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Future global ocean carbon storage: Quantifying warming impacts on zooplankton

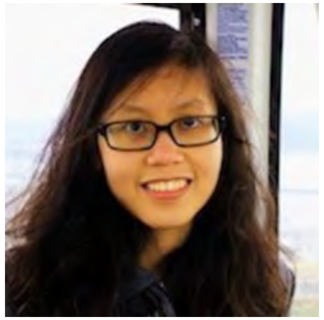

Daniel Mayor


Kathryn Cook


Tom Anderson


Andrew Yool


Alessandro Tagliabue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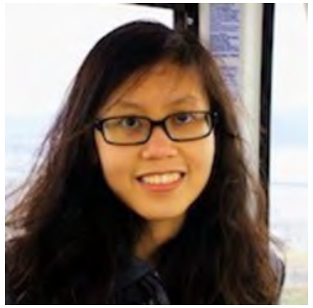


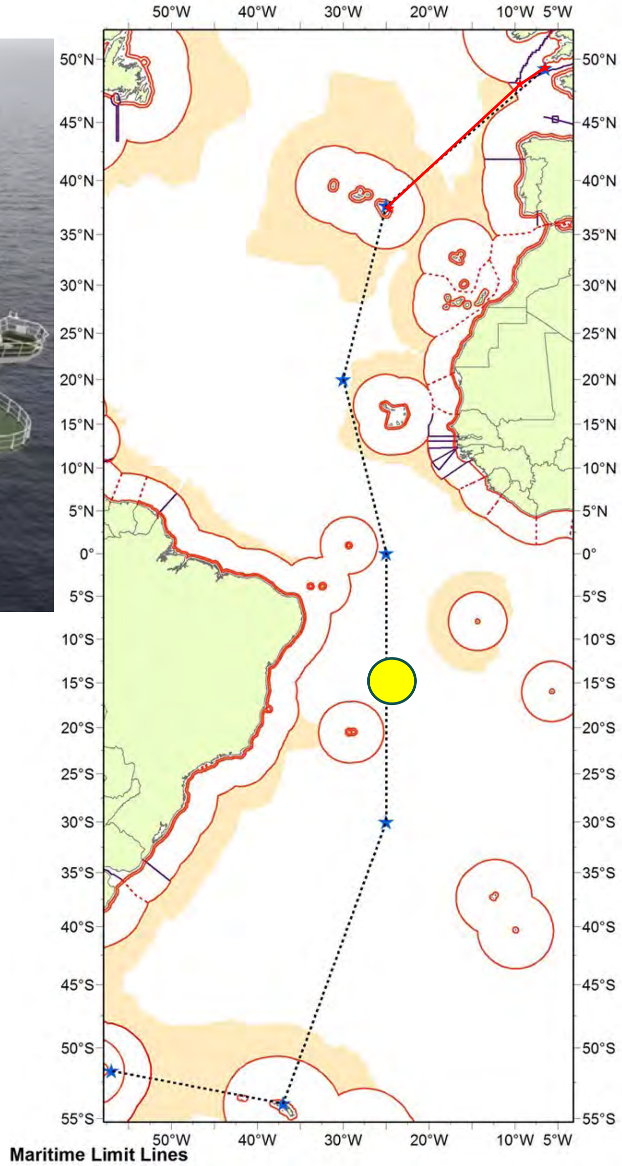

Apologies from Dan, Kathryn and Prima – we're on Discovery, netting zooplankton somewhere between the Falklands and the UK

Feel free to send queries to d.j.mayor@exeter.ac.uk

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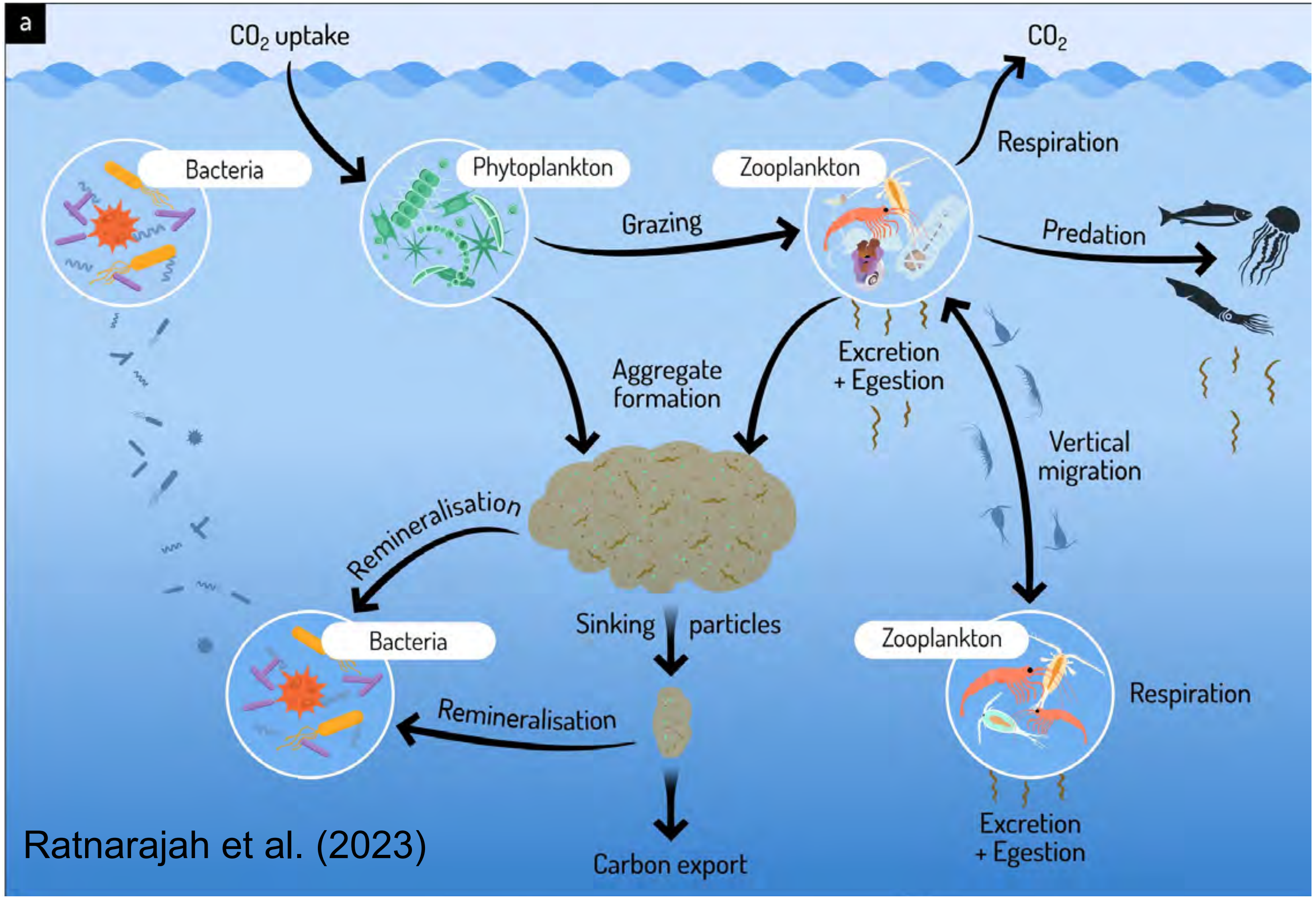

