



Can we detect change in Arctic Ecosystems?

@project_ARISE





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Edinburgh: Raja Ganeshram, Robyn Tueland, Antonia Doncila, Margot Debysier


Manchester: Bart van Dongen, Emma Burns


NOC: Jo Hopkins, Andy Foot

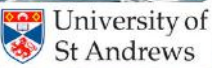
MBA: Rowena Stern


PML: Claudia Castellani









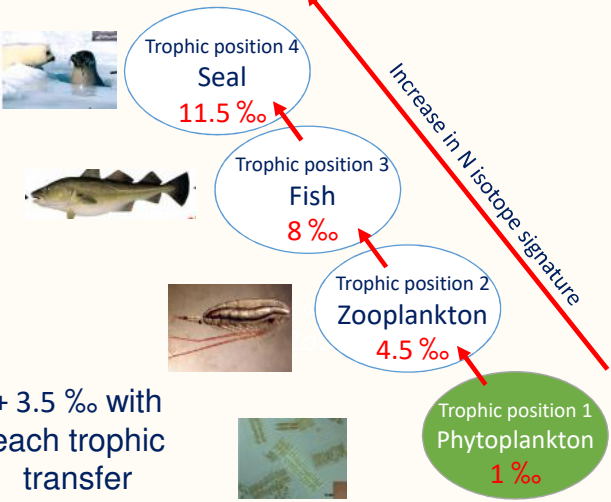






Quantifying ecosystem structure at pan-Arctic scales

Simplified Arctic food chain



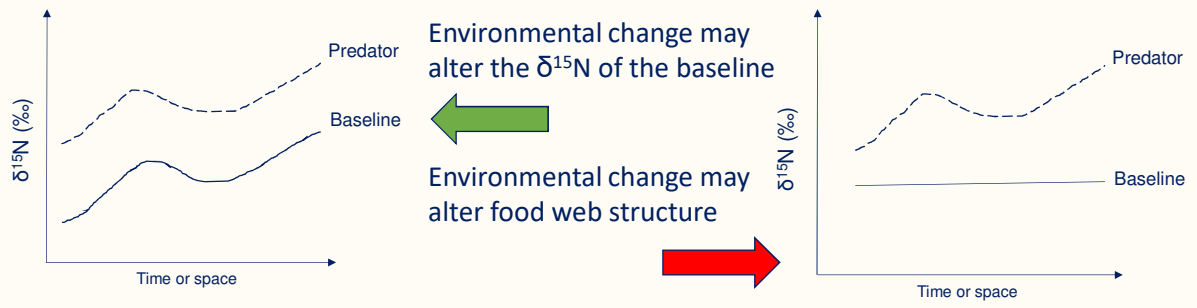
Increase in N isotope signature

+ 3.5 ‰ with each trophic transfer

Overarching goals of ARISE

- Develop a new framework to detect change in Arctic ecosystems
- Attribute ecosystem change to drivers
- Consequences for management and conservation

Stable isotopes and food web analysis: *The Challenge*



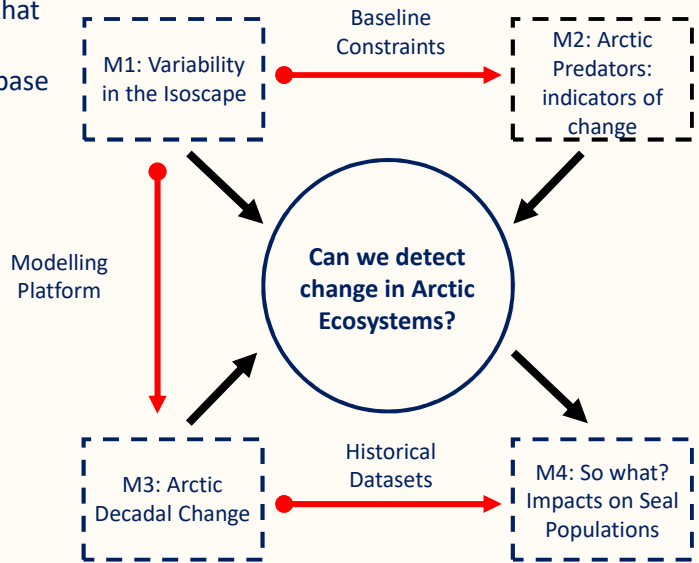
Change in the baseline is reflected in predators

No change in baseline, change in trophic level structure

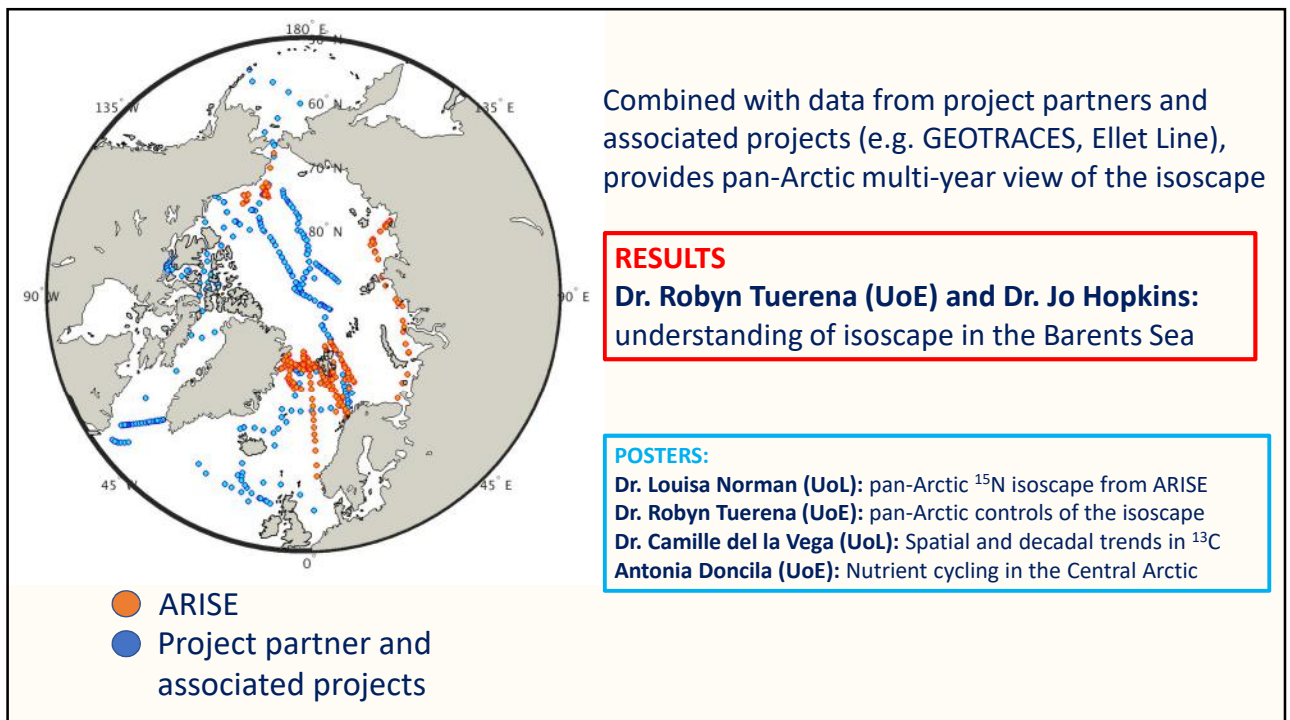
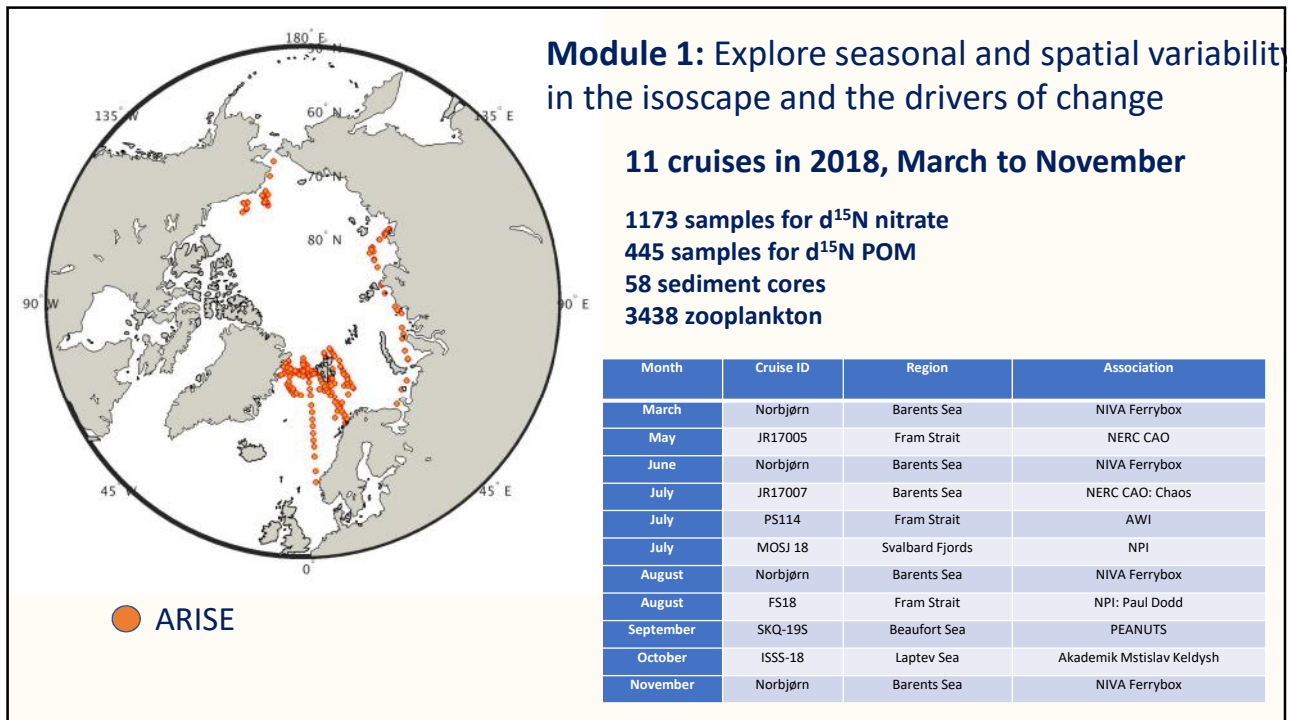
How do we accurately detect a change in trophic position beyond baseline variability?

