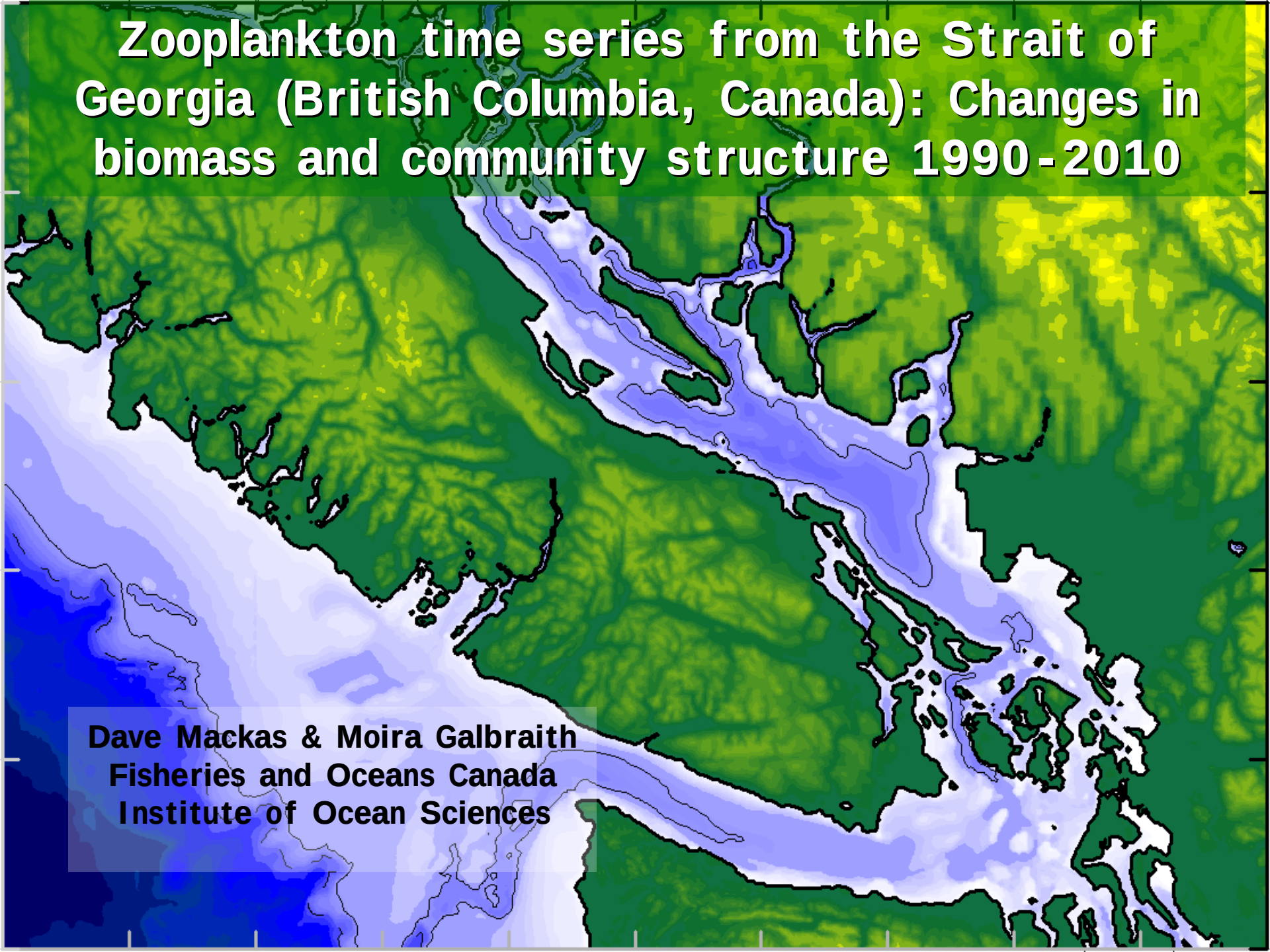
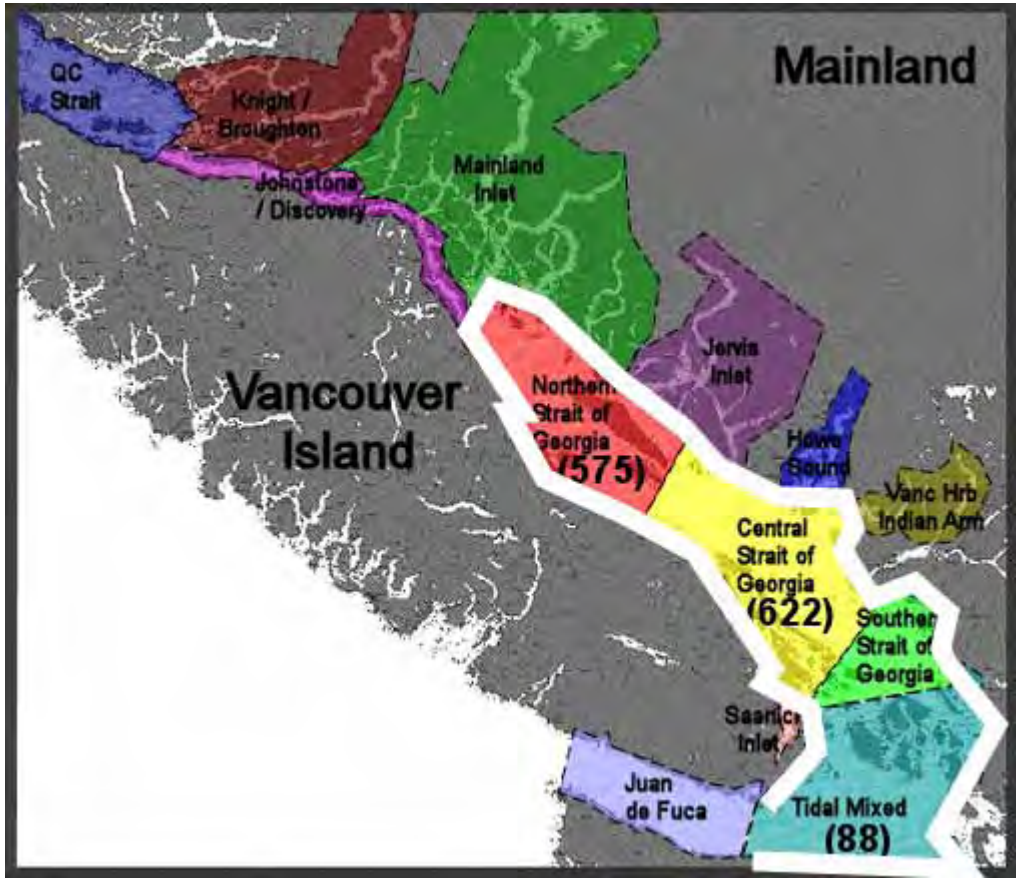
Zooplankton time series from the Strait of Georgia (British Columbia, Canada): Changes in biomass and community structure 1990-2010



Dave Mackas & Moira Galbraith
Fisheries and Oceans Canada
Institute of Ocean Sciences

Strait of Georgia statistical areas used for sample sorting & averaging

- Total number of samples per region shown in parentheses (all years)
- Good coverage within Northern and Central Strait (this analysis), intermittent elsewhere
- White band indicates 'nearshore' samples (bottom depth < 50m).



