# Zooplankton mediation of carbon cycling and export in the Amundsen Gulf system (southeastern Beaufort Sea)

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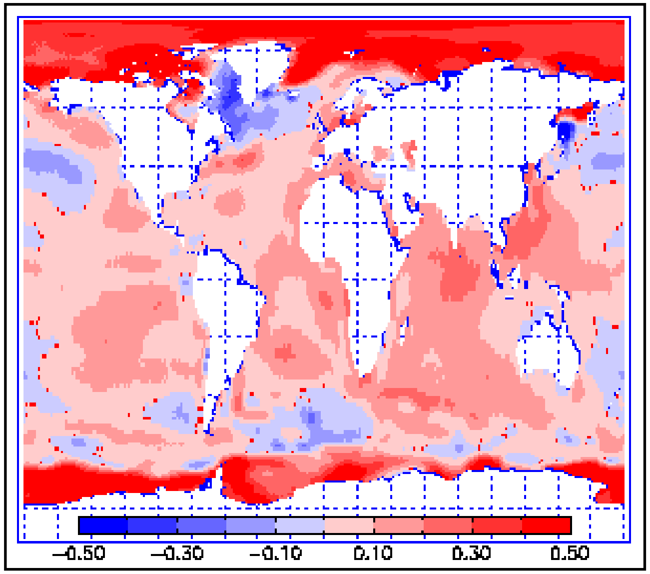
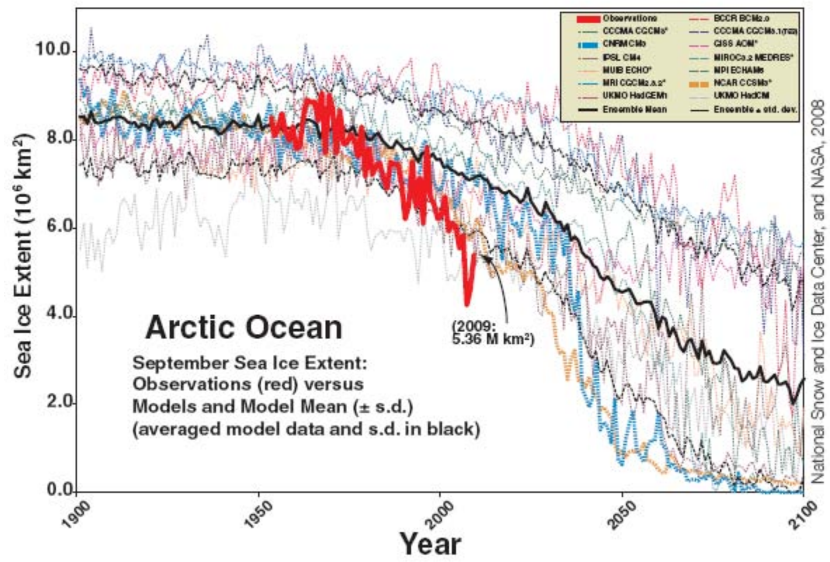
# Warming and Arctic meltdown

**1955-2003 linear trend of surface air temperature ($^oC$ decade$^{-1}$)**

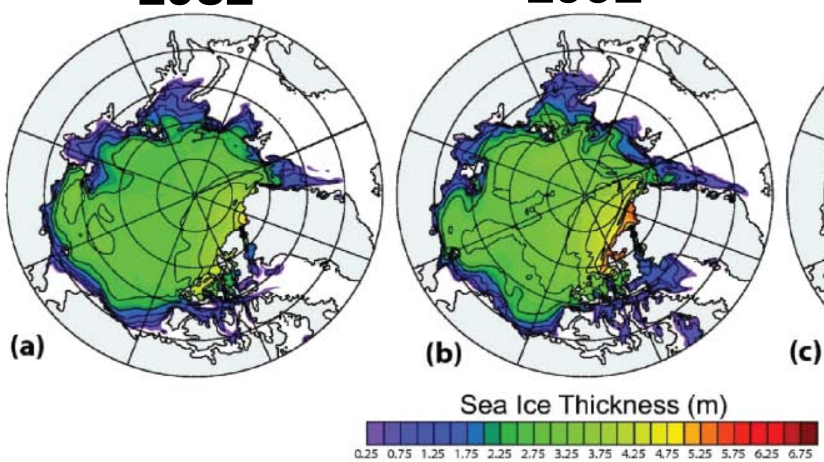



(Zhang 2005)

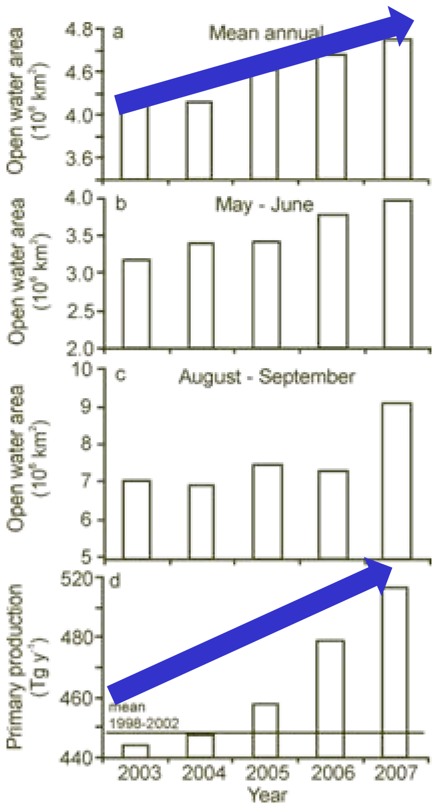



(NSIDC 2010)