ARISE: An integrated Approach

Isoscape: isotopic maps based on sources that integrate marine production at the base of the food web





- ARISE Tools:**
- Fieldwork
 - Isoscape
 - Biomarkers in seals
 - Remote sensing
 - Mechanistic model
 - Telemetry
 - Archive samples
 - Historical data
 - Population modelling



● ARISE
● Project partner and associated projects
● Seal Telemetry data

Module 2: Arctic Predators: indicators of change

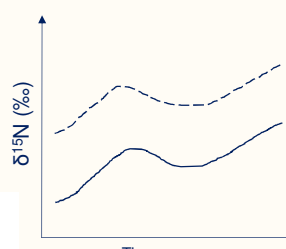
Harp Seal Ringed Seal

Pelagic feeding, ice-dependent predators
 Excellent 'indicator species' of food web functioning

RESULTS Dr. James Grecian (UoSt): Harp seal migration and drivers of distribution

● ARISE
● Project partner and associated projects
● Seal Telemetry data
● Harp and Ringed seals

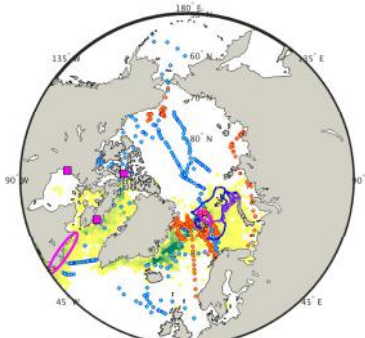
Module 2: Arctic Predators: indicators of change



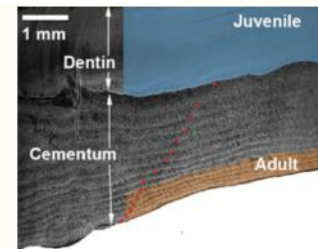
Bulk and compound specific stable N isotopes to study spatial and temporal change in food web structure

RESULTS: Dr. Camille de La Vega (UoL): Spatial variation in biomarkers in harp and ringed seals

POSTERS:
Elliott Price: Isotope variability in zooplankton

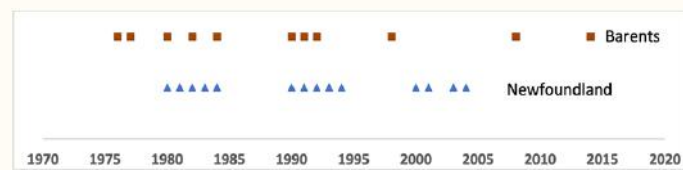


● Harp and Ringed seals




Module 3: Quantify past decadal change and project future 'signal to noise' ratio for detecting change

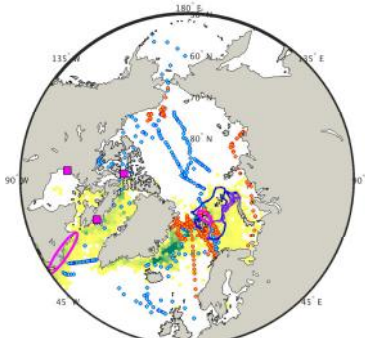
Harp seal teeth



Ringed seal




POSTERS:
Dr. Sophie Smout (UoStA): Seal teeth and isotopes



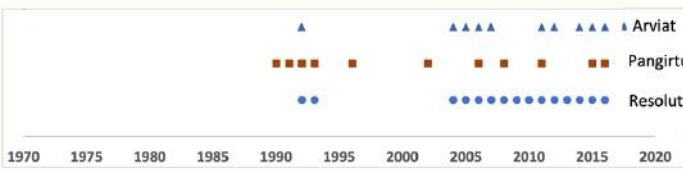
● Harp and Ringed seals

Module 3: Quantify past decadal change and project future 'signal to noise' ratio for detecting change

Harp seal teeth



Ringed seal soft

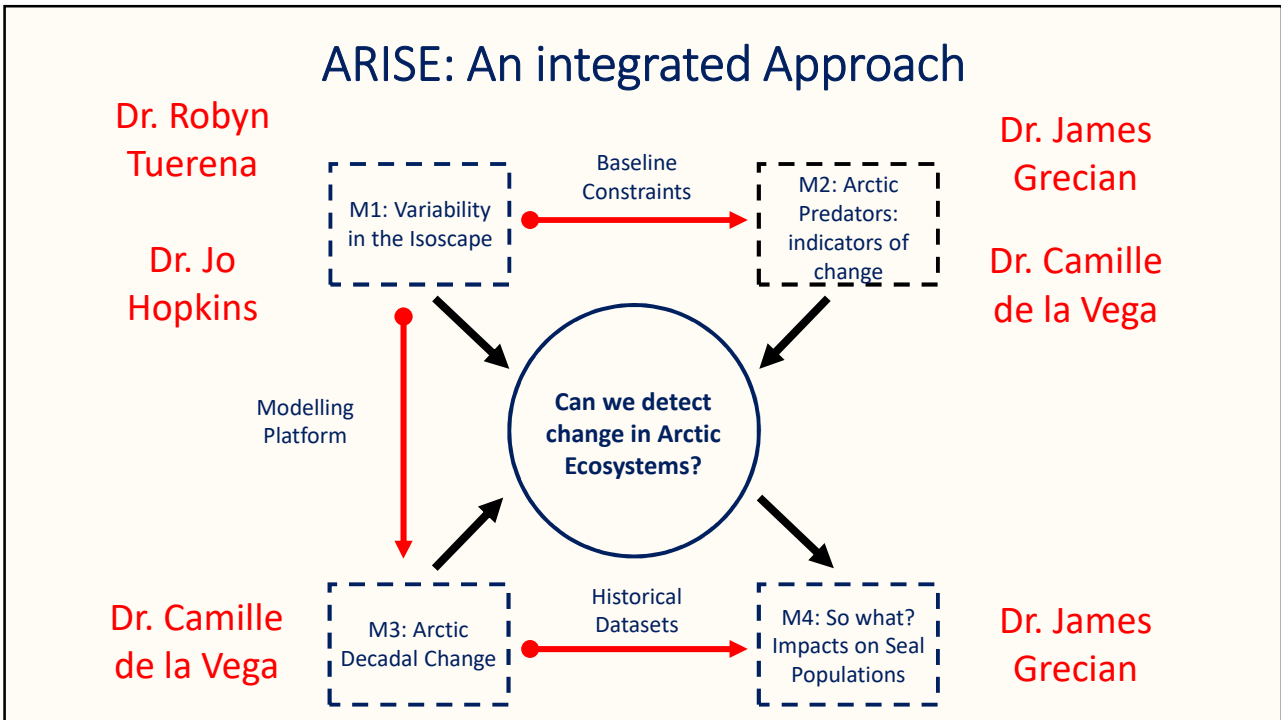


RESULTS: Dr. Camille de La Vega (UoL): Decadal variation in biomarkers in Ringed seals

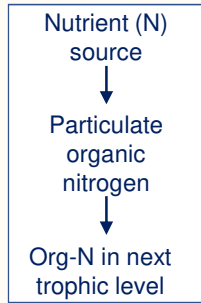
Module 4: So what? Quantify effects of environmental change on seal populations

RESULTS Dr. James Grecian (UoSt): Harp seal population modelling

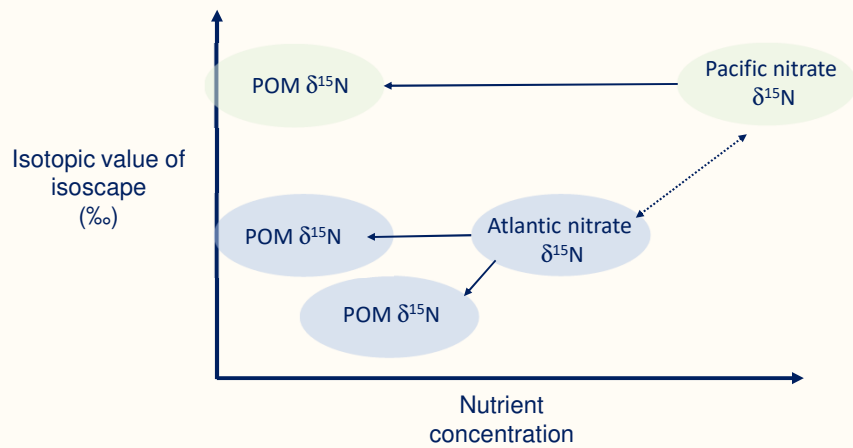
Hammill et al 2015, Biological Conservation



M1: Can we understand variability in the isoscape?



- $\delta^{15}\text{N}$ of source
- Magnitude of source
- Uptake fractionation



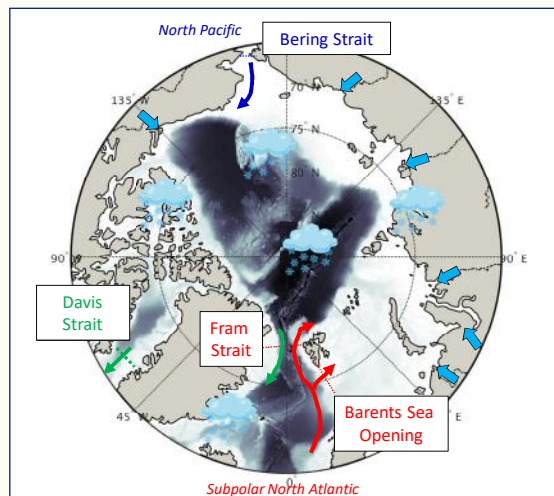
Arctic inflows, outflows and source waters

IN

4 ocean gateways

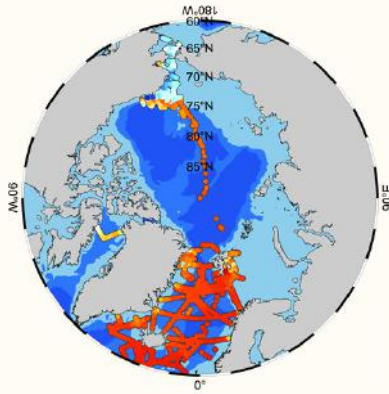
OUT

- Heat and salt
- Atlantic inflow
- Fresh water
- Pacific inflow
 - Rivers
 - Precipitation

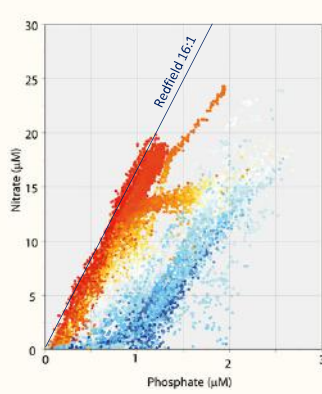


- Fresh water & ice
- Fram Strait
 - Davis Strait

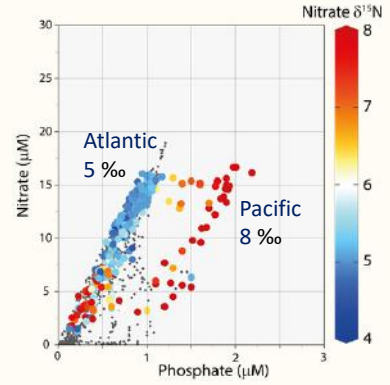
Pacific and Atlantic endmembers



Spatial variability in salinity (100-200m)

