

Contribution of diapausing copepods to the Southern Ocean lipid pump: data mining, parameterisations, and modelling

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This research contributes to two projects



NERC programme examining biogeochemical processes and ecosystem function in polar regions.

Q1. What biogeochemical processes modify nutrient balance *en route* from source to polar ocean ecosystem, and what are their sensitivities to climate change?

Q2. What are the influences of ecosystem processes on nutrient balance and carbon transport to deep waters, and how may these change in the future?

Q3. How may carbon transport to depth and nutrient export change in the future and what are likely global impacts on carbon cycling and fish stocks?

<https://biopole.ac.uk/>



EU Horizon 2020 research & innovation programme aiming to close critical knowledge gaps on the influence of polar changes on the global climate system.

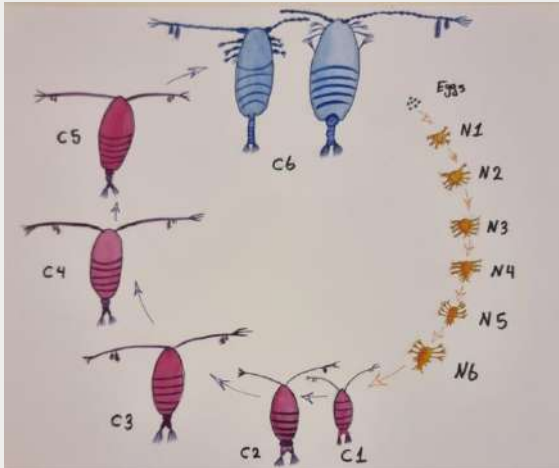
- Enhancing reliability of climate model projections in the polar regions.
- Model 'storyline' approach allows study of multiple potential future polar climates.
- Assessment of what these projections mean for the environment and society.

<https://polarres.eu/>



Copepods: brief overview

Ontogeny



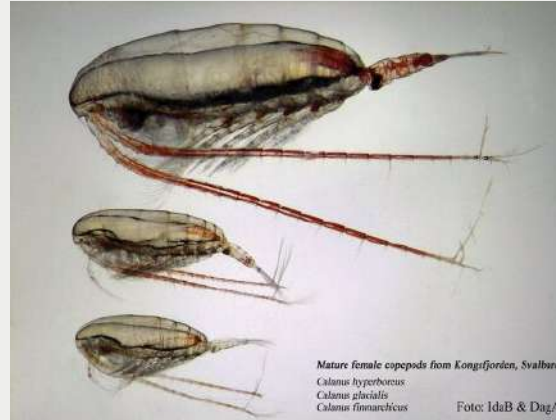
Abdulhussain (2021)

Complex life cycle – 12 distinct forms

- 6 nauplius stages
- 6 copepodite stages – C6 is adult

Life span dependent on species and environment

Lipid

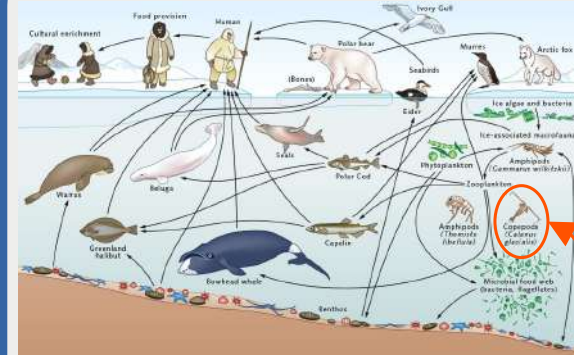


Berge et al. (2012) *J. Plankton Res.* 34(3)

Polar copepods (stages C3-C6) accrue lipid in body

- May be 70% of body mass
- Energy reserves to overwinter
- Food for higher trophic animals

Ecology

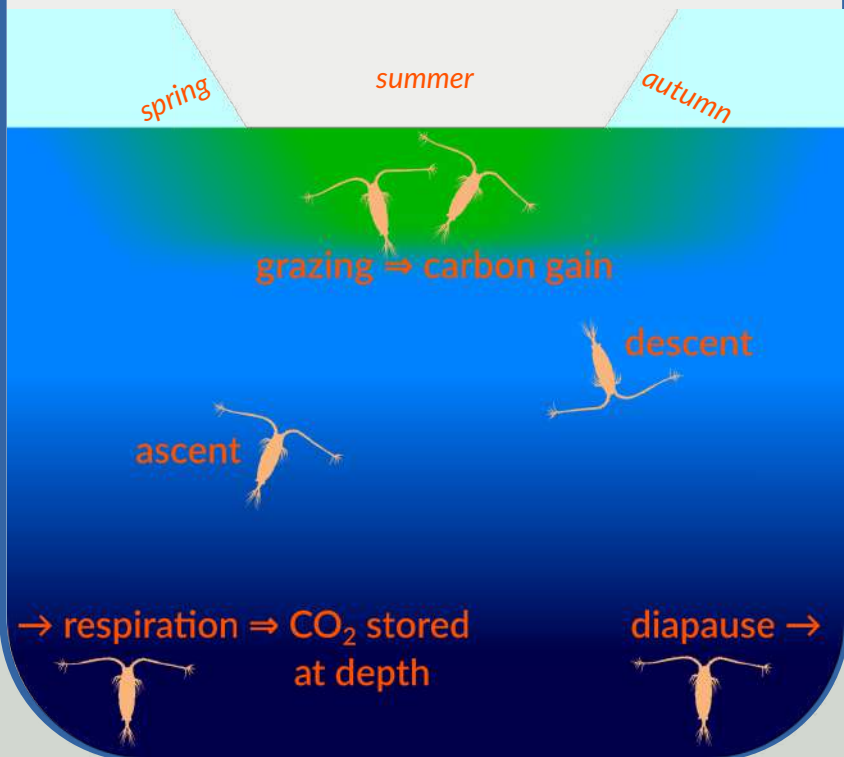


World Ocean Review 6 (2019)

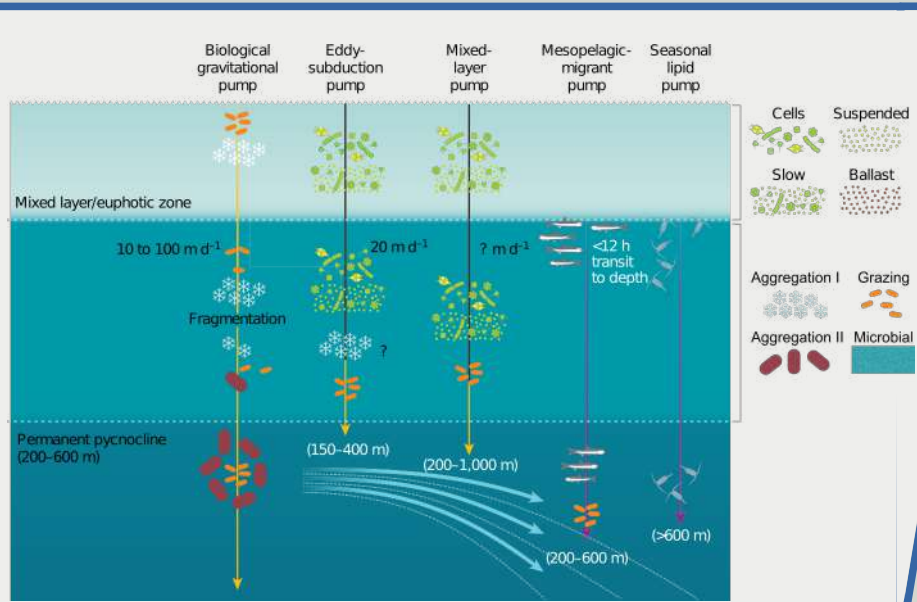
- Link primary productivity to higher trophic levels
- Food for large zooplankton, fish, baleen whales, seabirds
- Lipid flows through foodweb, nourishing marine & terrestrial predators, including humans



