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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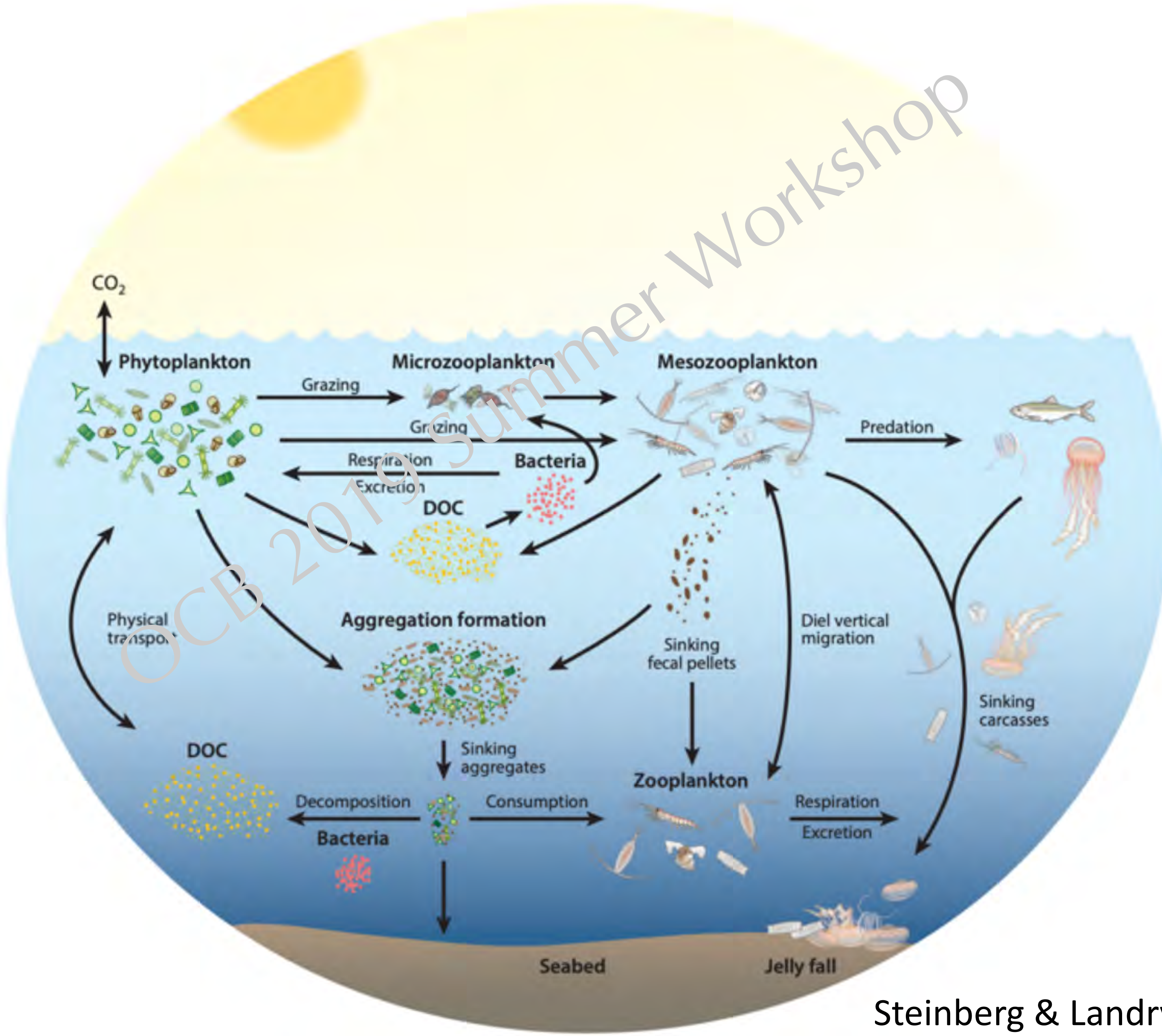
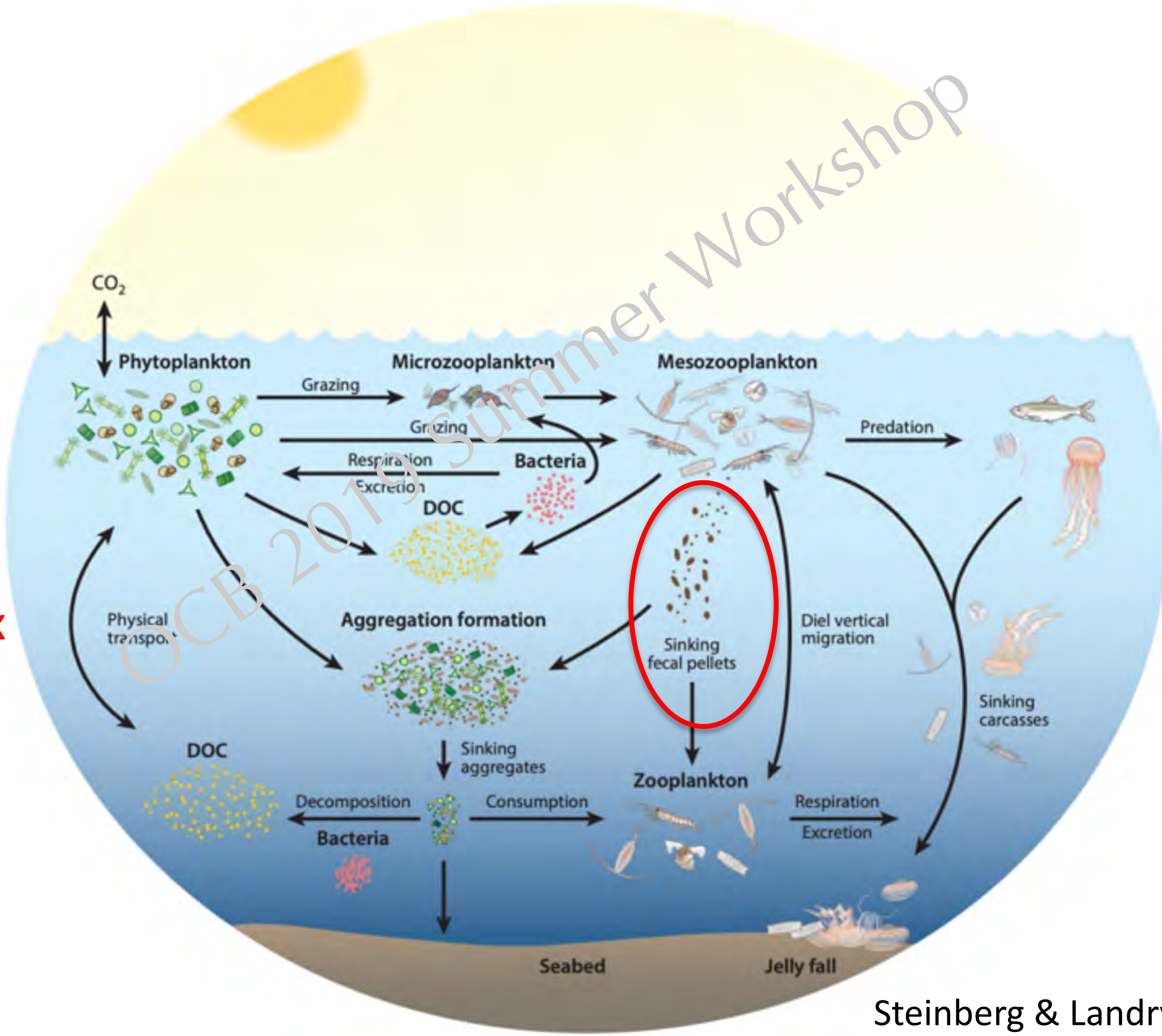
Biological carbon pump