"Reconstruction" combines historic data from multiple sources.

Advantages and limitations :

- Long history, but has gaps and "diversity"
- Collected by different investigators using different sampling methods for different target species
- Meta-data and QC often incomplete – especially for flow metering and extent of subsampling.
- Varying levels of taxonomic resolution
- Used "lowest common denominator" approach to describe community composition

Selection criteria within the Central & Northern Strait set:

Locations and depth ranges:

-Picked sites and tows deep enough to include the migratory ranges of zooplankton taxa

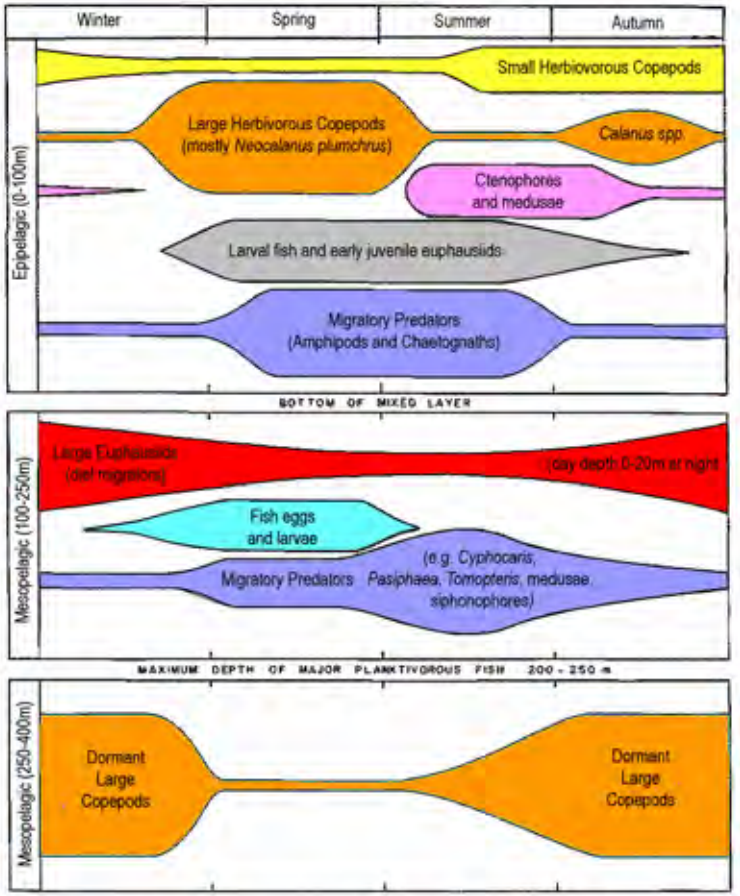
Sampling and processing methods:

-Vertical or oblique tows covering wide depth range;

- Samples sorted for full range of target taxa (not just a single species)

"Who, Where, & When" of SofG zooplankton: Average seasonal & depth distributions of the dominant zooplankton taxa

- Known generally since early 1980s
- The same species are present today and occupy the same depth ranges
- Important changes of relative abundance and phenology.
- Note for later: Many of the larger species are strong vertical migrators (either diurnal or seasonal) so...conditions >100m are important for at least part of their life cycle



(adapted from Harrison, Fulton, Taylor & Parsons, 1983)

Taxonomic selection & classification criteria:

- Used "*body size-classes within major taxa*" to get around analyst-specific differences in resolution and naming. Data set covers all important groups (crustaceans, chaetognaths, pteropods, jellies, annelids, meroplanktonic larvae)

- Focus today on the larger crustaceans: large and medium copepods, juvenile-adult euphausiids, hyperiid and gammarid amphipods. These dominate total biomass and are likely to be important direct or indirect prey for juvenile (and some adult) fishes.

Large copepods:

Neocalanus plumchrus & *Eucalanus bungii*

Herbivorous (in SofG), pronounced seasonal dormancy and deep ontogenetic migration, but weak diurnal migration during growing season

Medium copepods:

Calanus pacificus & *Metridia pacifica*

(plus younger stages of the 'big copepods')

- Both are herbivorous in SofG
- *Calanus* - seasonally dormant with ontogenetic migration;
- *Metridia*- very strong diurnal migration

Euphausiids:

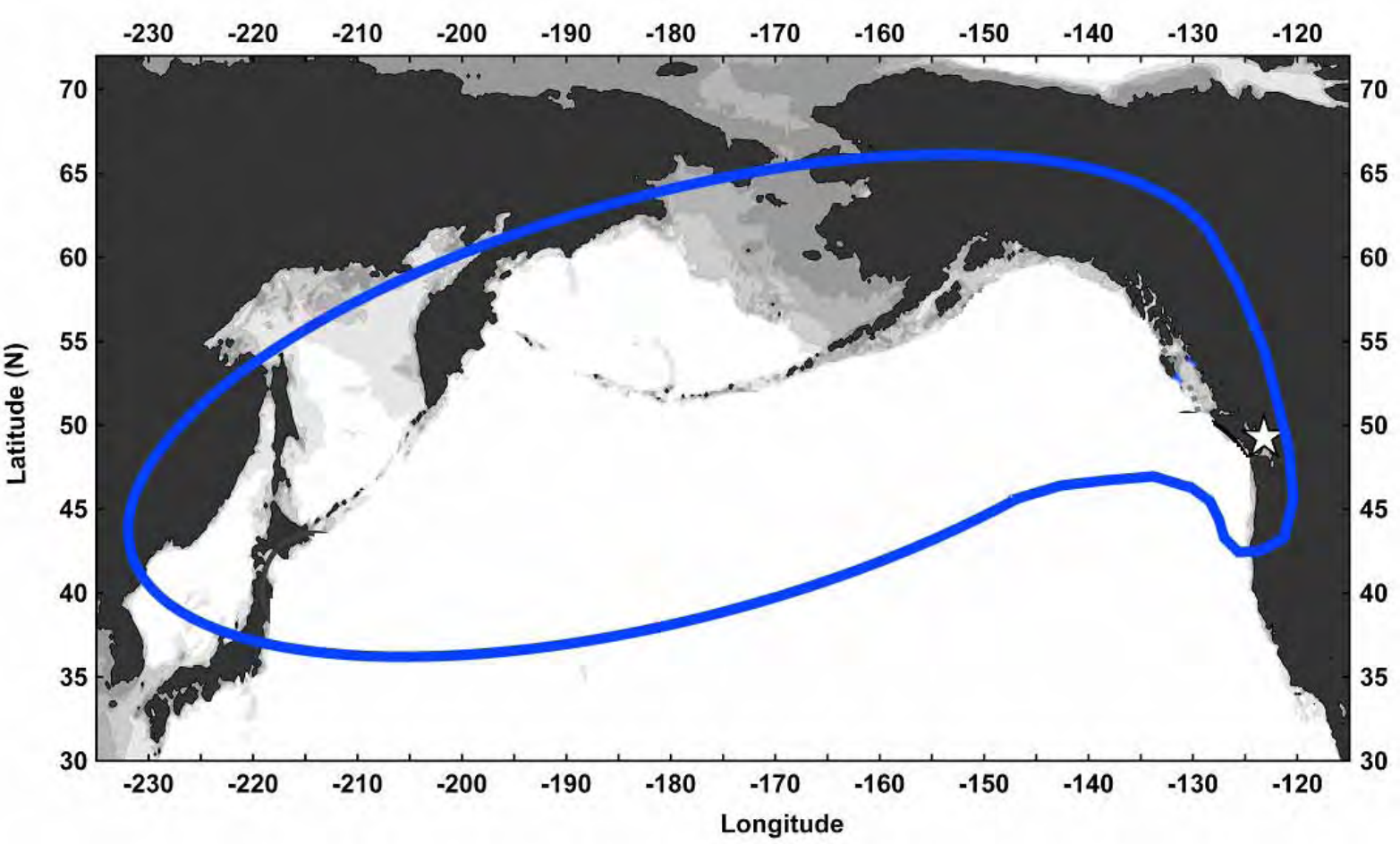
Euphausia pacifica & *Thysanoessa spp.*

- Mostly herbivorous in spring-summer, mostly carnivorous in winter
- Strongly pigmented & large (1.3-3 cm)
- Strong diurnal migrators year-round

Amphipods:
Gammarid & Hyperiid

- Carnivorous
- Strongly pigmented
- Strong diurnal migrators

Where else do they live?



- Trans-Pacific (except T. spinifera)
  - Mostly oceanic, not neritic
- Mostly subarctic but some extend to Cal Current

How does the SofG environment compare to other parts of the zoogeographic range?

"Marginal habitat"

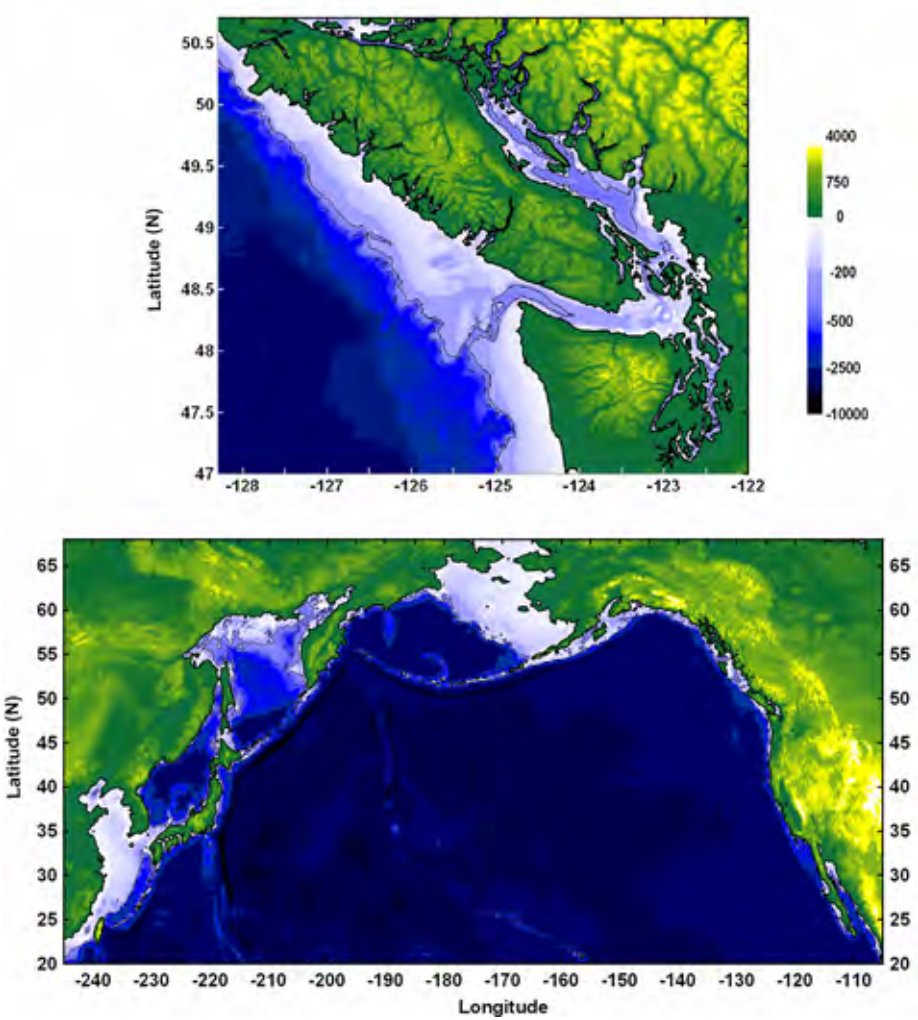
- Less deep
- Lower salinity
- Warmer, especially subsurface
- Earlier spring bloom
- Early, short growing season for the big copepods (phenology is strongly T dependent)