The seasonal lipid pump CO₂ storage pathway



- Diapausing copepods transport large quantities of lipid to deep water in autumn – released at depth as CO₂
- Efficient & direct carbon transport – no attenuation like particulate organic carbon gravitational pump
- Quantified in well-studied Arctic species – less known in Antarctic

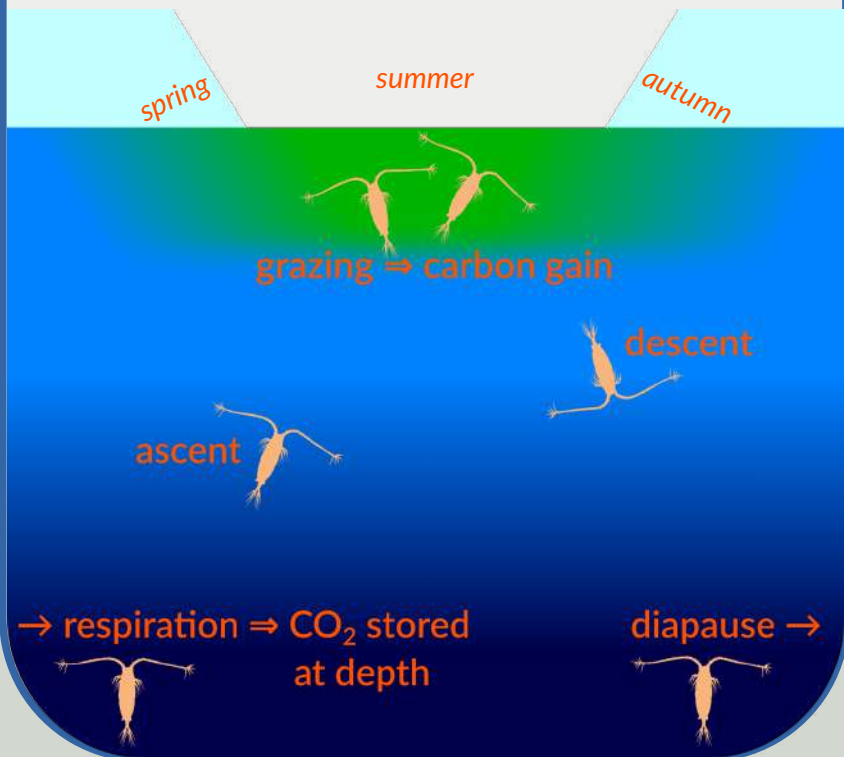


Boyd et al. (2019). Nature Res. Rev. 568

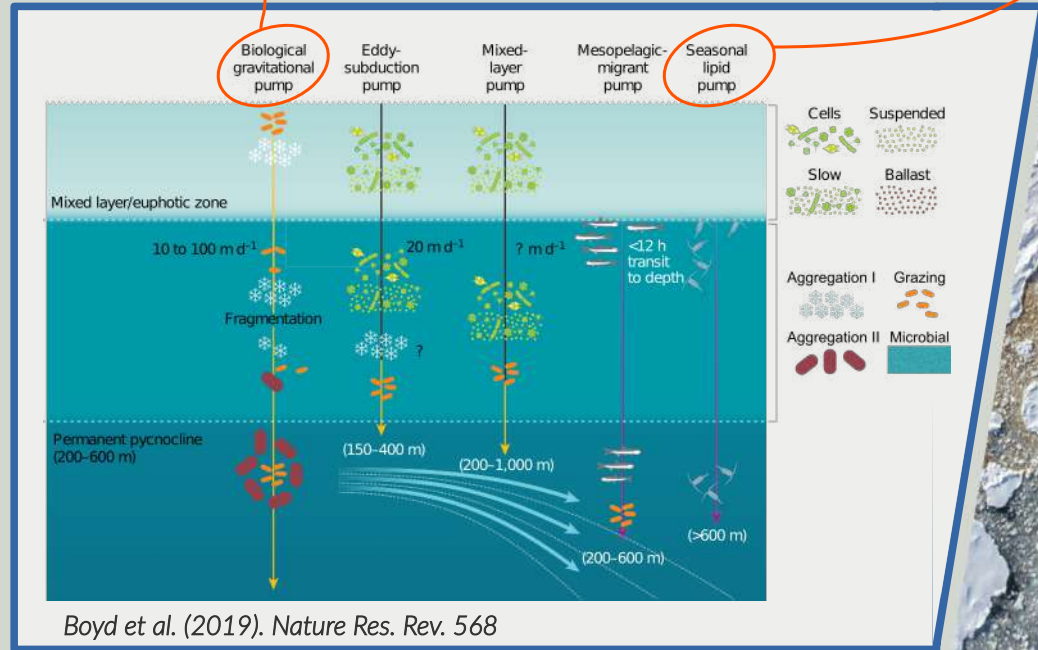


The lipid pump

The seasonal lipid pump CO₂ storage pathway



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To what extent do polar copepod lipid reserves contribute to carbon storage in the deep ocean?

Can we quantify this at ocean scales?

How are copepods distributed – what is the *lipid-scape*?

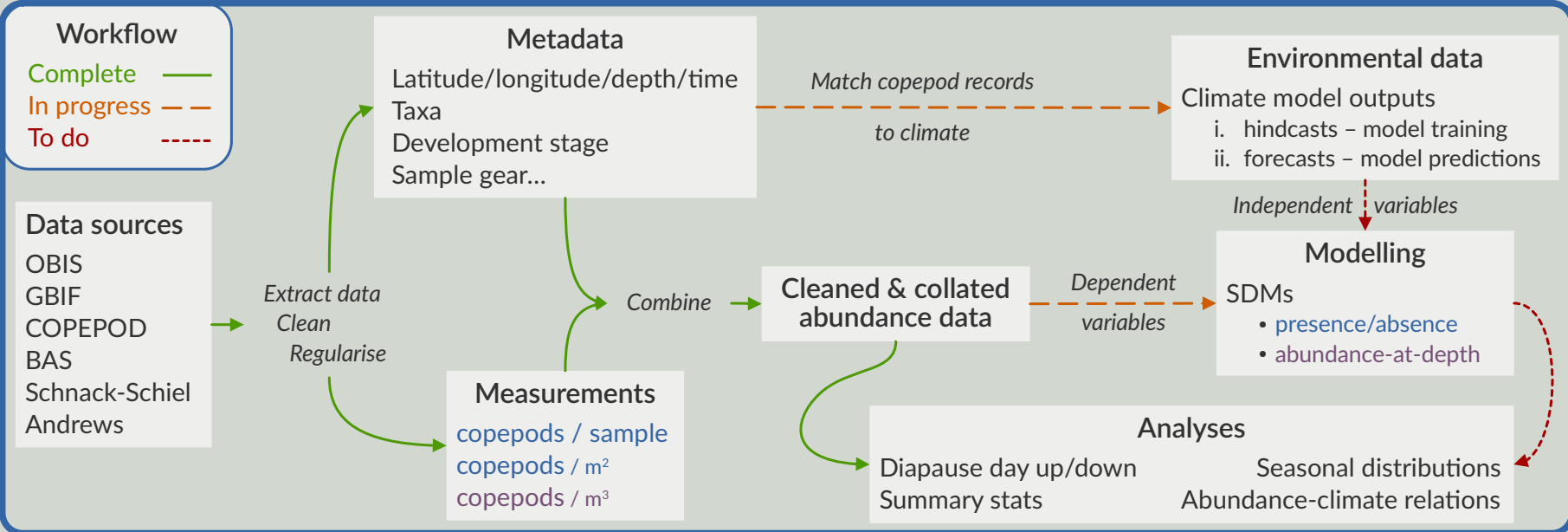
How to parameterise seasonal lipid depletion?