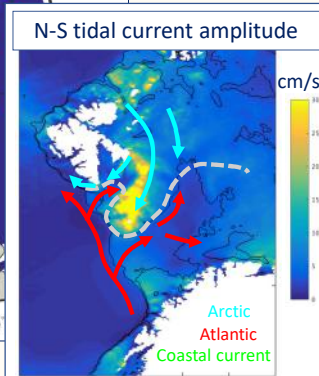
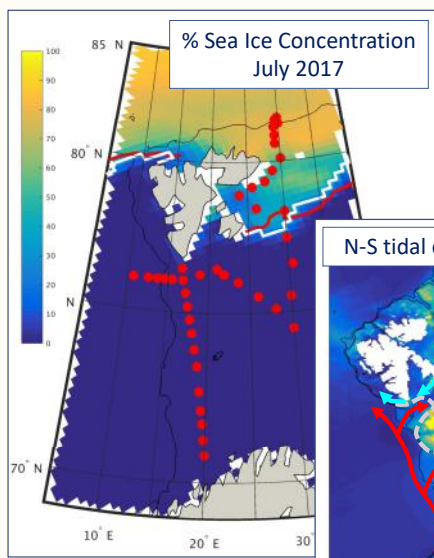


Data: Codispoti et al., 2013

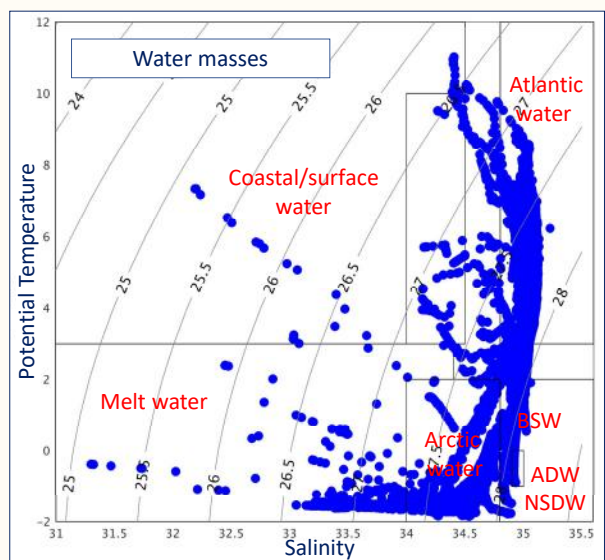


Data: ARISE project (this study), Casciotti et al., 2018, Fripiat et al., 2018

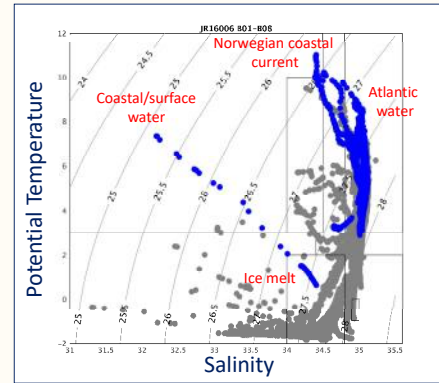
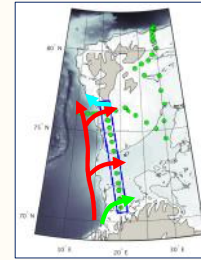
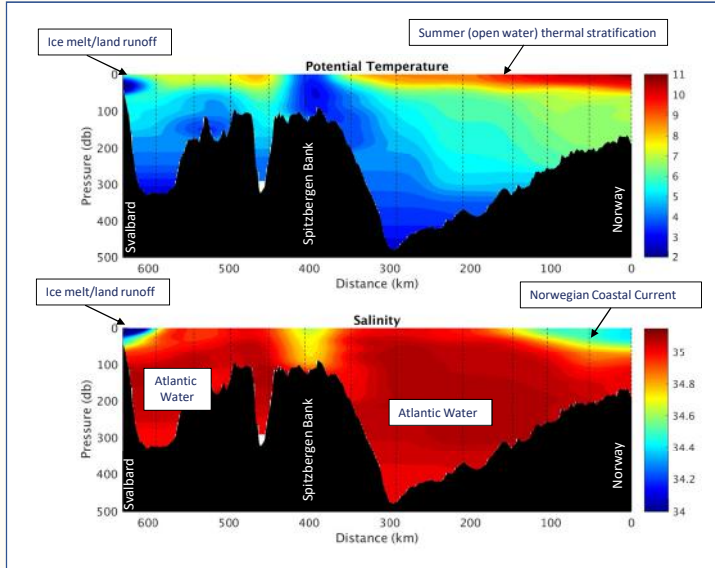
The Barents Sea in July 2017 (JR16006)



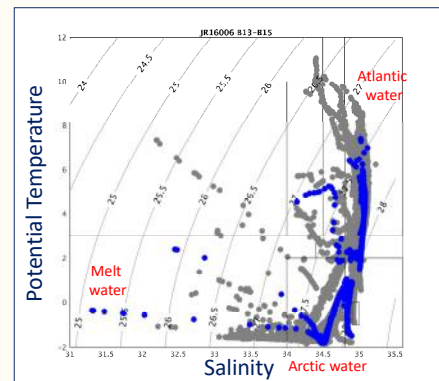
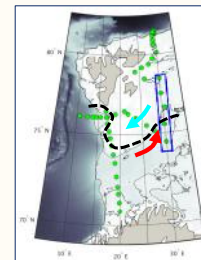
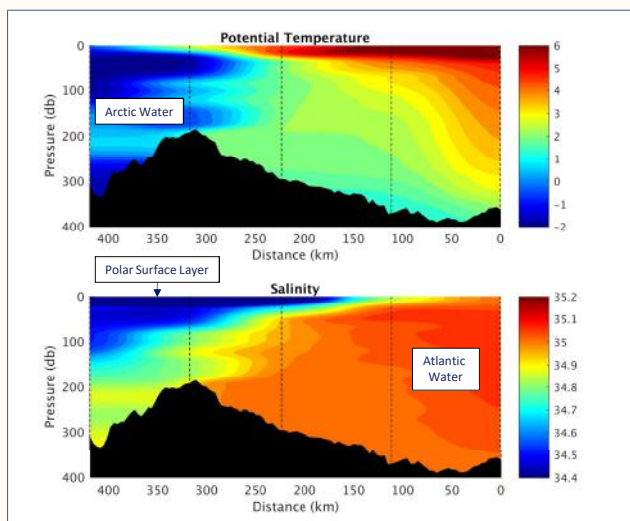
● JR16006 CTD stations



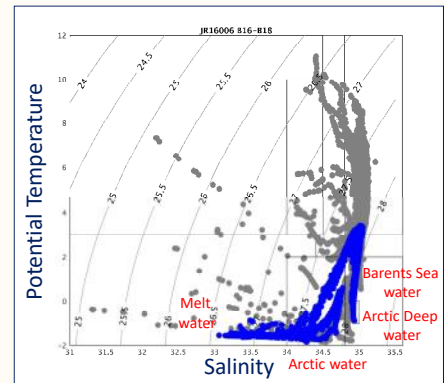
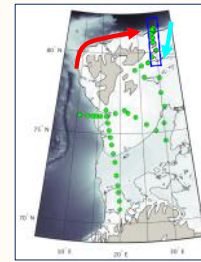
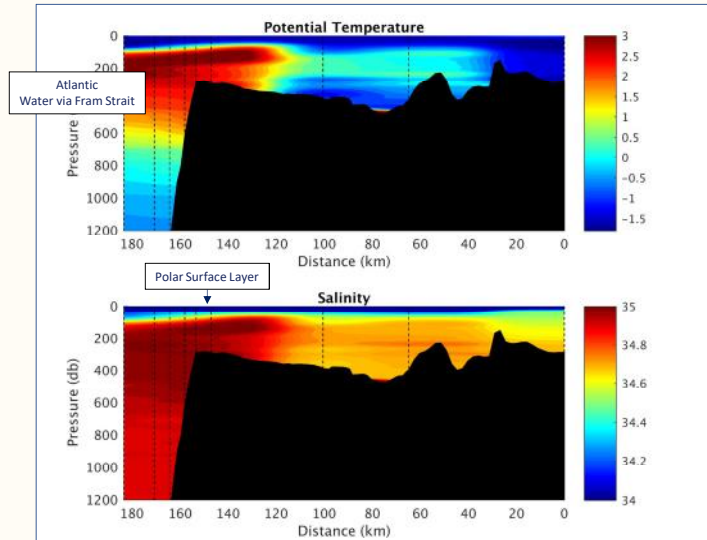
Barents Sea Opening – Atlantic source waters



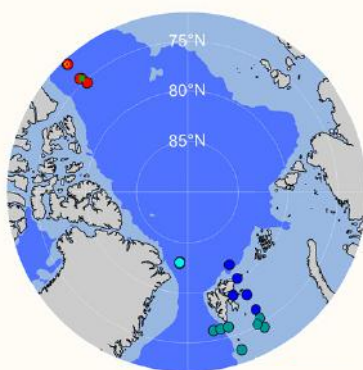
Polar Front (Atlantic → Arctic)



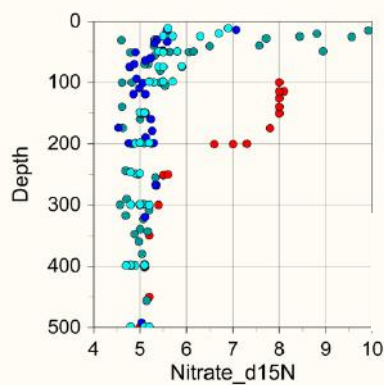
Northern Barents Sea shelf edge



Fram Strait and Barents Sea data

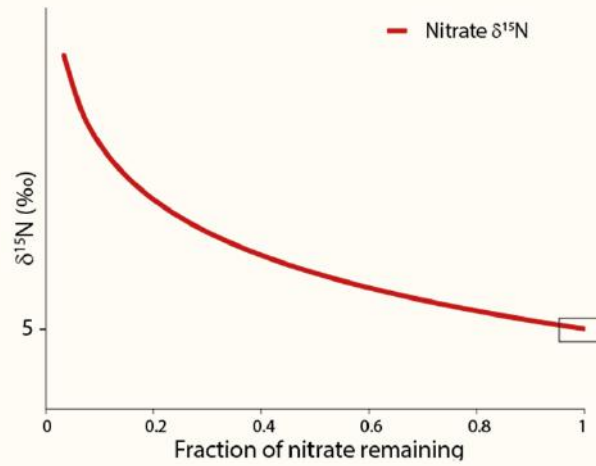


- Atlantic Water (this study)
- Arctic Water (this study)
- E. Arctic, Fripiat et al., 2018
- W. Arctic, Casciotti et al., 2018