Bathymetry & Connectivity:

SoG is deep compared to typical continental shelf (~50% of area is deeper than 200m, most is deeper than 100m)

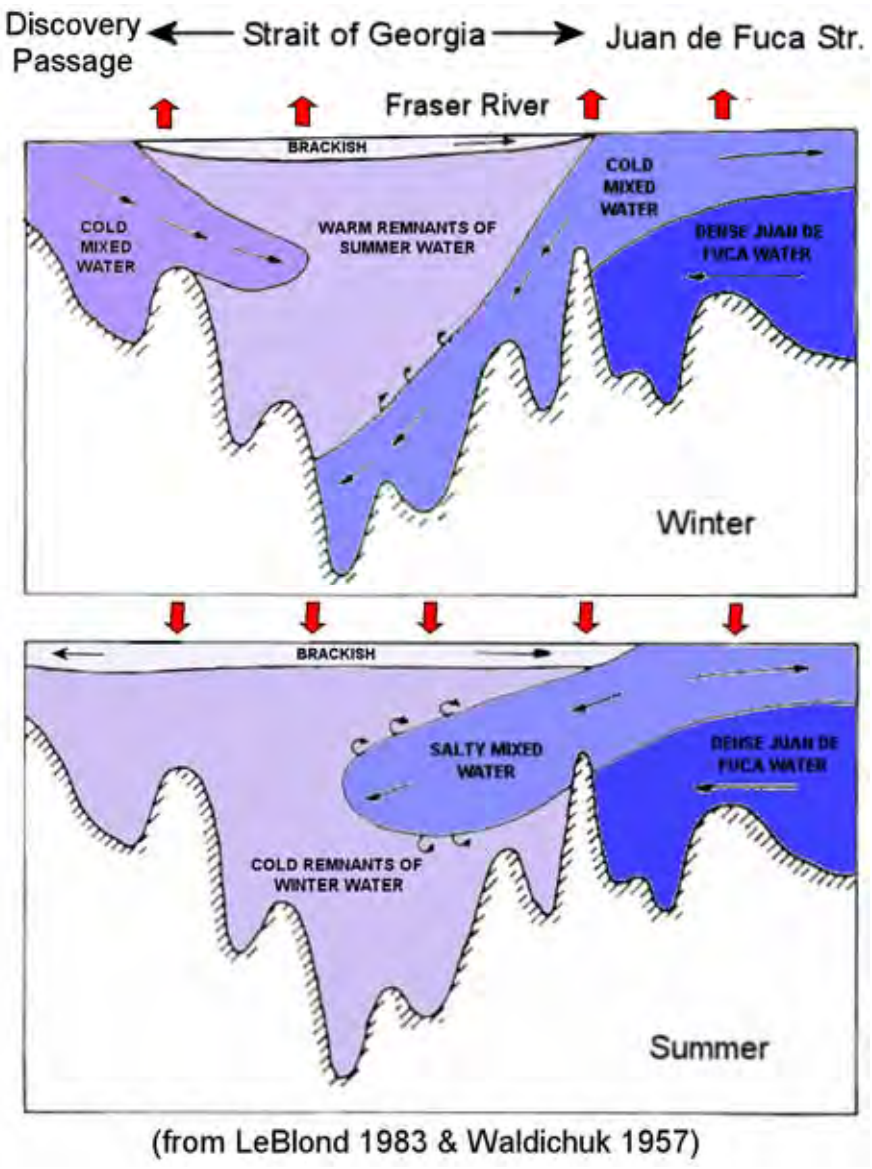
But much shallower than open ocean so seasonal vertical migration range of large copepods is shallower

Enclosed (connections to ocean are long & narrow tidal passes, with relatively shallow sills)



SofG bathymetry courtesy Isaak Fine, NPac bathymetry from ETOPO.

