Quantifying sea ice carbon uptake within polar ecosystems

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1) Introduction

Quantifying the importance of sea ice microalgae as an organic carbon source in Arctic ecosystems is becoming an increasingly important research objective as sea ice extent and thickness continue to reduce.

In order to quantify organic carbon derived from sea ice microalgae, it must first be possible to distinguish it from organic carbon derived from other sources (e.g. phytoplankton or terrestrial). This is achieved using highly branched isoprenoid (HBI) lipids derived from diatoms (Fig. 1).

- ✓ HBIs have been reported from all over the globe
- ✓ HBIs produced by >28 species of marine, brackish, freshwater, benthic and pelagic diatoms
- ✓ HBI synthesis is species selective: not all species produce the same HBIs

- ✓ Sea ice diatoms produce a unique HBI: IP_{25} = "Ice Proxy with 25 carbons"
- ✓ IP_{25} has been reported in >300 areas across the Arctic Ocean
- ✓ IP_{25} and HBIs II-VII have been found in a wide range of animals spanning copepods to polar bears.

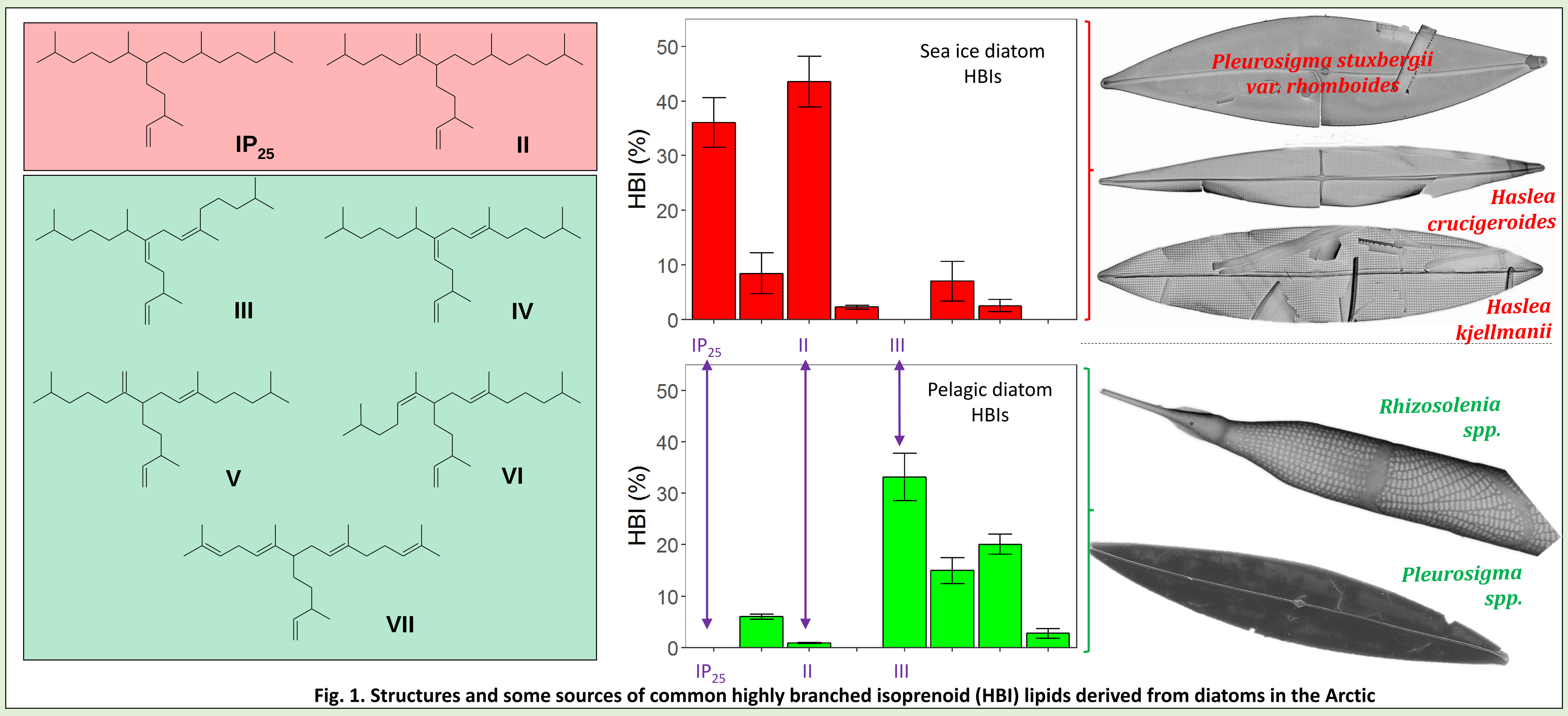


Fig. 1. Structures and some sources of common highly branched isoprenoid (HBI) lipids derived from diatoms in the Arctic

2) HBI-based marine carbon source index

The underlying source of organic carbon within Arctic consumers can be determined qualitatively by analysis of HBIs in animal tissue (usually liver).