Zooplankton play a range of fundamental roles in the ecological and biogeochemical functioning of the global ocean

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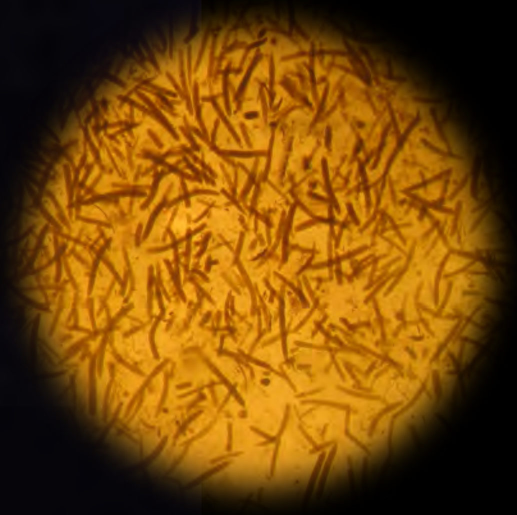
A typical herbivorous copepod

Copepod faecal pellets



Detritivorous copepods

1 mm **1 mm** **1 mm**

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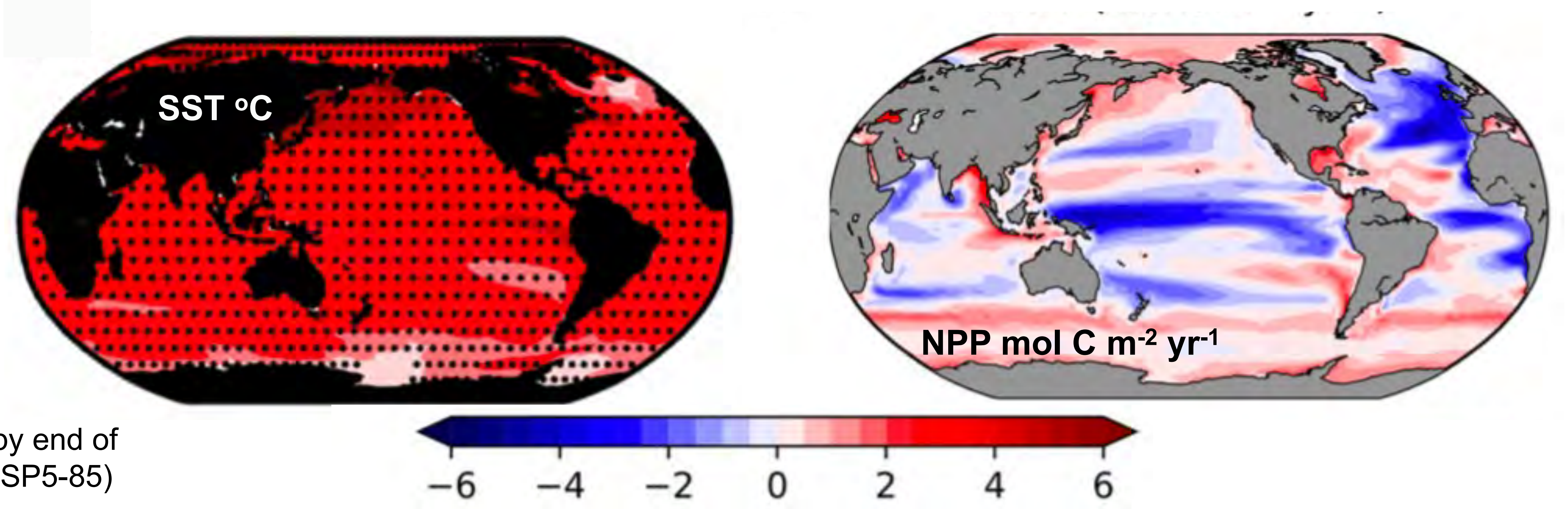

Changes by end of century (SSP5-85)

Kwiatkowski et al. (2020); Tagliabue et al., 2021

Sea surface temperature (SST) will warm throughout the 21st century under a high emissions scenario, affecting global patterns of plankton biomass and net primary production (NPP)

There remain major uncertainties in how these changes will affect the future role of zooplankton in ocean biogeochemistry