Steinberg & Landry 2017

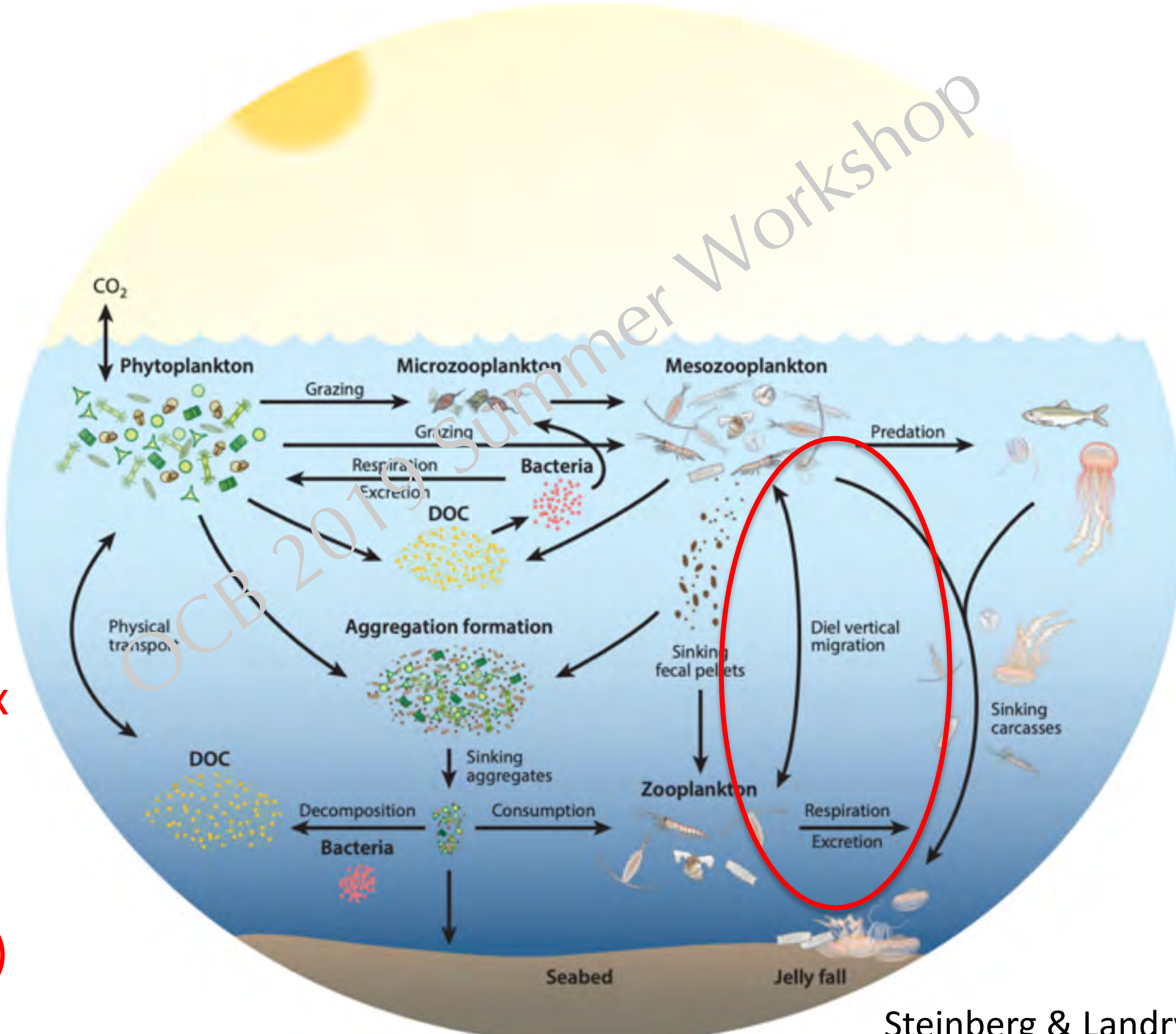
Biological carbon pump

Passive flux (Sinking fecal pellets)