- ✓ Works best for clearly defined end-member signatures
- ✗ Many animals have mixed organic carbon contributions to diet

Solution:
Where a consumers diet consists of both sea ice-derived as well as phytoplanktic-derived organic carbon, an index approach provides greater insight to mixed-diet composition (Eq. 1).

$$\frac{\text{(pelagic HBIs)}}{\text{(sympagic HBIs + pelagic HBIs)}} \quad \text{Eq. 1}$$

This HBI-based fingerprint, or the so-called **"H-Print"** provides context when comparing different consumers (Fig. 2).

$$H-Print\ (\%) = \frac{(III)}{(IP_{25} + II + III)} \times 100 \quad \text{Eq. 2}$$

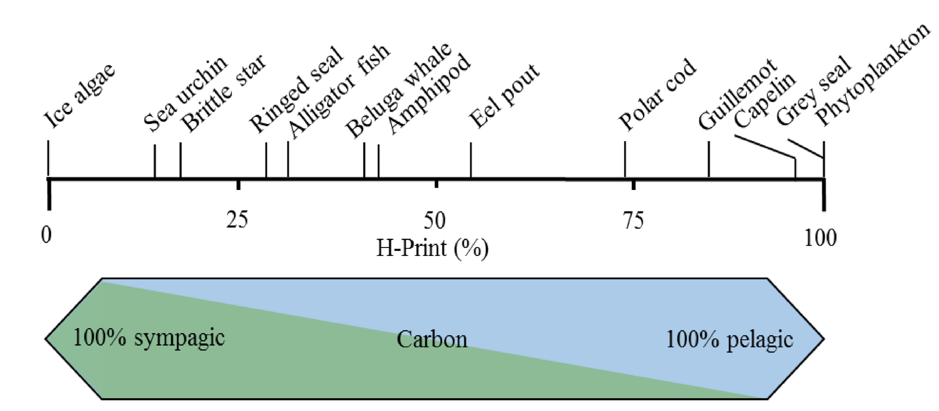


Fig. 2. H-Print values for a range of Arctic animals (Brown et al. 2017 L&O In press)

3) Calibration

To accurately estimate sea ice organic carbon for intermediate H-Print values, a calibration is needed to determine the best fitting model.

Q1) Does the proportion of HBIs remain the same following grazing?

✓ The proportion of HBIs was not significantly different from the food following grazing, or excretion

Q2) Is it possible to estimate the proportion of sea ice/phytoplanktic diatoms consumed by individuals?

✓ Calculated H-Prints (Eq. 2) were a close reflection of known diet. E.g. for 50:50 sea ice:phytoplankton diet, the H-Print was 50% (Fig. 3).

Q3) What model provides the best fit for H-Print values vs. known compositions of algae?

