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Mechanistic Modelling of Seasonal Vertical Migration in a Changing Climate

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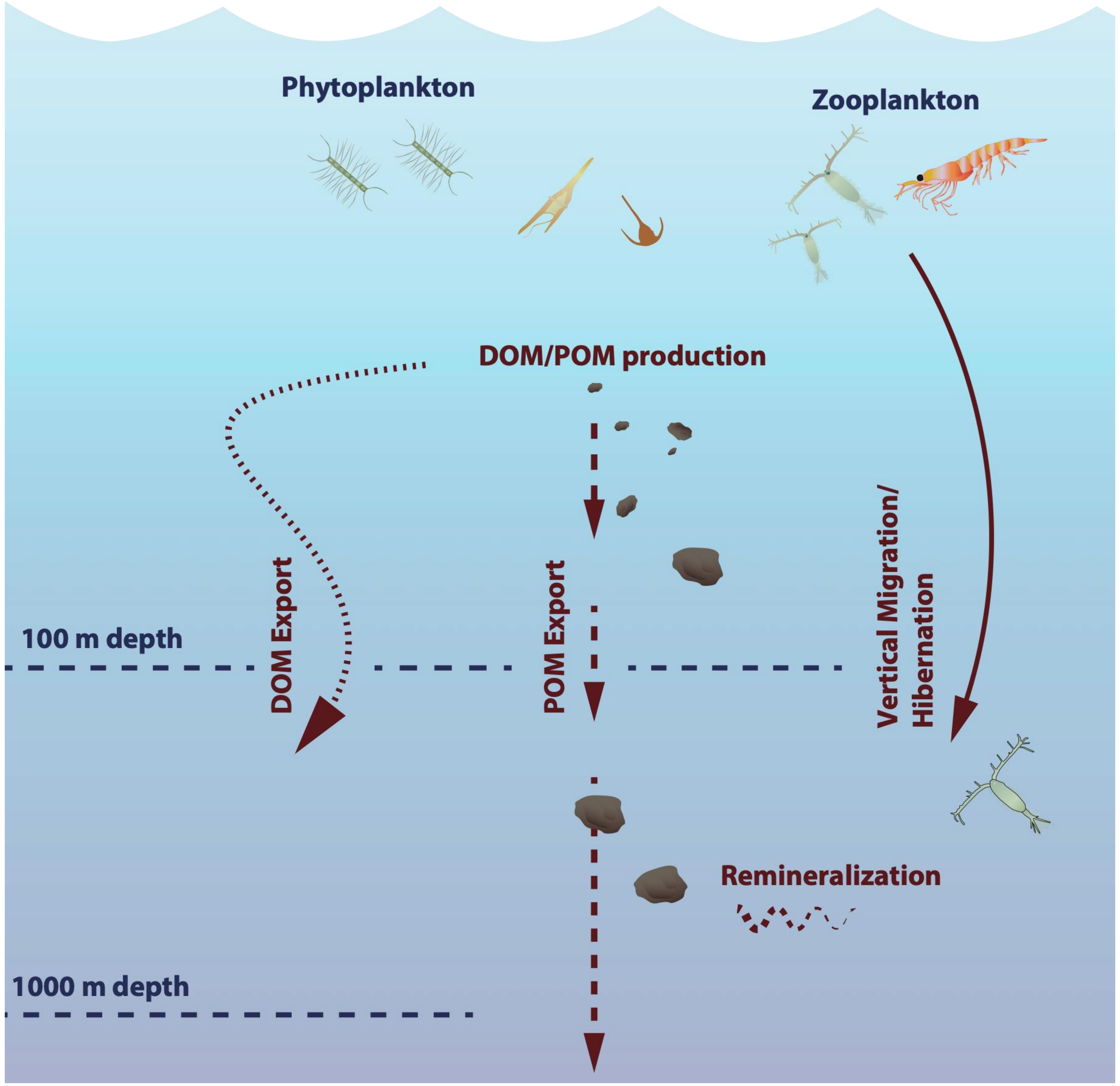
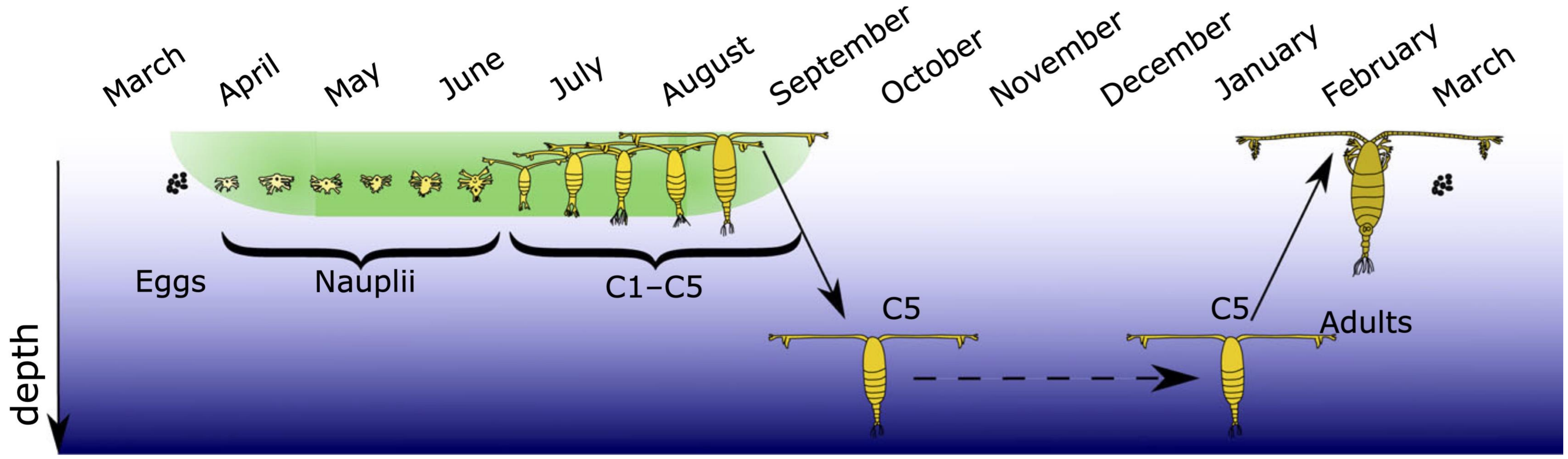
Should Seasonal Migration be in Earth System Models?