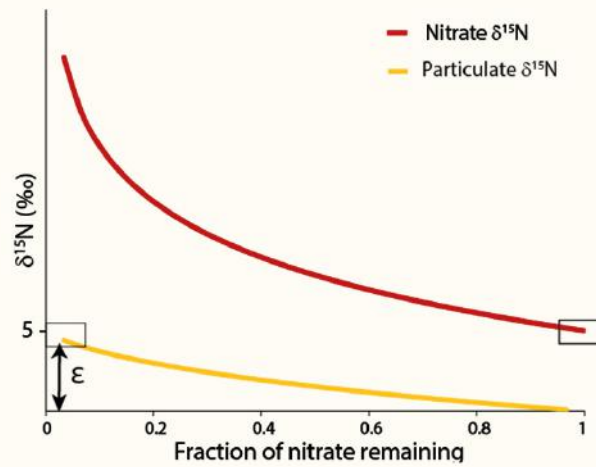


H1: No regeneration modification between 100m-500m
 H2: Regenerated $d^{15}N$ matches or is close to source $d^{15}N$

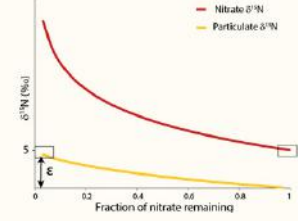
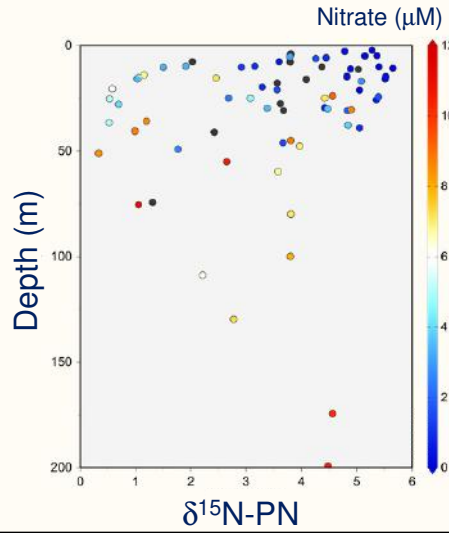
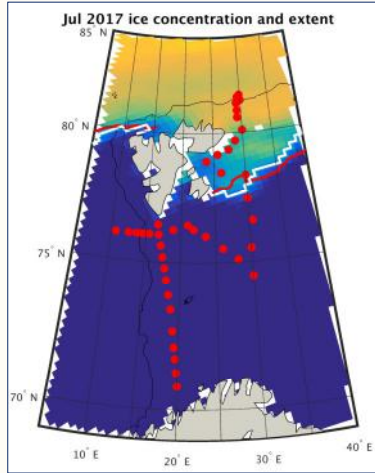
Nitrogen cycling in the Barents Sea



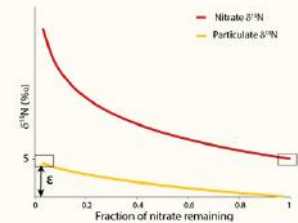
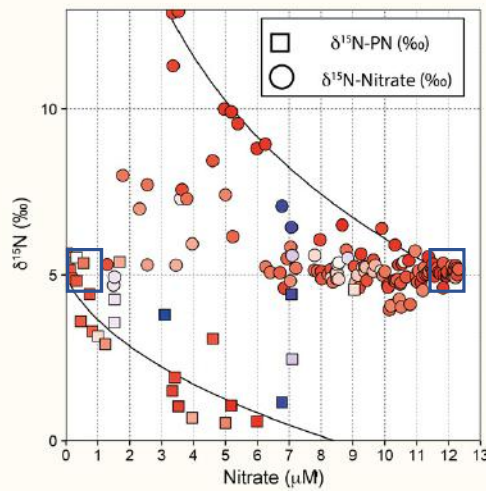
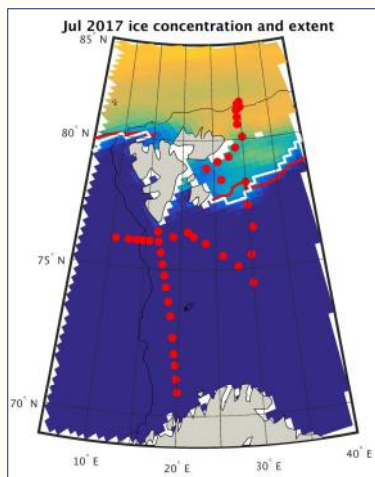
Nitrogen cycling in the Barents Sea



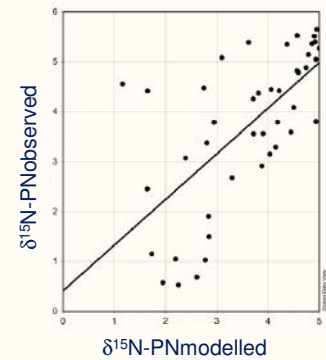
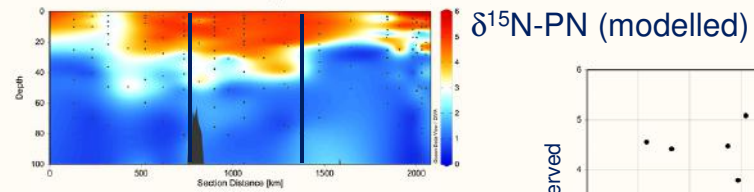
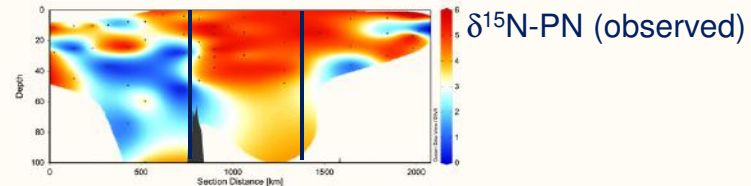
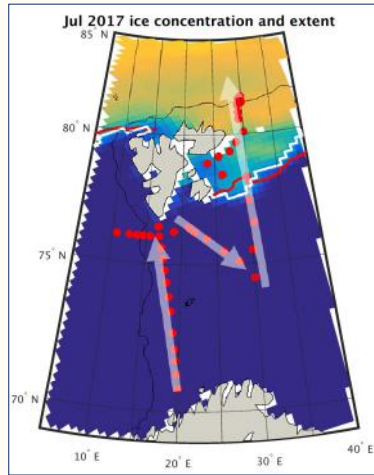
Nitrogen cycling in the Barents Sea – $\delta^{15}\text{N}$ -PN



Nitrogen cycling in the Barents Sea – $\delta^{15}\text{N}$ -PN



Nitrogen uptake in the Barents Sea – determining isoscape variability



Arctic wide $\delta^{15}\text{N-PN}$ – scaling up isoscape variability

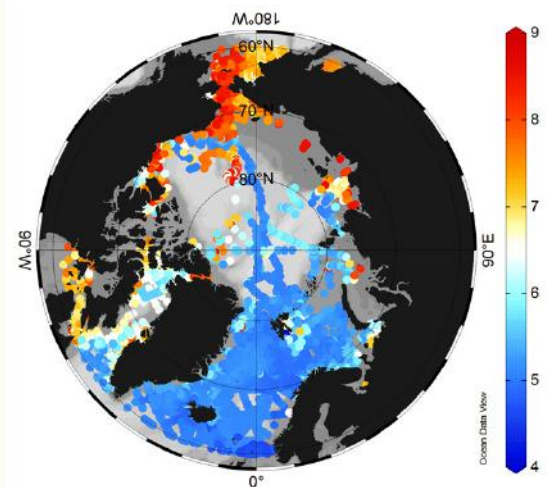
Assumptions:

- Nitrate fully consumed in euphotic zone over course of the season
- Atlantic and Pacific nutrients are the primary sources to the isoscape
- Limited N cycling processes affecting N isotope signatures internally within basin

Next Steps:

- $\delta^{15}\text{N-nitrate}$: rivers, east Siberian shelf, temporal variability
- $\delta^{15}\text{N-DON}$: spatial variability

$\delta^{15}\text{N-PN}$ modelled



What isoscape are the seals sampling?

Telemetry.....

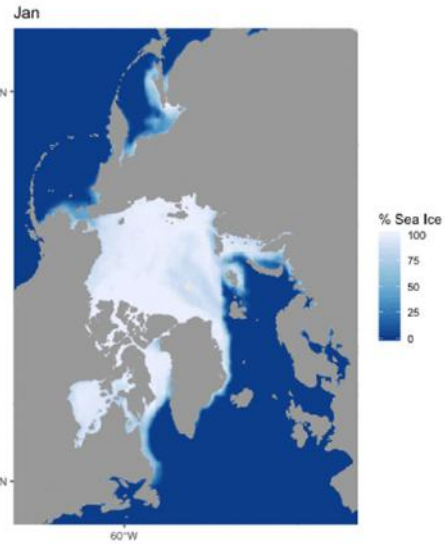
Harp seal migration

- Harp seals are the most abundant pinniped in the North Atlantic
- Generalist predator of krill, capelin and polar cod
- Exert large predation pressure on lower trophic levels
- Prey to higher predators such as polar bear



Harp seal migration

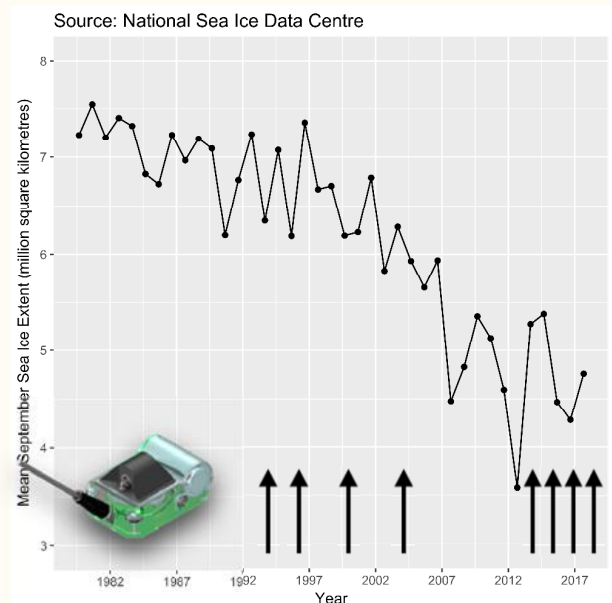
- Reliant on sea ice for breeding and foraging
- Long-distance migrant, following the seasonal sea ice retreat
- Understand links between harp seal migration, sea ice variability and food web structure; both seasonal and annual



