SPONSORED BY THE
Federal Ministry of Education and Research

NERC SCIENCE OF THE ENVIRONMENT

THE UNIVERSITY OF STRATHCLYDE IN GLASGOW

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

University of St Andrews

The Team

University of Strathclyde Glasgow

Michael Heath

Douglas Speirs

Vacancy

Robert Wilson
(DIAPOD project)

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Ute Daewel

Corinna Schrum

Richard Hofmeister

Deborah Benkort

University of St Andrews

Andrew Brierley

Roland Proud

See our posters at this meeting:

Richard: High resolution ecosystem modelling in the North Atlantic-Arctic ocean

Deborah: Implementing Ice-Algae into the biogeochemical model ECOSMO

Context for the project

On 30 November 2017, 10 major fishing nations agreed not to develop fisheries in the Central Arctic Ocean for at least the next 16 years, to give time for development of scientific understanding before fisheries are established.

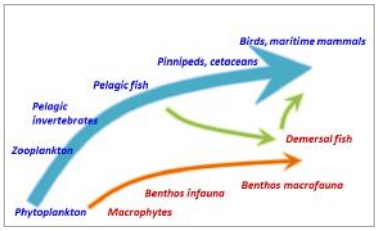
Our high-level objective is to scope the extent of trade-offs between fisheries and cultural values of the Arctic (reputation, wildlife) , and how these may change with warming.

Image: Michael Heath

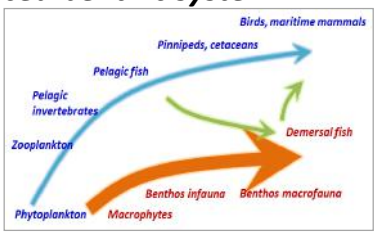
Central questions:

How will the propagation of primary production up the food web change as sea-ice retreats?

Enhanced pelagic system

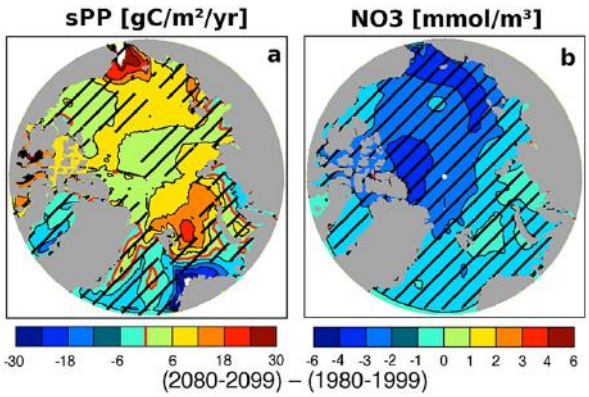


Enhanced benthic system



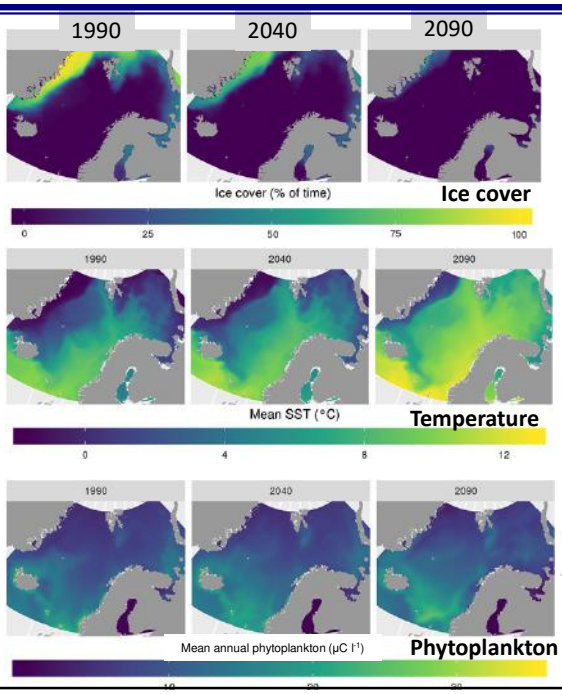
?

How will these changes be spatially distributed?