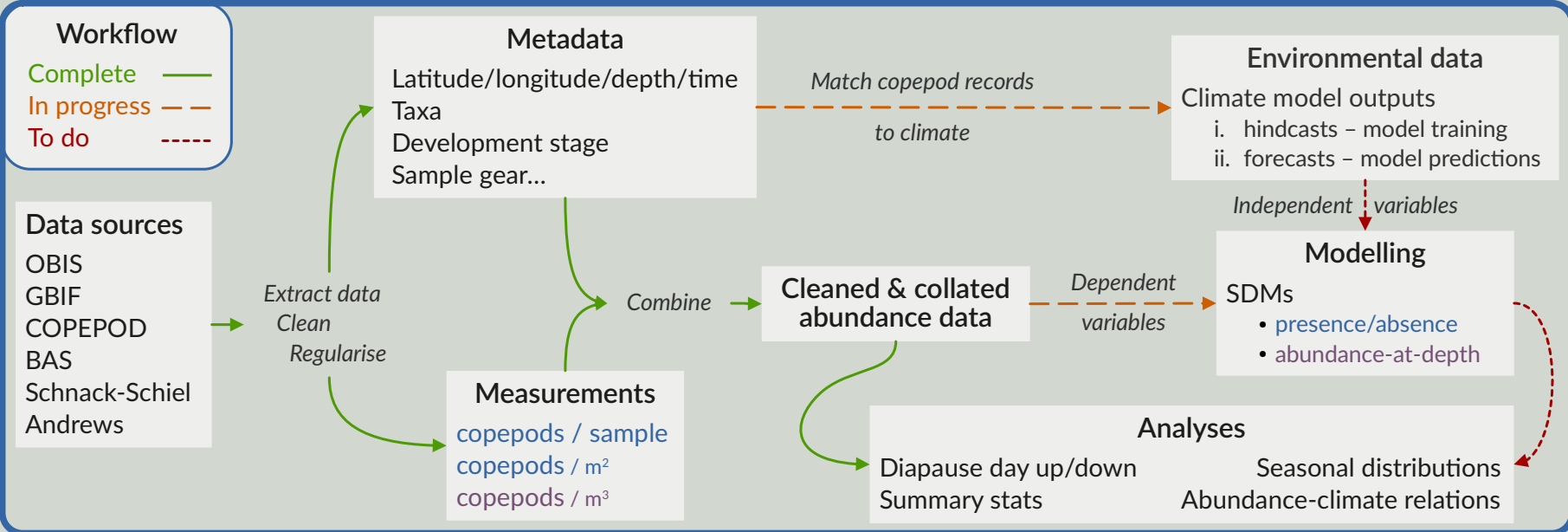
How may carbon storage via the *lipid pump* potentially respond to changing conditions?

Which environmental variables drive copepod abundance & lipid content?

Can we investigate possible futures of the lipid pump using species distribution models and climate forecasts?








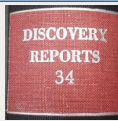




- I'll talk more on...
1. acquiring/cleaning/collating copepod data
 2. graphing & mapping these data
 3. parameterisations of diapause schedule & depth distribution
 4. finish by summarising plans for species distribution models






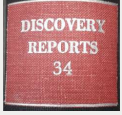


Data mining/cleaning copepod abundance records

	Data Source	Period	Location	Species	Equipment	Unit
Biodiversity data portals	 OBIS OCEAN BIODIVERSITY INFORMATION SYSTEM  GBIF Global Biodiversity Information Facility	1910–2020	Southern Ocean-wide	100s of taxa	varied	individuals ind. / m ² Ind. / m ³
Polar data centre	 British Antarctic Survey <small>NATURAL ENVIRONMENT RESEARCH COUNCIL</small>	1991–2019	Scotia Sea	100s of taxa	Bongo nets RMT nets MOCNESS	ind. / m ² Ind. / m ³
NOAA COPEPOD data portal		1932–2008	Southern Ocean-wide	100s of taxa	varied	individuals ind. / m ² Ind. / m ³
Schnack-Schiel's legacy archive	 AWI ALFRED-WEGENER-INSTITUT <small>HELMHOLTZ-ZENTRUM FÜR POLAR-UND MEERESFORSCHUNG</small>	1980–2005	Scotia & Weddell Seas	100s of taxa	Multinet	ind. / m ³
Historic Discovery Investigations cruise data		1926–1939	Southern Ocean-wide	<i>C. acutus</i>	NV70	individuals



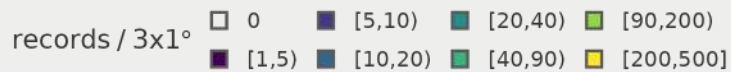
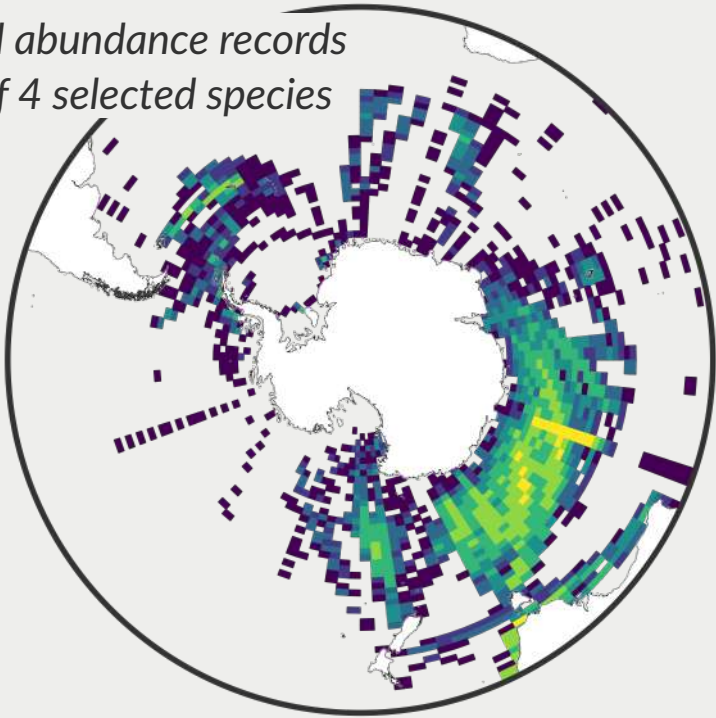
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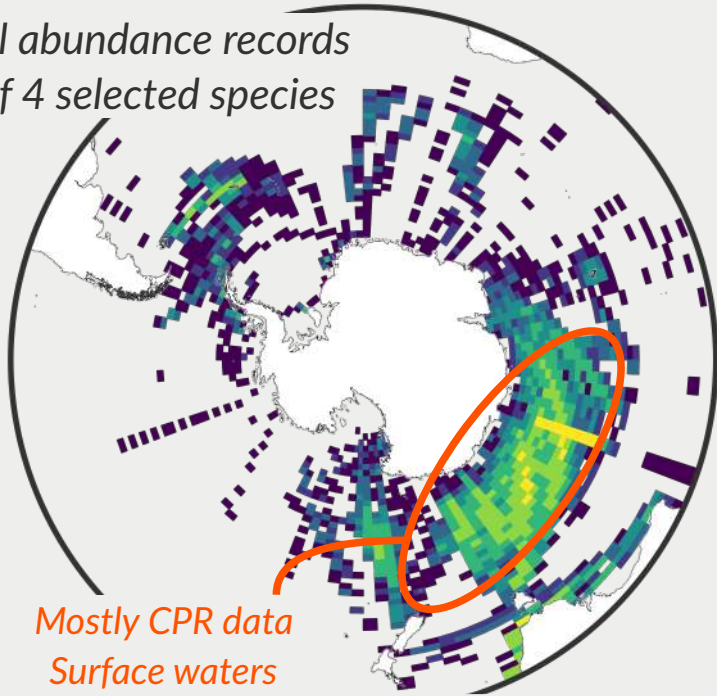
- ★ Cleaned, regularised, combined all abundance data (*who knew there were so many ways to write "C1-C5?!"*)
- ★ Compiled **large** table of Southern Ocean copepod abundance records – published upon completion of BIOPOLE project
- ★ These data will be response variables in species distribution models