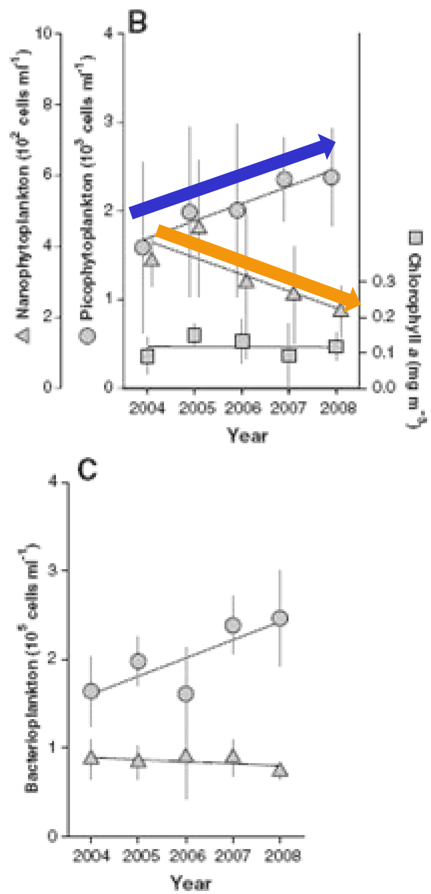
**1982** **1992** **2002**



# Arctic pelagic food web




(Arrigo et al., 2008)



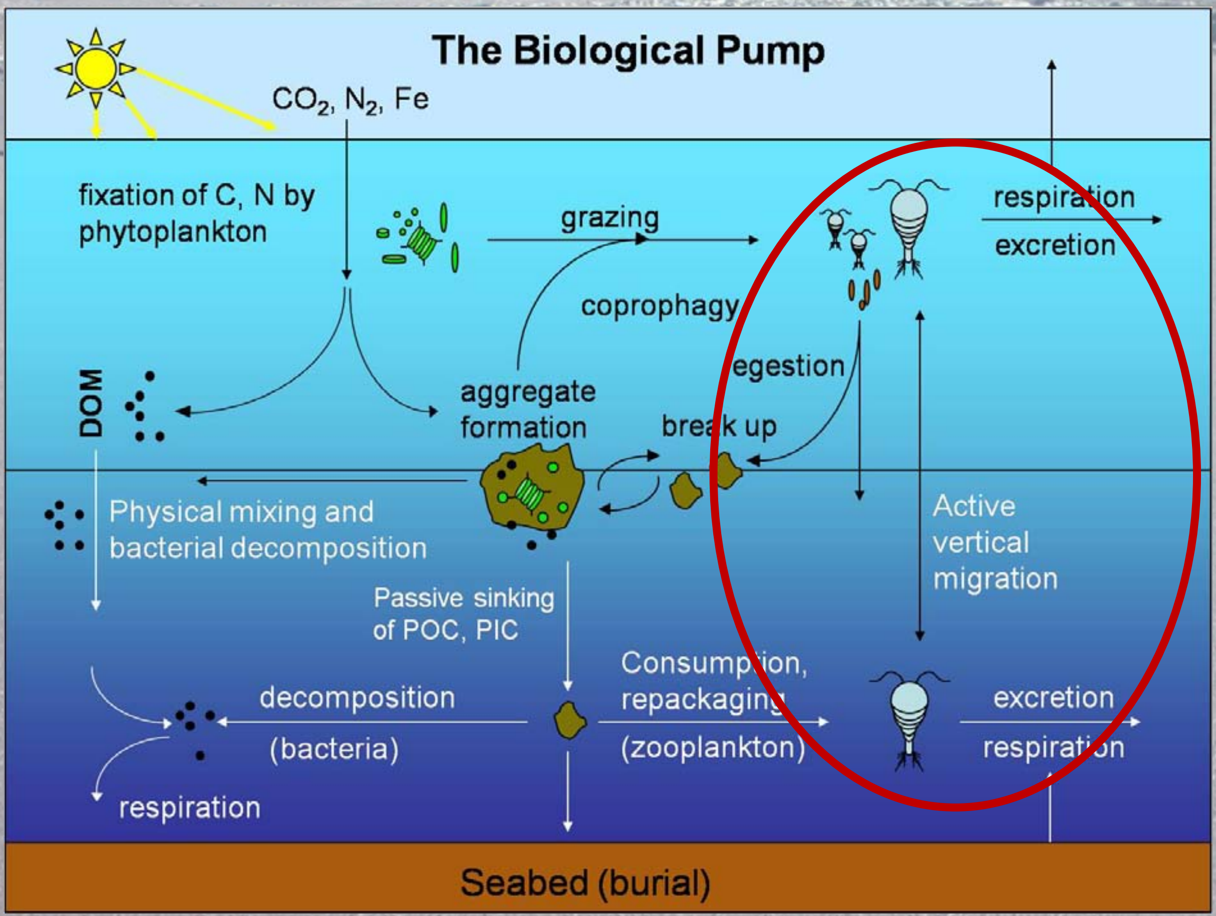

(Li et al., 2009)

- Mismatch between PP and consumers
- Shift in zooplankton size
- Establishment of new species
- Change in zooplankton behaviour (migration)