- **Particle flux:**
  - ~ 5-12 Pg C/yr (through 100m) *(Henson 2022)*
- **DOM export:**
  - ~ 2 Pg C/yr (through 100m) *(Hansel 2009)*
- **Seasonal migration:**
  - ~ 0.5 Pg C/yr (**600-1500m?**) *(Boyd 2019)*
  - 0.031–0.25 Pg C/yr *(Record 2018)*

Not represented in
any IPCC/CMIP6 model



Zooplankton Diapause Modeling



- Earth System Models are not Individual-Based Models (IBMs): zooplankton represented as nitrogen biomass density; no life stages
- Impossible to use individual lipid mass or life cycle stage to initiate diapause

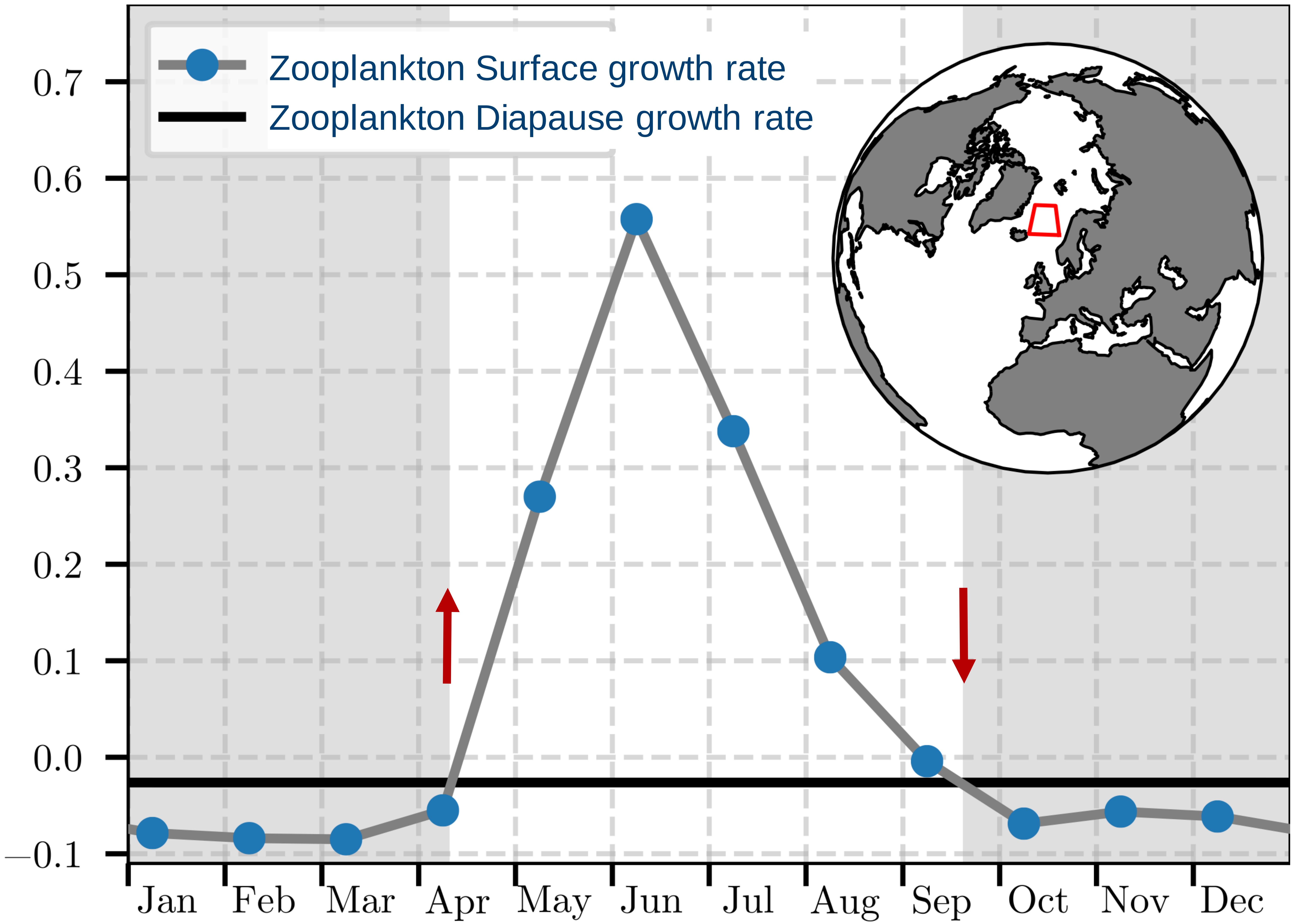
  (Record et al. 2018, Ji 2011, Maps et al. 2012a/b, etc…)