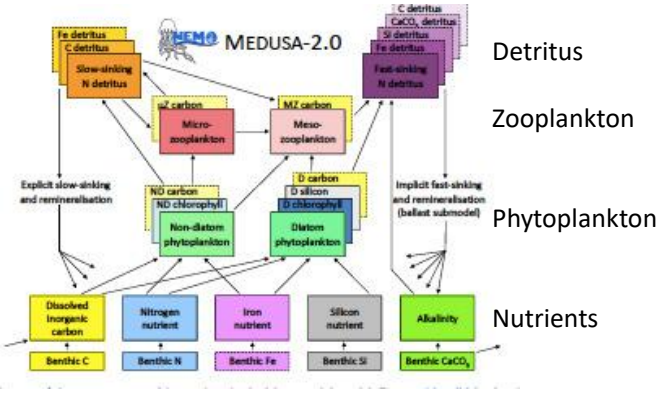


Spatial distribution of mean model 2080–2100 differences with respect to 1980–2000 for (a) annual sPP and (b) nitrate concentration. Hatched regions indicate where 80% of the models agree on the sign of the change.
(Vancoppenolle et al. 2013, Global Biogeochemical Cycles)

NEMO-MEDUSA outputs for the Barents Sea/Fram Strait region

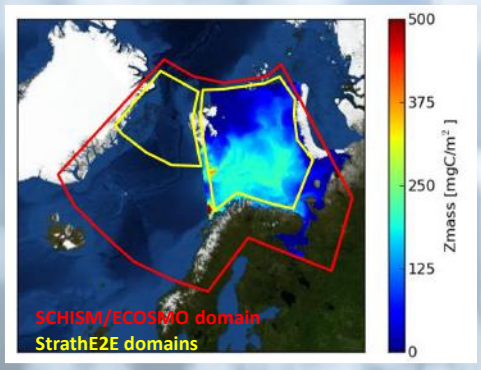


Few if any existing models are suitable for answering our central questions (designed for a different purpose)



Food web diagram from: Yool et al 2013. Geosci. Model Dev., 6, 1767–1811

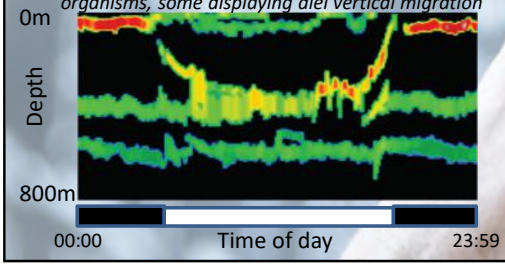
Our plan for the project…



Colour scale: zooplankton biomass simulated with ECOSMO

- **Two complementary models building on existing code**
- **Mathematics of processes not in initial models (e.g. ice algae dynamics)**
- **Analysis of key datasets – especially vertical migrations (*Univ. St Andrews*)**
- **Projections and scenario experiments**

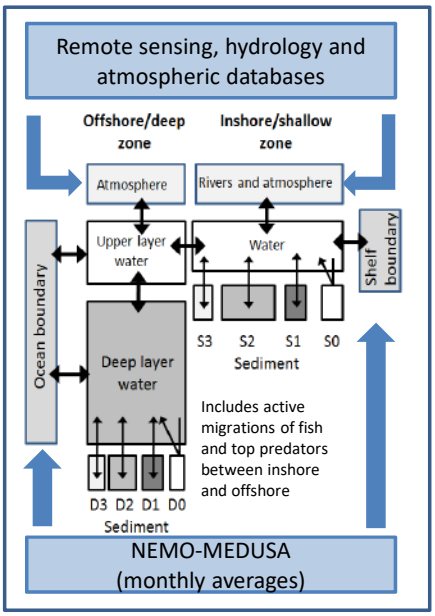
Echogram showing scattering layers of different organisms, some displaying diel vertical migration



	SCHISM/ECOSMO	StrathE2E
Home institute	Helmholtz Institute	University of Strathclyde
Spatial resolution	Fine (1-50km horizontal; 5-50m vertical)	Coarse regions (100s km horizontal; 30-100m vertical)
Computing requirements	Needs HPC	Runs on an ordinary laptop in < 1sec per year