Steinberg & Landry 2017

Biological carbon pump



Active flux (diel and seasonal vertical migration)

Steinberg & Landry 2017

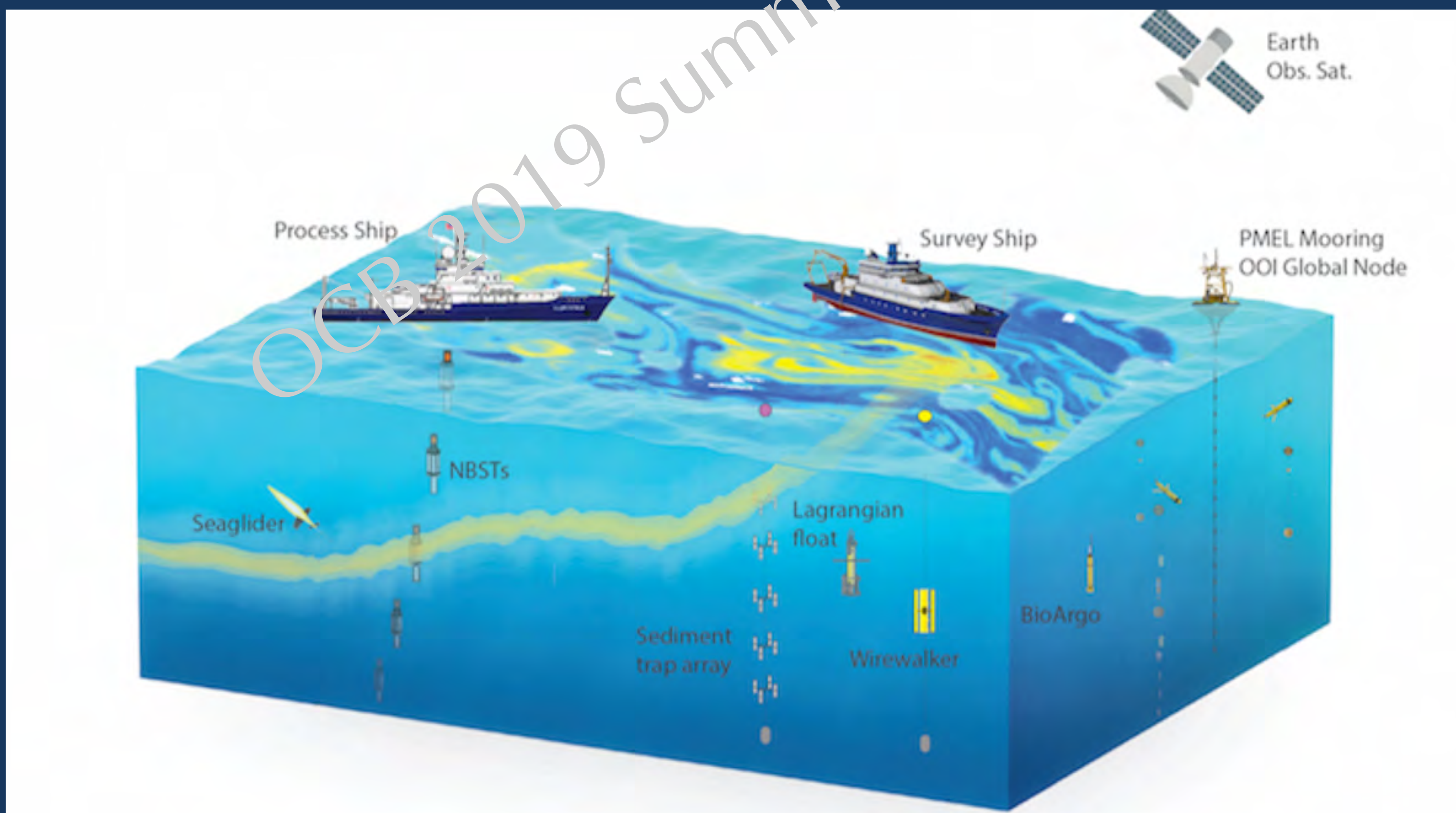
OUTLINE

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.

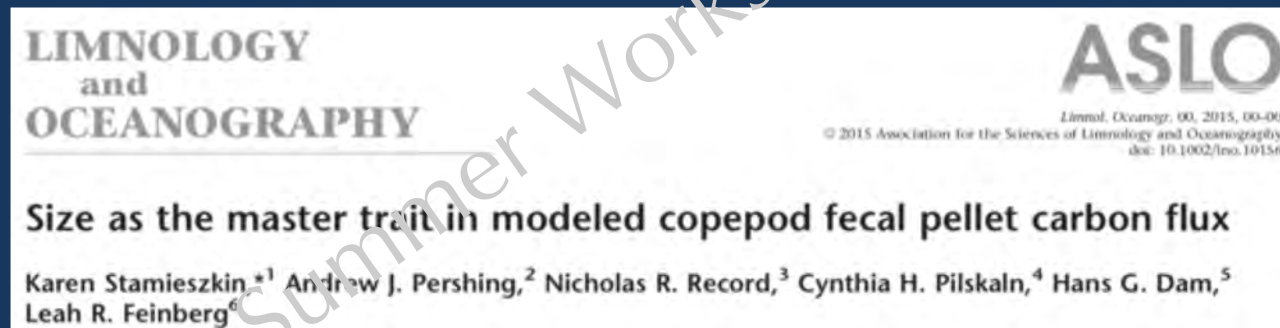
EXPORTS

EXport Processes in the Ocean from RemoTe Sensing



We can also model copepod-mediated carbon flux

Passive flux:



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doi: 10.1002/lno.10156

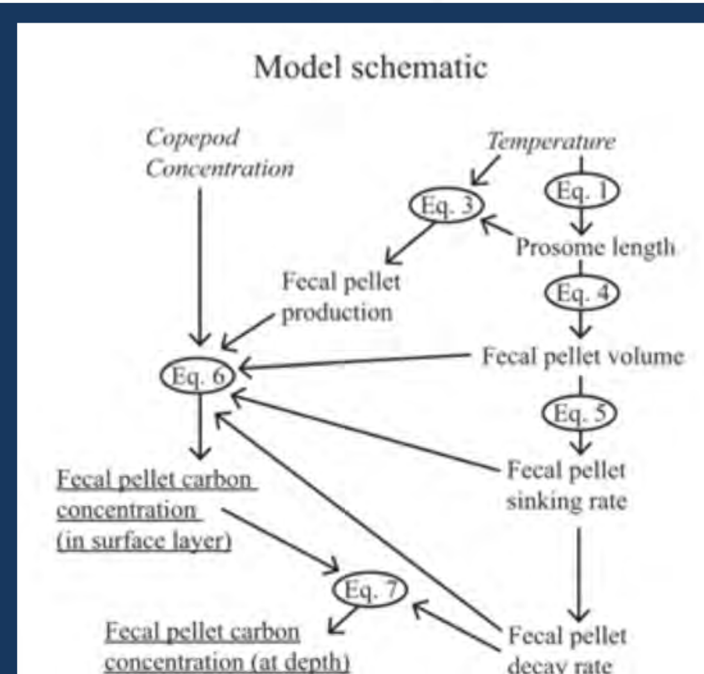
Size as the master trait in modeled copepod fecal pellet carbon flux

Karen Stamieszkin,*[1] Andrew J. Pershing,[2] Nicholas R. Record,[3] Cynthia H. Pilskaln,[4] Hans G. Dam,[5] Leah R. Feinberg[6]

Size fits the bill because…

Body size → metabolism (Kleiber 1932, Gillooly et al. 2001, Brown et al. 2004)

Particle size → sinking rate (Stokes Law)

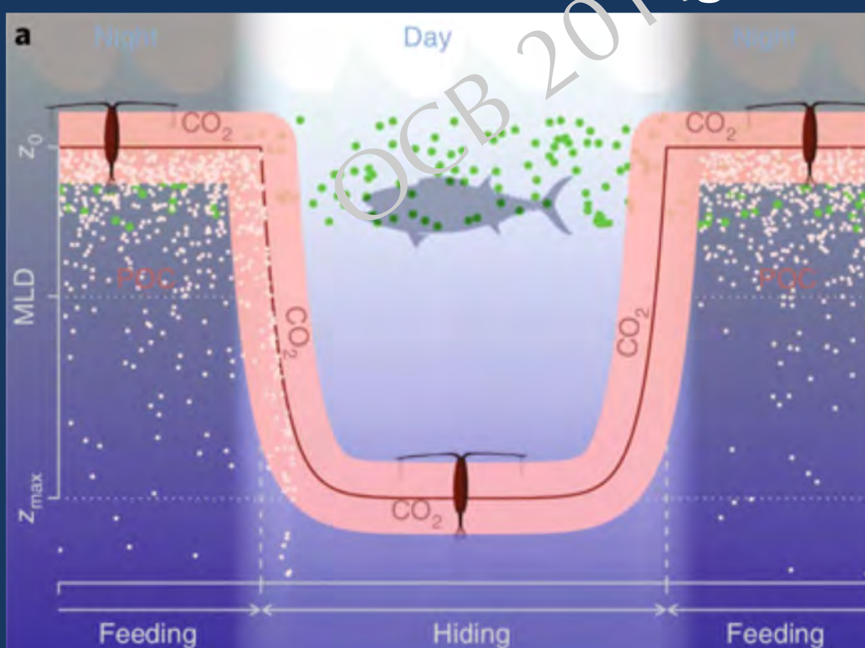


ARTICLES
https://doi.org/10.1038/s41559-018-0780-3
nature ecology & evolution

Climate change has altered zooplankton-fuelled carbon export in the North Atlantic

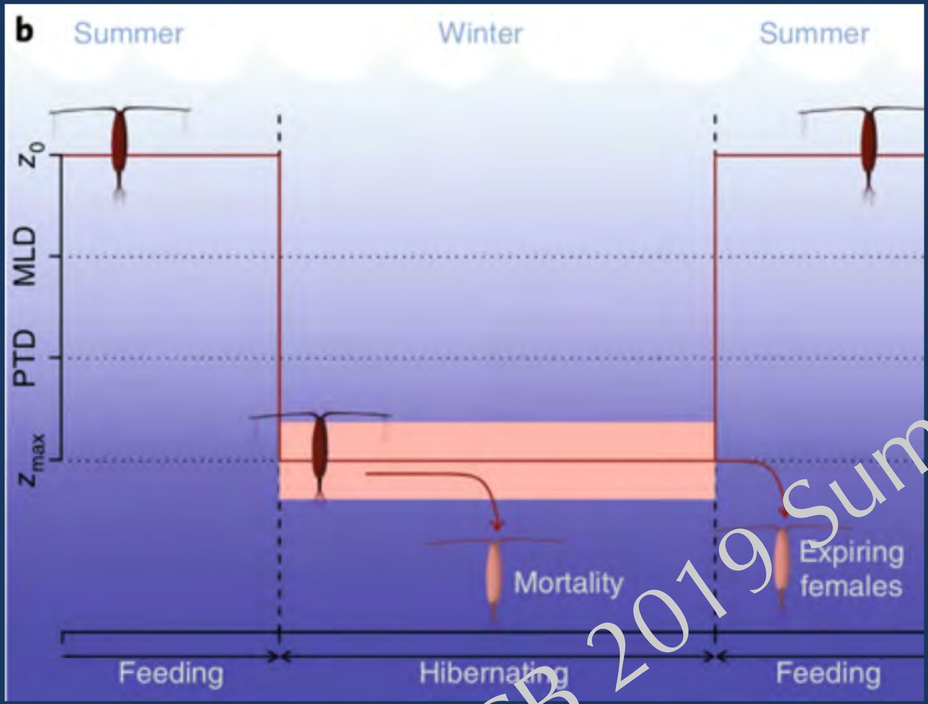
Philipp Brun[1,2*], Karen Stamieszkin[3,4], Andre W. Visser[1], Priscilla Licandro[5,6,7], Mark R. Payne[1] and Thomas Kiørboe[1]