→Optimise a Fitness Proxy: *Net* Population Growth

Phenomenological Diapause Model

Wienkers, et al. (*in prep*)

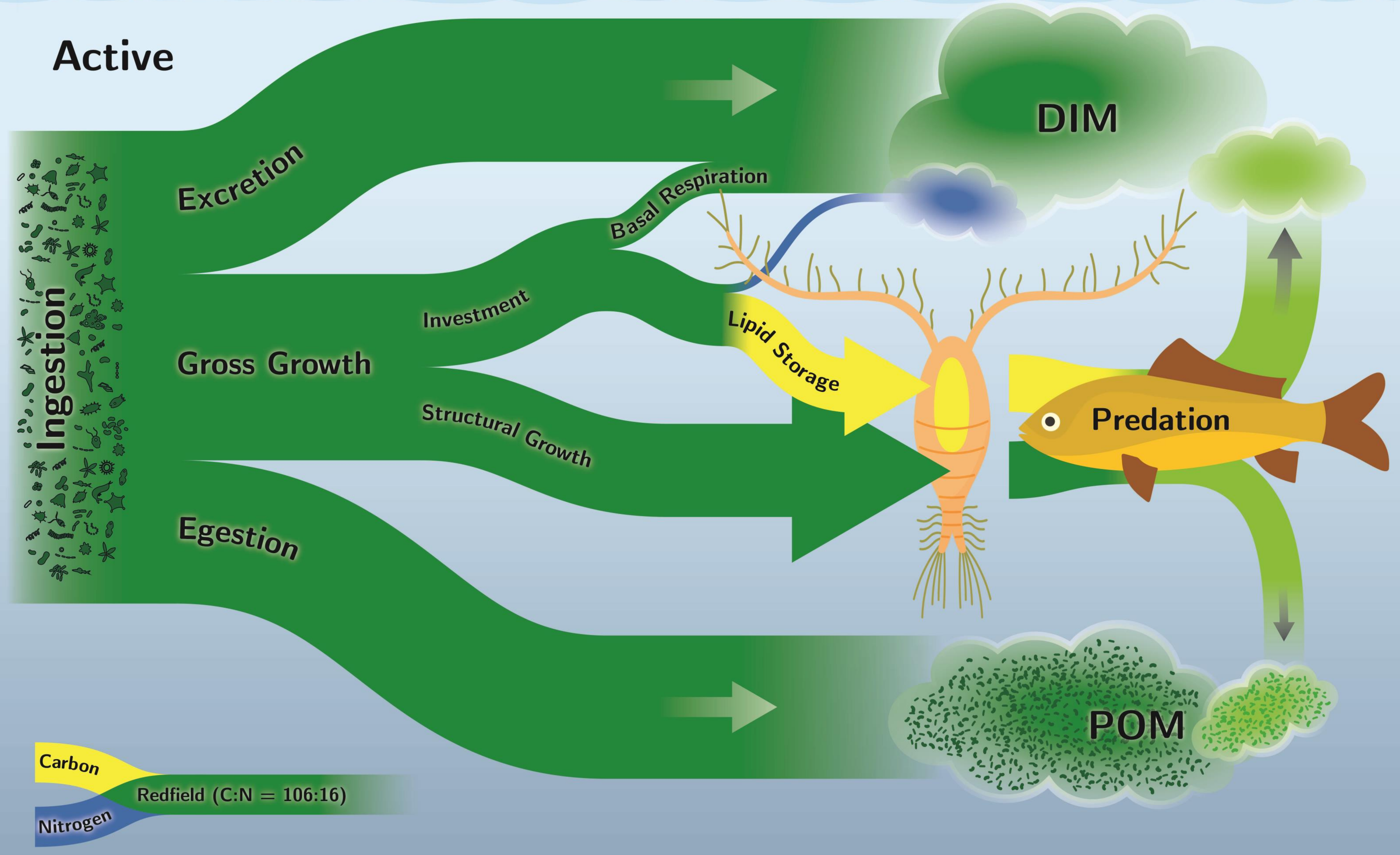
Climatological Average, 2020 (varies with location and over time)



