Influence of $p\text{CO}_2$, temperature, and feeding on the extracellular pH of *Calanus glacialis* during diapause

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Copepods of the genus *Calanus*

- Important grazers of ice algae and phytoplankton
- Biomass can be > 80% of zooplankton community
- Store lipids in high quantities
- Important food source for fish, whales and birds

From: Greenland Institute of Natural Resources (2010)
Objectives

1. To investigate the influence of environmental conditions on extracellular pH ($\text{pH}_e$) of *Calanus glacialis* during and at the end of the diapause

   Environmental conditions:
   - Ocean acidification
   - Warming
   - Feeding

2. To compare $\text{pH}_e$ in CV and ♀ to elucidate differences in developmental stage
Life cycle of *Calanus glacialis*

**Diapause**
- Reduced development
- Reduced growth
- Reduced metabolism
- Starvation
- No locomotion

**Activity**
- Reproduction
- Feeding
- Growing
- Lipid accumulation

Modified from: Diel (1991)
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Modified from: Diel (1991)
Regulation of ions and $pH_e$

- Diapause conducted at depth

**Ion regulation**
- To reach neutral buoyancy
- High density ions replaced by low density ions
- Antarctic copepods replace $Na^+$ by $NH_3$ (Sartoris et al. 2010; Schrönder et al. 2013)
- $NH_3$ is toxic
Regulation of ions and pH$_e$

- Diapause conducted at depth

- **Ion regulation**
  - To reach neutral buoyancy
  - High density ions replaced by low density ions
  - Antarctic copepods replace Na$^+$ by NH$_3$ (Sartoris *et al.* 2010; Schründer *et al.* 2013)
  - NH$_3$ is toxic

- **Regulation of pH$_e$**
  - To withstand toxicity
  - At low pH$_e$: NH$_3$ $\rightarrow$ NH$_4^+$
  - NH$_4^+$ is not toxic
  - Low pH$_e$ might trigger metabolic depression

- During winter (diapause) $\rightarrow$ pH$_e$ is low
Seasonality of $pH_e$ in *C. glacialis* CV

$pH_e$ was low in autumn/winter and high in spring/summer.

Modified from: Freese *et al.* (submitted)
Climate change

- **Ocean acidification**: reduction of pH with 0.3 - 0.6 units (Povopa et al. 2014)
- **Warming**: increase in sea surface temperature (IPCC 2007)

Modified from: Freese et al. (submitted)
## Experimental set-up

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1: during diapause</th>
<th>Experiment 2: end diapause</th>
<th>Experiment 3: end diapause</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sampling area</strong></td>
<td>Billefjorden</td>
<td>Billefjorden</td>
<td>Billefjorden</td>
</tr>
<tr>
<td><strong>Sampling time</strong></td>
<td>September 2013</td>
<td>January 2014</td>
<td>January 2014</td>
</tr>
<tr>
<td><strong>Amount animals</strong></td>
<td>3600</td>
<td>750</td>
<td>~ 200</td>
</tr>
<tr>
<td><strong>Stage</strong></td>
<td>CV</td>
<td>CV</td>
<td>♀</td>
</tr>
<tr>
<td><strong>Species</strong></td>
<td><em>C. glacialis</em></td>
<td><em>C. glacialis</em></td>
<td><em>C. glacialis</em></td>
</tr>
<tr>
<td><strong>Incubation time (d)</strong></td>
<td>15 – 30</td>
<td>31</td>
<td>37</td>
</tr>
<tr>
<td><strong>Temperature (°C)</strong></td>
<td>0, 5, and 10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>pCO₂ (ppm)</strong></td>
<td>390 and 2300</td>
<td>500 and 1500</td>
<td>-</td>
</tr>
<tr>
<td><strong>Food available</strong></td>
<td>no</td>
<td>no</td>
<td>yes / no</td>
</tr>
</tbody>
</table>
Results: No influence of temperature on pH_e during the diapause (exp.1)
Results: No influence of $p$CO$_2$ on pH$_e$ during the diapause (exp.1)
Results: No influence of $p$CO$_2$ on pH$_e$ at the end of the diapause (exp.2)
Results: No difference in pH$_e$ of CV and ♀ at the end of the diapause (exp.2)
Results: Feeding increased pH_e at the end of the diapause (exp.3)

Start feeding

Thalassiosira weissflogii
Synthesis

- $pH_e$ was not related to the environmental conditions
- No difference in $pH_e$ of CV and ♀
- Feeding increased $pH_e$ of ♀ -> copepods became active

Diapausing *C. glacialis* CV and ♀ will be able to regulate $pH_e$ at environmental conditions predicted for the end of the century

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We can confirm that feeding is crucial in the transition from diapause towards activity

- Future research -> climate change might change food quality can *Calanus* spp. cope?
Thank you!

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