Active flux: diel vertical migration

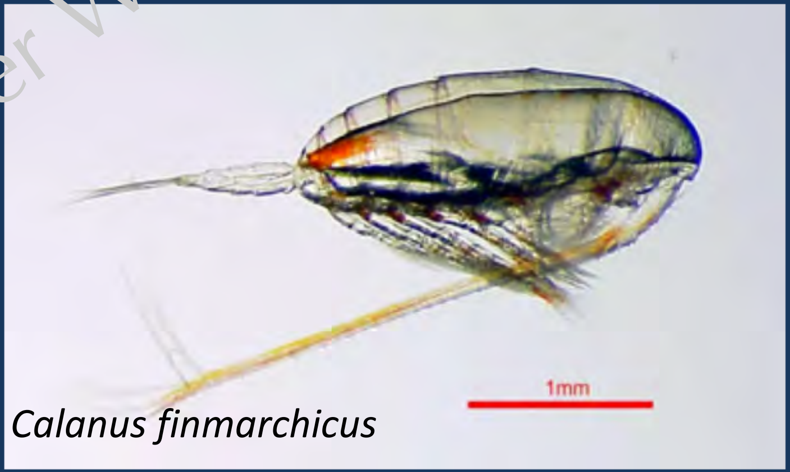


- Fitness optimization model for diel vertical migration behavior:
  - Trade-off between feeding at surface, and predation
  - Size impacts swimming efficiency, feeding rate, predation, metabolism

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*

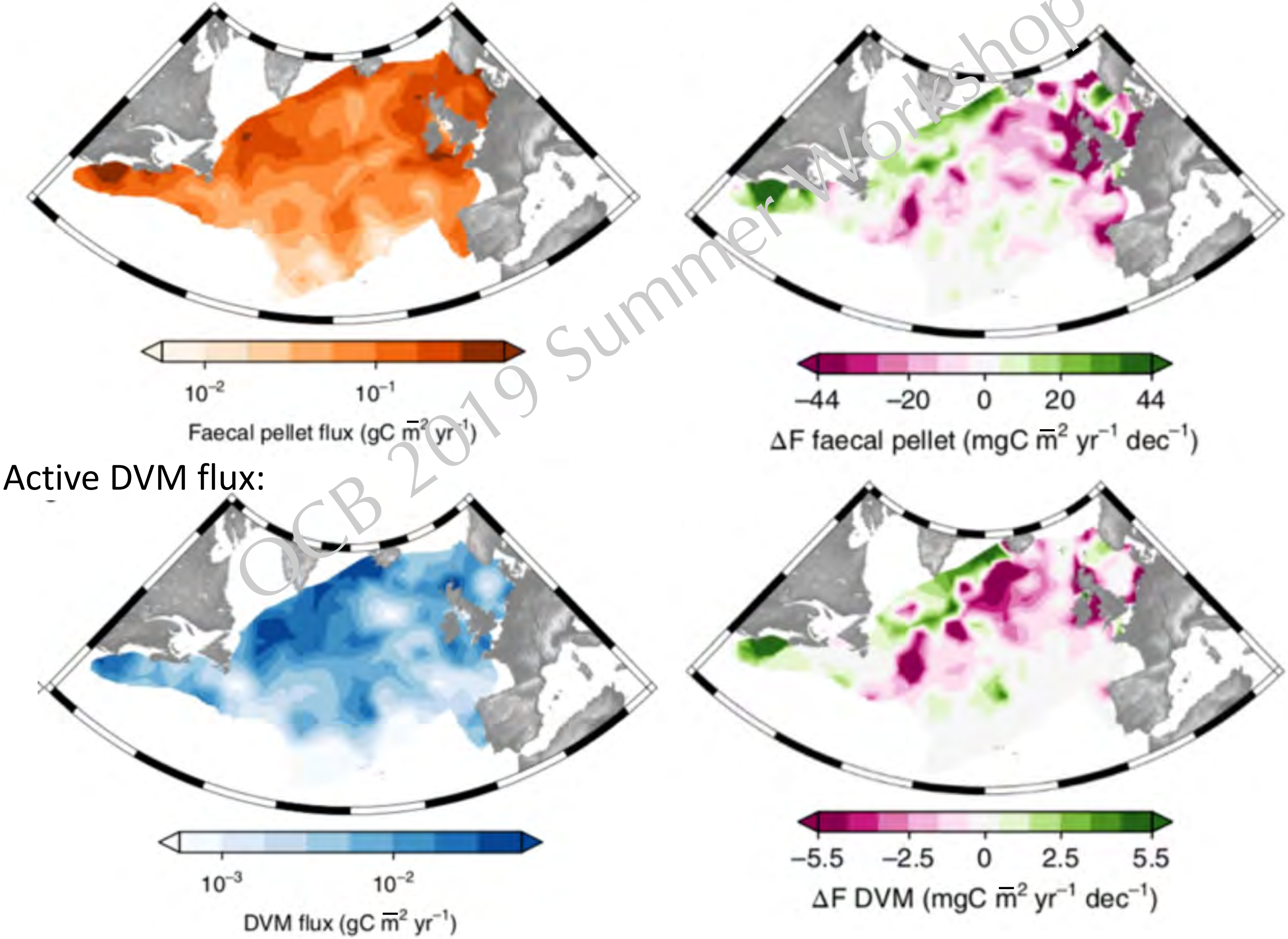
- Diapause and size are linked
- There are several different diapause strategies

RESULTS!