*All abundance records
of 4 selected species*











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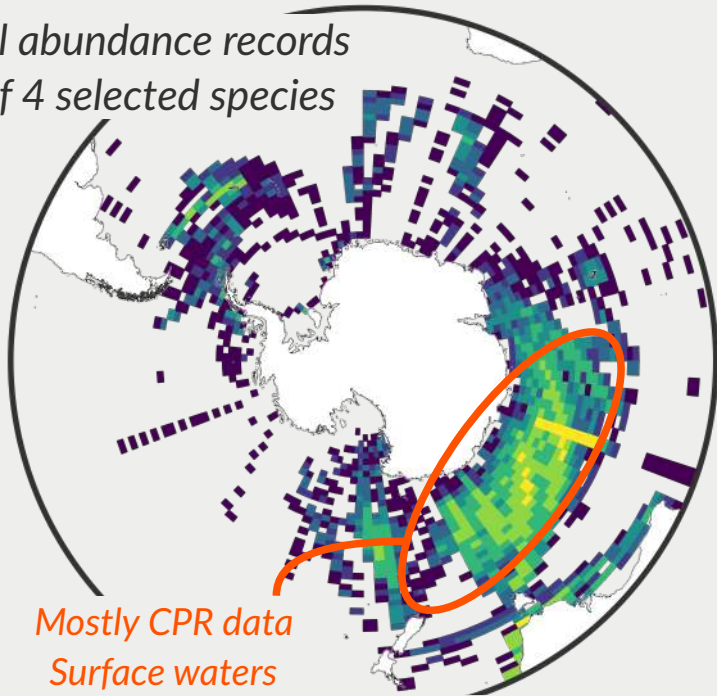
Mostly CPR data
 Surface waters
 Unresolved copepodite stage

records / 3x1°

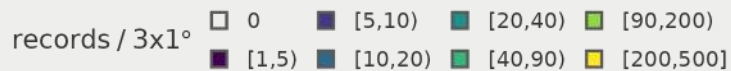
	0		[5,10)		[20,40)		[90,200)
	[1,5)		[10,20)		[40,90)		[200,500]



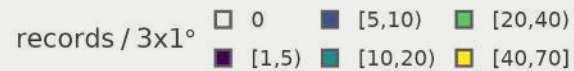
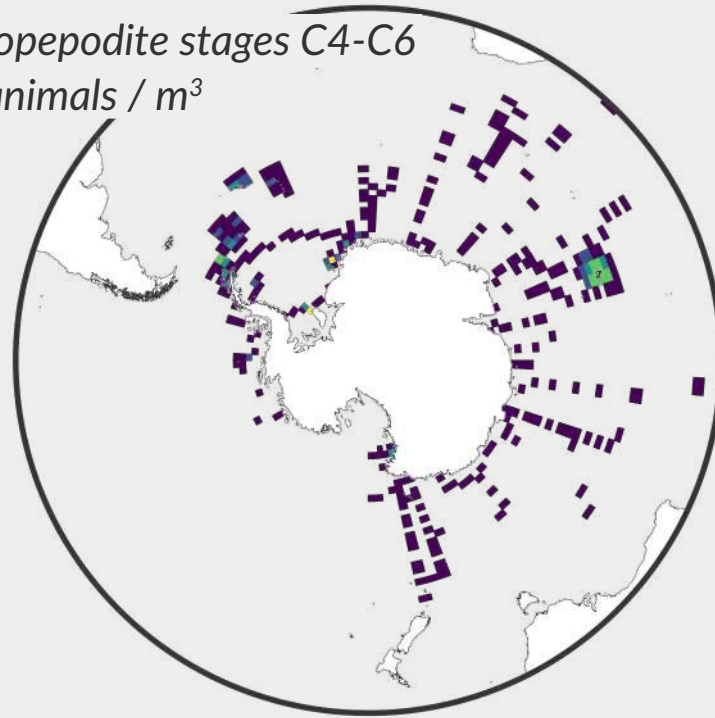
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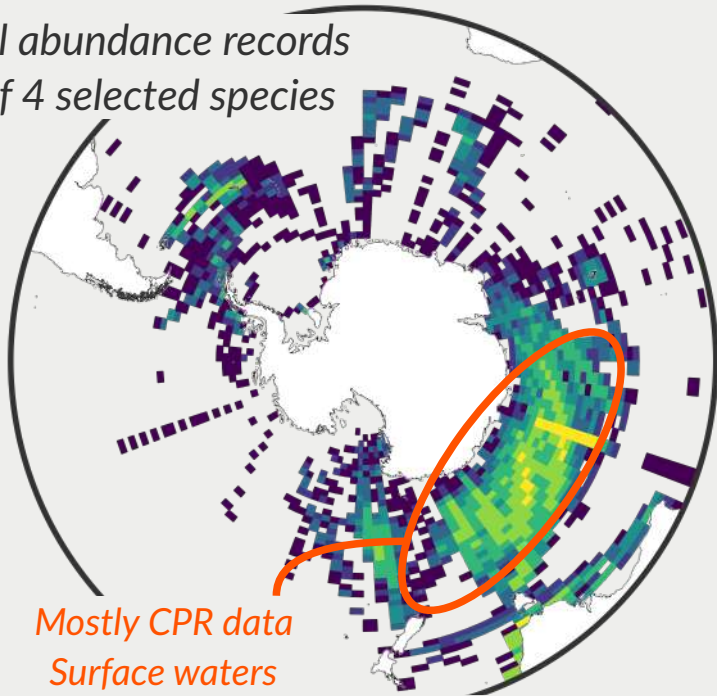
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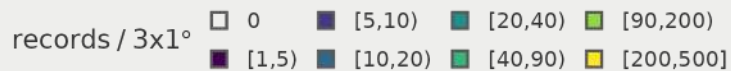
Copepodite stages C4-C6
animals / m³



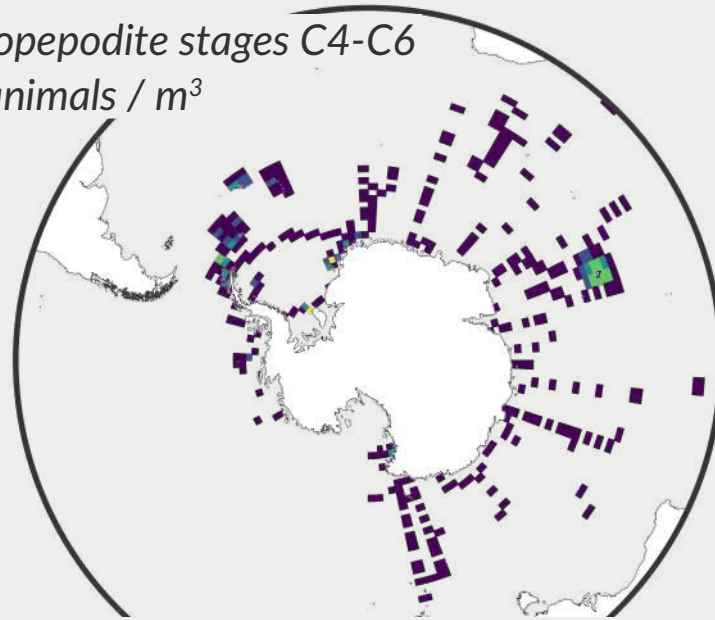
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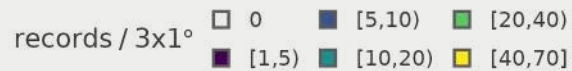
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Copepodite stages C4-C6
animals / m^3