A Diapausing Zooplankton Class in an ESM

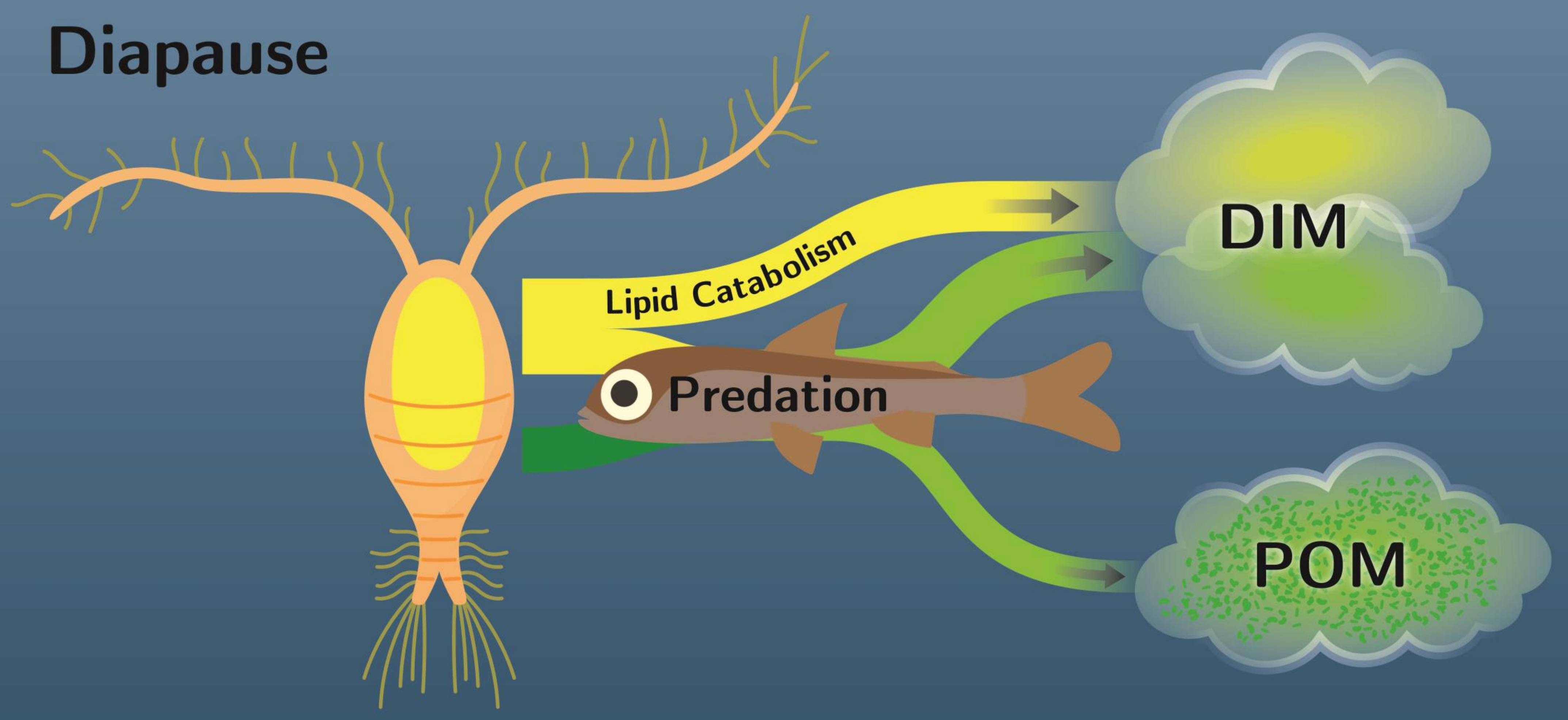
$$\mathcal{G}_{\text{active}} > b_{\text{dormant}}$$