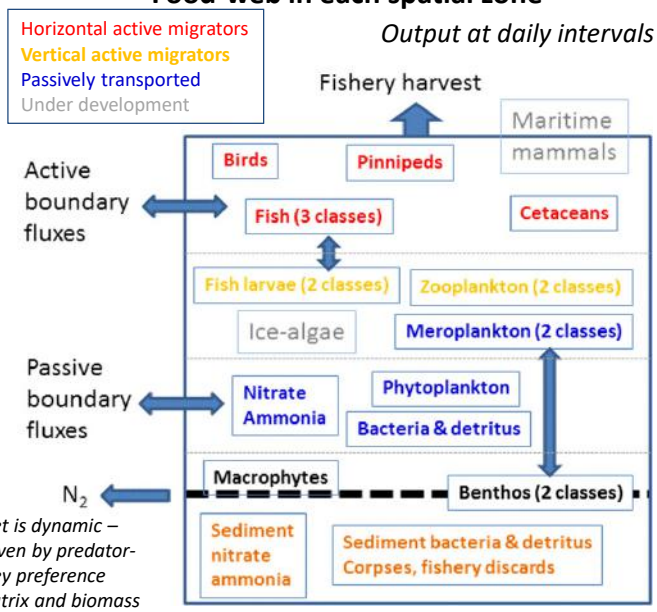
StrathE2E (low spatial resolution, high trophic resolution)

Spatial compartments and boundaries



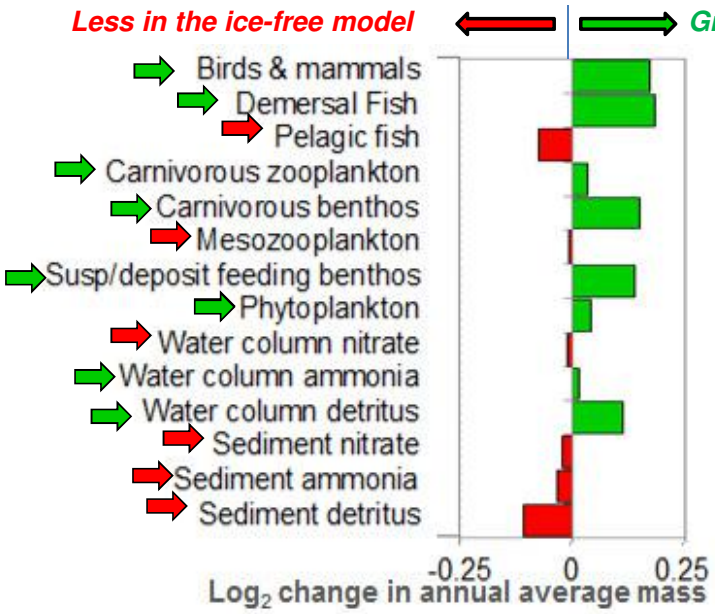
Food-web in each spatial zone

Output at daily intervals



Diet is dynamic – driven by predator-prey preference matrix and biomass dynamic in the web

Differences between annual average masses of ecosystem components in an ice-free model and a baseline 1980's ice cover model of the Barents Sea

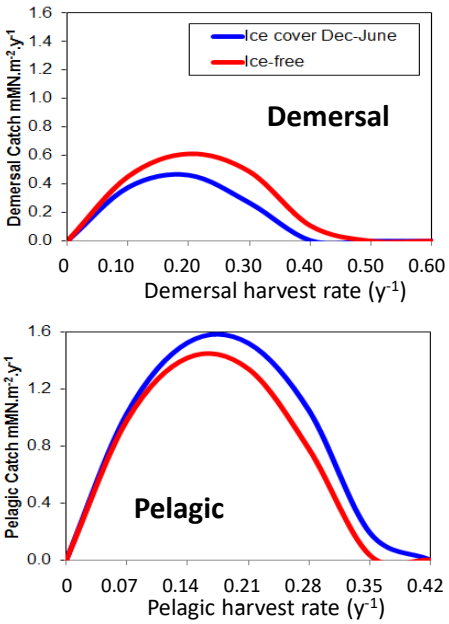


Ice cover:
Attenuates light penetration
Attenuates vertical mixing
Ice-free model:
+0.5C warmer
More continuous FW input

Higher phytoplankton production in ice-free model is amplified as it cascades up the food web.

