ENVIRONMENTAL CONDITIONS CONTROL SEA ICE ALGAL LIPIDS AND TROPHIC MARKERS

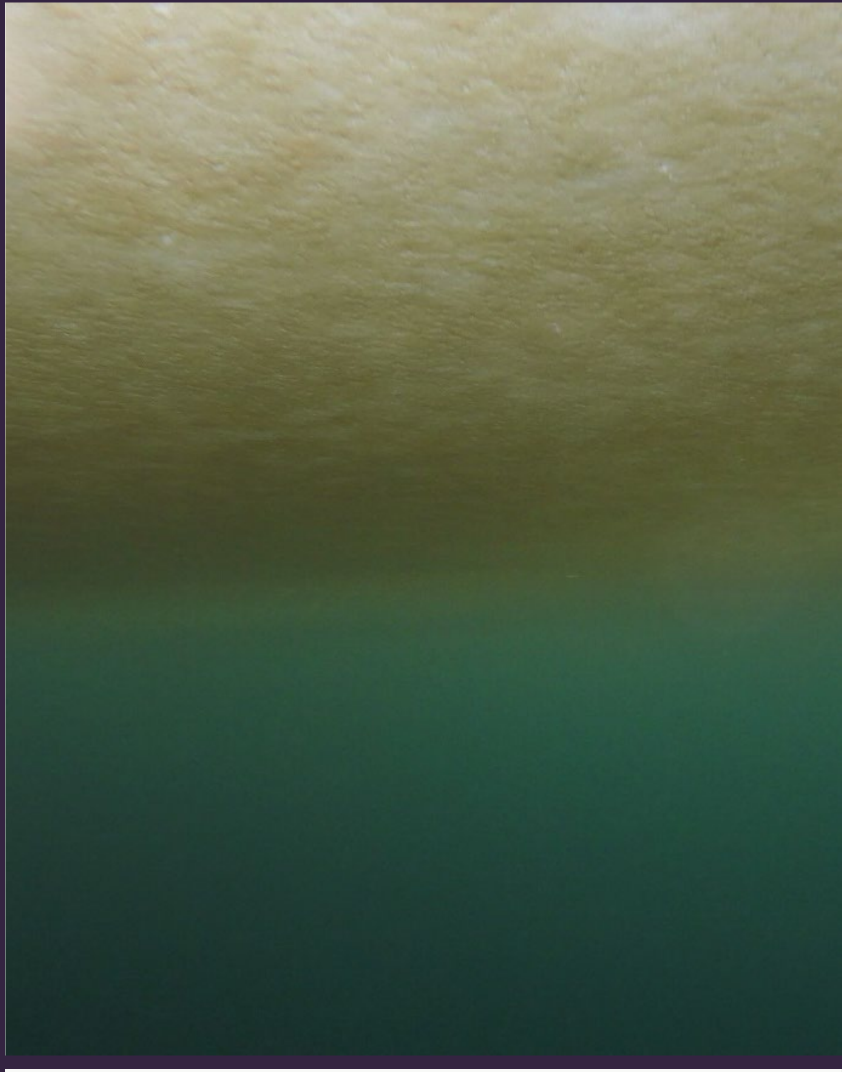
Eva Leu, Martin Graeve, Thomas Brown, C.J. Mundy, Karley Campbell

https://www.changing-arctic-ocean.ac.uk/project/diatom-arctic/

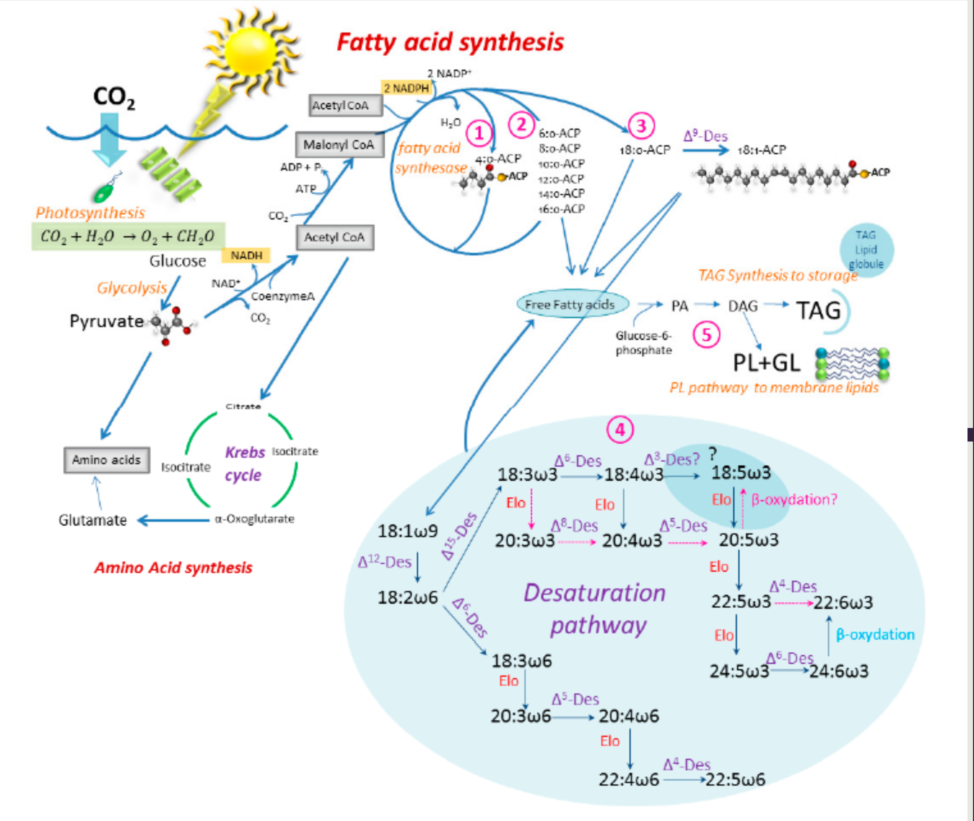
With funding from The Research Council of Norway

