Increased seawater temperatures cause temporal shifts in catabolic pathways of Antarctic krill *Euphausia superba*

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Photo: J. v. Franecker
Contents

• (Rationale - Why Krill?)

• Recap: Experiments at the AAD

• Results
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• Conclusions & Outlook
Fig. 3. Seasonal distribution of mean 0–10 m temperature (°C).

Whitehouse et al. 2008
Hypothesis

„Adult krill have a narrow temperature range of 0.5°C to 4°C for optimal growth and physiological functioning.“
Recap
Tobi's Experiments
V2/V3 09/10 + V3 08/09 RTA
1. Collect samples + O2,
   - Preserve in 95% Ethanol + record DO
2. Check temp + IR
3. Leave lights off
4. Prepare live algae/instant algae/flipper
   for later feeding (random times)

8L Phaco

8L Pyram

8 L Gem

until Phaco is back

Tank B3
500ml flipper
20ml Thi
10ml 150
10ml Pea

References with Loria
1L Phaco
1L Pyram
1L Gem
200ml flipper
2nd Thi
1ml Pea
1ml 150
Experimental Setup
Sampling Scheme

![Graph showing temperature changes over weeks. The graph includes two sets of data points: Treatment (circles) and Control (triangles). The x-axis represents weeks, and the y-axis represents temperature in °C. The trend line for the Treatment group shows a steady increase in temperature over the weeks, whereas the Control group remains relatively constant.]
Sampling Scheme

- **Treatment**
- **Control**

**Temperature [°C]**

- **Week**
  - 0: 24 x
  - 4: 6 x
  - 8: 6 x
  - 12: 6 x
  - 16: 6 x
  - 20: 18 x

**Graph**

- Black circles represent Treatment.
- Orange triangles represent Control.

**Legend**

- **Temperature** ranges from 0 to 8°C.

**X-axis**

- Week 0 to 20.
Respiration

![Graph showing respiration relative to control against temperature in °C.](image)
Respiration -> Energy Requirement

<table>
<thead>
<tr>
<th>Temperature [°C]</th>
<th>Equation from linear regression</th>
<th>Individual energy requirement [Joule/d]</th>
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How are energy demands met?
TCA cycle

Glycolysis/
Gluconeogenesis

beta oxidation
Malate Dehydrogenase MDH

- Key enzyme in TCA cycle, catalyzes oxidation of malate to oxaloacetate
- also involved in other pathways (shuttling of TCA intermediates to cytosol)
- mirrors respiration to some extent
Results

- TCA cycle
- Beta oxidation
- Malate dehydrogenase
- Citrate synthase
- Glycolysis/
  Gluconeogenesis
Citrate Synthase CS

- catalyzes first reaction in the cycle: condensation of the acetate residue from Acetyl CoA and one molecule oxaloacetate
- acts as central crossing point for various pathways
- balances oxidative and biosynthetic pathways
- entry point for fat synthesis (Acetyl-CoA shuttle to cytosol)
Pyruvate Kinase PK

- Key enzyme in glycolytic pathway, catalyzes transphosphorylation from PEP and ADP to pyruvate and ATP
- constitutes primary metabolic intersection (Munoz 2003)
- suggested to play an important role in the transition to anaerobic metabolism (Vial et al. 1992)
3-Hydroxyacyl-CoA-DH HOAD

- 3rd step in beta oxidation
- marker enzyme for utilization of lipids
Glucose Catabolism

• ATP is allosteric inhibitor of PK -> upregulation of PK when ATP required

• upregulation -> less gluconeogenesis, no demand for synthesis of glucose
Protein Catabolism

MDH going up <-> not mirrored by CS:

- points to a role of MDH other than that in the cycle series: downstream shuttling of intermediates of protein catabolism into TCA?

- other studies show higher capacity for protein breakdown with increasing temperature (Schwerin et al. 2009)
Lipid Catabolism

Normalization to CS as central crossing point in metabolism (Windisch et al. 2011):

- increase in ratio hints at tendency towards lipid oxidation, NOT lipid synthesis
Conclusions

• Increased seawater temperature possibly leads to:
  • earlier onset and heavier reliance on protein catabolism
  • prolongation of lipid oxidation
Implications:

• Krill relies on productive summer months to accumulate lipid reserves for winter - prolonged lipid oxidation may impede the buildup of these crucial reserves - overwinter-ability affected

• Energy channeled towards higher maintenance will lack elsewhere, for example maturation
Outlook

Differential Gene Expression

• validate enzyme activities on genetic level

• fill gaps in the puzzle
anaerobic pathways?
glycerol -> GAP?
protein catabolism?
PPP?
stress response?
Outlook

Temperature Compensation of Clock Genes

• Dissociation of environmental events (blooms, sea-ice retreat) and endogenously controlled physiology (regression, maturation, spawning)
Acknowledgments

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Thank You!