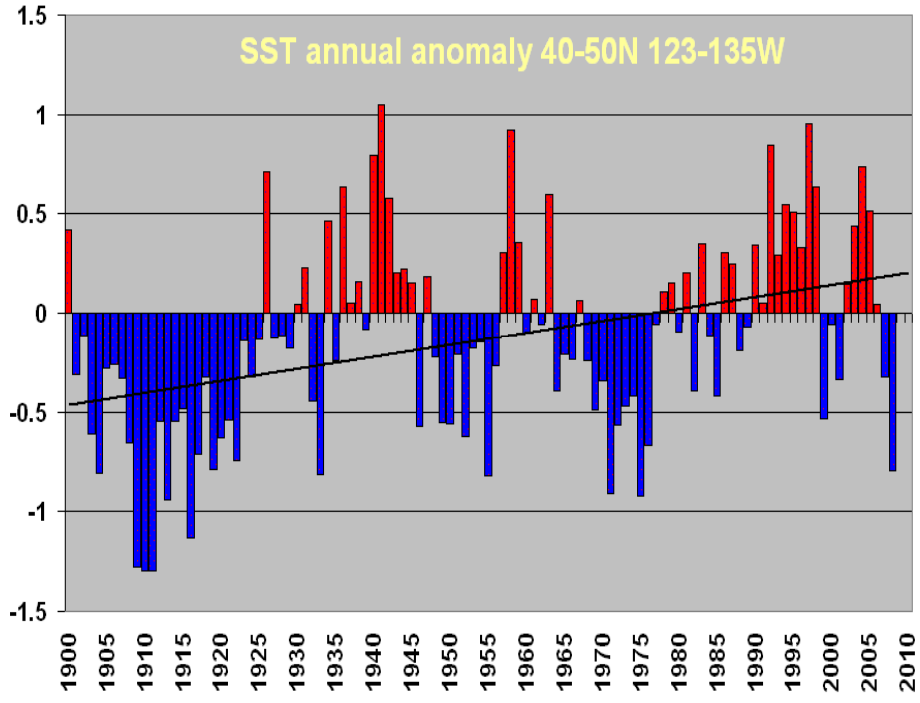
All of these taxa are non-crustacean. Is this meaningful??

So what could drive the apparent long-term (30+ year) trends in zooplankton?

- H1: Real trends in environmental forcing
- H2: Non-linear rectification of advective transport
- H3: Non-linear rectification/modulation of biological response (multiple 'attractors')
- H4: The dominant forcing and response signals are cyclic but multidecadal (longer period than our 30-50 year observational windows)

H1: Real underlying trends in environmental forcing





- *Plausible*: Many of our favorite "climate" indices remove trend (either by statistical pre-treatment [e.g. PDO] or by synoptic spatial differencing [e.g. NAO, SOI, AO]).
- Temperature is not the only candidate - recent sub-surface acidification and hypoxia signals are also monotonic

H2: Non-linear rectification of advective transport (interaction of perturbation and mean fields)

- *Plausible, at least along Eastern boundaries*: Mean flows are meridionally divergent. A transient perturbation transports a tracer to where it is more likely to continue advecting in the same direction. Also, the flow perturbations displace 'optimal habitat windows' in the same direction as the displacement of the biota (Kodasky, Mackas & Keister in prep.).

H3: Non-linear rectification/modulation of biological response (multiple 'attractors')

- *Possible on theoretical grounds (but I haven't yet seen convincing evidence)*

H4: Dominant forcing and response signals are cyclic but multidecadal (longer period than our 30-50 year observational windows)

- *Possible, but unlikely to remain dominant in the future (magnitudes of IPCC projections of temperature change equal or exceed amplitudes of fluctuation in detrended observational time series).*

My conclusions and recommendations:

- *We should EXPECT progressive change in zooplankton time series, especially for community composition and phenology*
- *In any given region, we WILL encounter 'new' biological players in the local ecosystem. Most will come from lower latitudes. Some will become dominants (but I have little skill so far at prior identification).*
- *Local 'Past' may become a poor predictor of 'future'? Consider out-of-region histories in development of regional forecasts ??*