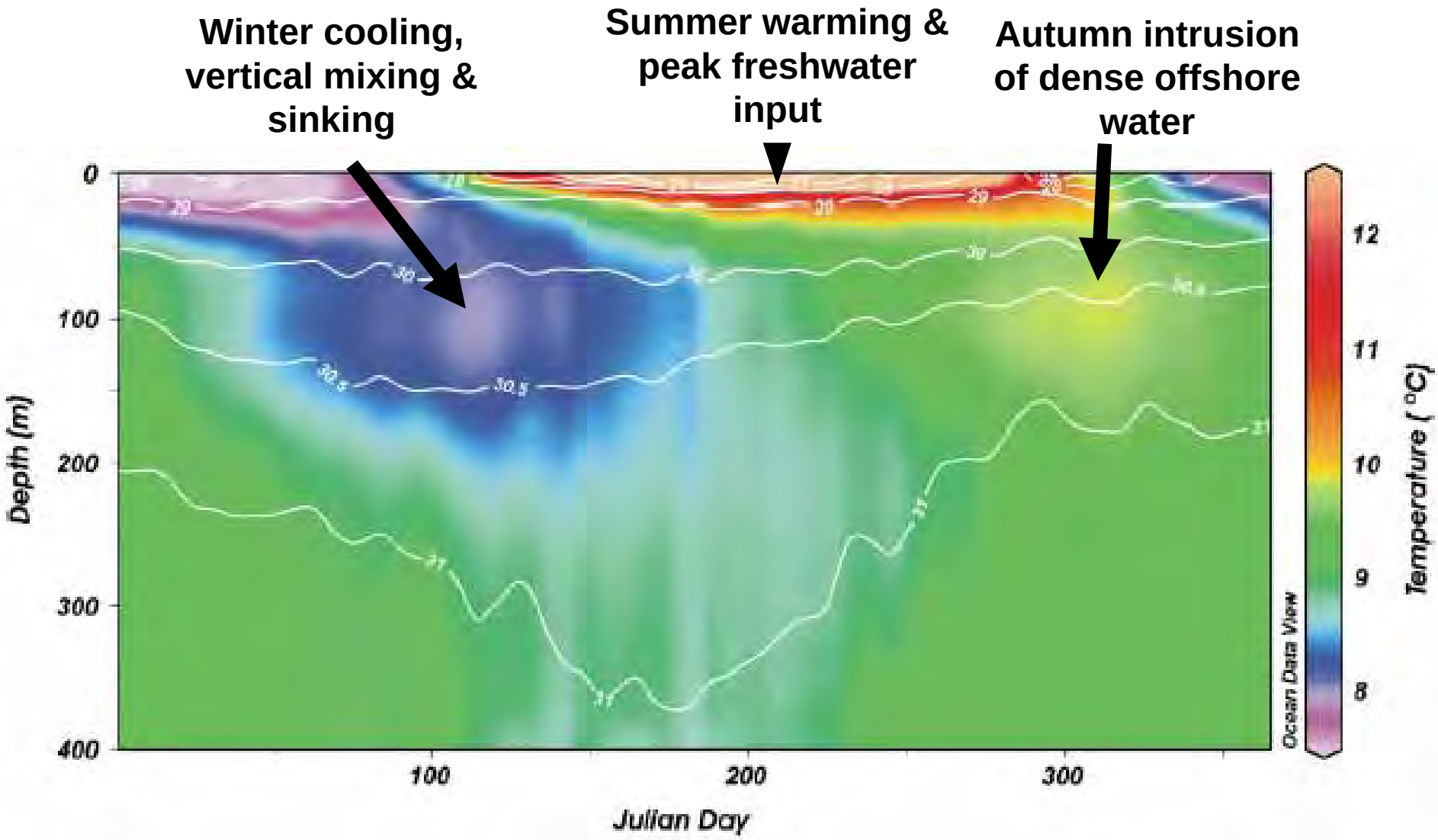
Circulation and Water Properties



(from LeBlond 1983 & Waldichuk 1957)

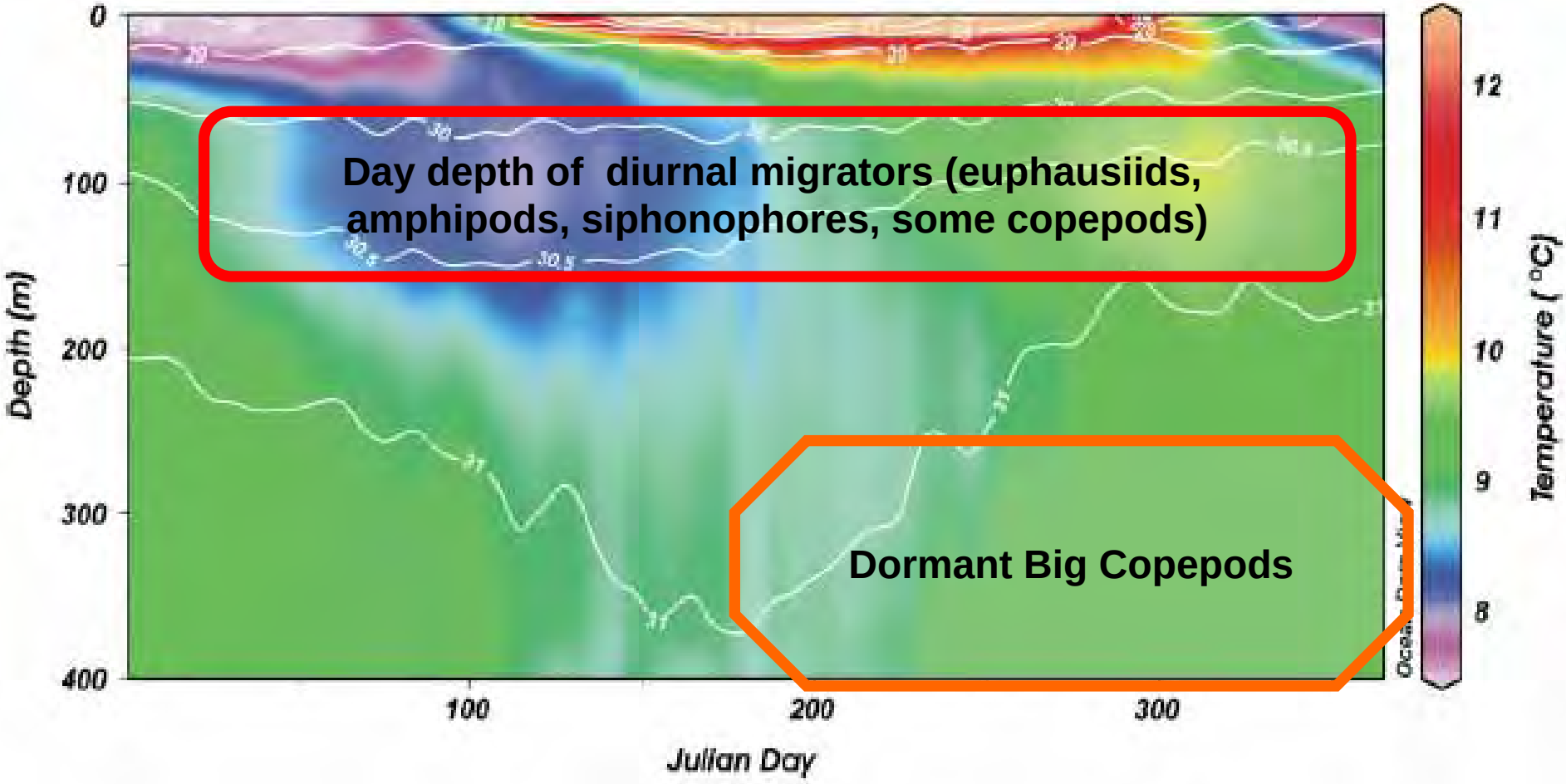
- Large riverine freshwater input (Fraser R. discharge is dominated by snowmelt in early summer)
  - Positive estuarine circulation,
  - Strong vertical stratification within Strait of Georgia
  - Strong vertical mixing in tidal passes at each end
- Offshore is source of salty, cold, deep water entering via Juan de Fuca Strait (mostly) and Discovery Passage.
- Surface heat exchange with atmosphere (red arrows)

Drives climatologies of T°(color) and S (white contours)

