GLOBAL WARMING, ZOOPLANKTON SHIFTS, AND BIOGENIC CARBON FATE IN THE SOUTHERN OCEAN

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1 The facts
- Krill and salps are efficient grazers and contributors to the vertical carbon flux.
- While krill are a fundamental link between autotrophs and upper consumers, salps are quite indifferent as food- but more efficient than krill in packing biogenic carbon into large, heavy faecal pellets1.

2 A future problem
- Rising temperatures, ice retreat and whale decimation are predicted to lead to crucial ecosystem changes in the Southern Ocean, like the substitution of krill by salps as the dominant grazer and the reduction of individual size (biomass) of zooplankton [1].

3 Main questions
- In the case of krill-salps shift and individual biomass reduction, will the present metabolic C requirements of the zooplankton community change?
- What will be the fraction of primary production required by zooplankton to compensate for the metabolic C requirements, and the fate of the biogenic C?

4 What we did and how
We analysed primary production (total and particulate, TPP and PPP respectively), taxonomic composition, individual biomass and metabolism (respiration rates) of zooplankton in the vicinity of the Antarctic Peninsula. We compared the percentage of PPP allocated to zooplankton respiration losses in this study and for the future zooplankton shifts.

- Total and particulate primary production (TPP and PPP, respectively) were measured by the 14C technique1 and in situ incubation.
- Zooplankton was sampled with a double 200-µm WPZ net. Mesozooplankton biomass (as µmol C m⁻³) was calculated by the relationships between volume (Zooimage®) and organic C relationships4. Krill biomass was measured with a Simrad® EK60 multifrequency echosounder5.
- C-specific respiration rates (Cₚ) for krill, salps and copepods were estimated by incubation experiments at “in situ” temperature4 and measured by semi-continuous analysis of O₂ concentration using OXY-10 PreSens® optodes.
- Respiration (Cₚ) was used as a proxy of the metabolic C requirements of zooplankton. Assimilation efficiency was used to calculate ingestion (Cᵢ) and vertical carbon export (Cₑ).

5 Results

5-1

<table>
<thead>
<tr>
<th>Krill</th>
<th>Salps</th>
<th>Copepods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass (µmol C m⁻³)</td>
<td>4726.99</td>
<td>7.51</td>
</tr>
<tr>
<td>Cᵢ (day⁻¹)</td>
<td>0.0136</td>
<td>0.0841</td>
</tr>
</tbody>
</table>

- Krill biomass: 92% of total zooplankton.
- Specific metabolic rates of salps higher than those of krill by a factor of 7.

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- Cₚ specific respiration rates inversely related to individual biomass.
  \[ Cₚ = 0.030 \times Cᵢ^{-0.15} \]
  \[ r = -0.70, p < 0.01, n=63 \]

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<table>
<thead>
<tr>
<th>Present</th>
<th>Salp-krill shift</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

- Carbon ingested by zooplankton (Cᵢ). Present and in a future Salp-krill shift, from respiration, Cᵢ, (µmol C m⁻³ day⁻¹) corrected for the assimilation efficiency of krill* (70%) and salps** (52%).

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Salp-krill shift:
- The carbon ingested (Cᵢ) by zooplankton will increase by a factor of 7
- The vertical carbon export (as faecal pellets) will increase by a factor of 10.

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<table>
<thead>
<tr>
<th>Product</th>
<th>Ingest</th>
<th>Export</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP</td>
<td>2000</td>
<td>500</td>
</tr>
<tr>
<td>NP</td>
<td>400</td>
<td>50</td>
</tr>
<tr>
<td>Cᵢ</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Cₑ</td>
<td>100</td>
<td>20</td>
</tr>
</tbody>
</table>

6 Conclusions
- In a future salps-dominated Southern Ocean and in which the average individual biomass has decreased by temperature rising, more than 50% of the carbon fixed by primary producers will be necessarily allocated to compensate for the respiratory losses of zooplankton (Cᵢ). In the present krill-dominated community less than 8% of PPP will be necessary.
- Near 50% of the carbon ingested (Cᵢ) will be packed in the form of large, fast settling faecal pellets, intensifying the rate of carbon export (Cₑ) to the long-lived and/or sequestered biogenic carbon pool, while the present community structure less than 30% of the ingested carbon is eggested (Cₑ) as fragile krill faecal pellets.
- The expected major shift in the structure of the Southern Ocean zooplankton would thus induce changes in the food webs that will affect the whole Antarctic ecosystem, with a decrease of the P/R (production/respiration) quotient with, paradoxically, a simultaneous decrease of the regenerative processes in surface waters.

7 Bibliography

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