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 (°C decade⁻¹)

(Zhang 2005)


(Arctic Ocean
September Sea Ice Extent: Observations (red) versus Models and Model Mean (± s.d.) (averaged model data and s.d. in black)
(NSIDC 2010)
Arctic pelagic food web

- 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

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

(Ducklow et al 2001)
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**

- 35 profiles of zooplankton biomass and respiration in Amundsen Gulf
Sampling

Multinet Hydrobios fitted with nine 200µm nets

Sea floor

20 m
40 m
60 m

Surface

CCGS Amundsen

70 m above
50 m above
30 m above
10 m above
Sea floor

Sub-sampling

1/2 Taxonomy

1/4 Biomass

1/4 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 \( \times \) \( \frac{R}{ETS} \)

- Determination of \( \frac{R}{ETS} \) ratios
  
  Sealed chamber incubation for direct measurement of respiration prior to ETS assay.

- Conversion from \( O_2 \) 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):
  
  \[ I = \frac{100R}{(70-30)} = 2.5R \]
  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

200-1000 μm
Resp. = 3.627 (ETS) + 13.756 ; $r^2 = 0.76$
R/ETS$_W = 4.5 \pm 2.1$

R/ETS$_{SA} = 10.3 \pm 2.9$

>1000 μm
Resp. = 3.187 (ETS) - 0.935 ; $r^2 = 0.71$
R/ETS= 3.2 ± 1.3
Zooplankton respiration and biomass

\[
\ln R_W = -3.844 + 0.840 \ln DW; \quad r^2 = 0.64 \\
\ln R_{S-A} = -3.318 + 0.921 \ln DW; \quad r^2 = 0.72 \\
\ln R_{A-W} = -3.875 + 0.753 \ln DW; \quad r^2 = 0.80 \\
\ln R_{S-S} = -3.517 + 0.800 \ln DW; \quad r^2 = 0.75
\]
Zooplankton respiration and vertical distribution

![Graph showing zooplankton respiration and vertical distribution. The graph illustrates the respiration rate (mg C m$^{-3}$ d$^{-1}$) at different depths (m) ranging from 0 to 600. Two panels are shown, one for 200-1000 μm size range and another for >1000 μm size range, with seasonal variations marked by months (N for November, D for December, J for January, etc.).]
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

ZCD ~ 21% of GPP

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.
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