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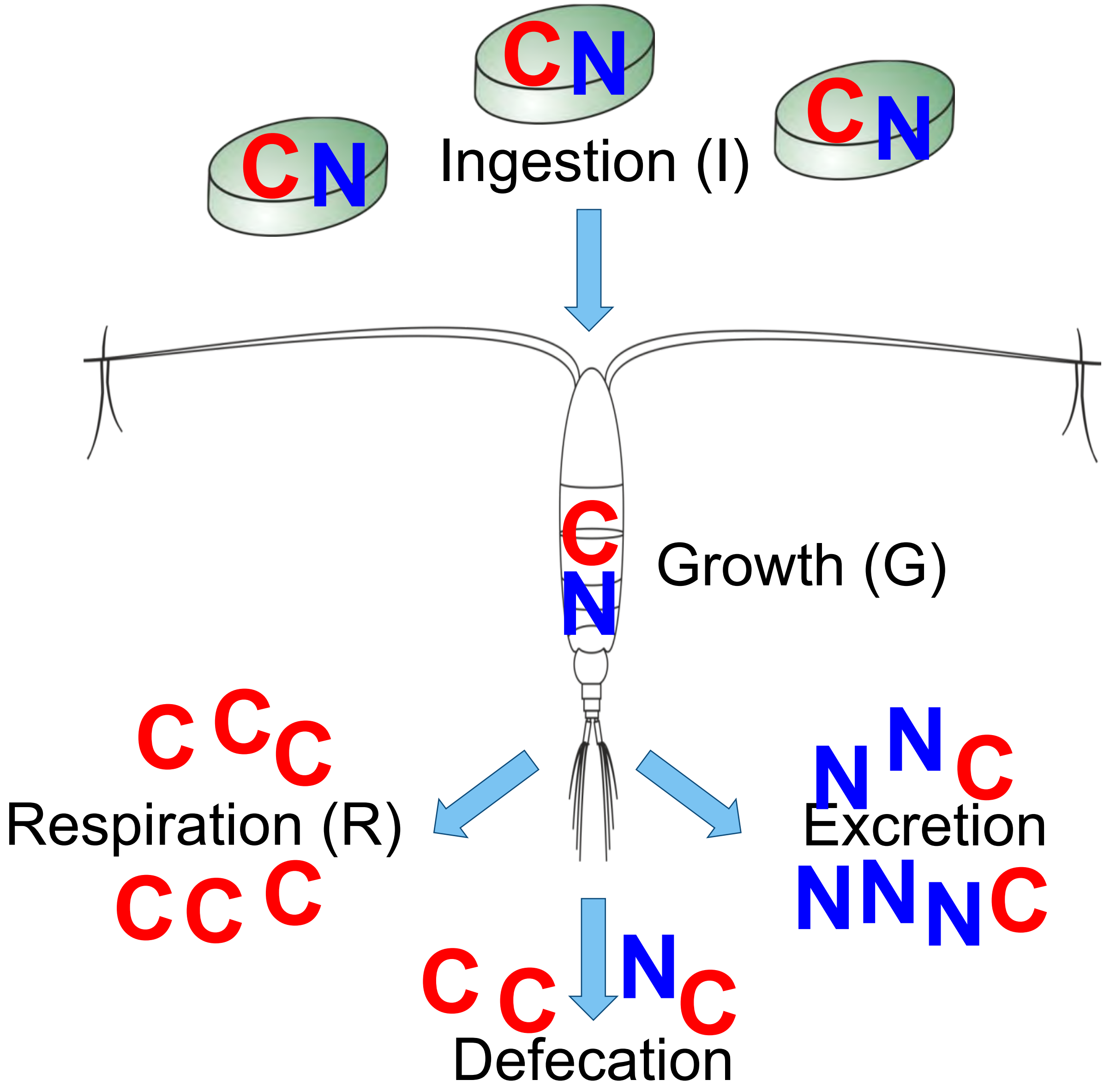

Gross growth efficiency (GGE) = Growth/Ingestion

GGE is a key parameter in ecosystem models:

It is element specific and determines how much primary production becomes available to higher trophic levels, and how much is lost to respiration and faeces (and hence export flux)

There is major uncertainty in how zooplankton GGE will respond in a future ocean

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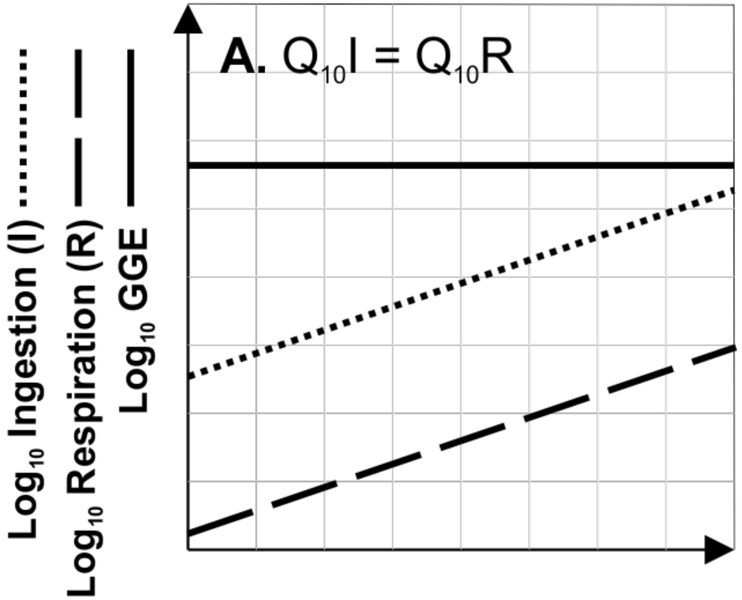
Zooplankton are cold-blooded; their physiological rates respond directly to temperature



If respiration and ingestion show same thermal response, GGE remains constant

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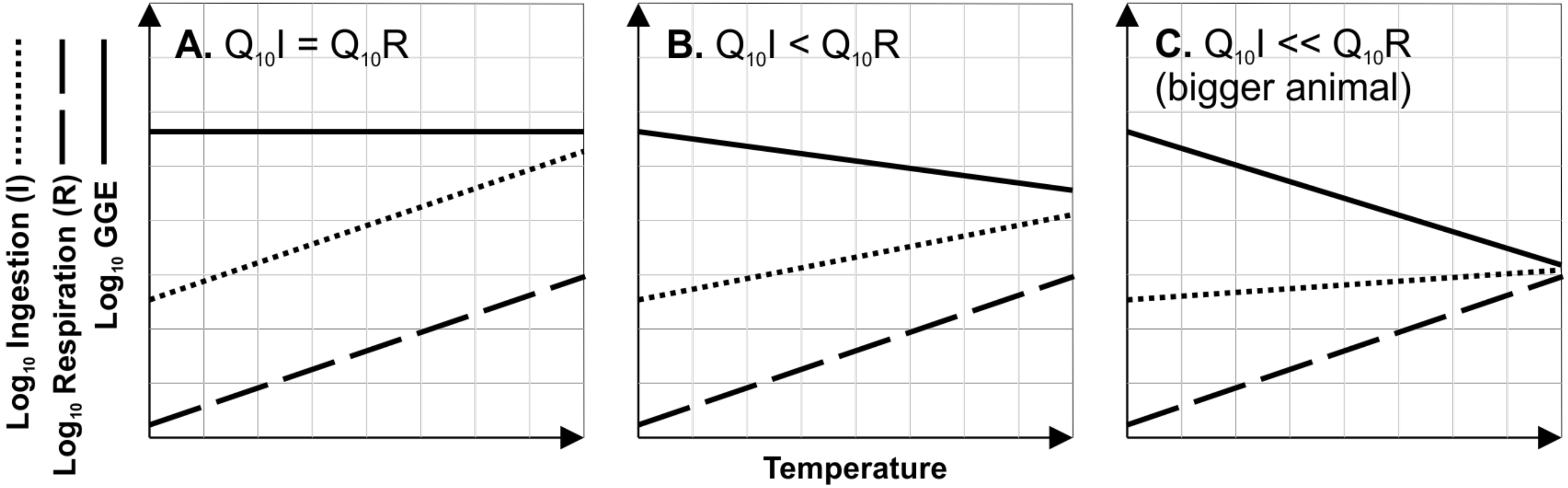
Zooplankton are cold-blooded; their physiological rates respond directly to temperature