Fecal pellet flux:

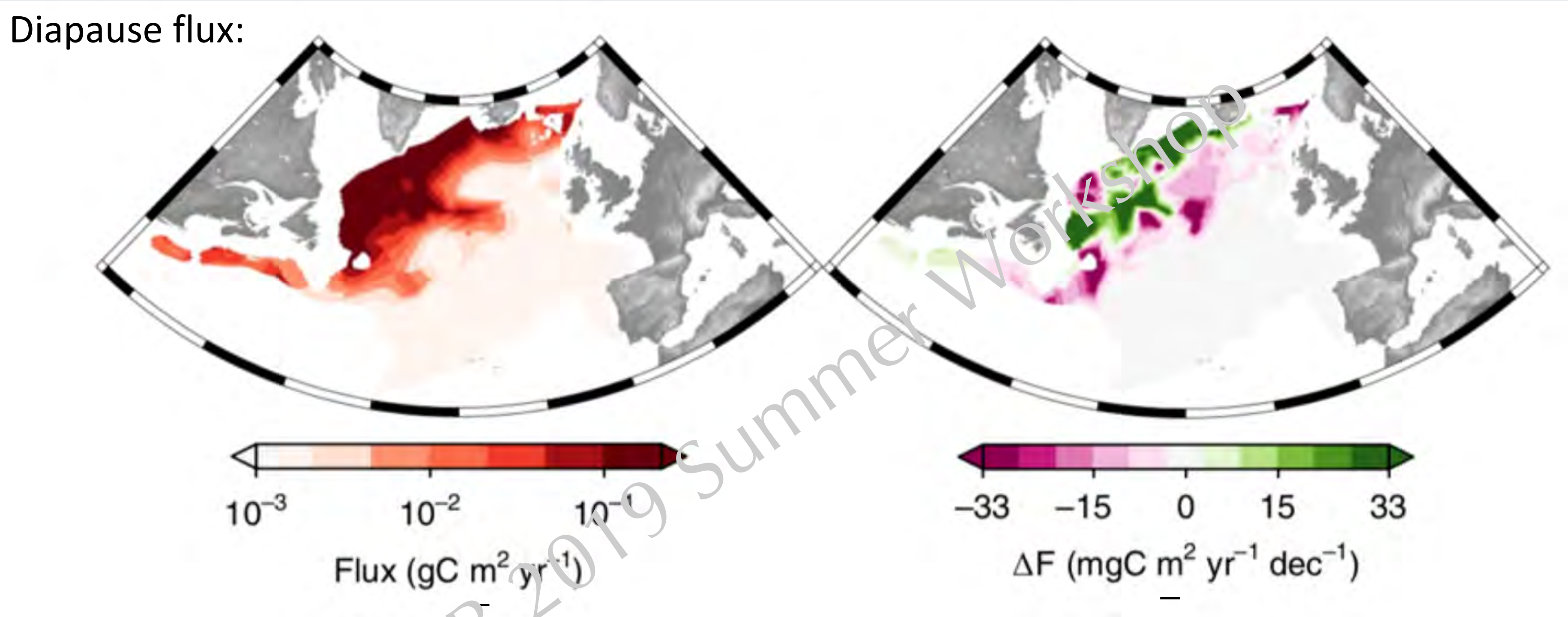
1960-2014

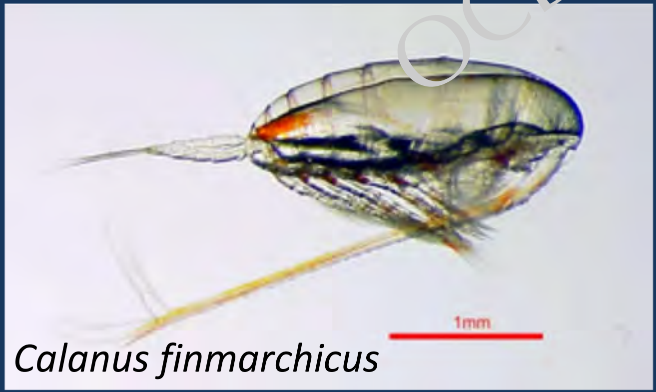
Active DVM flux:



MORE RESULTS!

Diapause flux:





Calanus finmarchicus

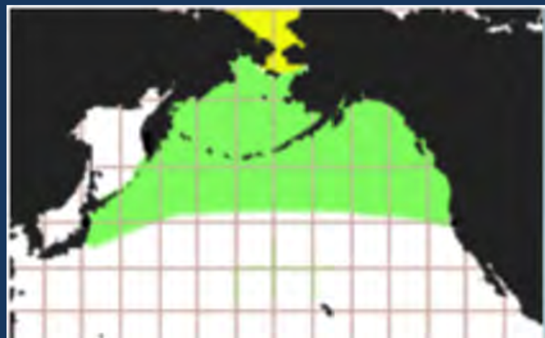
Distribution of *Calanus finmarchicus*

Pershing & Stamieszkin, 2019

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

Meanwhile, in the North Pacific…

Range of *Neocalanus cristatus*



Census of Marine Life, Seward Line

Note the red!