$\Longrightarrow$ Surface



A Diapausing Zooplankton Class in an ESM

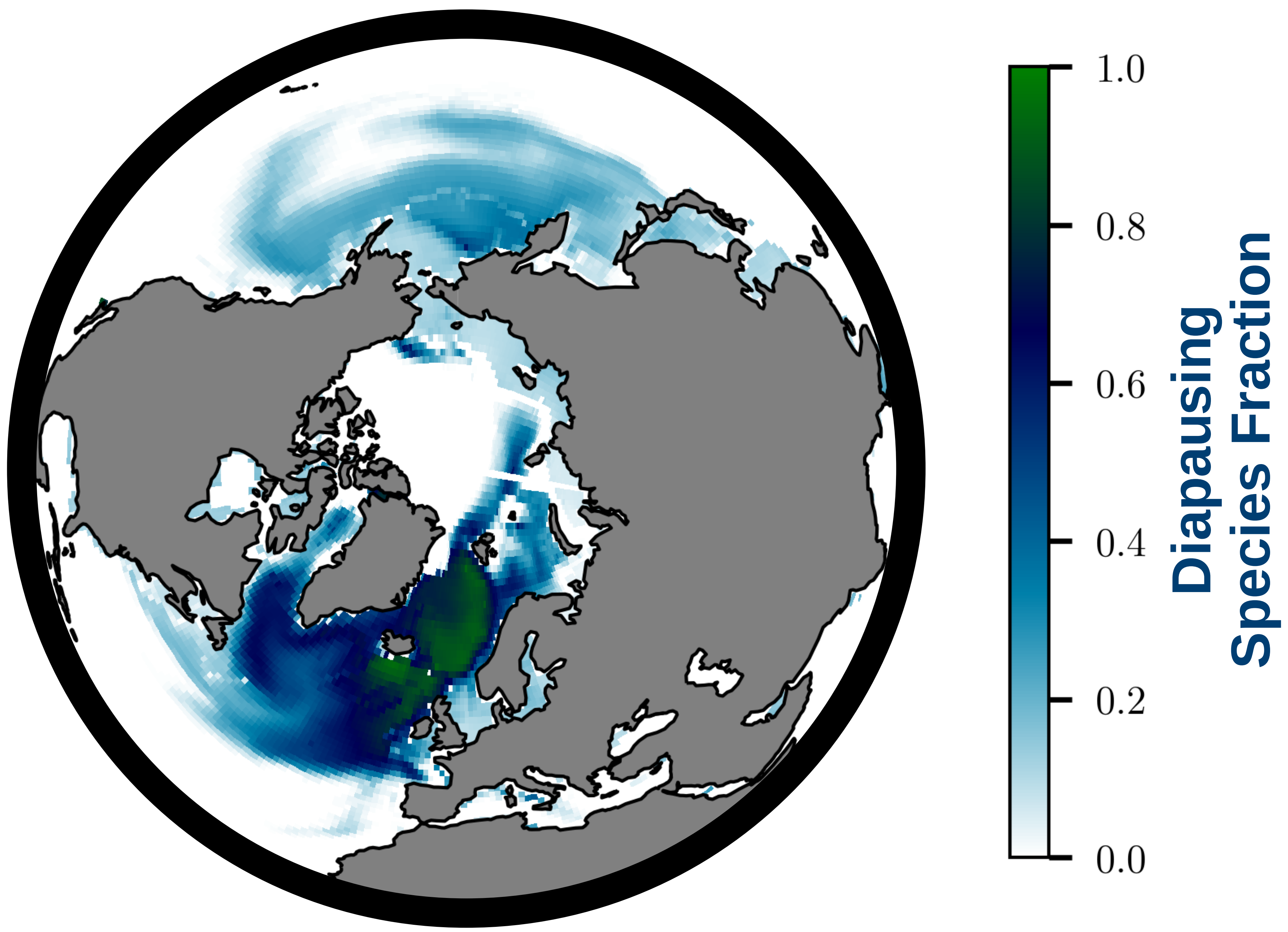
$\mathcal{G}_{\text{active}} < b_{\text{dormant}}$
$\implies$ Diapause