If respiration and ingestion show same thermal response, GGE remains constant	If respiration is more strongly affected by temperature than ingestion, GGE declines	Bigger animals have lower max. ingestion rates – and may therefore be more strongly affected than smaller ones

Impact of changes in food supply are also important!

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WP1. Investigate how temperature, body size and food availability influence zooplankton GGE **using laboratory experiments**

H1. Zooplankton GGE will decline with warming
H2. Zooplankton GGE will decline more rapidly with warming at non-saturating food concentrations
H3. The rate at which zooplankton GGE declines with warming will be greater in larger animals, relative to smaller ones

WP2. Quantify how global NPP and carbon export are affected by ocean warming impacts on zooplankton throughout the 21st century **using a global biogeochemical model**

H4. Climate-driven changes in zooplankton physiology will reduce NPP and weaken the future strength of the Biological Carbon Pump

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WP1. Investigate how temperature, body size and food availability influence zooplankton GGE **using laboratory experiments** with *Acartia tonsa*.

3-factor experimental design:

Temperature (low, medium, high)

Animal body size (small, medium, large)

Food availability (low, medium, high)

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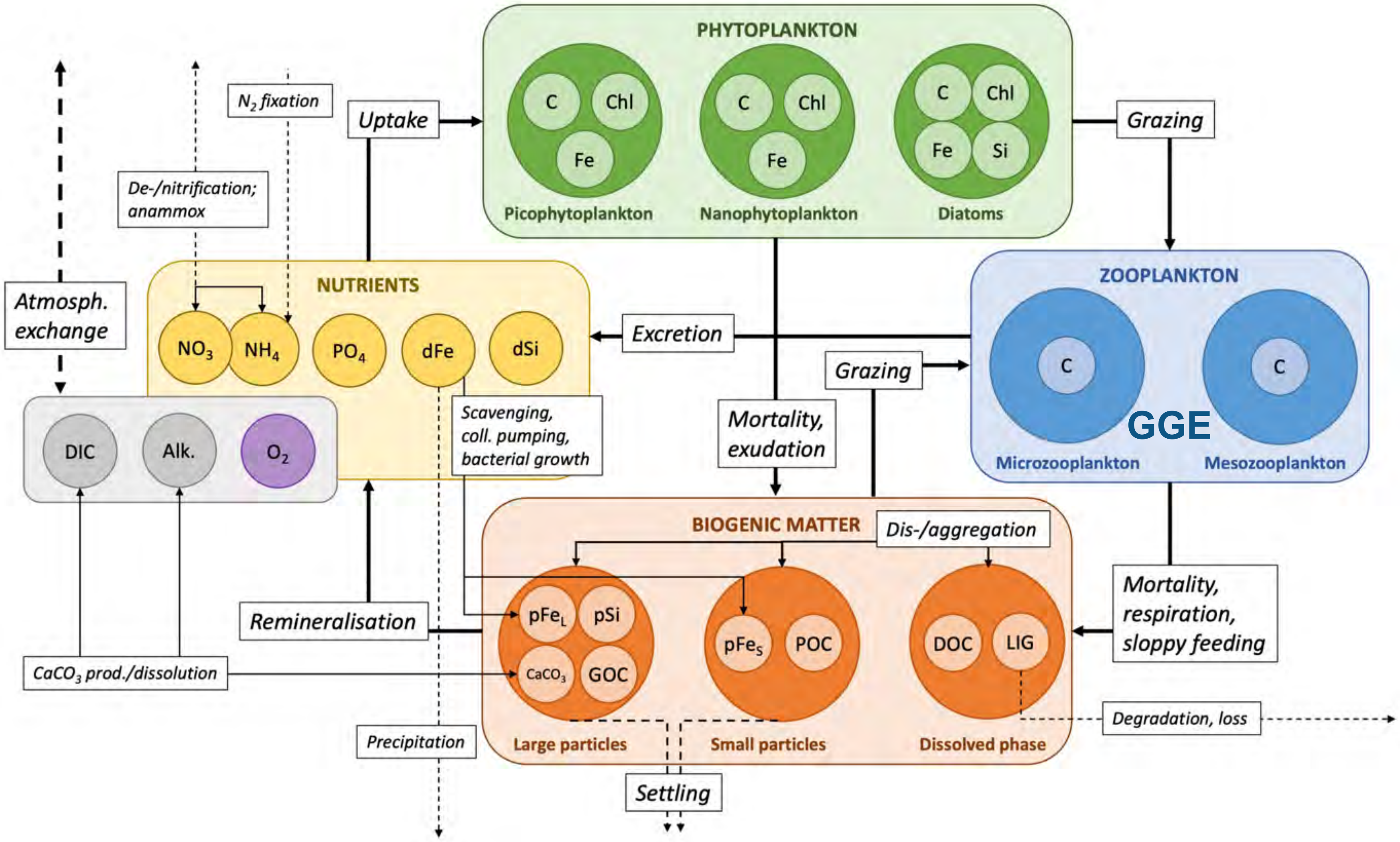
WP2. Quantify how global NPP and carbon export are affected by ocean warming impacts on zooplankton throughout the 21st century **using a global biogeochemical model (PISCES).**



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Progress to date:

- Dan and Kathryn have moved to the University of Exeter – experimental work delayed
- Two project meetings (one in-person, one virtual) to discuss the project, and modelling activities in particular – great new links between experimental biologists and modellers!
- Prima has joined Dan and Kathryn on AMT cruise to get first-hand experience of oceanographic sampling and zooplankton biology
- Modelling work on-going