Grouping-dependent data distribution
Spatially diffuse model training domain



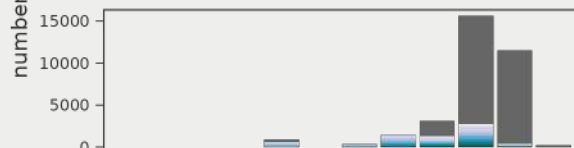
Calanoides acutus



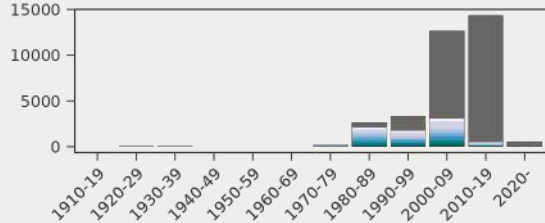
Calanus propinquus



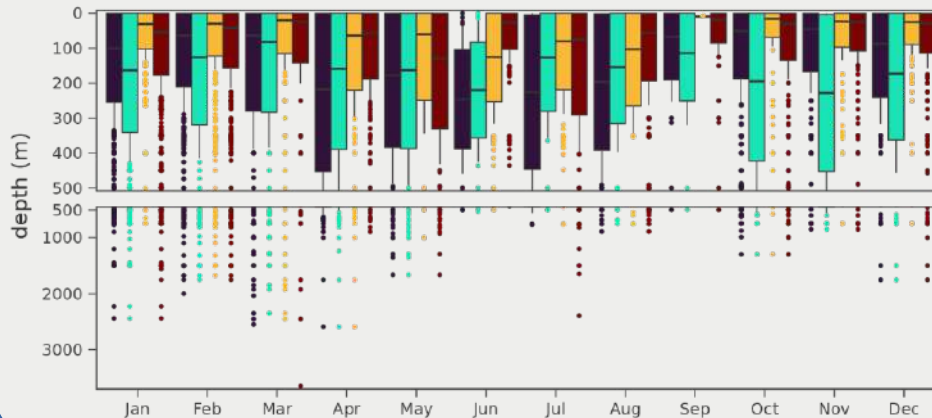
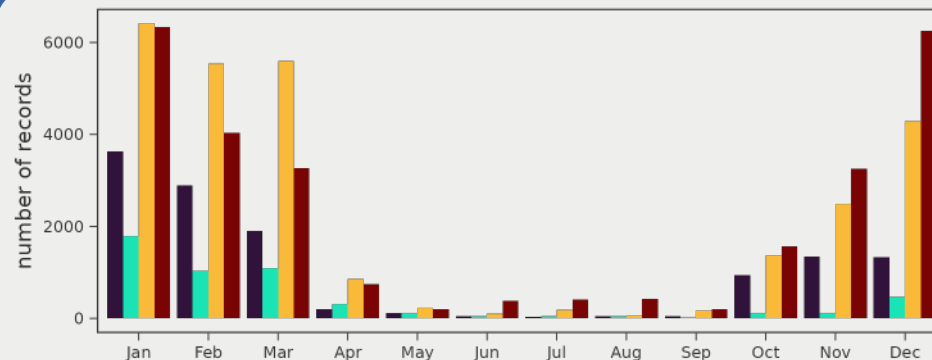
Calanus simillimus

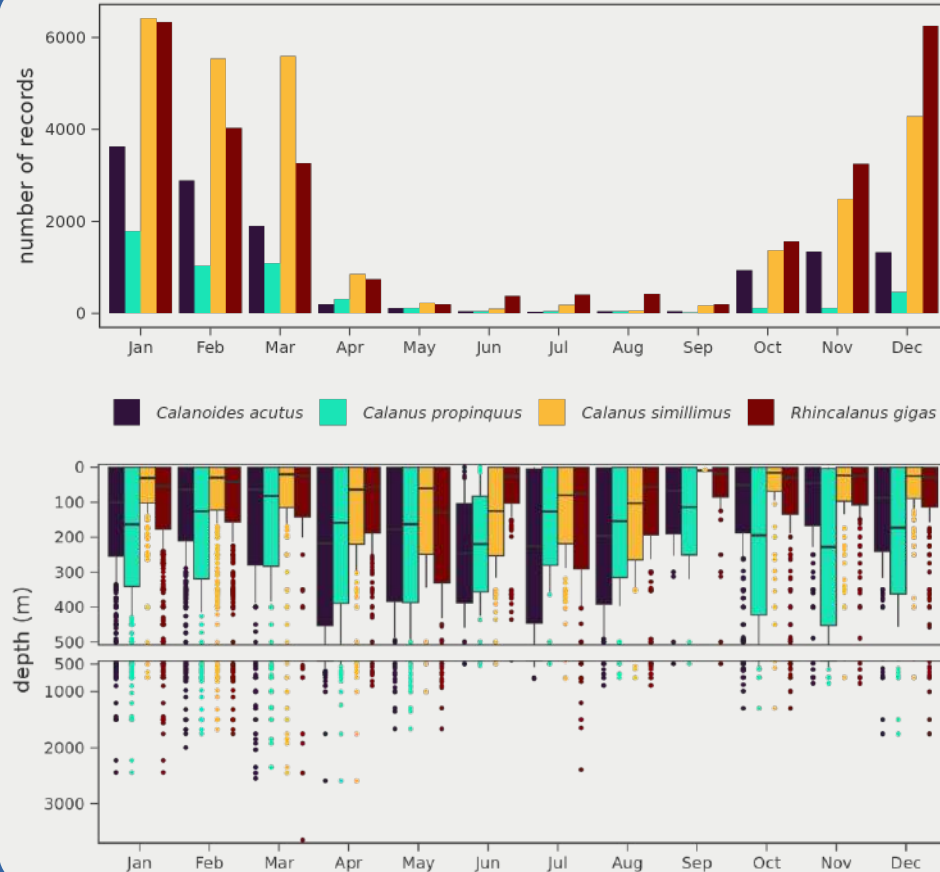
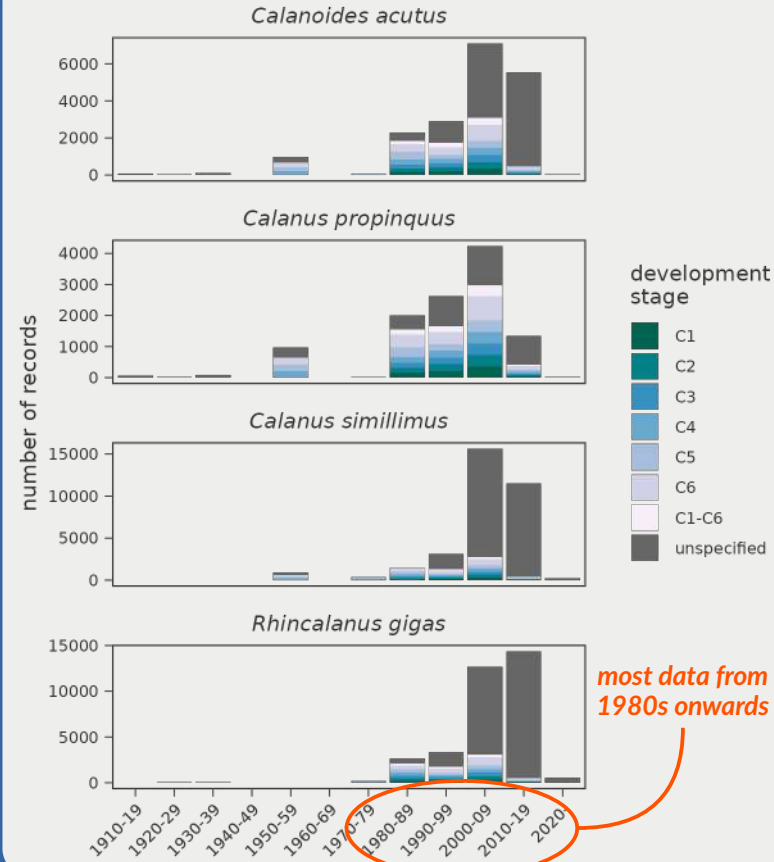