Annual primary production:
($gC.m^{-2}.y^{-1}$)
Ice-cover model: **50.9**
Ice-free model: **55.4**

Sensitivity of steady state fisheries yield to ice cover



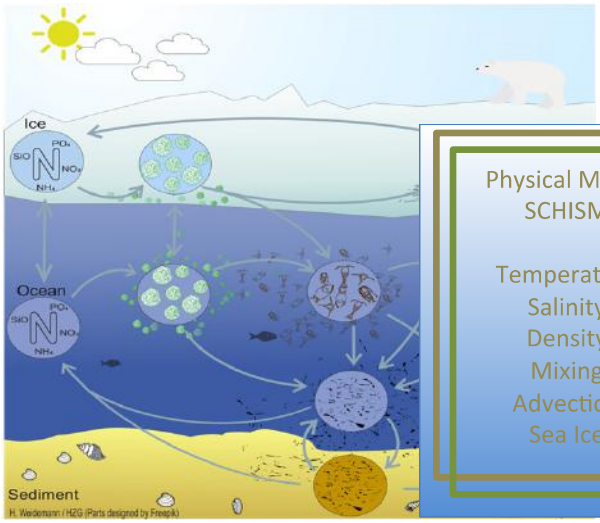
Modelled fish catches in relation to annual harvest rate (≡ fishing mortality rate)

- **Demersal fish yields are greater in the ice-free model than in the baseline**
  – *due to enhanced benthos production*
- **Pelagic fish yields are smaller in the ice-free model than in the baseline**
  – *due to enhanced predation*

Initial model seems capable of producing interesting and relevant results

SCHISM-ECSOMO (high spatial resolution, lower trophic resolution

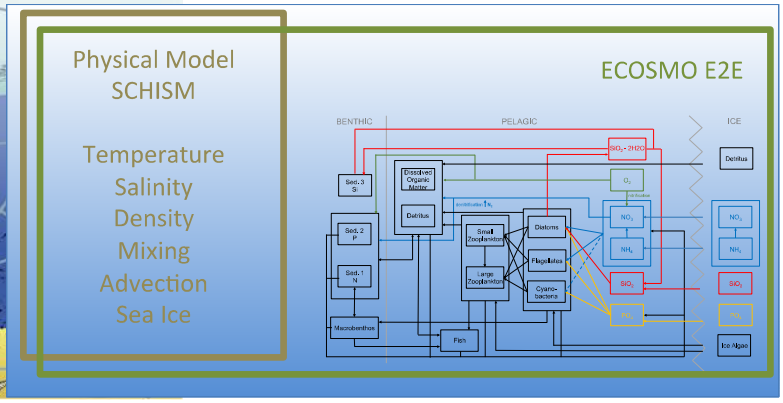
Development of a complex ecosystem model for the Arctic (including Ice algae, fish, macrobenthos, migration strategies)



Fully coupled physical-biological model SCHISM-FESIM-ECOSMO E2E

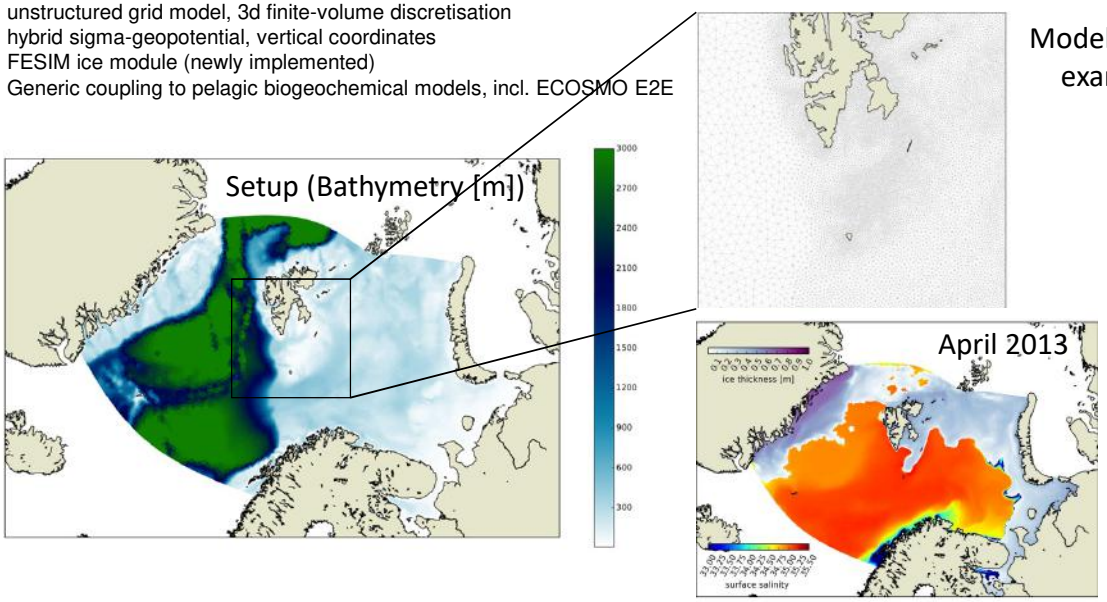
Required forcing data:

- Atmosphere
- Boundaries (physics, biogeochemistry, Ice)
- River runoffs & nutrient loads

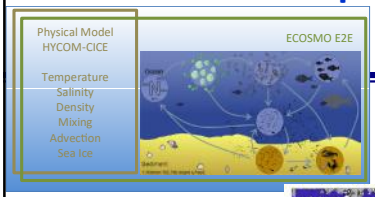


SCHISM [ski-zəm]
A cross-scale model for regional applications

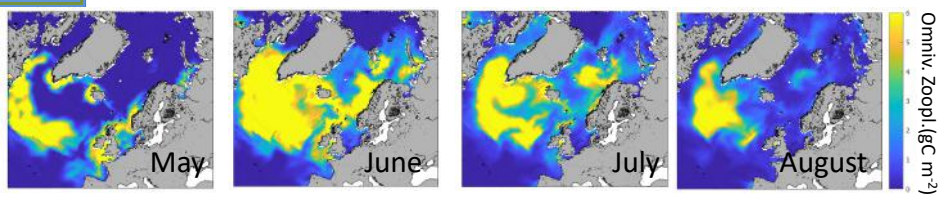
- unstructured grid model, 3d finite-volume discretisation
- hybrid sigma-geopotential, vertical coordinates
- FESIM ice module (newly implemented)
- Generic coupling to pelagic biogeochemical models, incl. ECOSMO E2E

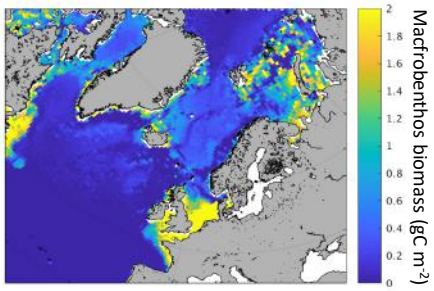


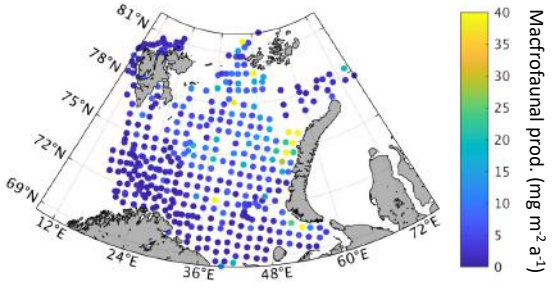
ECOSMO E2E implementation in the North Atlantic/Arctic with the physical model HYCOM



Monthly mean omnivorous zooplankton 1990 after 10 year spinup







Degen et al. (2016): PANGAEA, https://doi.org/10.1594/PANGAEA.857279

Some of the critical mathematical and coding developments needed for both models

- Under- and within-ice light environment in relation to ice thickness
- Ice algae
- Importance of ice for predators (pinnipeds, birds, polar bears)
- Motivations for vertical and horizontal migrations

Need interaction with other CAO projects

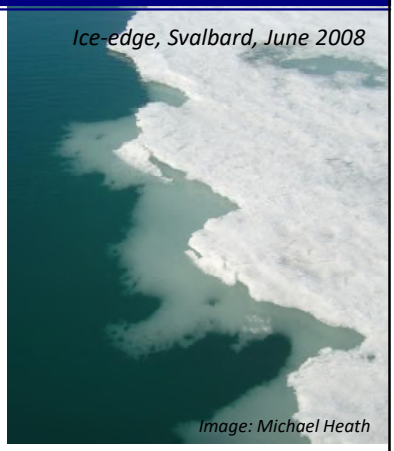
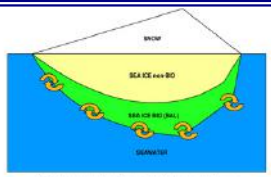

Ice-edge, Svalbard, June 2008

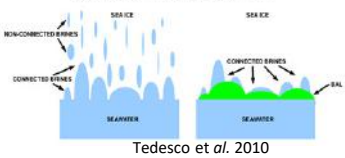
Image: Michael Heath

Biologically Active Layer (BAL) model of sea-ice biology for coupling with ECOSMO (poster Déborah Benkort)

Ice biology model components:

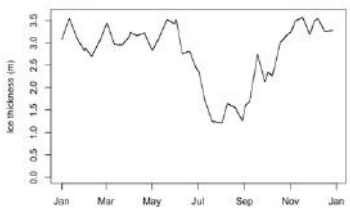
- Inorganic nutrients (Nitrate, Ammonium, Phosphate and Silicate)
- Algae (diatoms)
- Detritus
- **Algal dynamics depend on**: physical properties of sea-ice, nutrient availaibility, and exchanges at the ocean/ice interface
- **Nutrient dynamics depend on:** exchanges at the ocean/ice interface, and sea-ice algae dynamics





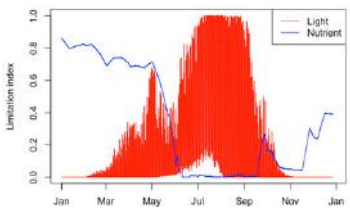
Tedesco et *al.* 2010

Ice thickness



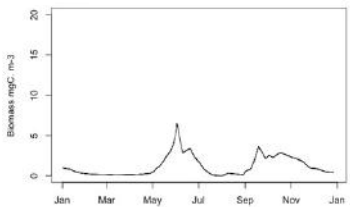
Time (months)

Modelled light & nutrient limitation



Time (months)

Ice algae biomass



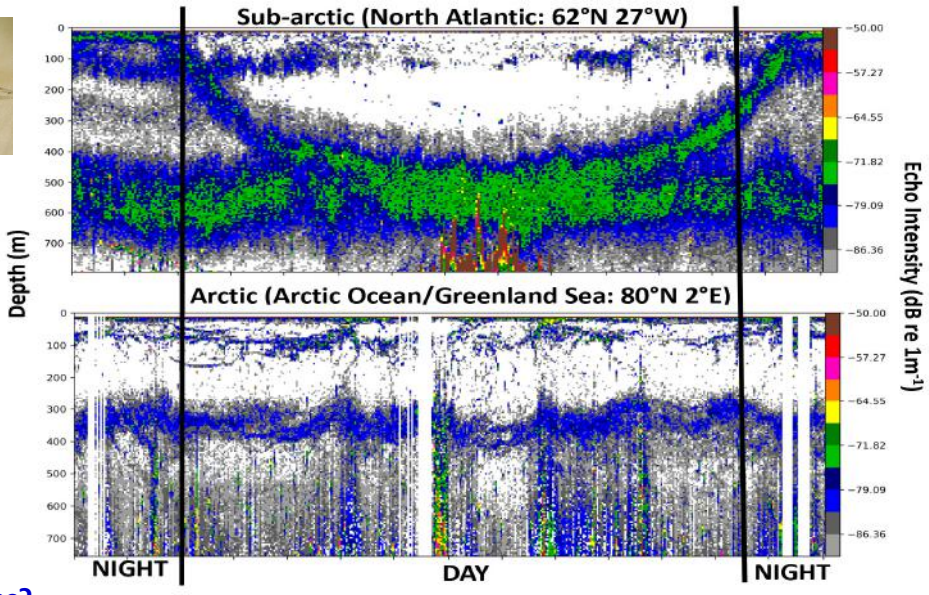
Time (months)

Arctic Deep Scattering Layers and Diel Vertical Migration

Strong DSLs and clear & diel Vertical Migration (DVM) signal

Weak DSLs and absence of DVM signal

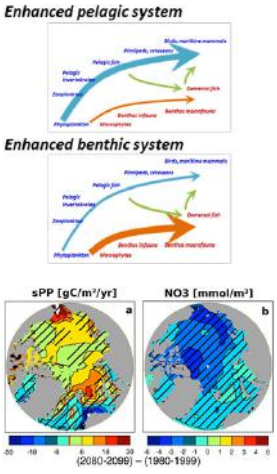
Why?
Different species?
Different motivations?



38 kHz echosounder data from JC049 (AUG 2010) and PS107 (AUG 2017)

Returning to our central questions…

- **How will the propagation of primary production up the food web change as sea-ice retreats?**
- **How will these changes be spatially distributed?**



Following on from these science questions:

- ***What type of fisheries will emerge in an ice-free Arctic?***
- ***Where are they likely to be concentrated?***
- ***How will they interact directly and indirectly with wildlife?***
- ***How to minimise the risk to wildlife?***

- Initial discussions with Arctic Council, Conservation of Arctic Flora and Fauna (*CAFF*) Working Group secretariat

- Getting back to them in ~6 months when we have more results to show