**Impact biogeochemical processes under zooplankton mediation**

# « The biological pump »

**Export to the Ocean's interior of carbon fixed by photosynthesis in the euphotic zone**




(Ducklow et al 2001)

## Arctic zooplankton

***Calanus glacialis* female**

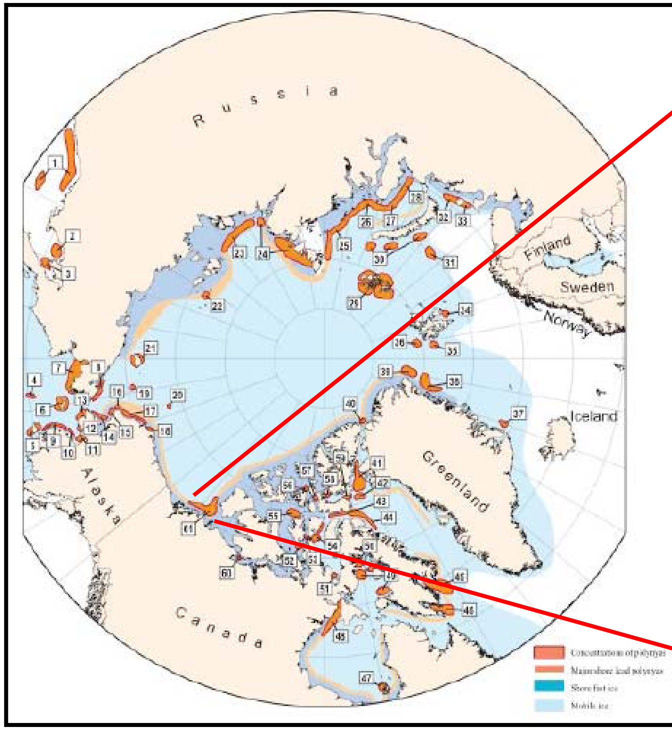
- **Long-range vertical migration by *C. glacialis* and *C. hyperboreus***
- **Short-range diel vertical migration (DVM)**
- **No extensive vertical migration by small taxa**

# Central objective

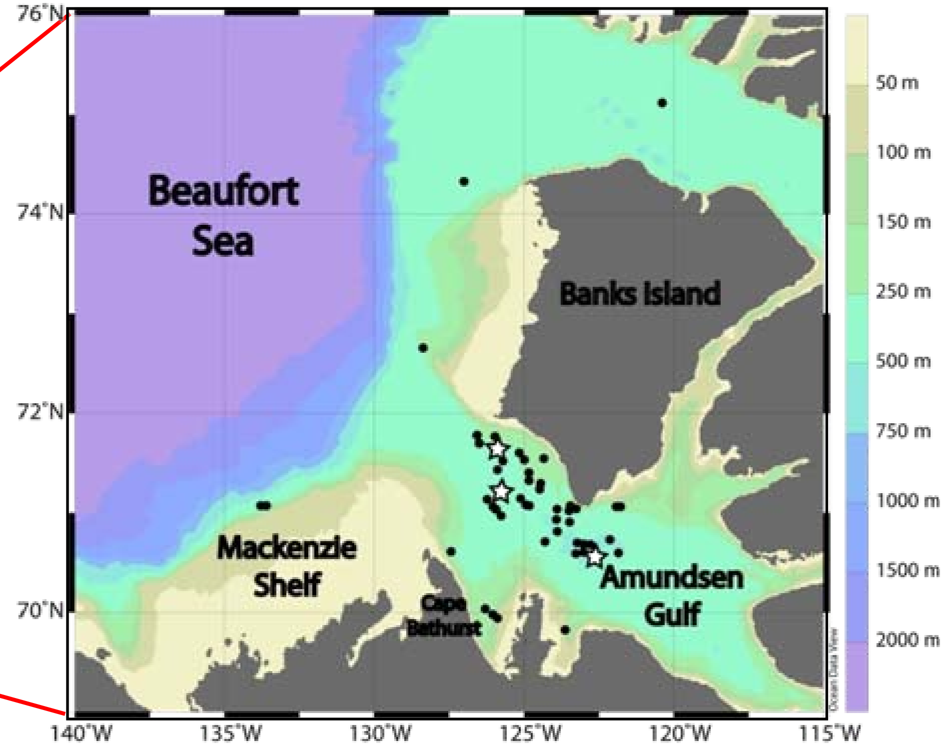
**to examine the relative role of two zooplankton size classes in the attenuation of POC flux and in the downward flux of respiratory carbon in the Amundsen Gulf pelagic ecosystem.**

# Circumpolar Flaw Lead System Study

## IPY-CFL 2007-08



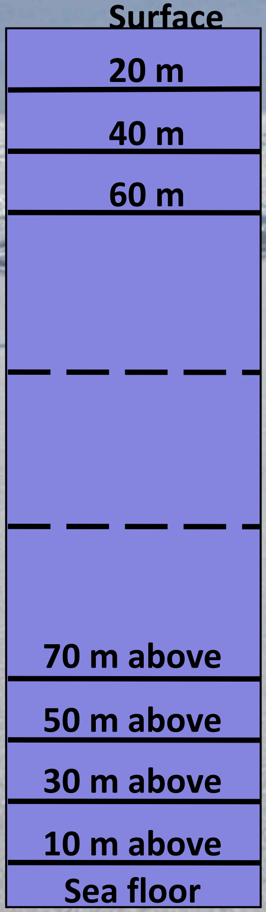

## Study area




- 24 October 2007-30 July 2008
- 35 profiles of zooplankton biomass and respiration in Amundsen Gulf