✓ A linear model provided the best fit (R^2 = 0.97, df = 23, P = < 0.01)

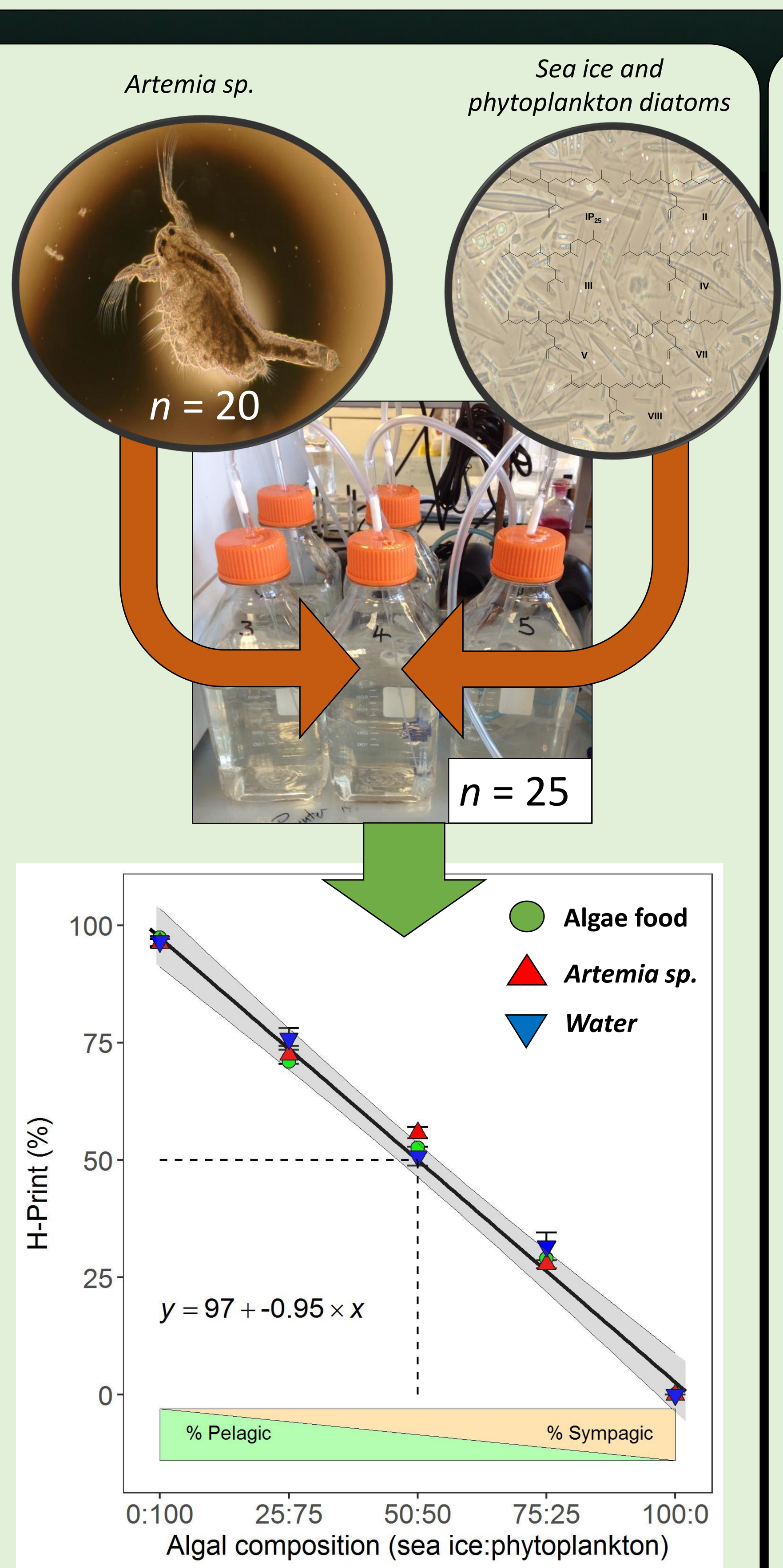


Fig. 3. Experimental design and results from feeding HBI containing diatoms to *Artemia* sp. (Brown and Belt 2017 JEMBE)

4) Quantification of sea ice organic carbon

Using the regression formula from calibration (Fig. 3) H-Prints can be converted to quantify sea ice derived organic carbon as a proportion of the marine (sea ice / phytoplanktic) derived component of an animals diet.