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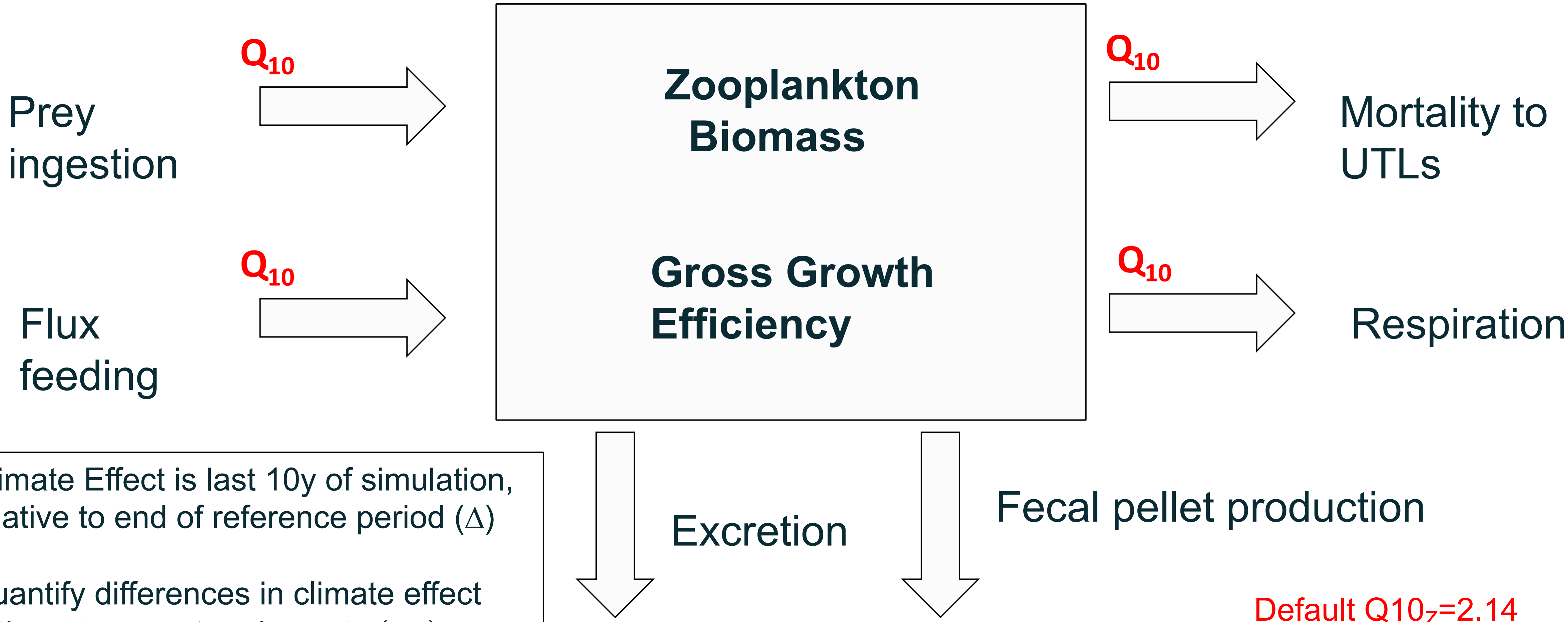

Climate Effect is last 10y of simulation, relative to end of reference period (Δ)

Quantify differences in climate effect without temperature impacts (ΔΔ)

Default $Q10_Z$=2.14
Default $Q10_P$=1.88

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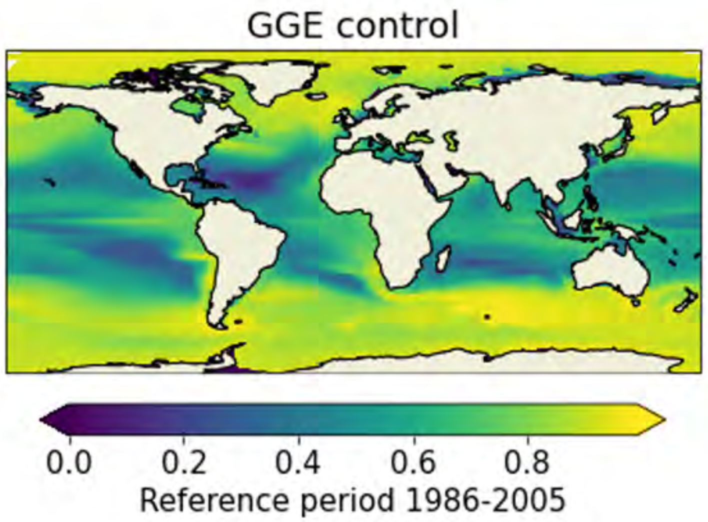
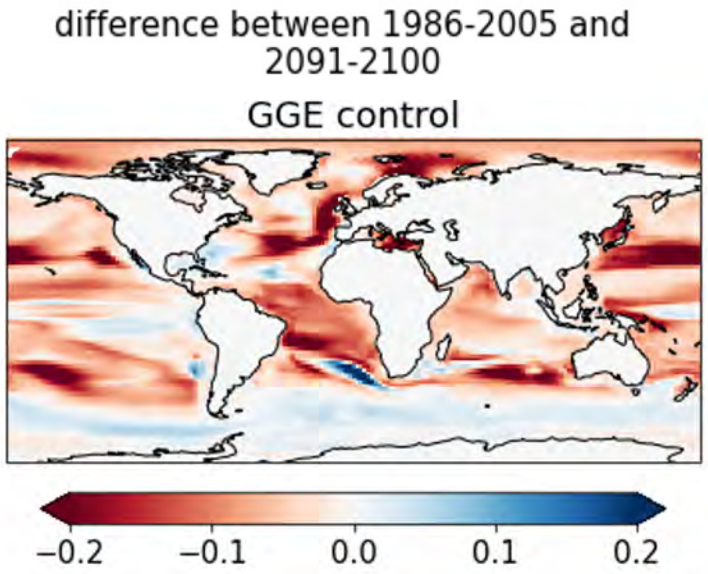


- GGE is lowest in nutrient poor waters
- GGE declines due to climate change at low latitudes in particular, due to reduced food quality (higher C/N ratios) or changing zooplankton respiration/ingestion rates