# Sampling

## Multinet Hydrobios fitted with nine 200µm nets




## CCGS Amundsen

## Sub-sampling

½ Taxonomy

¼ Biomass

¼ Respiration

## Size fractionation

→ Small size fraction (200-1000 µm)

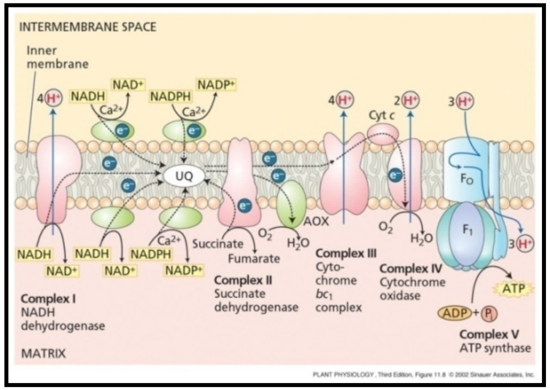
→ Large size fraction (>1000 µm)

**Additional integrated tows with 200µm net for end-point respiration experiments**

# Vertical profiles of respiration

- **Activity of the Electron-Transport System (ETS)**

  **ETS assays following the protocol of Båmstedt (2000).**




  **Respiration rate (R) = ETS activity x (R/ETS)**

- **Determination of R/ETS ratios**

  **Sealed chamber incubation for direct measurement of respiration prior to ETS assay.**

- **Conversion from $0_2$ consumption to $CO_2$ release**

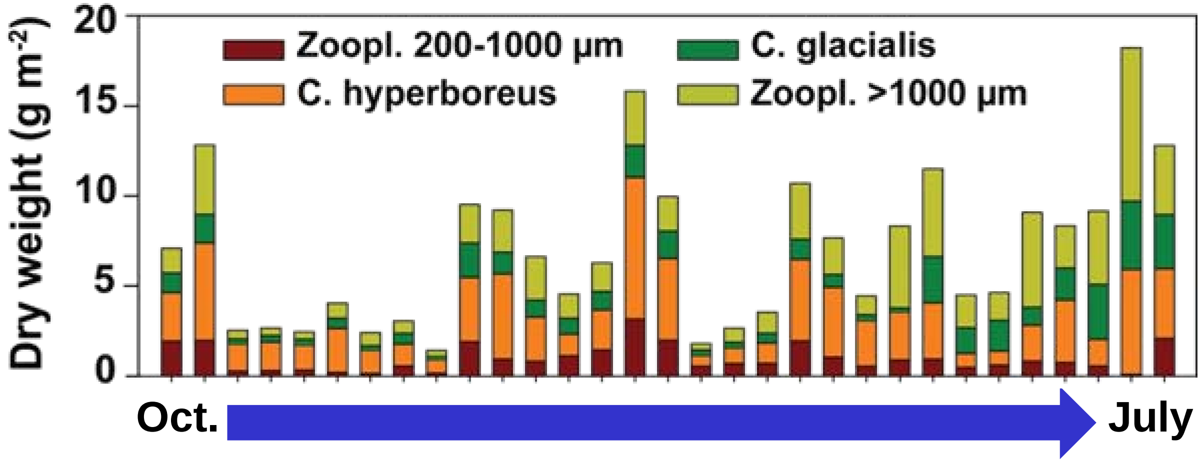
  **RQ = 0.75; for metabolism essentially based on lipids**

  **RQ = 0.97; for metabolism mainly based on proteins**

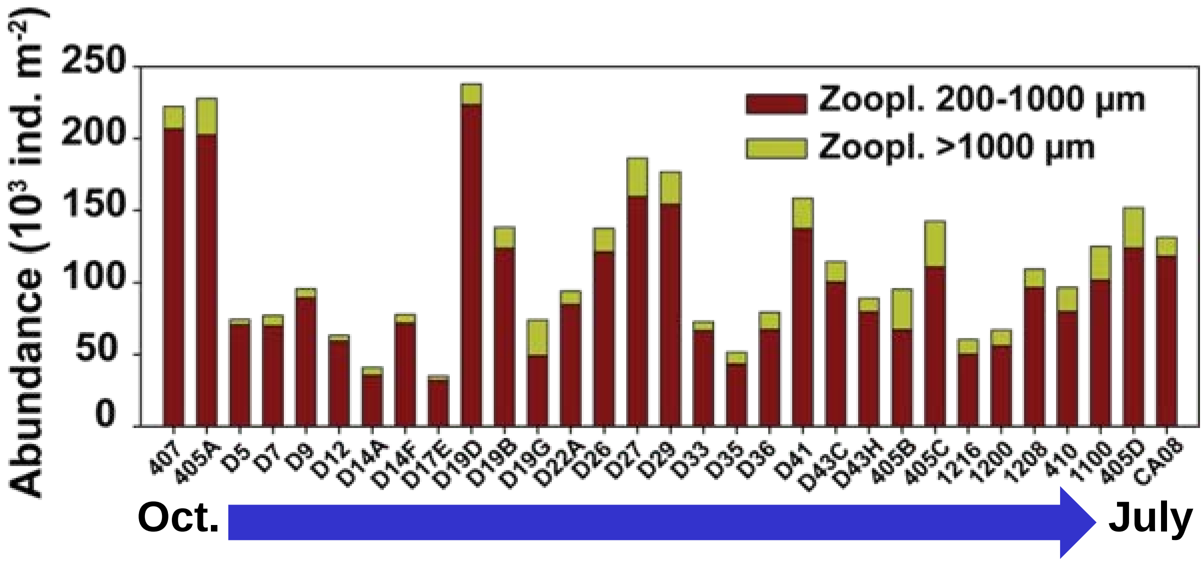
- **Potential ingestion (I), using the equation of Ikeda & Motoda (1978):**