Scott Inlet, Canada: a case study

There is interest in expanding coastal community fisheries in Baffin Bay. However, the sustainability of such activities requires a better understanding of how fisheries might be impacted by reducing sea ice cover as climate is changing.

Q1) Sea ice microalgae provide organic carbon to the ecosystem in spring, but is this still accessible later in the year and, if so, do fish use it?

✓ Yes, sea ice derived organic carbon still comprises up to 75% of the diet of some fish in September (Fig. 4)

Q2) Do all fish living on the seafloor share similar sources of organic carbon?

✓ No, Some fish species (e.g. sculpin) obtain more sea ice origin organic carbon that has been stored in the sediment while others (e.g. snail fish) get more energy from sinking phytoplankton at this time (Fig. 4)

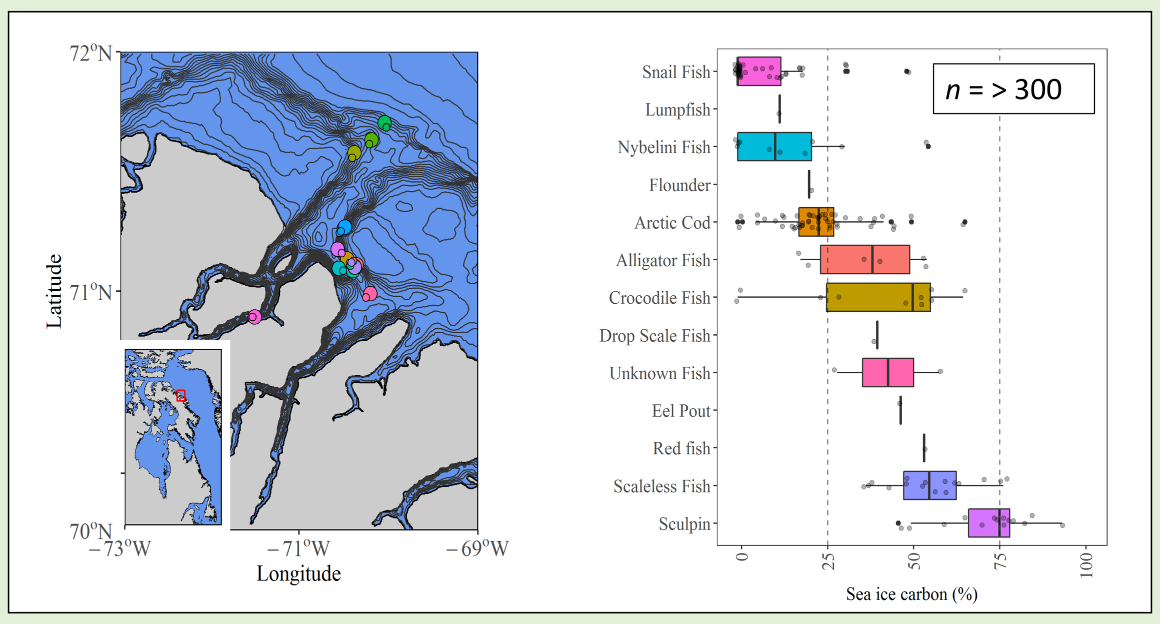
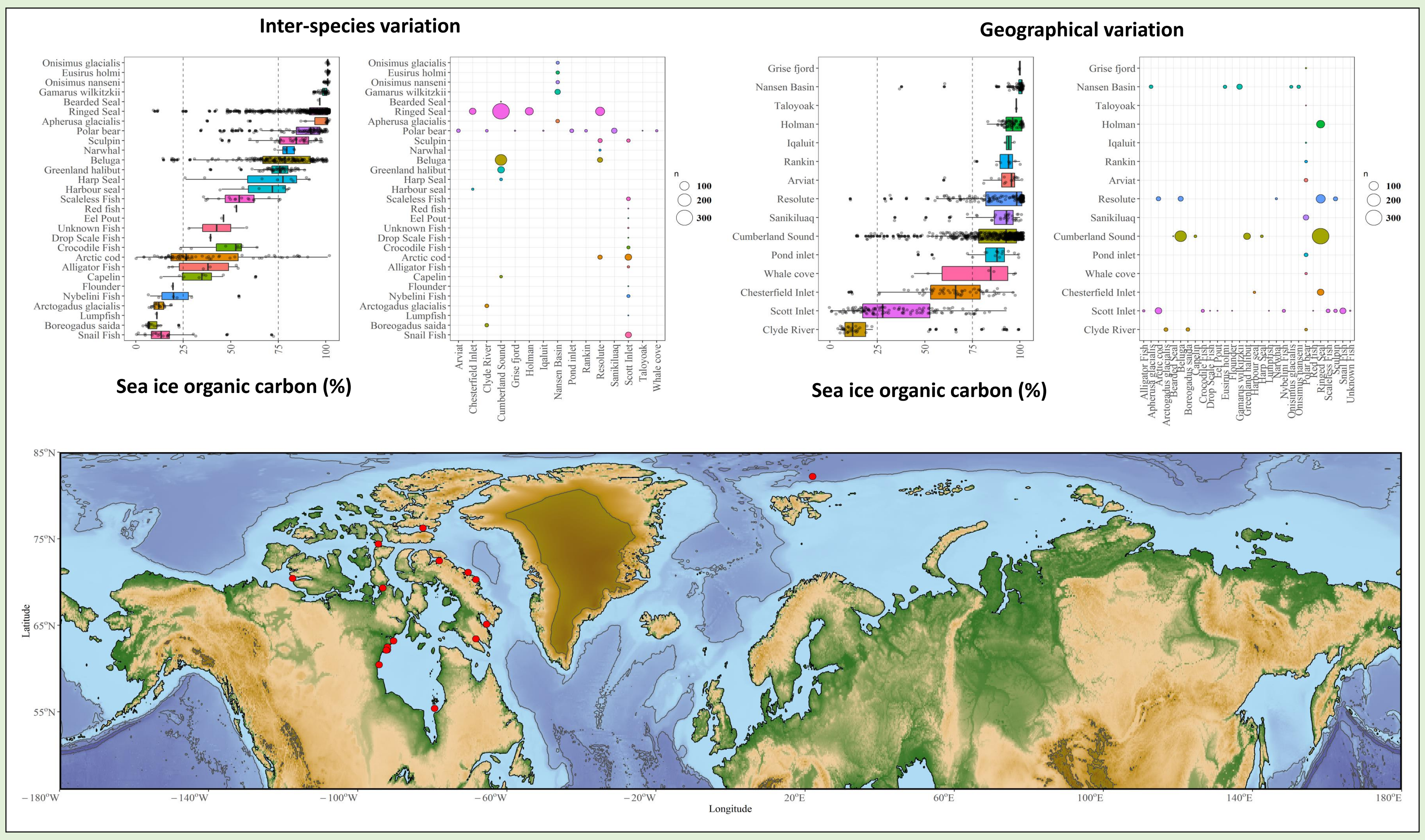


Fig. 4. Locations of benthic trawls (left) and some preliminary data on the proportion of sea ice carbon in benthic fish (right) for September in Scott Inlet

5) Application

Fig. 5. Sea ice organic carbon (%) data for >1000 Arctic animals. Considerable variability exists, both geographically and between species, in the proportion of sea ice organic carbon used. For a list of publications relating to this data please visit www.IP25.co.uk



6) Research direction – what's next?

- Accurately assess metabolic turnover of HBIs following consumption in a range of animals
- Determine which animals derive the most energy from sea ice organic carbon to enable better management in a period of rapid climate change

7) Further reading

- Brown, T. A. and S. T. Belt (2017). "Biomarker-based H-Print quantifies the composition of mixed sympagic and pelagic algae consumed by *Artemia* sp." Journal of Experimental Marine Biology and Ecology 488: 32-37.
- Brown, T. A., S. T. Belt, A. Tatarek and C. J. Mundy (2014). "Source identification of the Arctic sea ice proxy IP_{25}." Nature Communications 5(4197).

A list of all publications relating to the analysis of HBIs is on www.IP25.co.uk

8) Acknowledgments

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