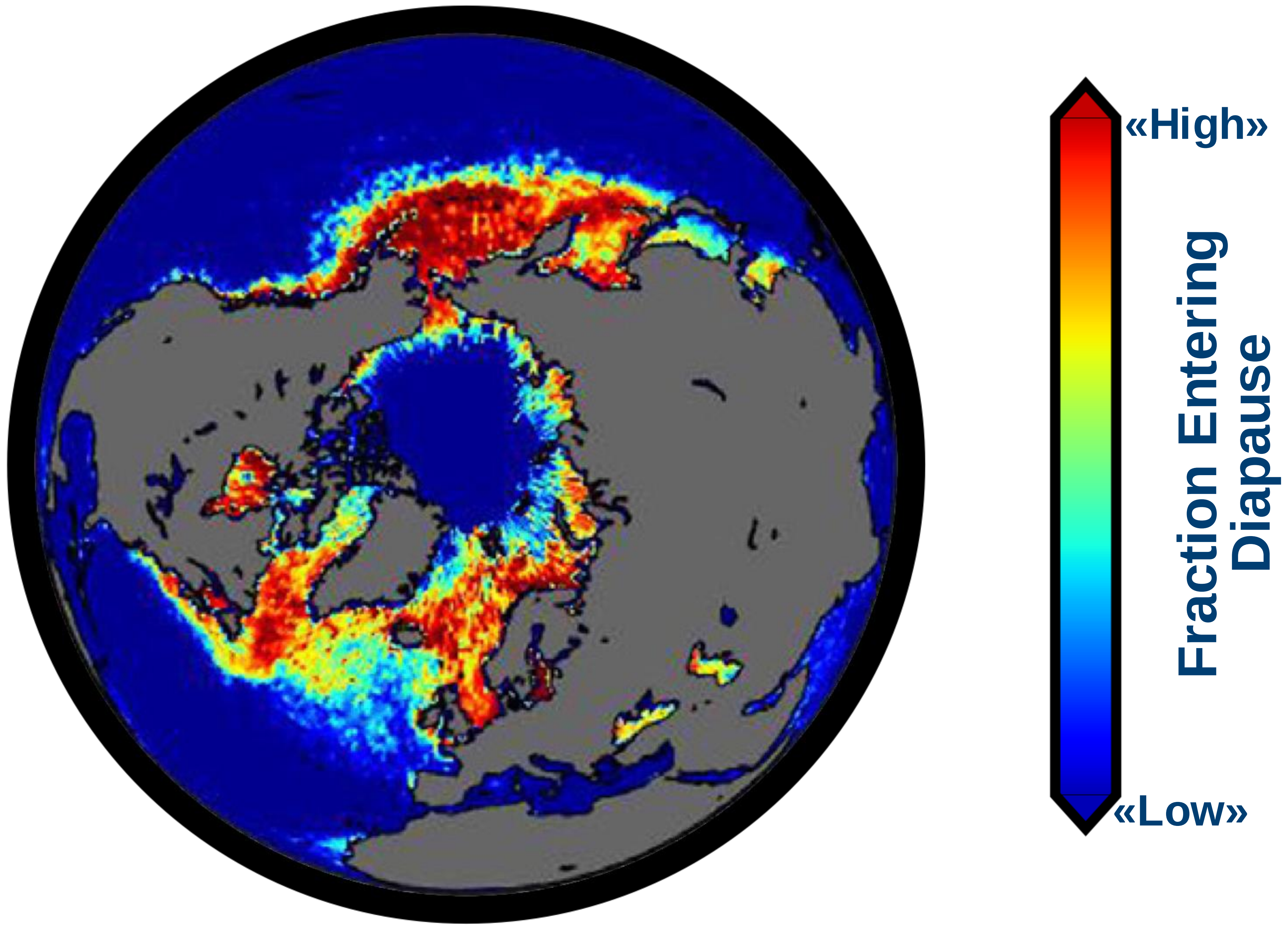
Resulting Global Diapause Patterns

We reproduce expected Diapause patterns
(with effectively a **single** parameter knob)

GFDL–ESM2M+COBALTv2
ft. New Diapause Model



Ji (2011) Life-History Model
ft. Record (2018) IBM



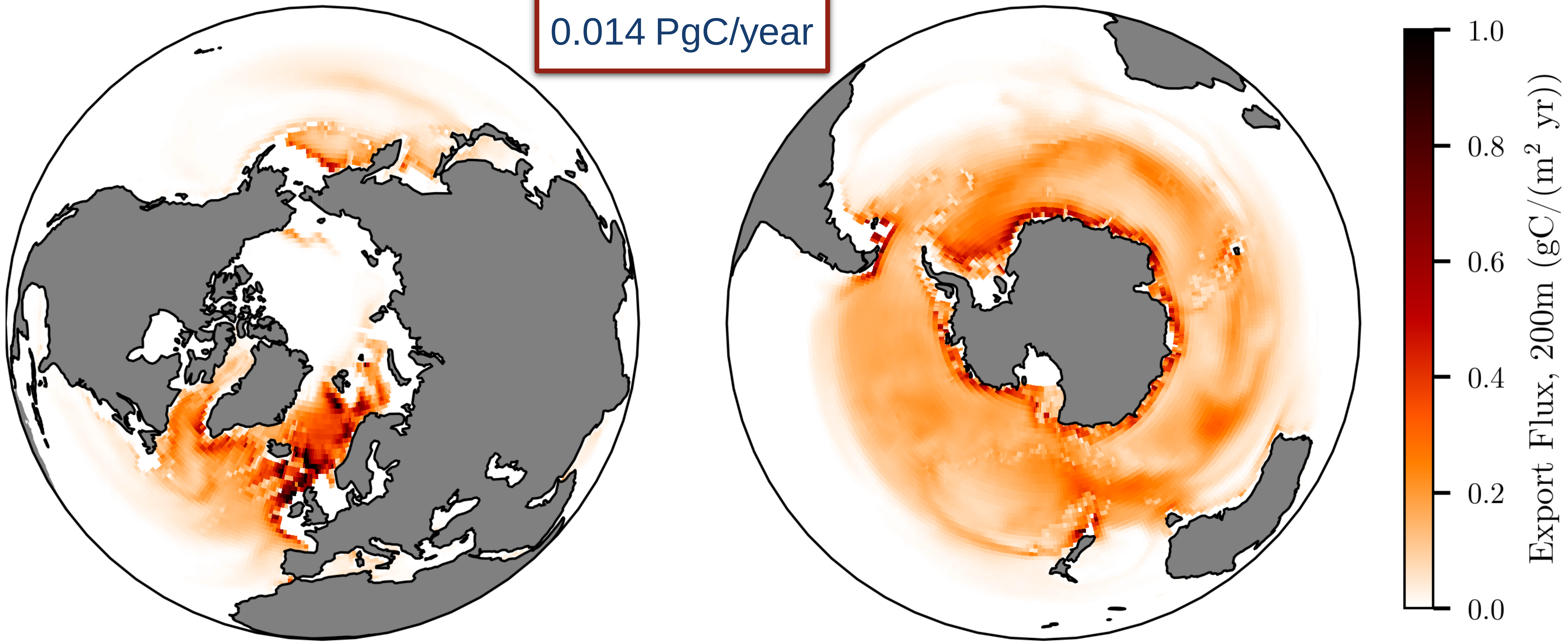
Resulting Global Diapause Patterns

We reproduce expected Diapause patterns
(with effectively a **single** parameter knob)