  **I = 100R/(70-30) = 2.5R ;      AE and GGE of 70 and 30%, respectively**

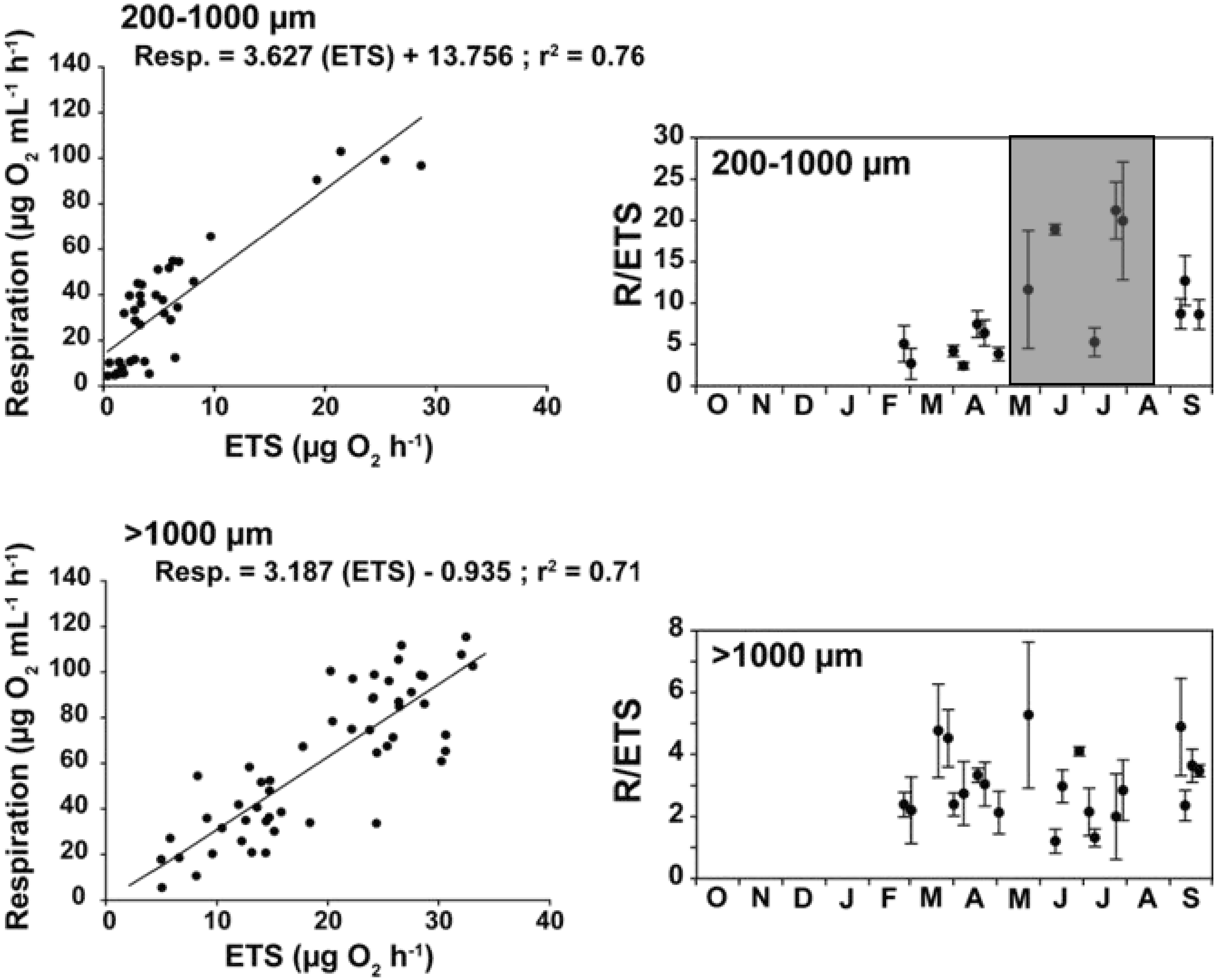
# Zooplankton biomass and distribution




• *Calanus* spp. accounted for 36-83% of large zooplankton biomass



# Zooplankton respiration and R/ETS ratio

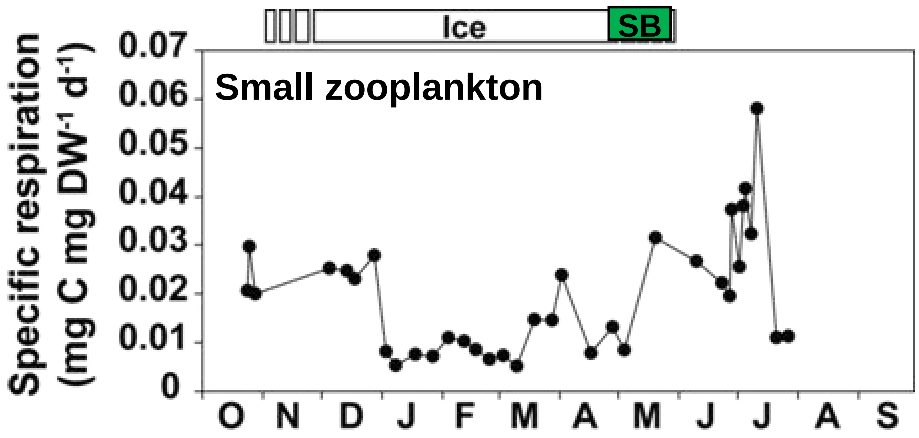