EXPORTS

EXport Processes in the Ocean from RemoTe Sensing

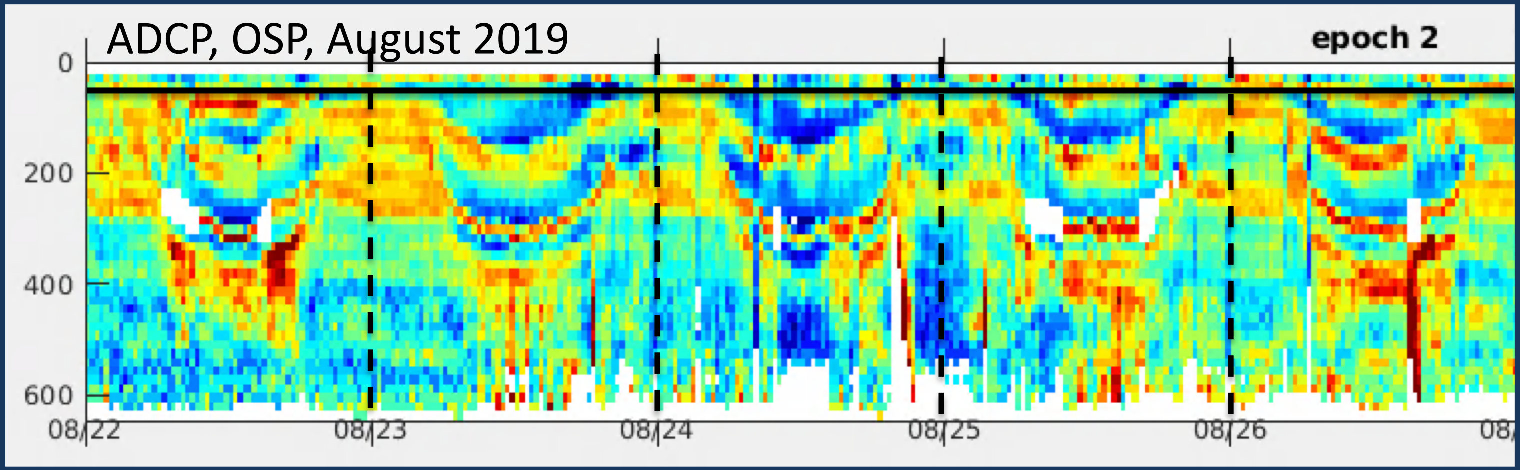
Measuring rates to estimate export pathways

Fecal pellet production experiments:

MOCNESS tows for abundance and water column distribution:

Respiration experiments:

Active respiratory flux



~MLD = 33 m

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}

Passive fecal pellet flux

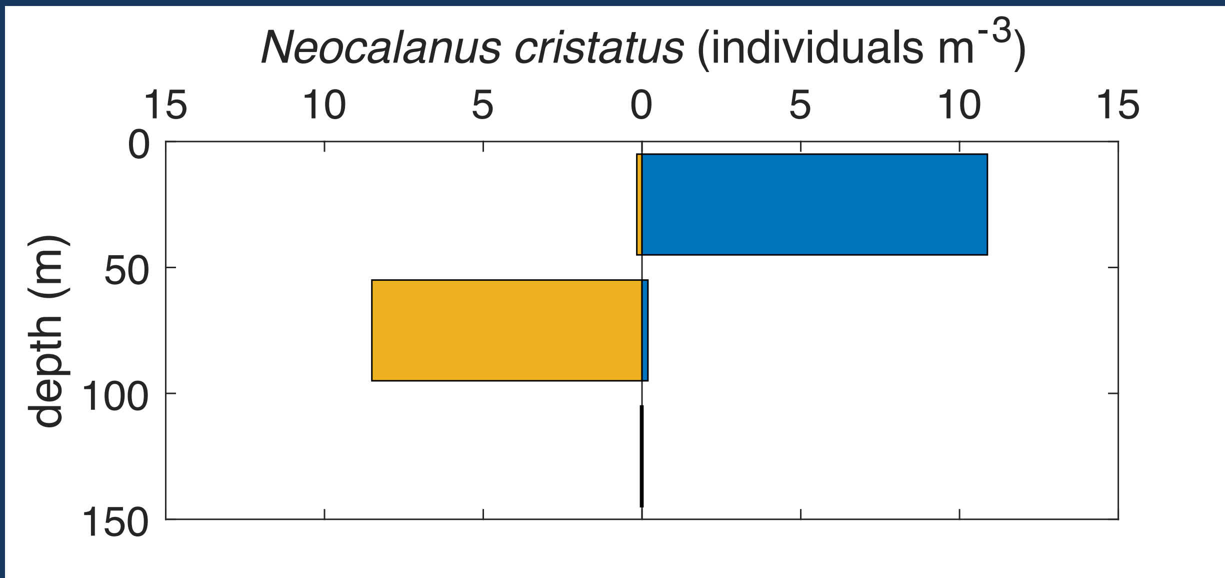
Measured fecal pellet carbon production *N. cristatus* in upper 100 m:

Modeled fecal pellet carbon flux from *N. cristatus* in upper 100 m:

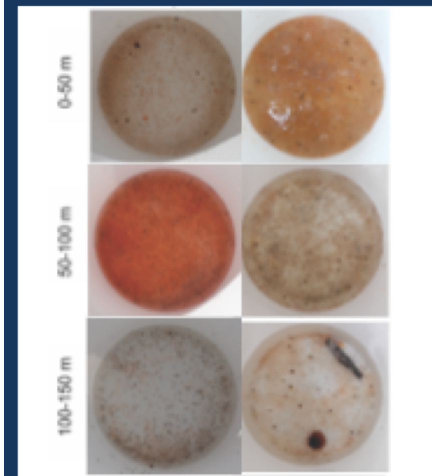
Feeding only at night: 3.3 mgC m^{-2} d^{-1} > 1.4 mgC m^{-2} d^{-1}