0.031–0.25 PgC/year

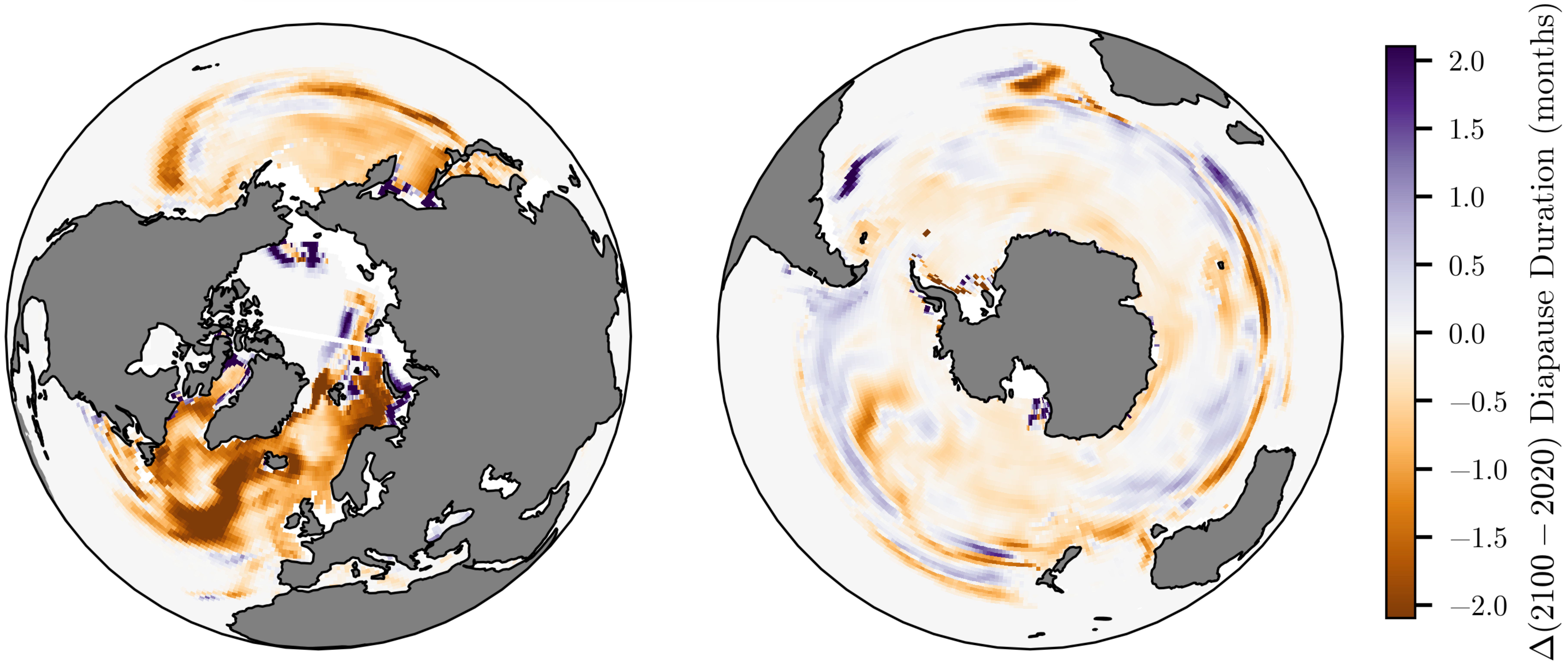
Record et al. (2018)

0.014 PgC/year



Results: Changing Migration Behaviour

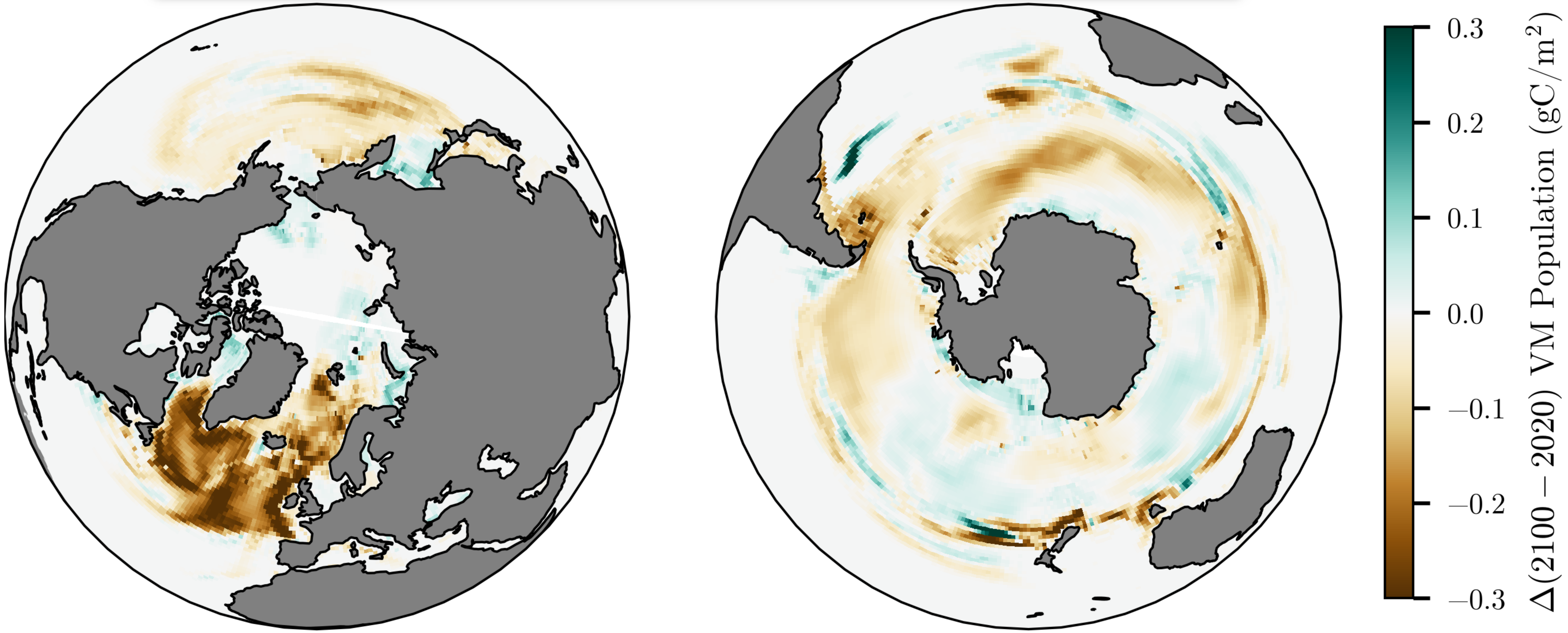
Model diapause duration decreases nearly 2.5 months by 2100 !