Climate Effect



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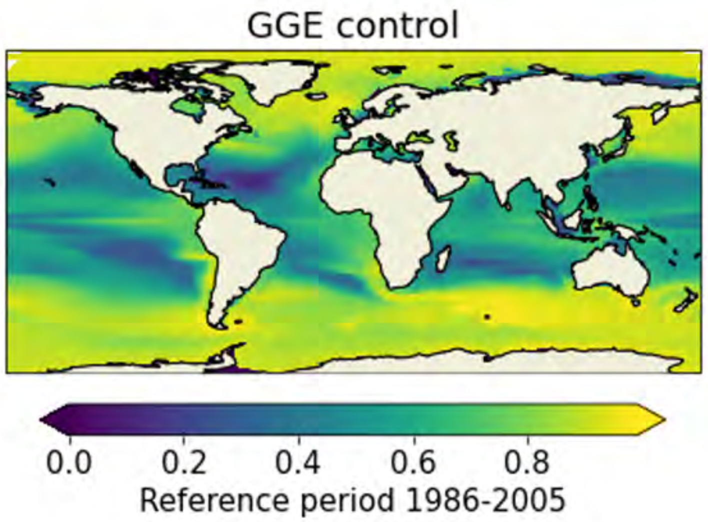
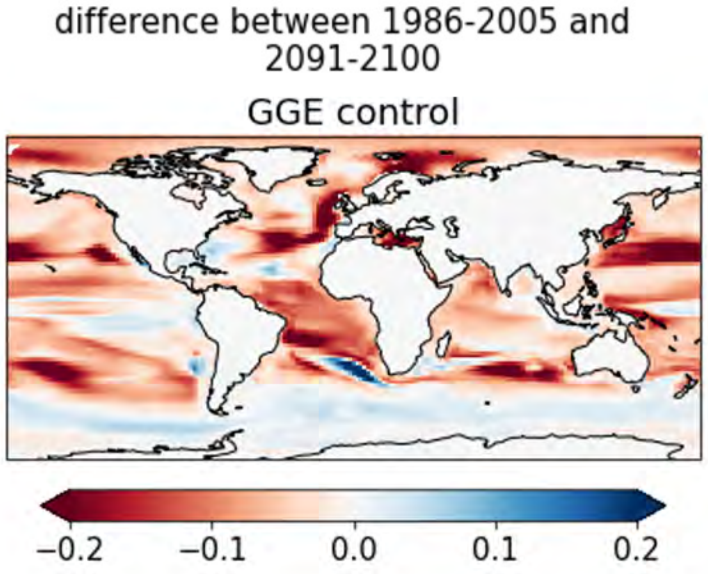
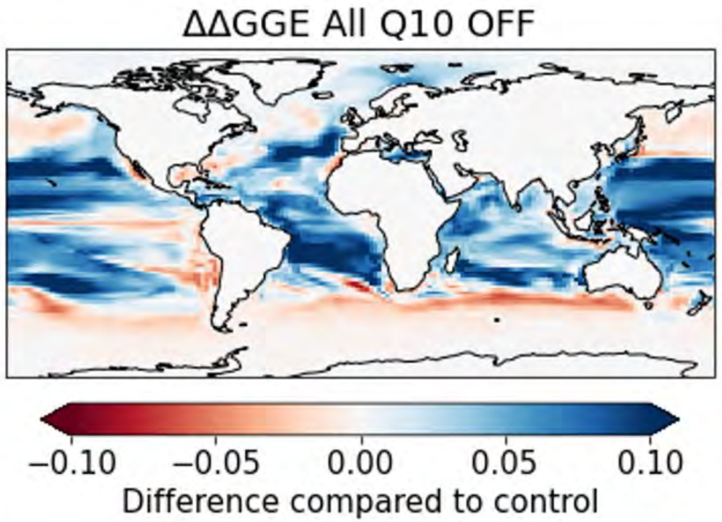


- GGE is lowest in nutrient poor waters
- GGE declines due to climate change at low latitudes in particular, due to reduced food quality (higher C/N ratios) or changing zooplankton respiration/ingestion rates
- Around half of the total decline in GGE can be removed if we assume no temperature sensitivity to zooplankton ingestion, respiration, mortality and flux feeding rates

Climate Effect





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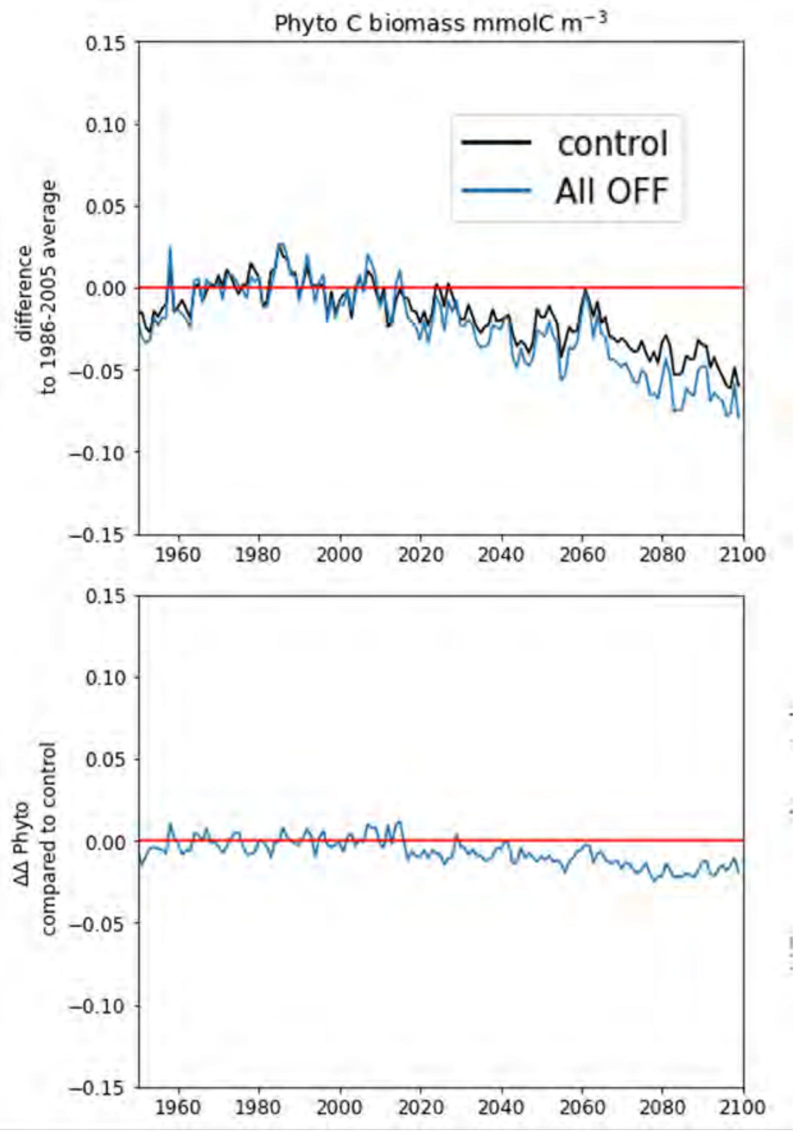
- At global scale, it seems like the simulations with and without warming are actually similar (e.g. to within around 10%)