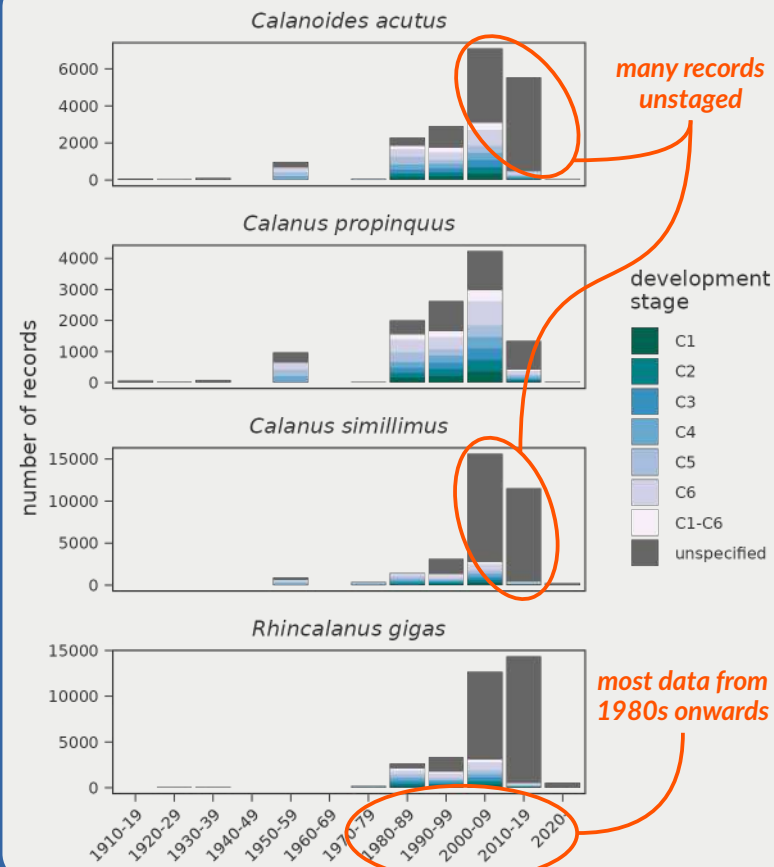
Rhincalanus gigas

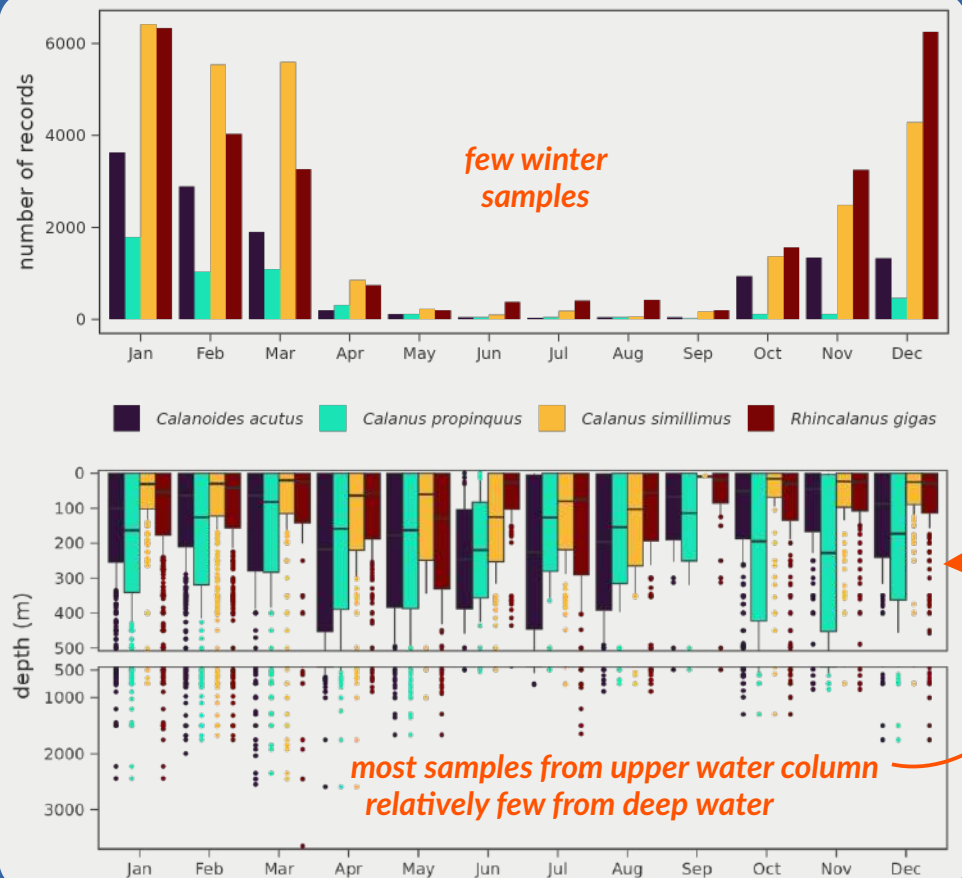
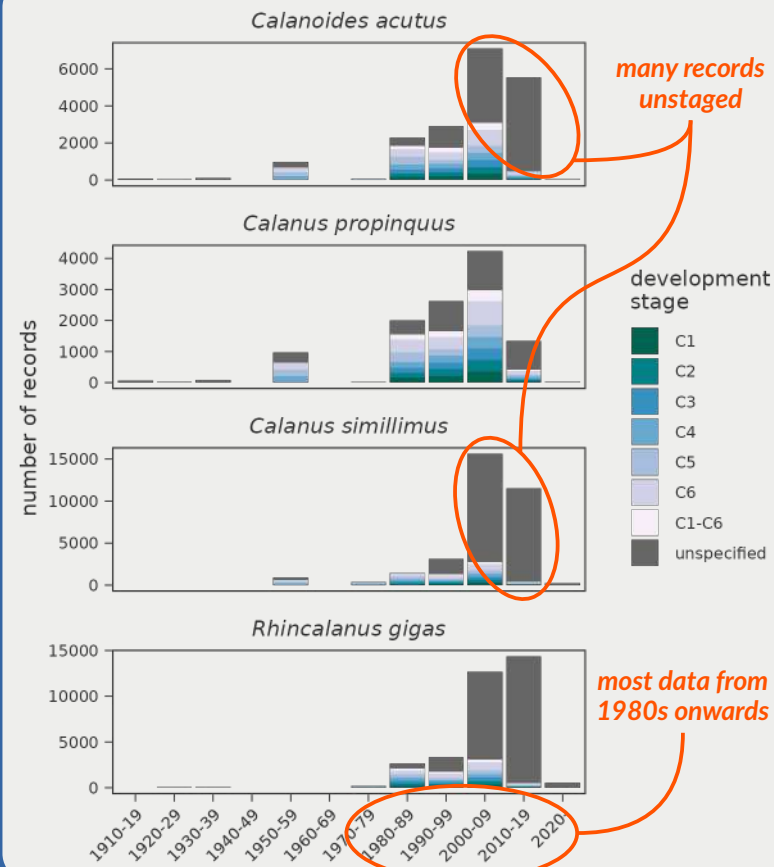