RCP8.5

Results: Changing Diapausing Biomass

Diapausing Zooplankton population consequently decreases as hibernation become less advantageous

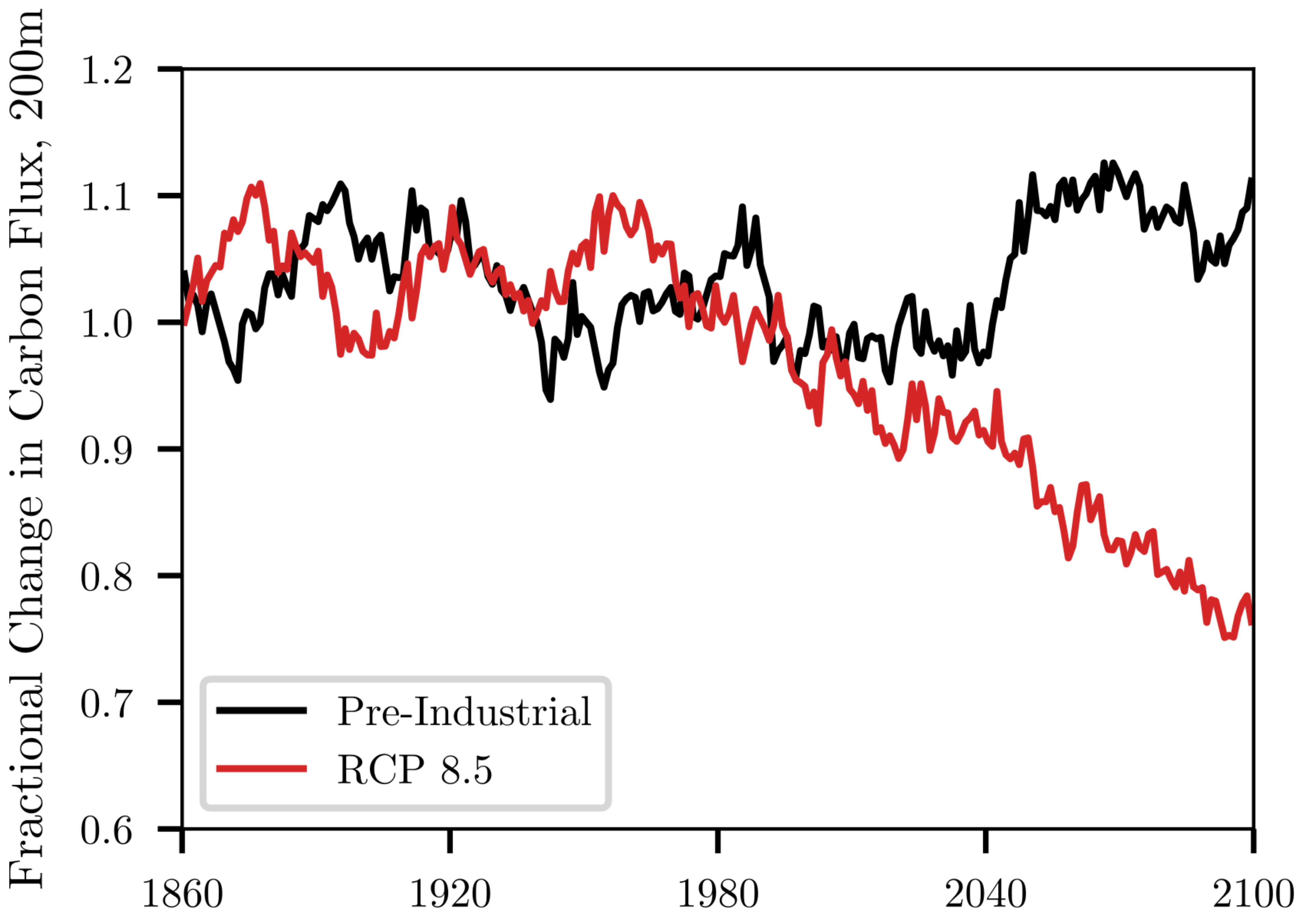


RCP8.5

Results: Changing Diapause Carbon Export

- Combination of shorter diapause duration and a smaller diapausing population:

  ⇒ c. 20% decrease in Lipid Carbon Export from diapause by 2100 (RCP8.5)



Conclusions

- Phenomenological diapause model captures migration pattern reasonably well
- Zooplankton diapause in ESMs cause significant carbon export into **deep polar ocean**
- **Diapause duration decreases nearly 2.5 month by 2100 because diapausing becomes less advantageous (drivers yet to be determined)**
- **20% decrease in lipid carbon export by 2100**
- First exploration of diapause carbon flux - associated with high uncertainties (migration depth, migration biomass, timing of diapause)