- Example here for phytoplankton biomass (similar message for zooplankton biomass, NPP and export production)



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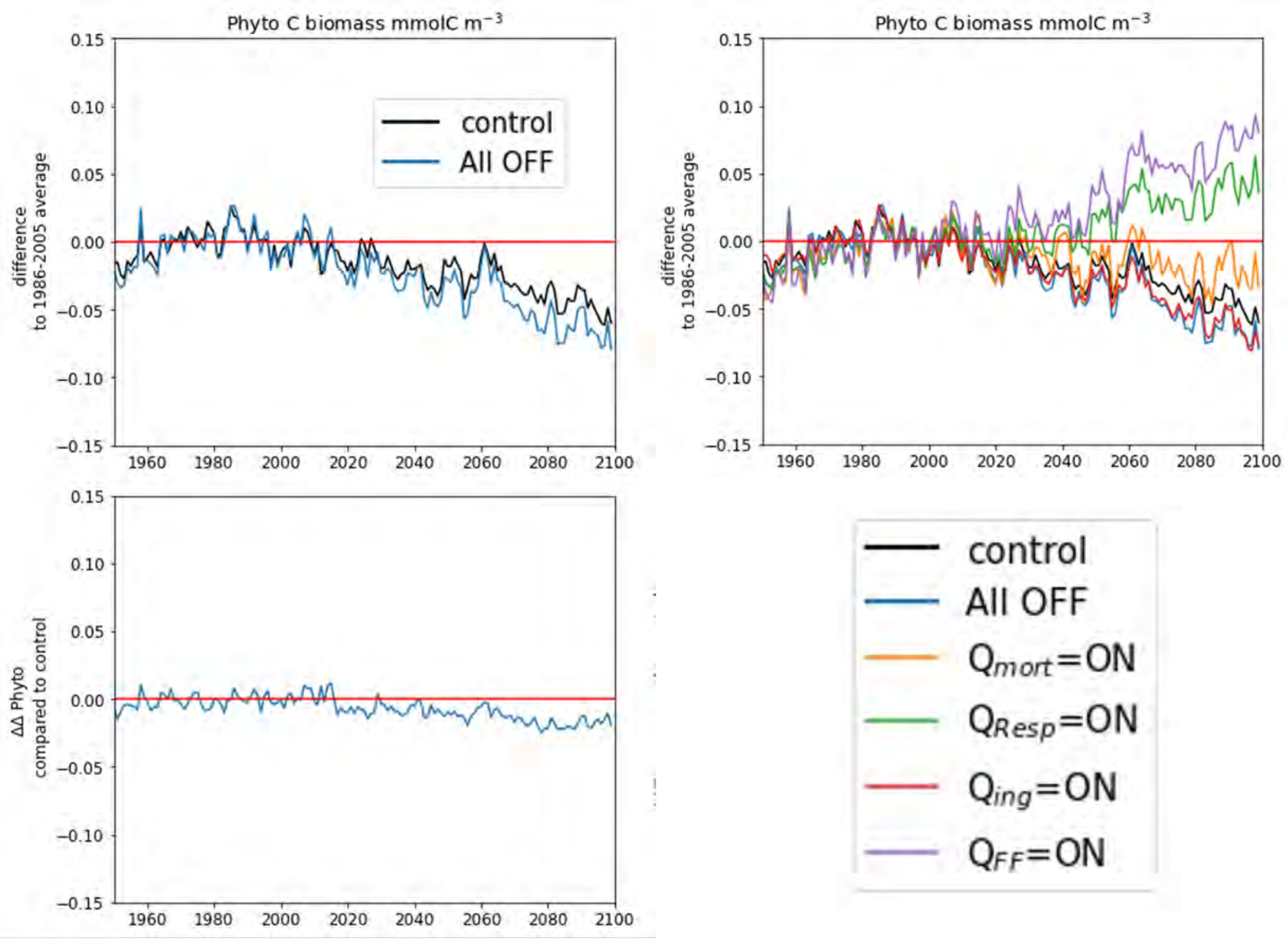
- At global scale, it seems like the simulations with and without warming are quite similar (e.g. to within around 10%)
- Example here for phytoplankton biomass (similar message for zooplankton biomass, NPP and export production)
- But … this hides a range of overlapping and distinct impacts associated to the thermal sensitivity of different zooplankton processes: ingenstion, respiration, mortality and flux feeding