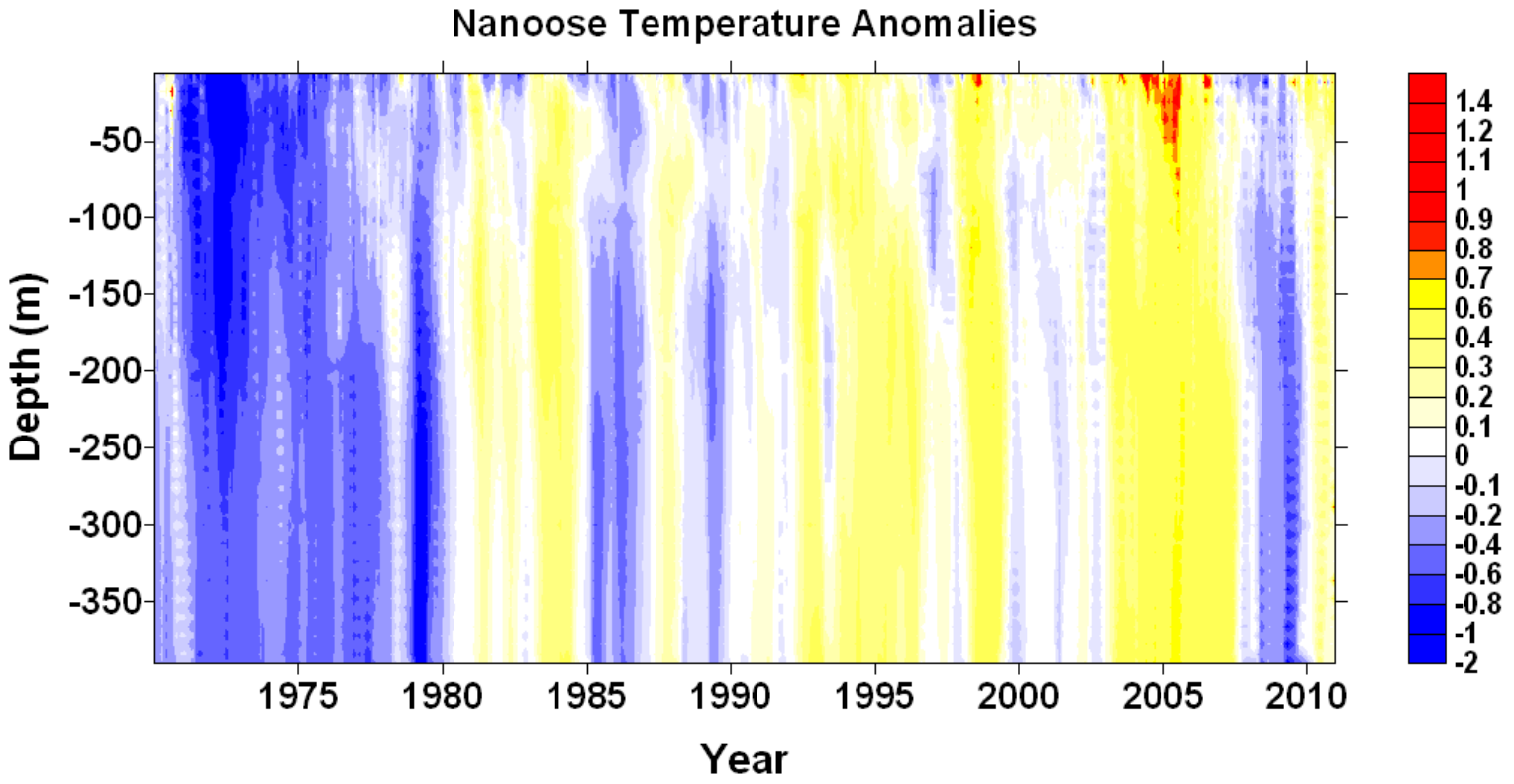


(Masson & Cummins, 2007)

Recall: many of the dominant SofG zooplankton spend a lot of time deep in this water column



How is the Strait of Georgia environment changing??

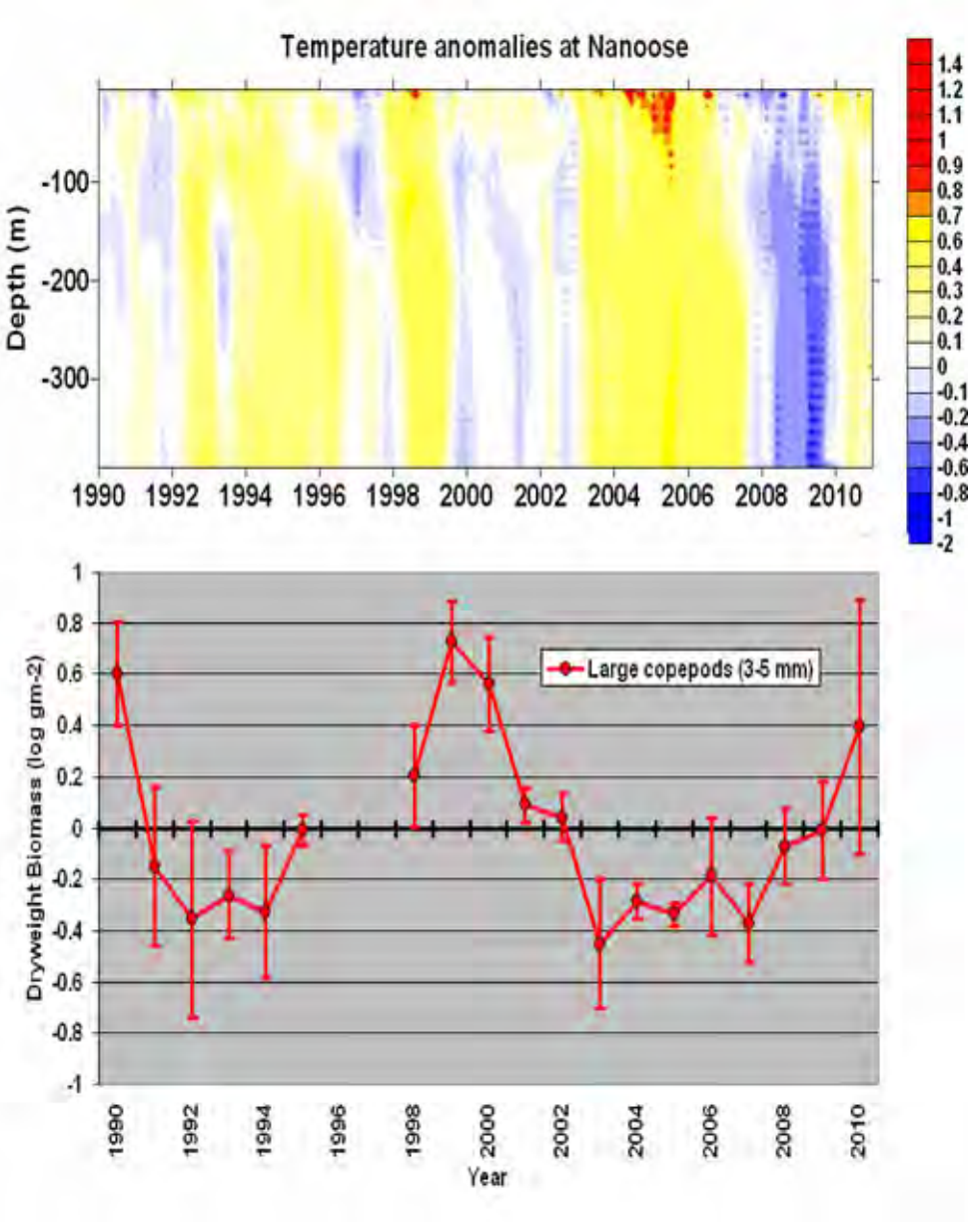


- Long-term warming at all depths
- Surface T° trend is similar to offshore, but subsurface trends are ~2X stronger than offshore (Masson & Cummins 2007)
- Spring freshet is getting earlier
- Spring phytoplankton bloom is (often) earlier