development stage

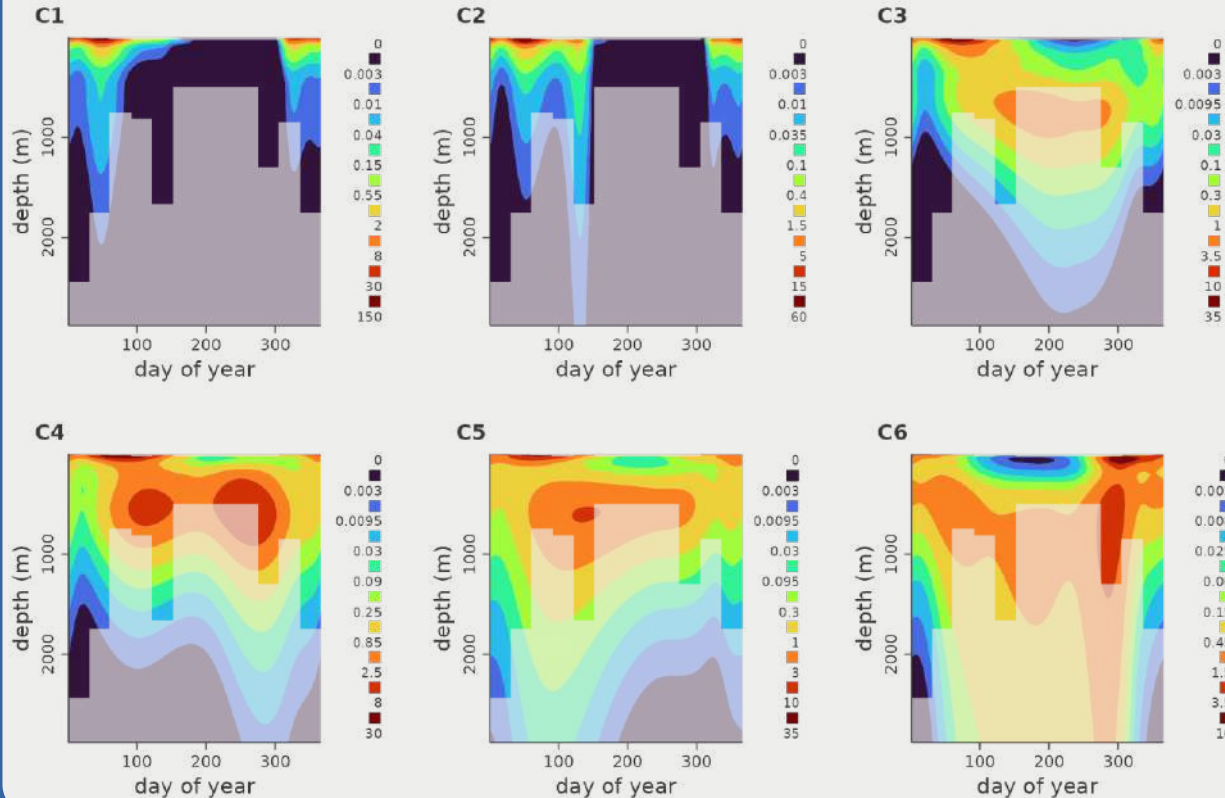




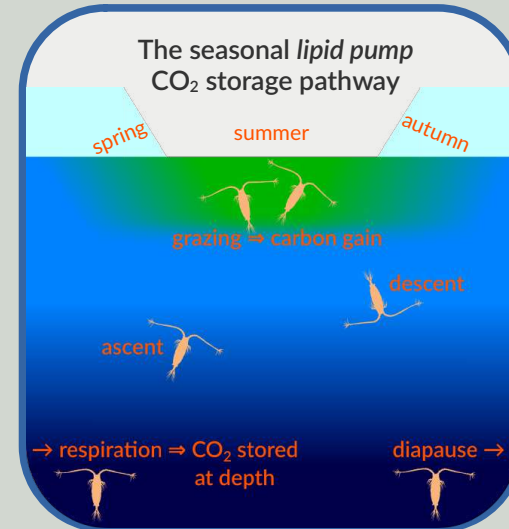




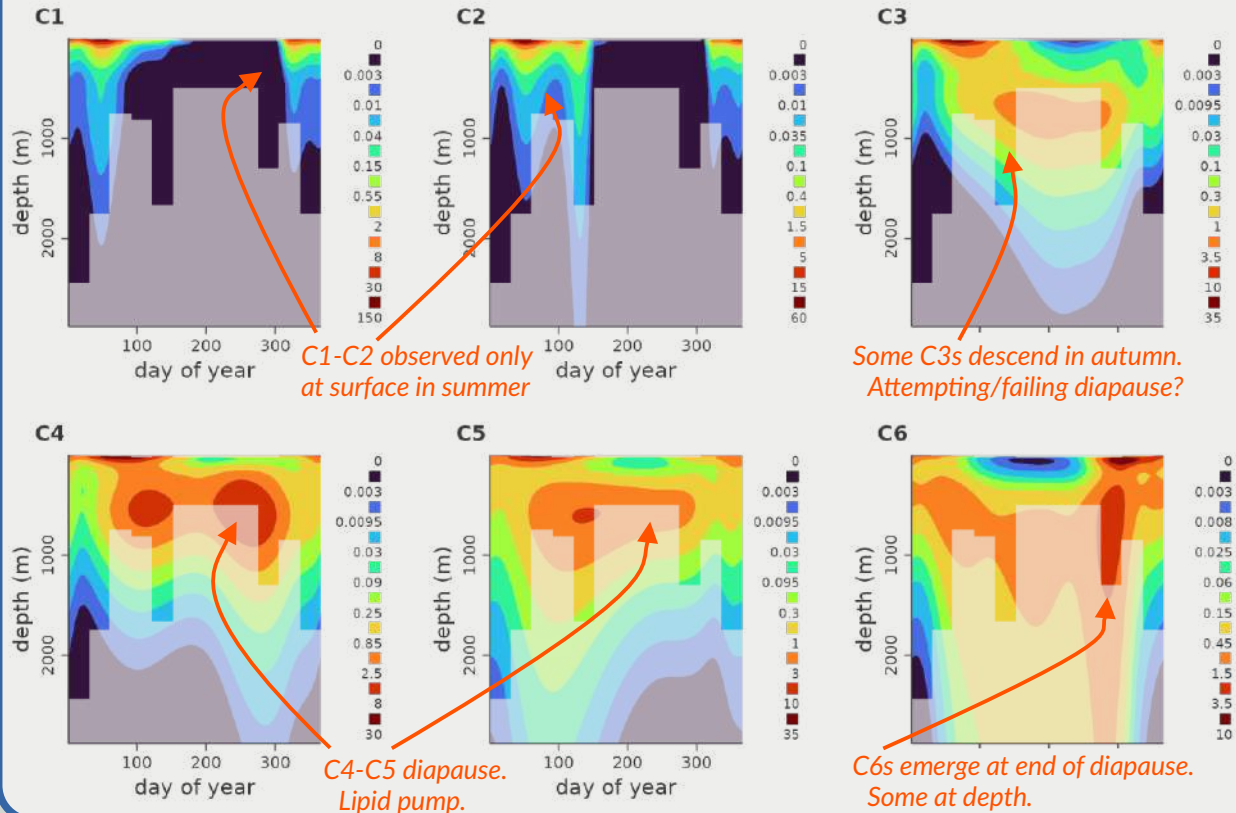
Copepods / m³ grouped by development stage



