Using allometry to model copepod-mediated carbon flux – how well do we estimate key rates and variables?

*A test case from the NASA EXPORTS expedition*

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Biological carbon pump

Steinberg & Landry 2017
Biological carbon pump

Passive flux (Sinking fecal pellets)
Biological carbon pump

Active flux (diel and seasonal vertical migration)

Steinberg & Landry 2017
OUTLINE

1. The biological carbon pump
2. EXPORTS: a field campaign to quantify the biological carbon pump
3. Modeling three flux pathways for copepods: passive flux, active DVM flux, active seasonal migration flux
4. Results from a size-based model, applied in the North Atlantic Ocean
5. Zero in on one copepod species (*Neocalanus cristatus*) to compare field measurements to estimates of key variables from size-based modeling
6. Conclusions
Zooplankton-mediated carbon export is important, but difficult and expensive to measure, e.g.
We can also model copepod-mediated carbon flux.

Passive flux:

Size fits the bill because...


Particle size → sinking rate (Stokes Law)
• Fitness optimization model for diel vertical migration behavior:
  • Trade-off between feeding at surface, and predation
  • Size impacts swimming efficiency, feeding rate, predation, metabolism
Diapause and size are linked
There are several different diapause strategies

Active flux: seasonal migration

Brun et al. 2019

Calanus finmarchicus

Calanus species that use diapause in the North Atlantic: *C. finmarchicus*, *C. hyperboreus*, *C. glacialis*
RESULTS!

Fecal pellet flux: 1960-2014

Active DVM flux:
**More Results!**

Diapause flux:

Distribution of *Calanus finmarchicus*

**Changes in flux are being driven by changes in *Calanus* species biomass**

Pershing & Stamieszkin, 2019
Meanwhile, in the North Pacific...

Range of *Neocalanus cristatus*

Census of Marine Life, Seward Line

Note the red!
Measuring rates to estimate export pathways

Fecal pellet production experiments:

MOCNESS tows for abundance and water column distribution:

Respiration experiments:
Active respiratory flux

Measured respiration by migrating *N. cristatus*:

5.0 mgC m\(^{-2}\) d\(^{-1}\)

Modeled respiration by migrating *N. cristatus*:

0.4 mgC m\(^{-2}\) d\(^{-1}\)

~MLD = 33 m
Passive fecal pellet flux

Measured fecal pellet carbon production *N. cristatus* in upper 100 m:
- Feeding only at night: 3.3 mgC m\(^{-2}\) d\(^{-1}\)
- Feeding day and night: 4.7 mgC m\(^{-2}\) d\(^{-1}\)

Modeled fecal pellet carbon flux from *N. cristatus* in upper 100 m:
- 1.4 mgC m\(^{-2}\) d\(^{-1}\)  
  \(\approx\) 3.3 mgC m\(^{-2}\) d\(^{-1}\)
Neocalanus cristatus (individuals m$^{-3}$)

- Day: ~MLD = 33 m
- Night: ~MLD = 33 m

ADCP, OSP, August 2019

~MLD = 33 m
Nonlinear effects of body size and optical attenuation on Diel Vertical Migration by zooplankton

Mark D. Ohman, Jean-Baptiste Romagnan

~50-100 m (amplitude)  68.6 m (amplitude)

Optical environment matters

Ohman & Romagnan 2016
Measurement-to-model comparison

<table>
<thead>
<tr>
<th></th>
<th>Field measurement</th>
<th>Model estimate</th>
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<tbody>
<tr>
<td>Respiratory flux</td>
<td>5.0 mgC m⁻² d⁻¹</td>
<td>0.4 mgC m⁻² d⁻¹</td>
</tr>
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<td>FPC prod. vs. flux</td>
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<td>DVM amplitude</td>
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<td>68.6 m</td>
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</table>

**FYI:** Thorium-derived POC flux: 36 mgC m⁻² d⁻¹  
(Roca-Martí, Buesseler)
CONCLUSIONS!

Modeling needs field work and field work needs modeling.

Does size suffice?

What about non-copepod zooplankton...?