How have the Strait of Georgia zooplankton changed in 1990-2010?

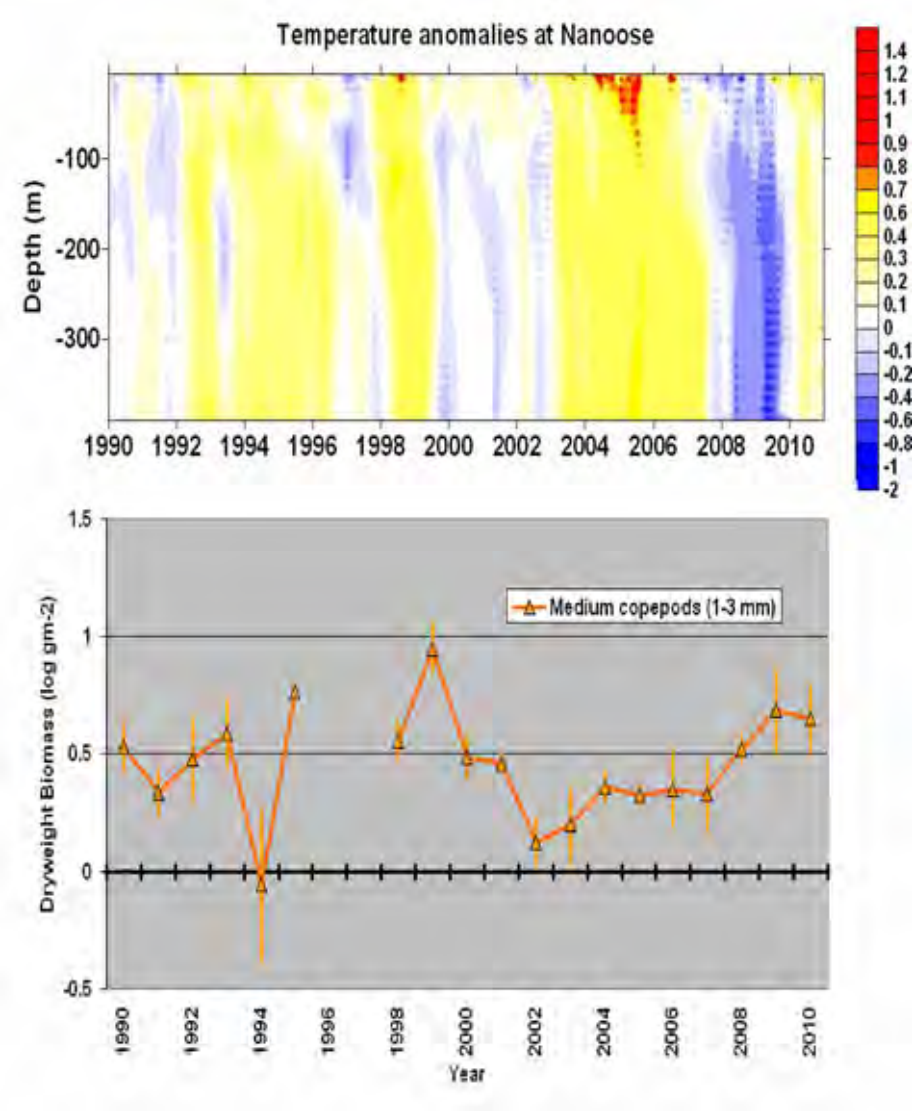
1. Large copepods (3-5 mm)

- Current biomass is below levels reported from the 1960s-80s (when SoG was much cooler than now).
- Less abundant in warmest years since 1990.
- Much of this change is due to lower abundance of *Neocalanus plumchrus,* which has also shifted to earlier seasonal timing (Sastri & Dower 2009, El Sabaawi et al. 2009)
- Minima in 1992-1994 and 2003-2007.
- Deep temperature anomalies also affect the large copepods. Strongest negative correlation with depth-specific T anomalies <90m and >250m