Source: NSIDC. Data for 2017

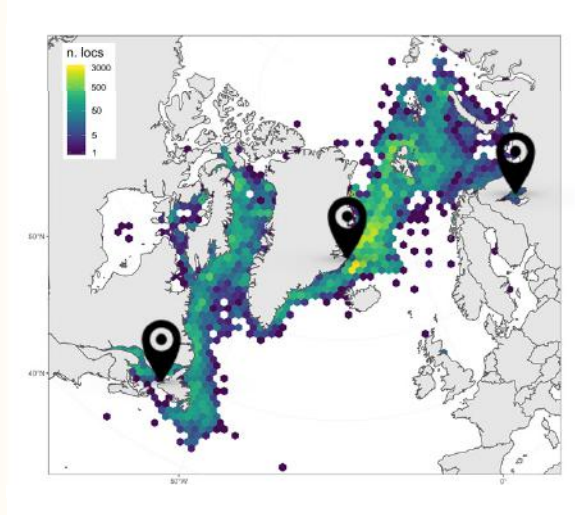
Harp seal migration

- Collate historical telemetry data on harp seal migration
- ARISE collaboration with colleagues from IMR Norway and DFO Canada
- 8 field campaigns since 1995
- More tagging in 2019
- Estimate the impacts of projected future changes to sea ice extent



Harp seal migration

- Comprehensive dataset of all harp seal SRDL deployments
- Tagged > 80 individuals across the three main populations
- > 60 k animal locations collected



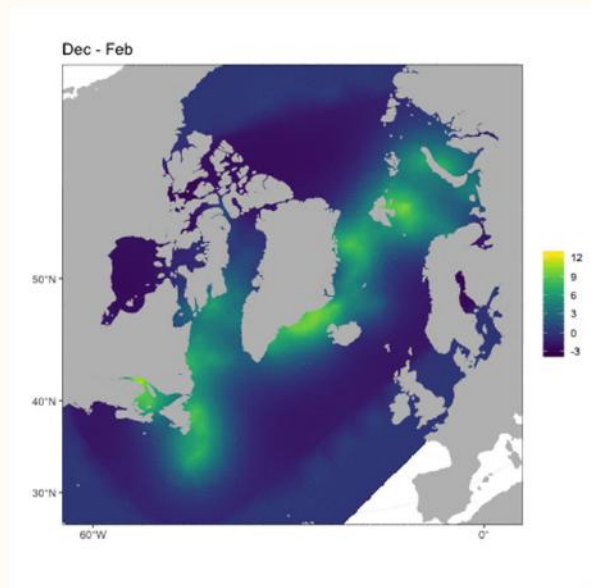
Harp seal migration

- Two complementary approaches we are developing to model telemetry data:
- Eulerian: understand properties of distribution at population level
- Lagrangian – understand properties of movement paths at individual level



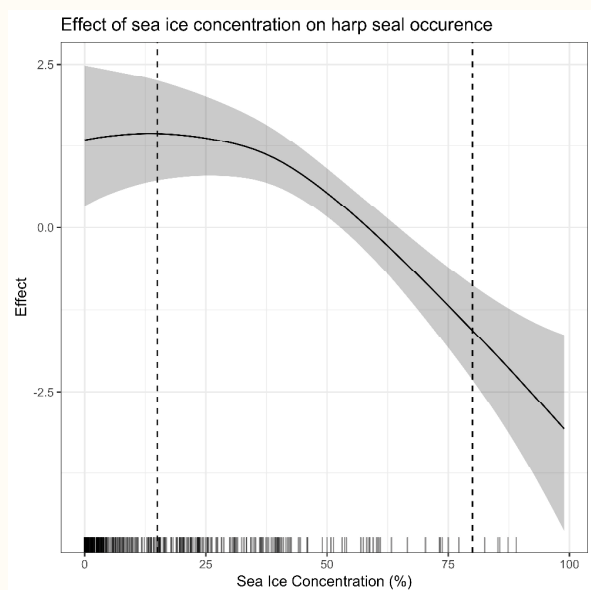
Drivers of distribution

- Harp seals make seasonal migrations following sea ice retreat
- Capture seasonal variation in distribution
- Model spatial and temporal structure using GMRF implemented in R-INLA



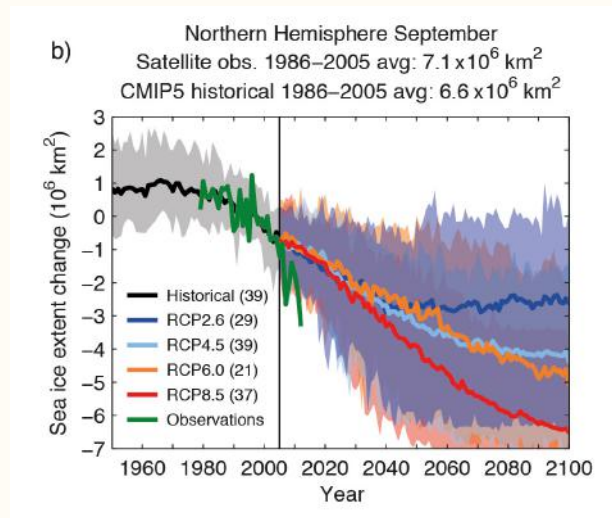
Drivers of distribution

- Incorporate environmental covariates to model habitat preference:
- Model indicates strong effect of sea ice concentration – suitable foraging habitat.



Drivers of distribution

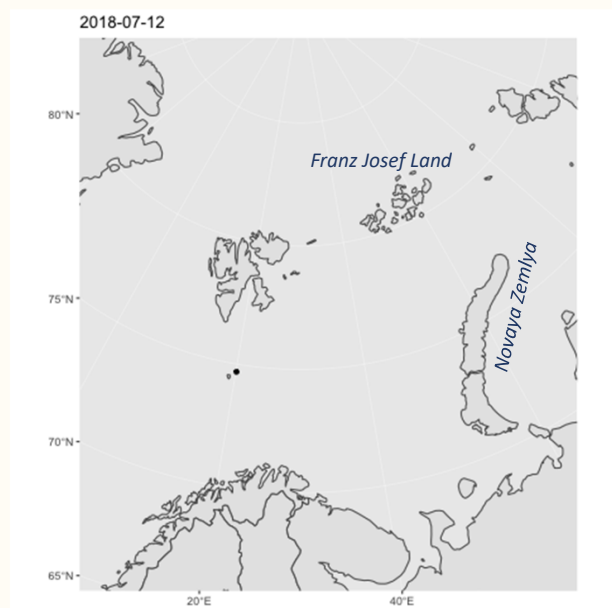
- Incorporate long-term trend in Arctic sea ice concentration
- Estimate response to future changes in Arctic sea ice
- How do these movement patterns reflect changes in the isoscape?



Source: IPCC

Drivers of movement

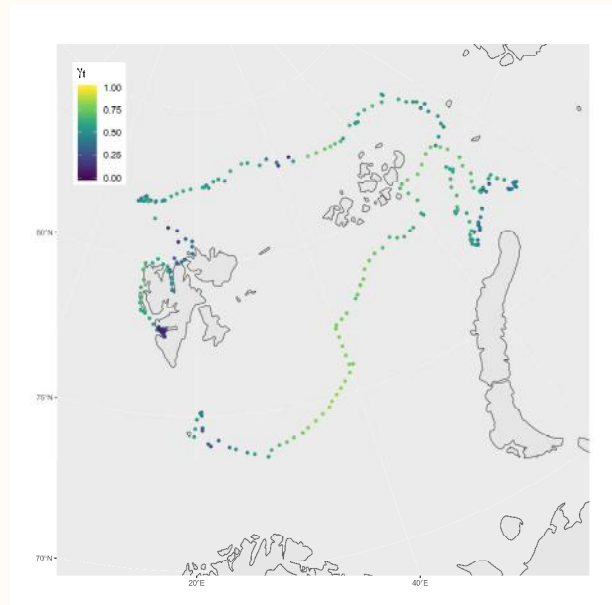
- How do individuals respond to the environment as they experience it?
- How is the environment linked to changes in behaviour?



Drivers of movement

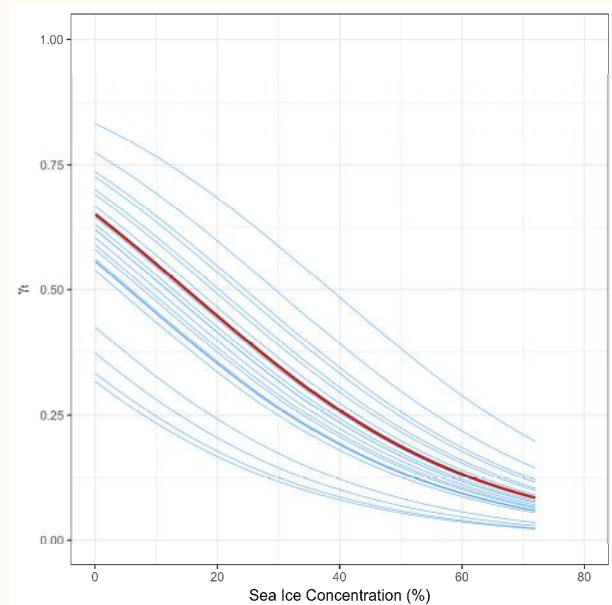
- Identify periods of persistent movement (correlation in velocity)
- Link these to environmental covariates

Jonsen *et al.* 2019 Ecology



Drivers of movement

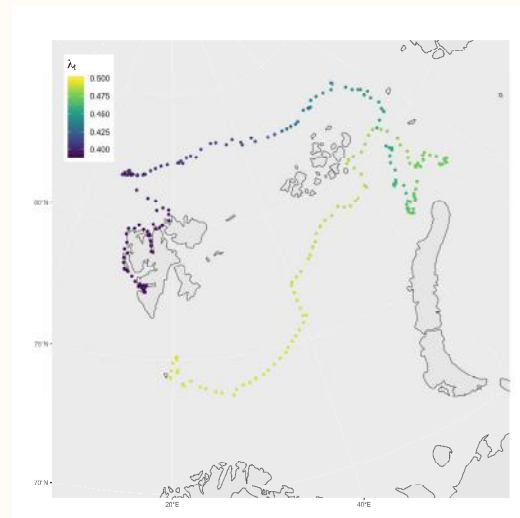
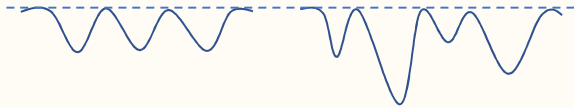
- Move persistence (γ_t) linked to sea ice concentration
- Lower speed and directionality in areas of increased sea ice concentration



Drivers of movement

Work in Progress...