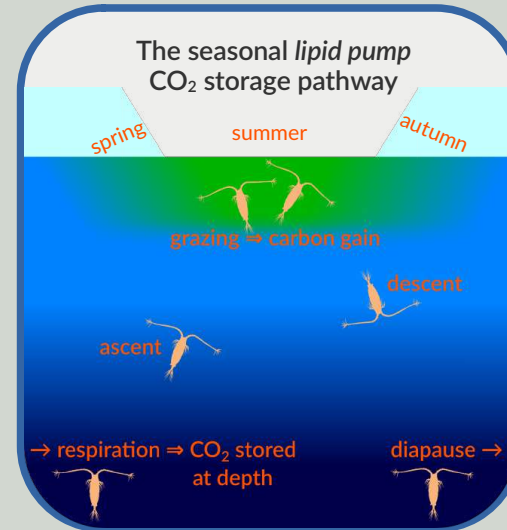
- Gold standard data
 - Fractioned by copepodite stage
 - Statistically rigorous consistent protocol
- Depth-discrete abundance data like these are most valuable for modelling the *lipid pump*



Copepods / m³ grouped by development stage



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Utilising historic data Discovery cruises – Andrews (1966)

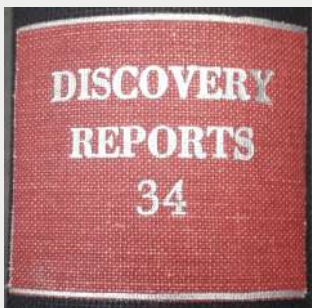
Digitised all *Calanoides acutus* data in Discovery Reports 34

18 tables summarising data collected in 1925–39 from 1031 stations

- Abundances at depth and month
- Copepodite stage progression

Useful for:

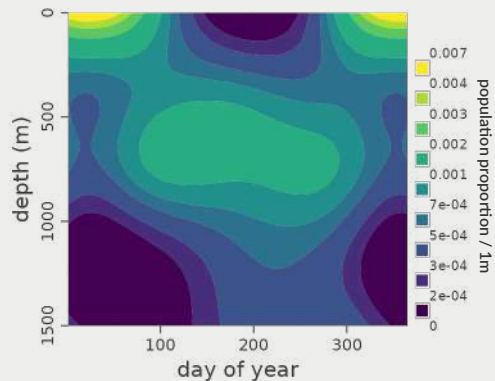
- Comparing modern and historic measurements
- Parameterising models – seasonal depth distributions & diapause schedules



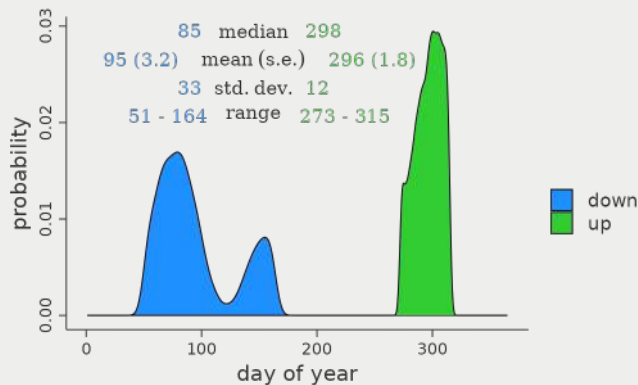
Discovery sample stations



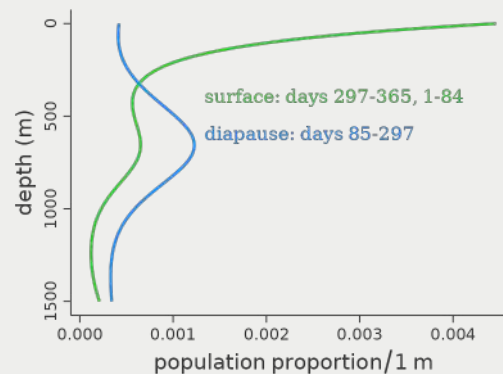
Intra-annual depth distribution



Diapause ascent/descent days



Diapause & active depth distributions



Can we simulate the (3D) distributions of diapausing polar copepods now and into the future?

Abundances of *C. acutus*, *R. gigas*, and *C. propinquus*

Lipid-storing, diapausing species

Modelled (GAMs) as functions of environmental variables

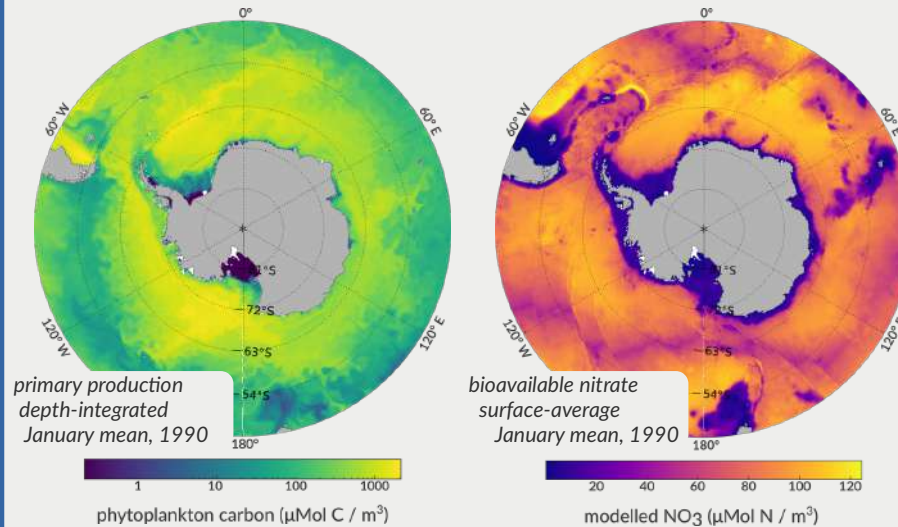
1. PolarRES model hindcasts (1990–2020) to train models.

Which variables drive copepod abundance & diapause schedules?

2. Model forecasts (2020–2100) to predict copepod distributions.

How may polar lipid pumps respond to potential future climates?

Example PolarRES model outputs
preliminary runs



- Multiple climate models – various forecast ‘storylines’
- High resolution – depth-resolved – 1990–2100
- Large suites of output variables – some models simulate biogeochemistry



Polar oceans have global impacts

- Our results will help inform representations of the lipid pump in global models – NEMO-MEDUSA
- Wider impacts of changing polar lipid-scape...
 - Food webs – trophic transfer efficiency – prey quantity/quality
 - Carbon cycling/storage

Final thoughts

- Communication between biologists and modellers...
 - What data is important for modelling – thorough metadata reporting makes it fit-for-purpose
 - Statistical rigour in sampling designs – plenty of metadata – stored in consistent format
- Data discovery...
 - Not always easy to find highly relevant data
 - Data rescue projects (digitising historic logbooks) very valuable and worthy of funding





<https://biopole.ac.uk/>



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