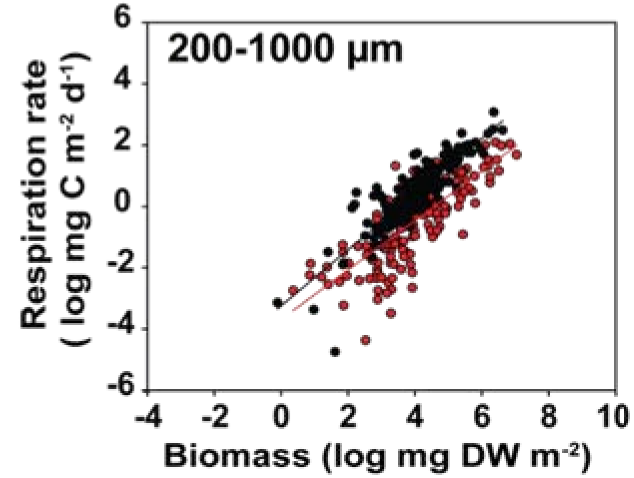

$R/ETS_W = 4.5 \pm 2.1$

$R/ETS_{SA} = 10.3 \pm 2.9$

$R/ETS = 3.2 \pm 1.3$

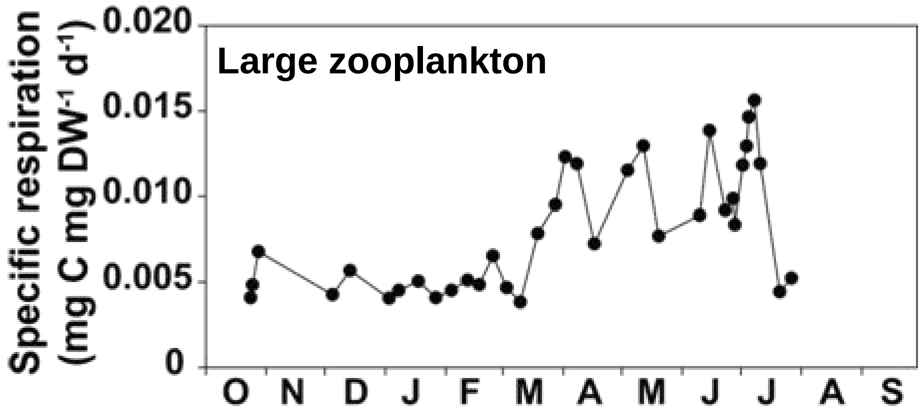
# Zooplankton respiration and biomass

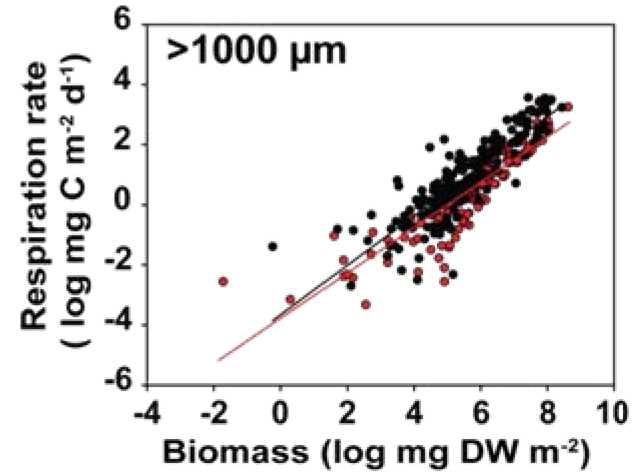



$\text{Ln } R_{W} = -3.844 + 0.840 \text{ ln DW}; r^2 = 0.64$