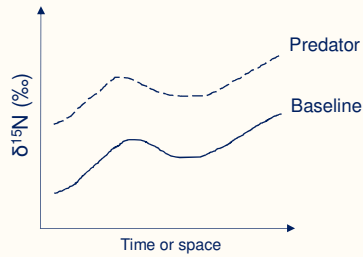
- Seals dive!
- Incorporate dive parameters in models of persistence
- Examine changes in average dive depth through time
- Ongoing work with Ian Jonsen (Macquarie, Australia)



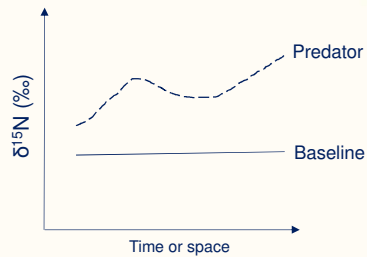
How is the food web changing in time and space?

Biomarkers in seals.....

Bulk nitrogen stable isotopes: the principle

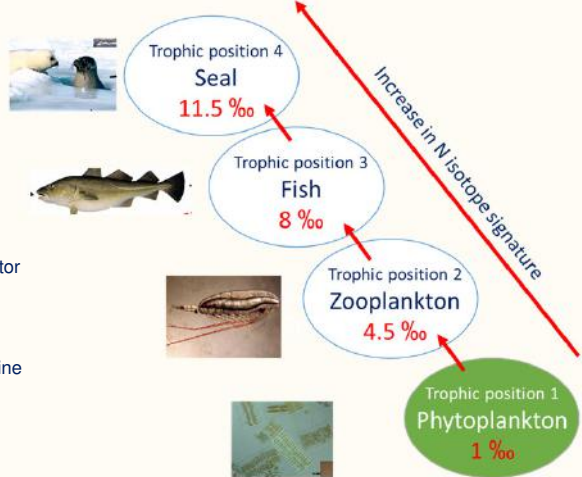


Change in the baseline



Change in the trophic structure

Simplified Arctic food chain



Amino acid stable isotopes: the principle

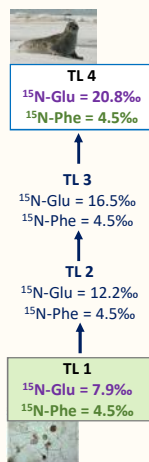


Glutamic Acid (Glu) = Trophic amino acid

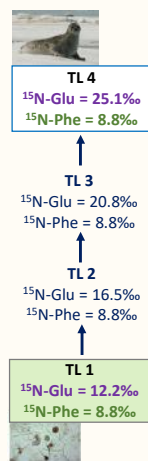
TFF = 4.3‰

Phenylalanine (Phe) = Source amino acid

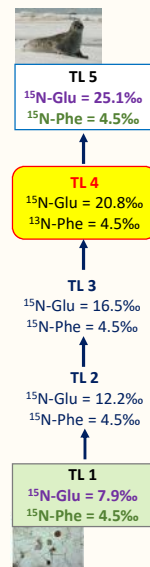
TFF = 0‰



Shift in the baseline



+ 1 trophic position



Harp seals

2016-2018



Garry Stenson

Fisheries and Oceans Canada,
St John's Newfoundland



Tore Haug and Martin Biuw

Institute of Marine Research
Tromsø, Norway



Erling Nordøy

Arctic University of Norway



UiT / THE ARCTIC UNIVERSITY
OF NORWAY



Harp seals : Spatial trends

liver

2016-2018



15 and 15 for AA-SI

17
16
15
12
11
10

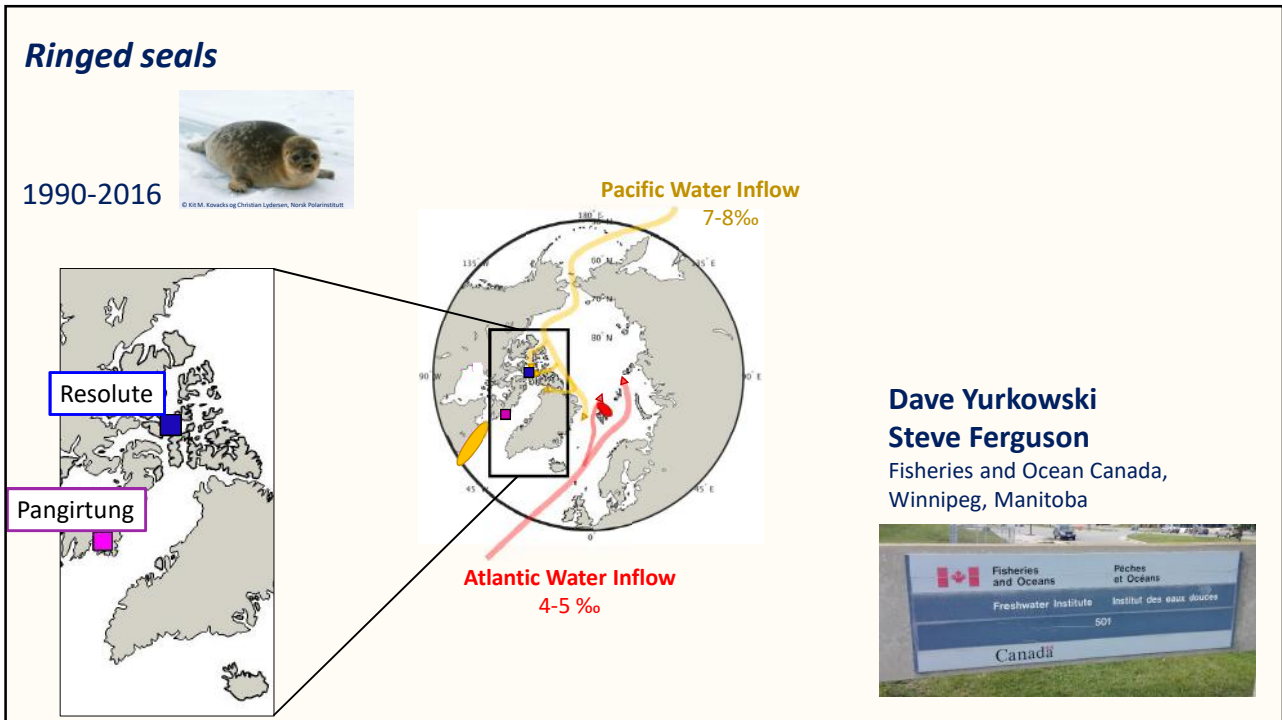
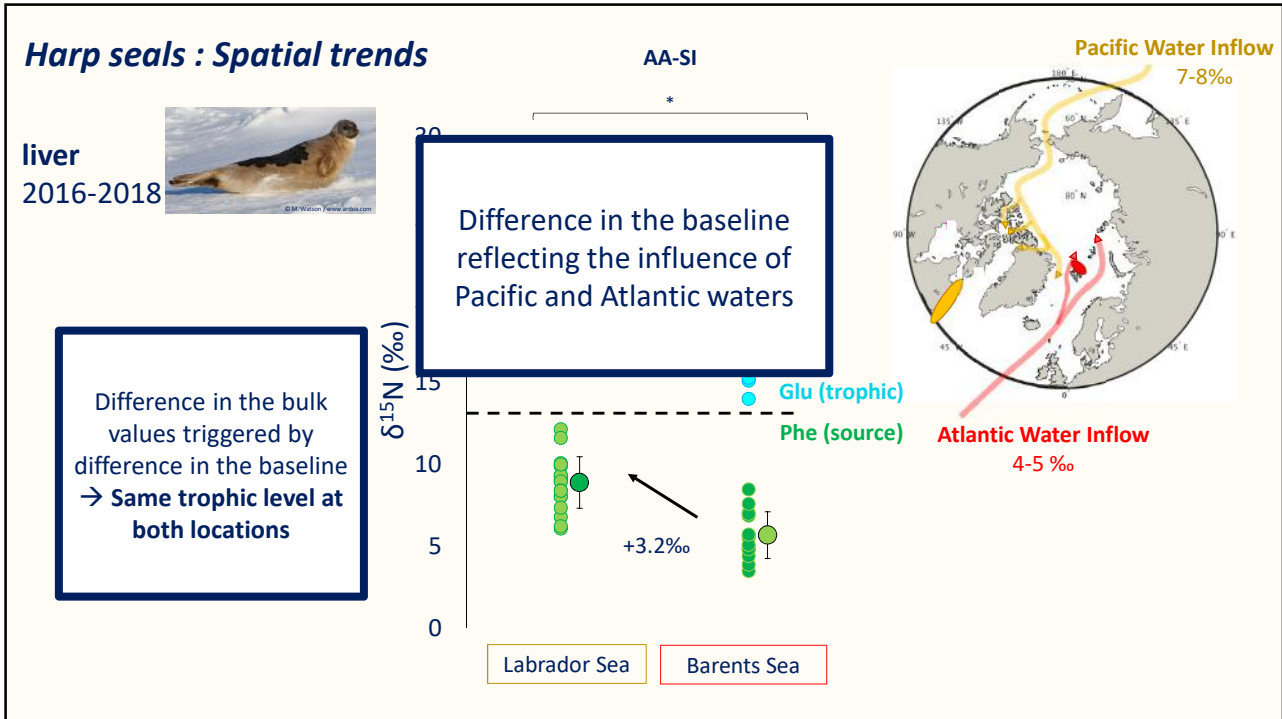
BULK