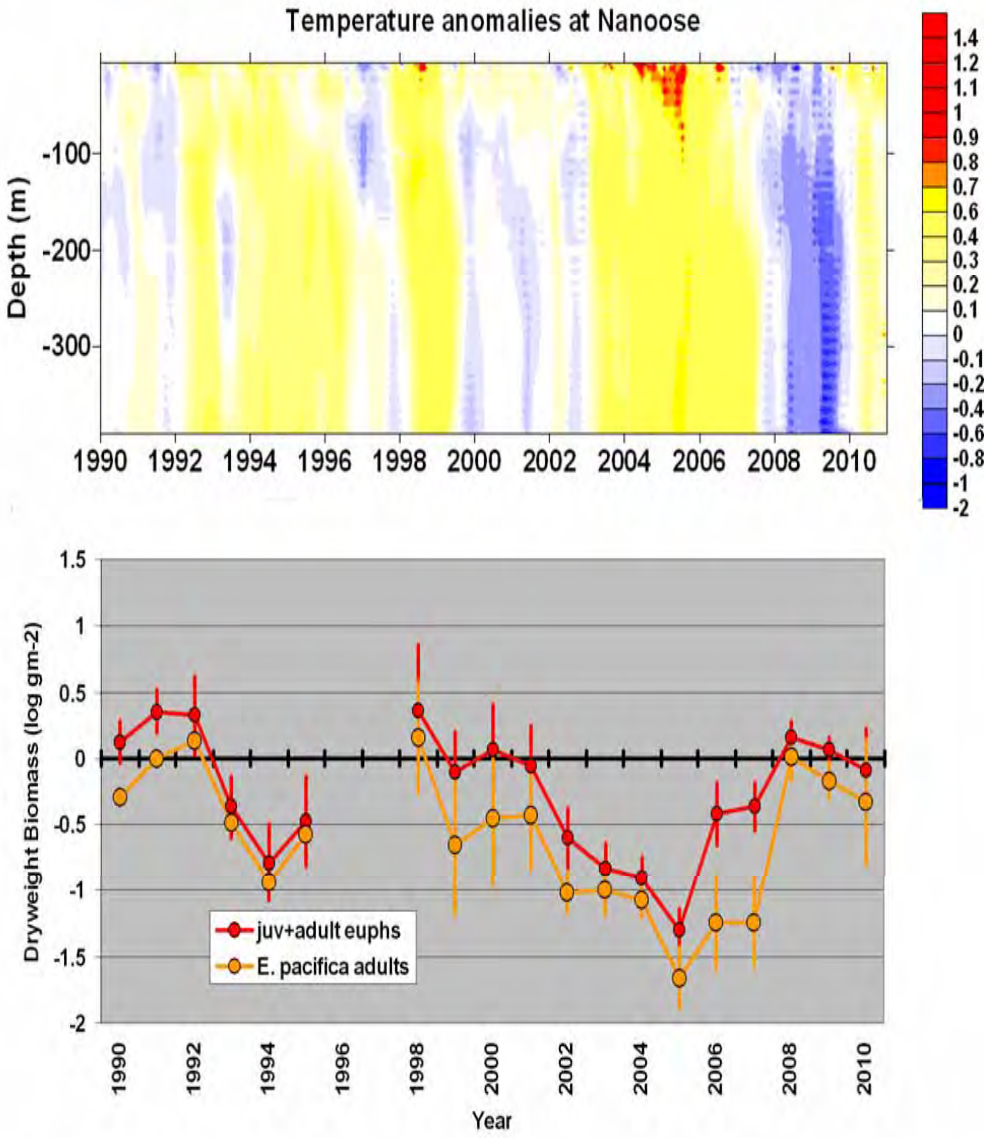


2. Medium copepods (1-3 mm)

- Time series is less variable, but biomass also tends to be low in warm years.
- Positively correlated with 'Large Copepods' (maybe from including young stages of the "Large copepods")
- Biomass minima 1994 and 2003-2007.
- Strongest negative correlation with T in the 45-90m depth band.

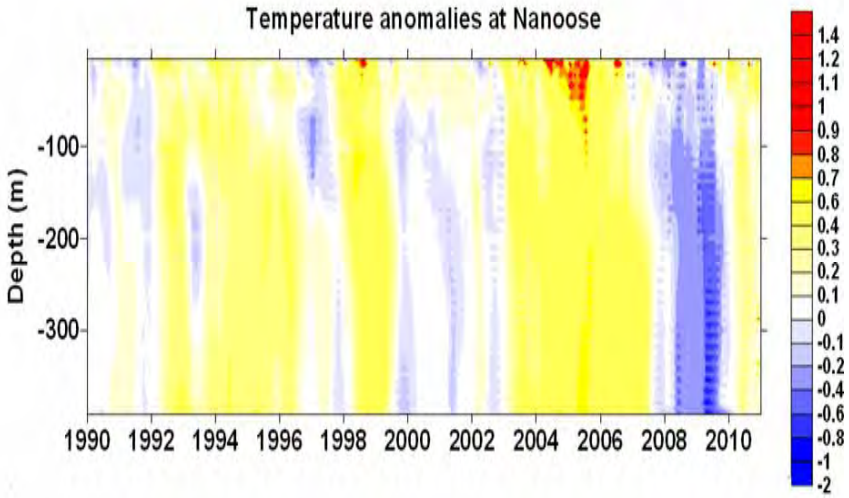


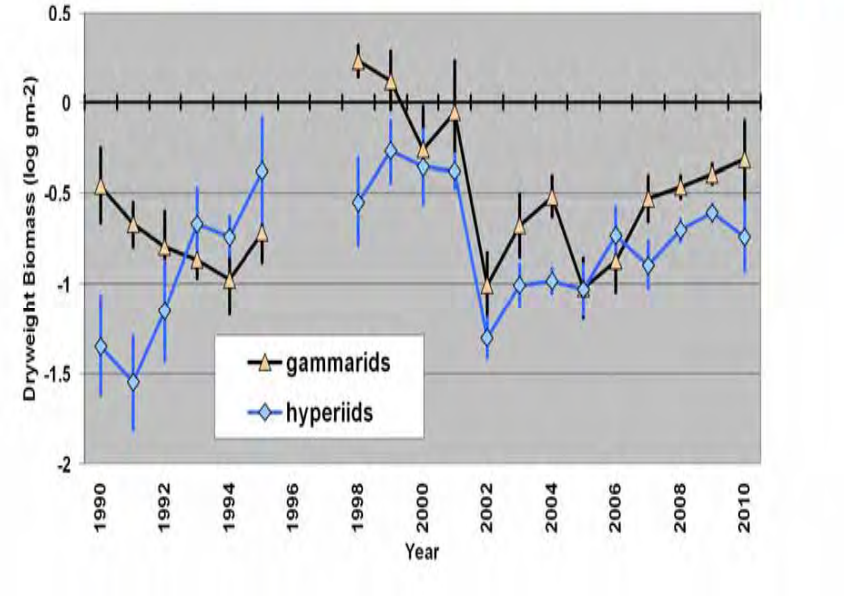
3. Euphausiids



- Changes in Total euphausiid biomass (red) dominated by changes in biomass of adult *E. pacifica* (orange)
- Prolonged minimum 2004-2008, overlaid on longterm downward trend (r = -0.34)
- Negatively correlated with temperature anomalies at all depths (but several outlier years)

4. Amphipods





- Lower average biomass than copepods and euphausiids
- Maxima 1998-2001, minima early 1990s (different from copepods and euphausiids) and 2002-2006 (similar to copepods and euphausiids)
- Weak correlation with temperature anomalies at all depths.

Summary

- Most of the larger crustacean taxa in the Strait of Georgia show strong multi-year fluctuations and/or downward trends of annual average biomass
- Strong subsurface warming of the Strait is likely an important environmental driver
- Changes of the zooplankton community are likely to have contributed to reduced growth and survival of planktivorous fish (e.g. juvenile salmon)