$\text{Ln } R_{S\text{-}A} = -3.318 + 0.921 \text{ ln DW}; r^2 = 0.72$

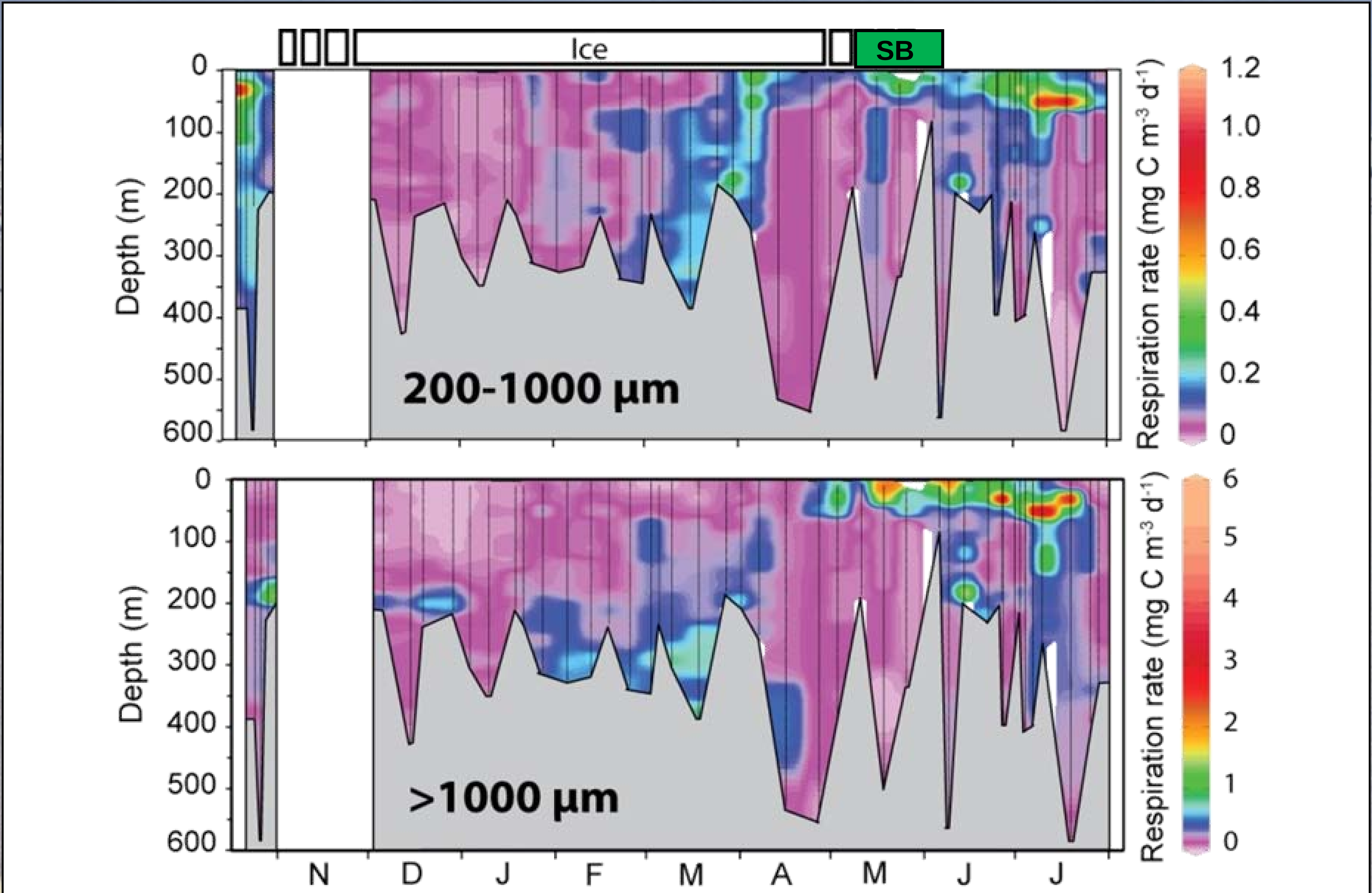



$\text{Ln } R_{A\text{-}W} = -3.875 + 0.753 \text{ ln DW}; r^2 = 0.80$

$\text{Ln } R_{S\text{-}S} = -3.517 + 0.800 \text{ ln DW}; r^2 = 0.75$

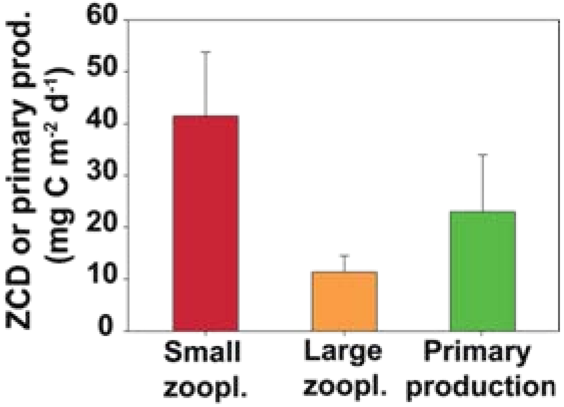
# Zooplankton respiration and vertical distribution