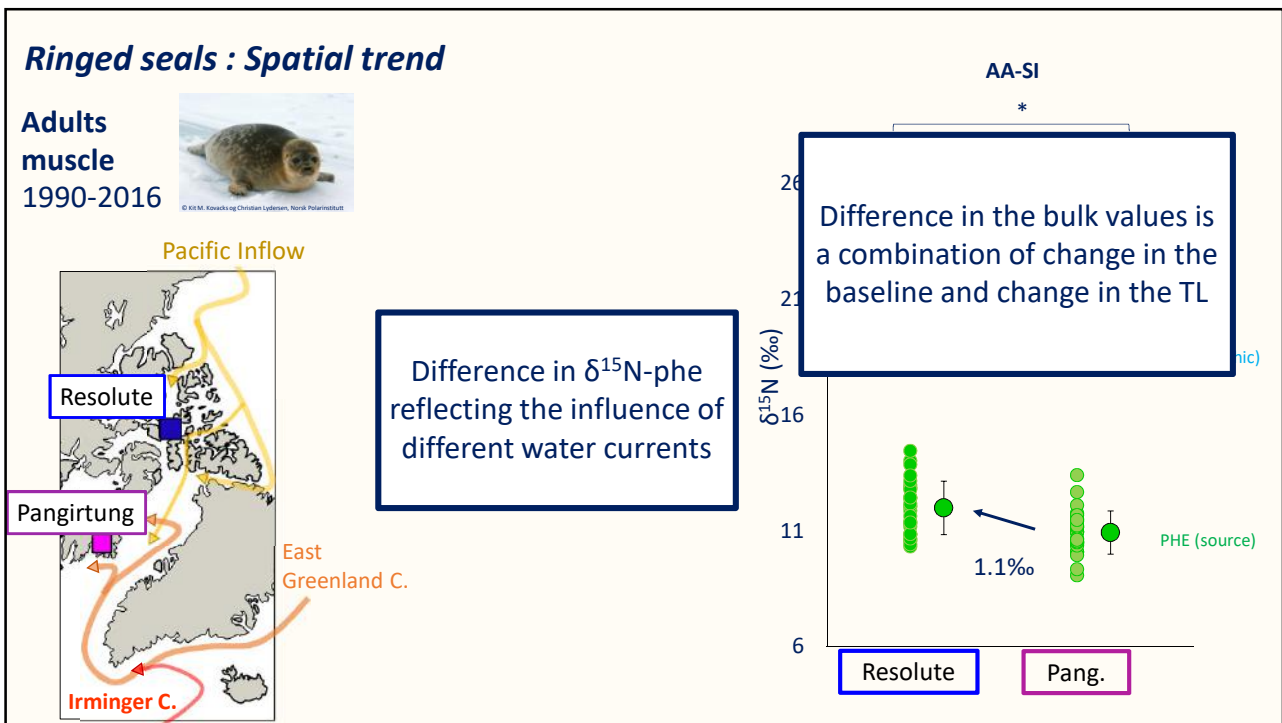
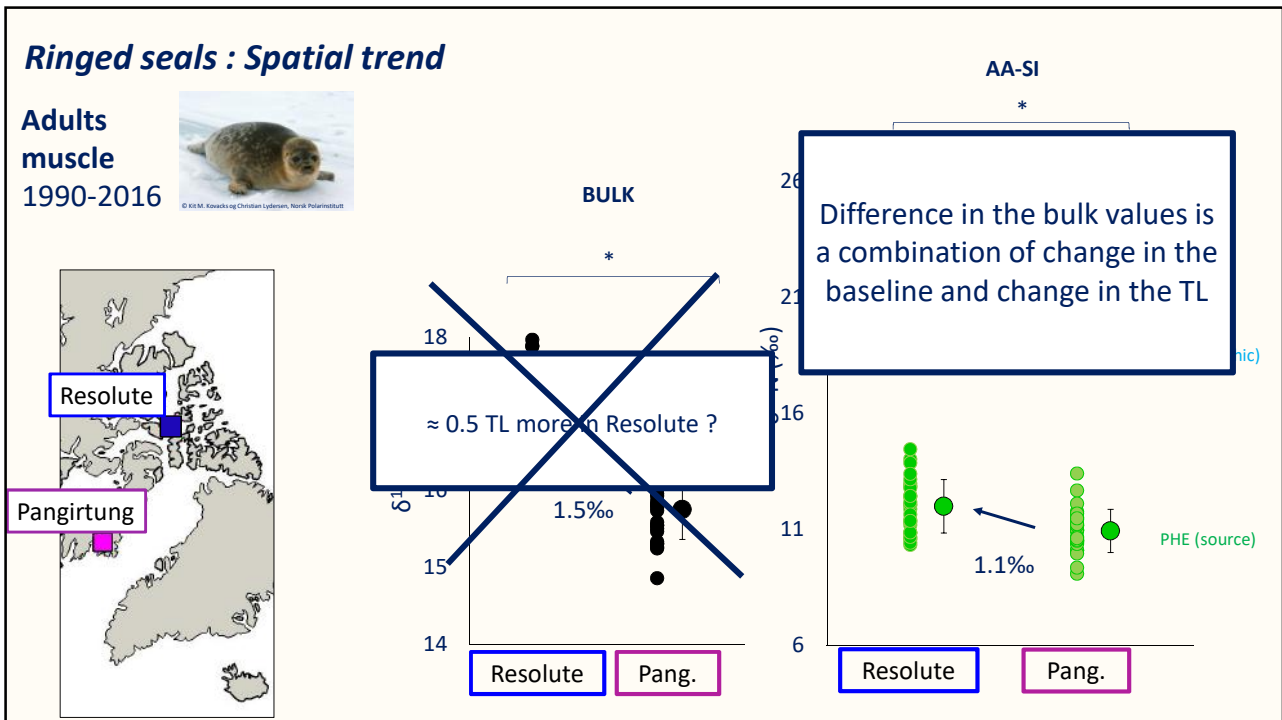
≈ 1 more TL in Labrador Sea ?

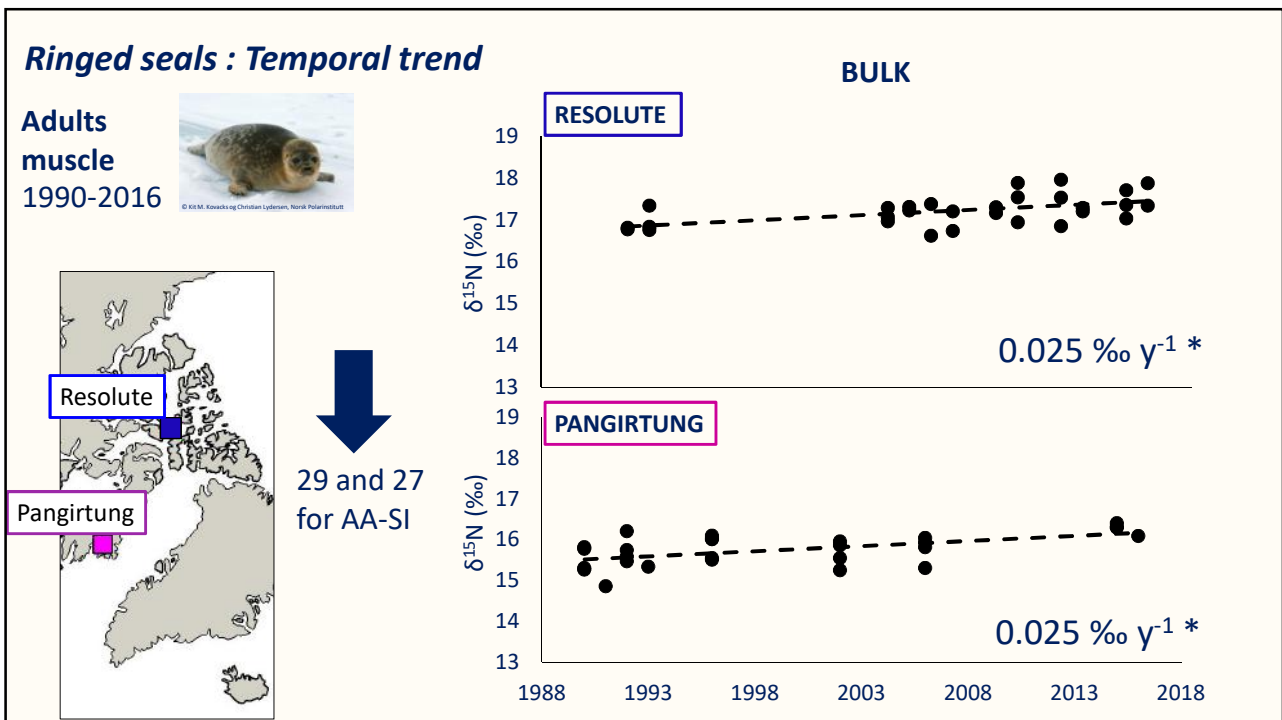
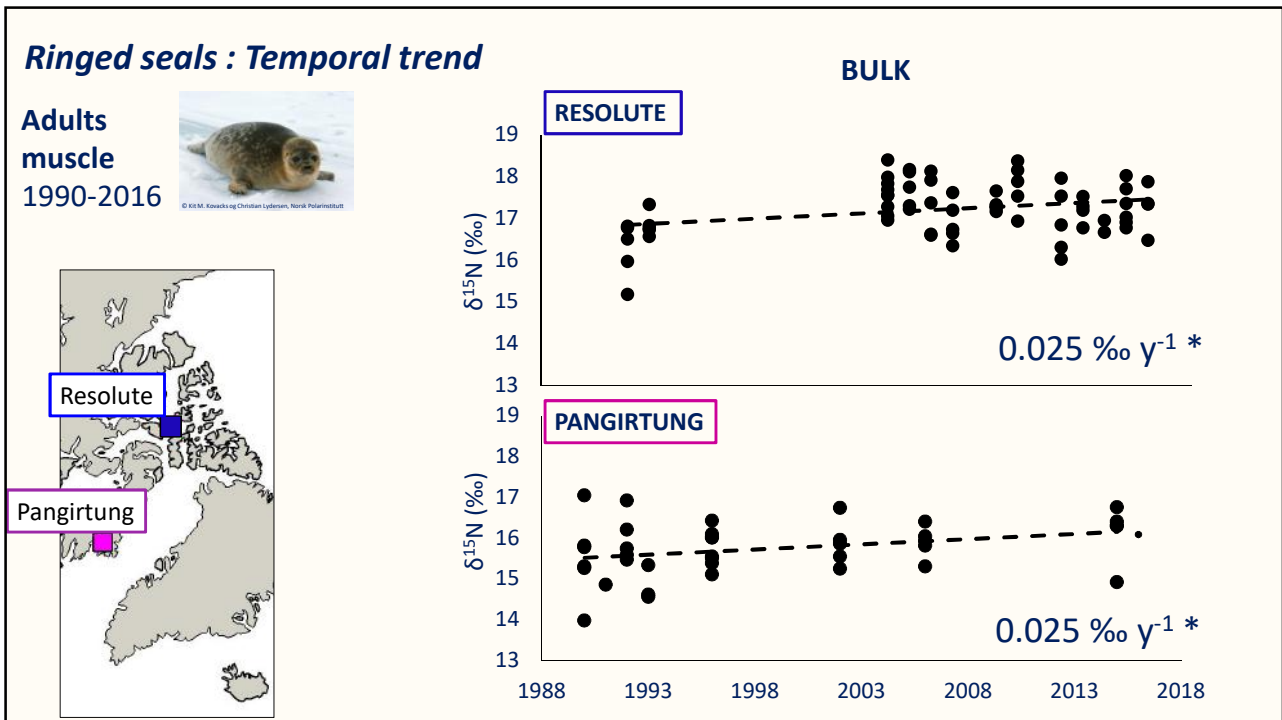
Labrador Sea