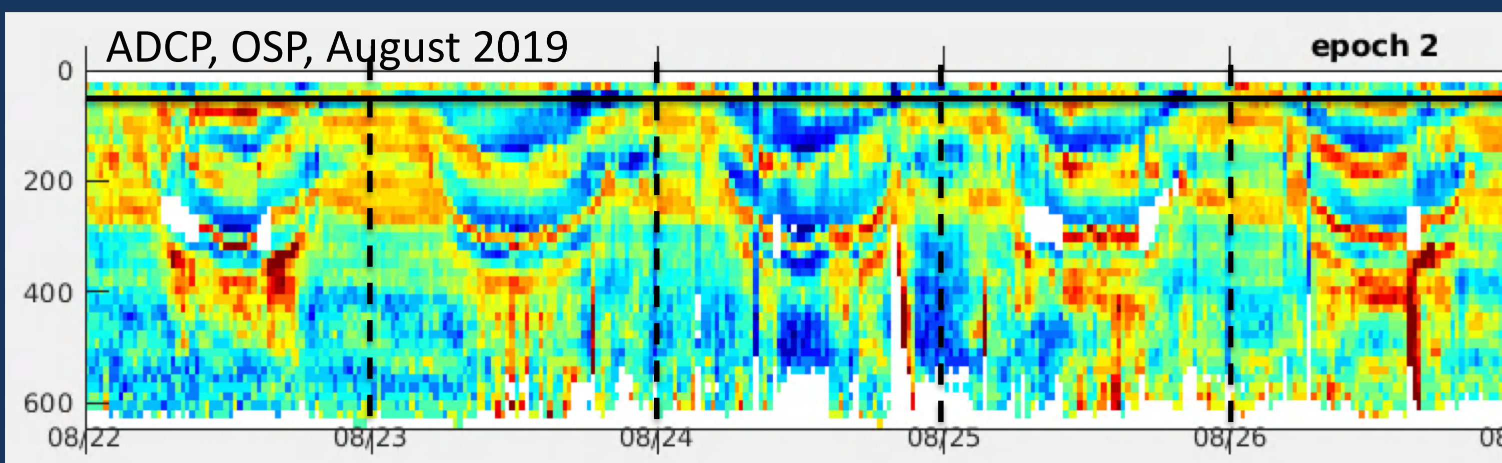
Feeding day and night: 4.7 mgC m^{-2} d^{-1} ≈ 3.3 mgC m^{-2} d^{-1}

Measured DVM depth



Day: Night:





~MLD = 33 m

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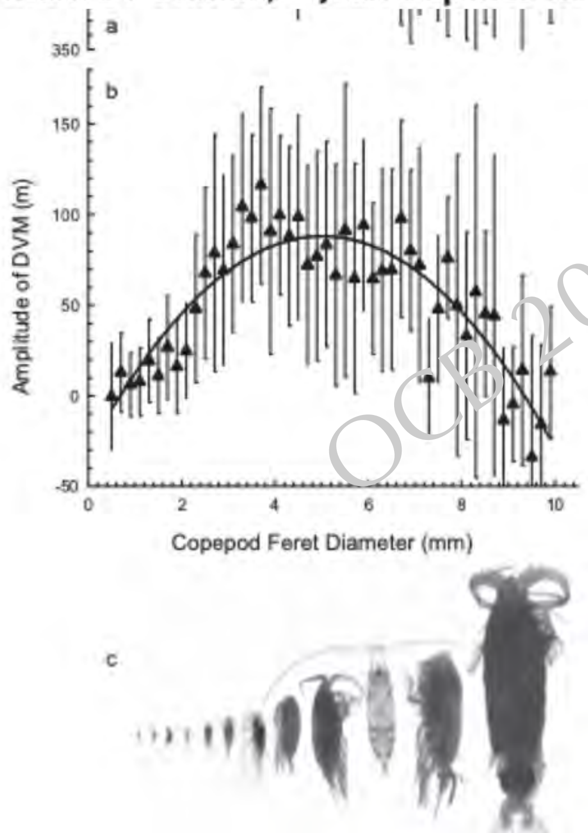
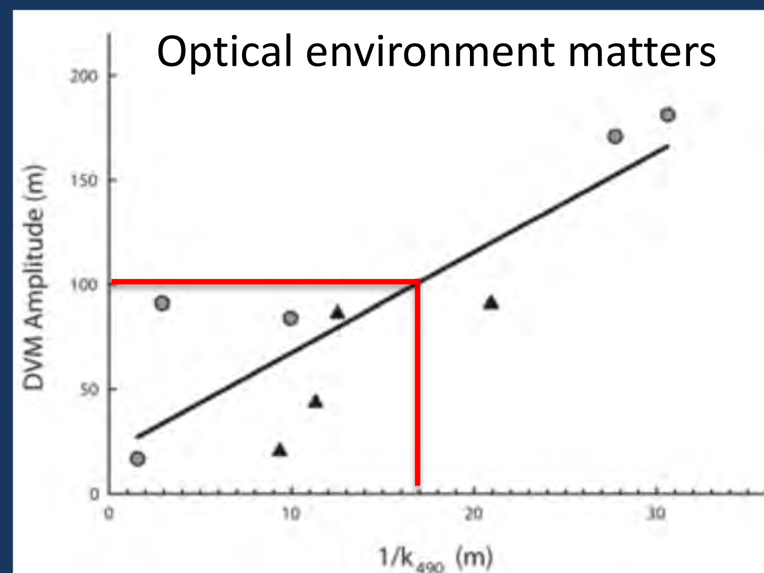
Nonlinear effects of body size and optical attenuation on Diel Vertical Migration by zooplankton

Mark D. Ohman,*[1] Jean-Baptiste Romagnan[2]



~50-100 m (amplitude)

68.6 m (amplitude)



Ohman & Romagnan 2016

Measurement-to-model comparison

		Field measurement	Model estimate
	Respiratory flux	5.0 mgC m^{-2} d^{-1}	0.4 mgC m^{-2} d^{-1}
10 h eat	FPC prod. vs. flux	3.3 mgC m^{-2} d^{-1}	1.4 mgC m^{-2} d^{-1}
24 h eat	FPC prod. vs. flux	4.7 mgC m^{-2} d^{-1}	3.3 mgC m^{-2} d^{-1}
	DVM amplitude	~ 50-100 m	68.6 m

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…?

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