# Zooplankton ingestion and POC attenuation

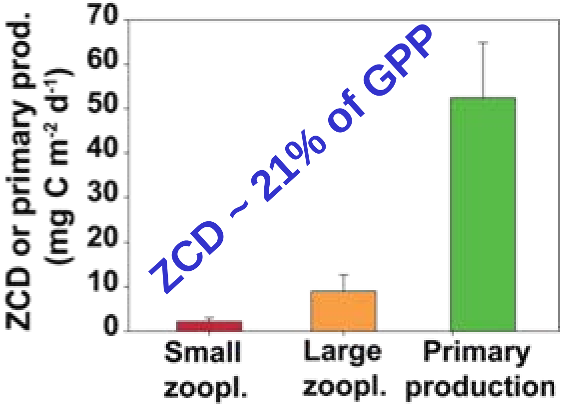
- **Autumn**

**Zooplankton potential ingestion compared to primary production in the surface 100 m layer**

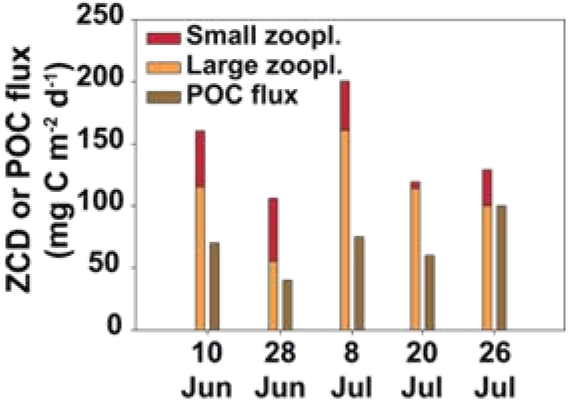



- **Spring-summer**

**Zooplankton potential ingestion compared to primary production in the surface 100 m layer**




**Zooplankton potential ingestion and POC flux below 100 m depth**



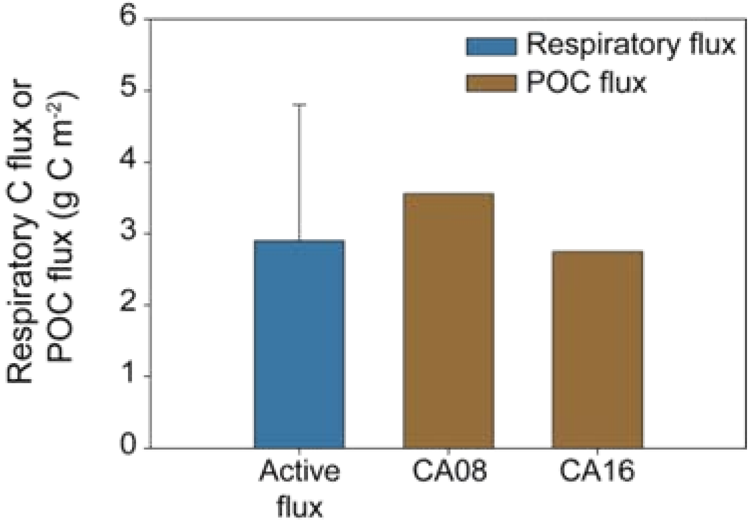
# Active respiratory flux by Calanus seasonal migrants

*Calanus* spp. share of the bulk zooplankton respiration in winter at depth was estimated pro rata their contribution to the biomass of large zooplankton.

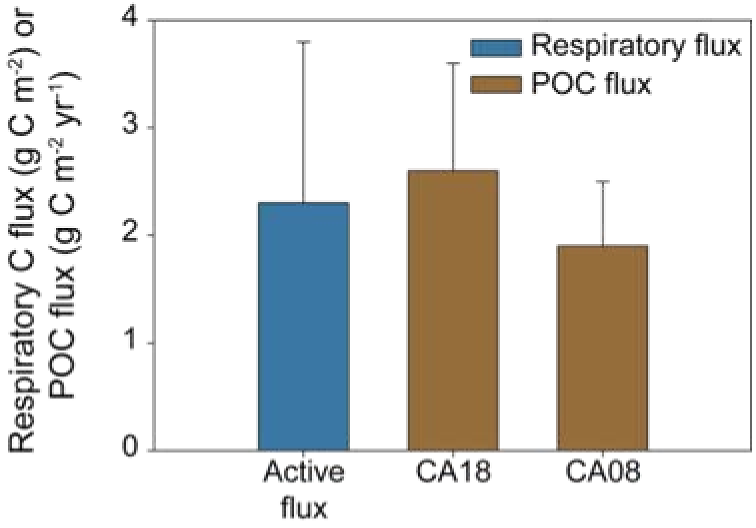
**Assumptions:**

1. *Calanus* spp. do not feed at depth in winter
2. Their winter specific respiration rates were similar to other large zooplankton

**Active respiratory flux and gravitational POC flux below 100 m depth in 2007-2008**




**Active respiratory flux in 2007-2008 and gravitational POC flux below 200 m depth (mean for 2004-2006)**



# Summary

- **Small zooplankton were the main POC consumers and recyclers in autumn when the bulk of large organisms were already at depth with a reduced metabolism.**

- **Zooplankton were in place and physiologically ready to exploit the fresh POC supplied by the 2008 precocious spring phytoplankton bloom.**

- **In spring-summer, large zooplankton were the main grazers of primary production at the surface and the main interceptors of POC flux at depth.**

- **Respiratory losses of carbon brought from the surface by the *Calanus* population overwintering in the deep layers were equivalent to POC annual passive fluxes.**

# Conclusion

- **The large and small zooplankton may be viewed as different functional groups when considering their distinctive roles in the biogeochemical carbon flux within arctic pelagic ecosystems.**

- **Large zooplankton take the largest share of zooplankton metabolism in the system but small zooplankton have a considerable impact on POC attenuation in autumn and during the overwintering season.**

- **The *Calanus* spp. active respiratory fluxes can double the efficiency of the biological pump of $CO_2$ to the deep water masses, as assessed by long-term sediment traps .**

- **Arctic zooplankton are well prepared to cope with the high variability in the timing of pelagic primary production.**

- **A shift toward smaller zooplankton, anticipated under climate warming, should enhance recycling over carbon export to the deep ocean.**

# Acknowledgements


- Z team: Alex, Anaïs, Anette, Brigitte, Caroline, Catherine, Hélen, Josée, Keith, Louis, Luc, Makoto, Marc, Samuel, Sherpa, Stéphane, Stig,…

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