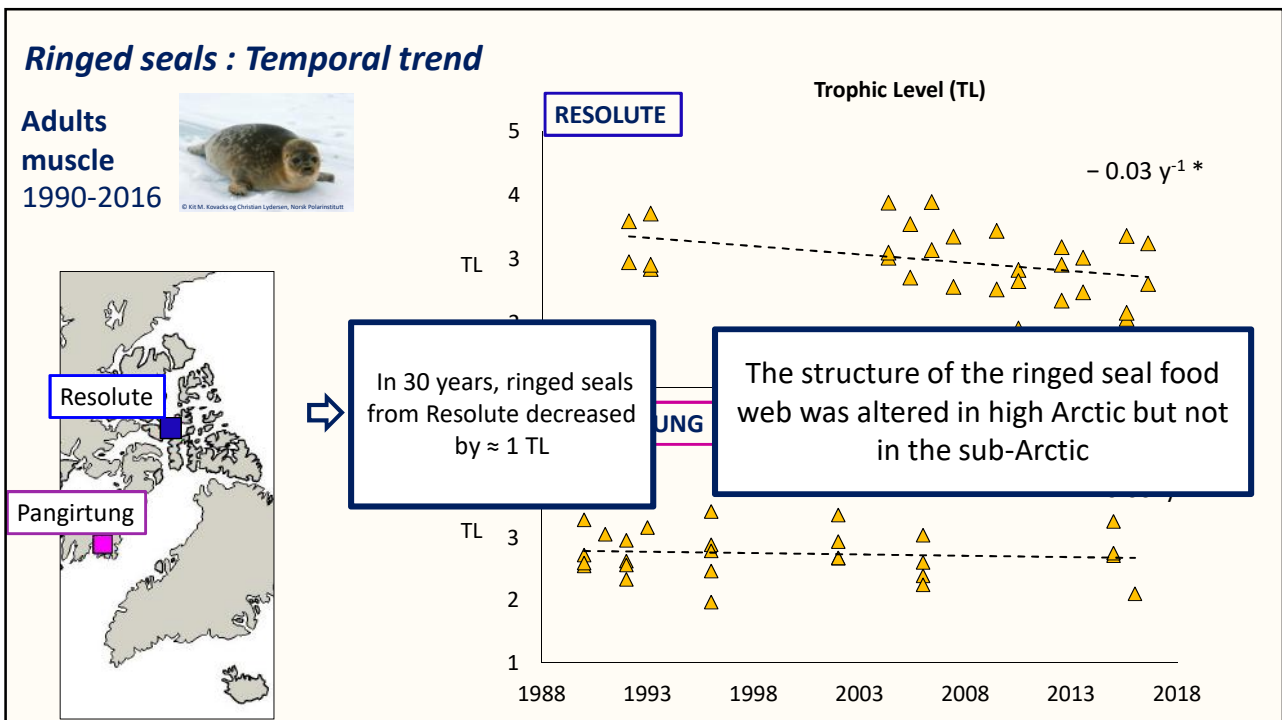
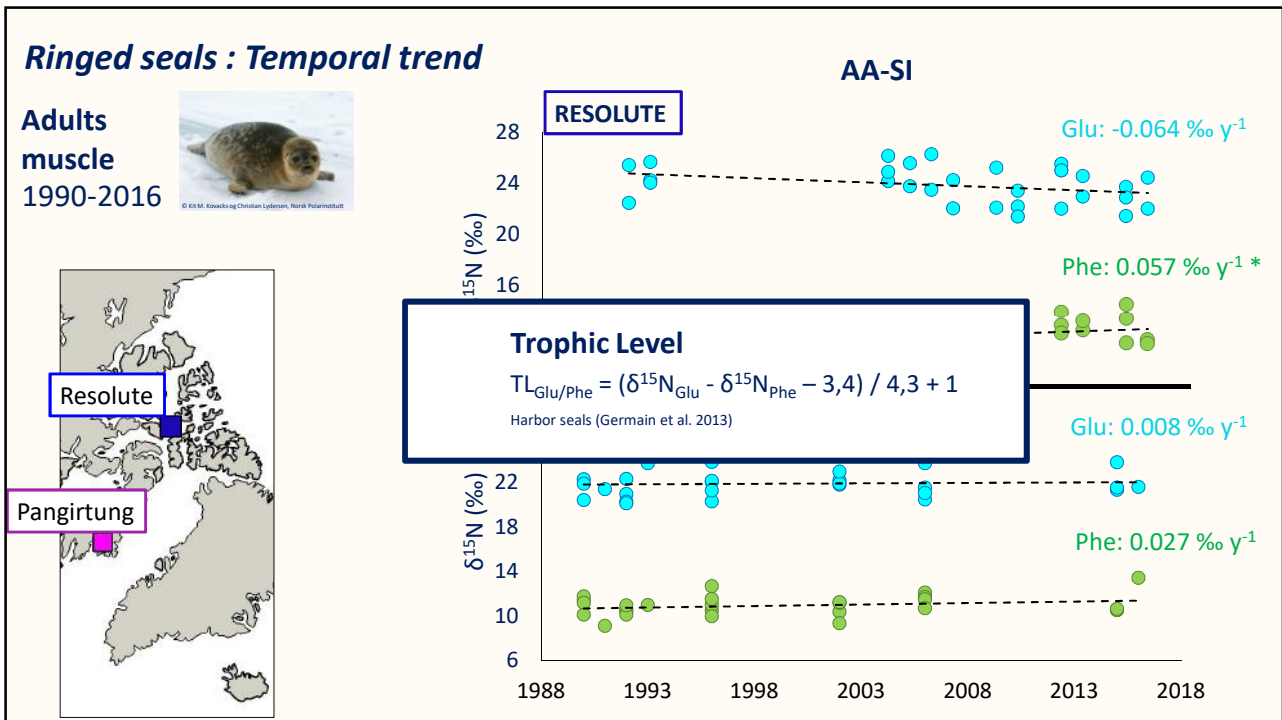
Barents Sea











Conclusions



- AA-SI methods allowed us to avoid misinterpretations from bulk SI results



- The spatial heterogeneity of $\delta^{15}\text{N}$ at the baseline (nutrient + POM) is reflected in predators ($\delta^{15}\text{N}$ -Phe)



- The food web in the Canadian archipelago (high Arctic) was altered in the last 30 years. This alteration was not detected in lower latitudes (Labrador Sea)

How will a change in the environment and/or food web structure affect harp seal populations and vital rates?

So what.....

Drivers of populations

- To understand populations dynamics we need information on:
 - Population size
 - Fecundity
 - Survival
- This is really hard to collect!
- Existing monitoring program



Image © Michael Poltermann / NAMMCO

Drivers of populations

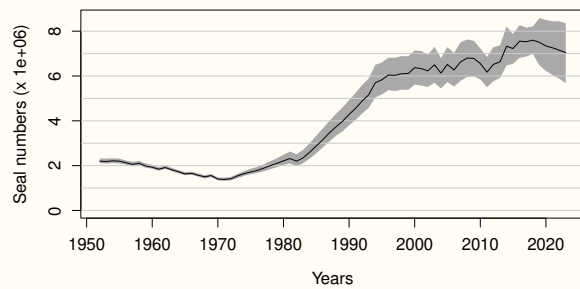
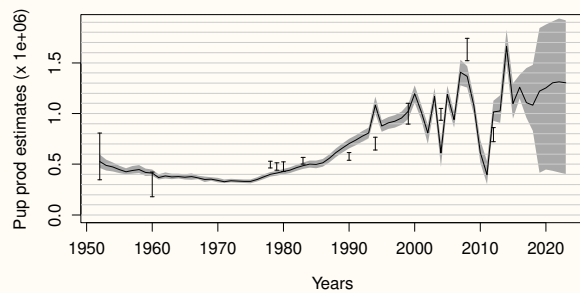
- Population size estimated from aerial surveys of pupping grounds
- Pregnancy rates based on sampling females prior to pupping
- Pup production estimated from mark-recapture
- Mortality from hunt known, but natural mortality unknown



Image © Michael Poltermann / NAMMCO

Drivers of populations

- This data is used for harp seal management in Canada and Norway
- ARISE will build on existing integrated population model from Hammill *et al.* 2015.



Hammill *et al.* 2015 Biol. Cons.

Drivers of populations

- Female fecundity correlates with food quality
- Infer how diet quality has changed over time from stable isotope data
- Pup survival correlates with ice cover
- Infer how pup survival may change in future IPCC scenarios



ARISE in 2019

- Isoscape will be explored using (PISCES-ISO), Dr. Pearse Buchanan will start in March 2019
- We have remote sensing data sets on chlorophyll, ice and production from 1998 to 2017, will be deployed across ARISE to compare with data sets
- Stable isotopes of teeth: February 2019 with Dr. Joanne Kershaw at UoSt
- Fieldwork: 4 cruises on the N/S Norbjorn in the Barents Sea, plus other potential opportunities in East Siberian Sea.
- Seal tagging activities in Canada: led by Dr. James Grecian with support from the UK Arctic Office
- Meetings with project partners for interpretation and synthesis



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Other ARISE activities

Outreach activities

- Posters on key components of the GCSE Science Curriculum
- On going development of a puppet show with Mimika
- Registered for 'Pint of Science' in 2019

Other activities

- James Grecian working with BBC Frozen Planet and submitted proposal to Ocean X to support tagging fieldwork

ARISE associated PhD students

- New ARISE associated PhD students at Edinburgh Antonia Doncila and Margot Debyser and Liverpool: Ed Doherty (with DFO) plus new hire.



ARISE and IMPACT



IMPACT: essential within ARISE and CAO so that our research makes an impact beyond academia, e.g. in management and conservation of ecosystems and policy

- **Alessandro Tagliabue** Lead Author on the IPCC Special Report on the Oceans and Cryosphere in a Changing Climate
- **Sophie Smout** is a member of the ICES working group on harps and hood
- Outputs from seal population modelling will directly feed into harp seal management (from Module 4: So what....), led by **James Grecian** and **Sophie Smout**

The End