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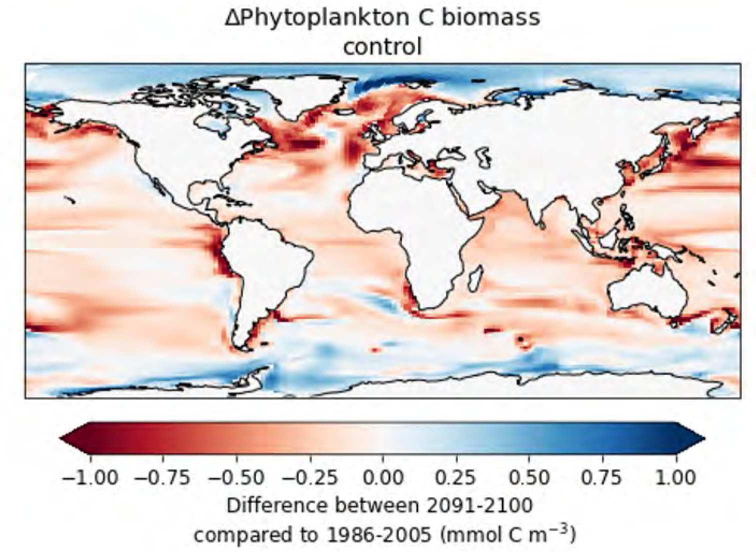
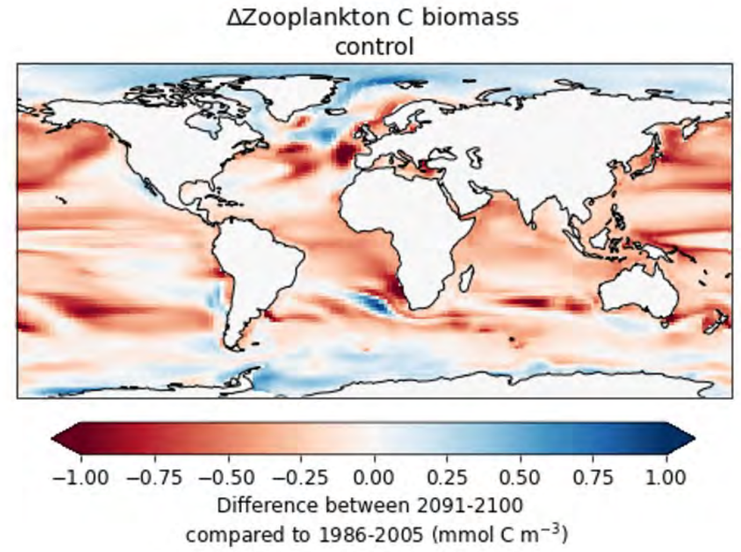
- Climate causes regionally distinct changes in phyto- and zoo-plankton biomass - more strongly for zooplankton

- Removing the thermal effects leads to complex spatial patterns: can be ±40% of the overall climate signal

- Ongoing work with further experiments to unpick individual contributions of ingestion, respiration, mortality and flux feeding

- Importance of isolating the direct and indirect effects of temperature (e.g also role of food supply) on zooplankton processes





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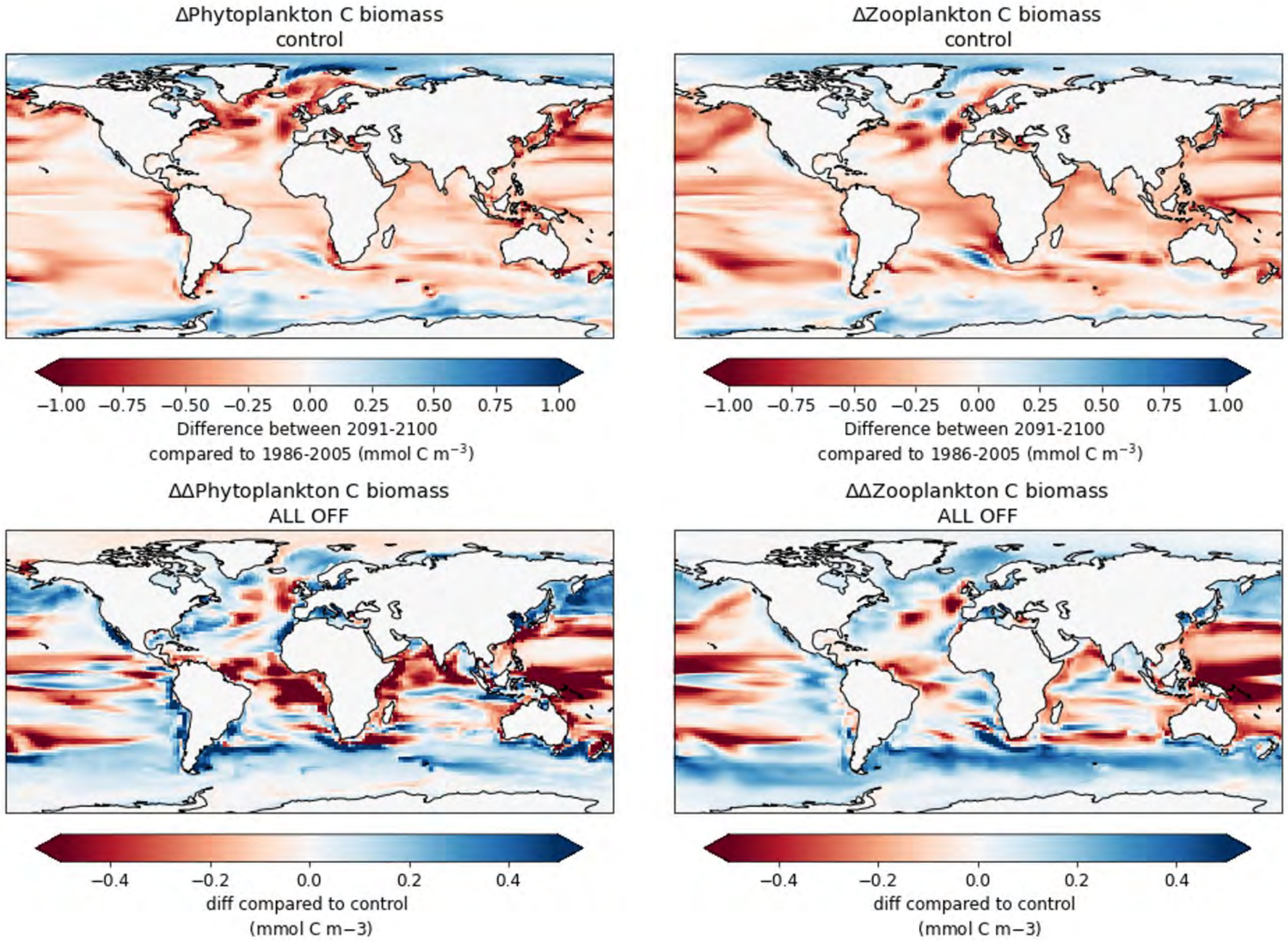

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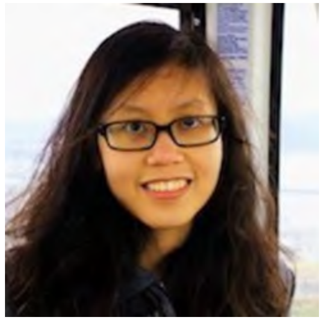

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Thanks for listening!

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