Context

- Estimating the relative importance of sea ice algae vs. phytoplankton as primary producers in Arctic marine food webs is important
- Rapidly changing environmental conditions affect these two algae groups differently; implications for ecosystem structure and carbon flux
- Ecosystem and food web analysis can be challenging – trophic markers based on lipids or stable isotope signals are widely used tools



Trophic markers I: Fatty acids



Jonasdottir, 2019

Algae groups differ in the set of fatty acids that they produce (+/- specific desaturases)

Coarse taxonomic resolution: diatoms vs. dinoflagellates

Relative abundances depending on physiology

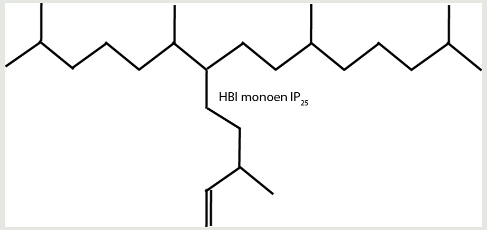
$$\delta^{13}C = \left(\frac{\left(\frac{^{13}C}{^{12}C}\right)_{\text{sample}}}{\left(\frac{^{13}C}{^{12}C}\right)_{\text{standard}}} - 1 \right) \times 1000\ ‰$$

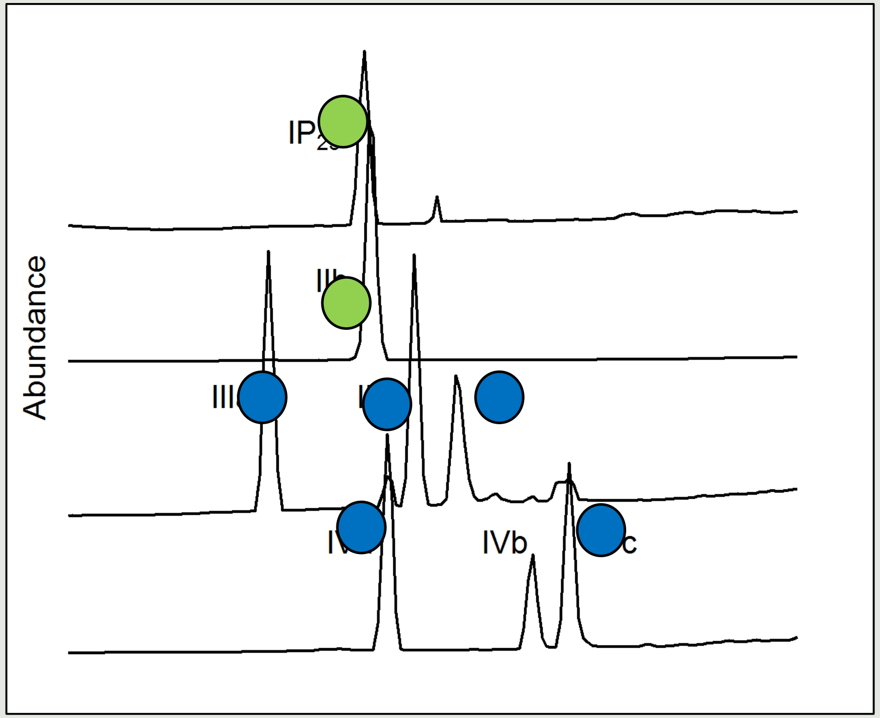
Trophic markers:

II Stable isotope ratios

- Fractionation between ^{13}C and ^{12}C:
- Dependent on:
  - $\delta^{13}C$ in dissolved inorganic carbon (DIC): CO_2 / HCO_3
  - Availability of carbon source
  - Species-specific differences in fractionation efficiency
  - Physiological status

- Sympagic algae: more likely to be DIC limited due to habitat





Trophic markers: III Highly branched isoprenoids (HBIs), e.g. IP_{25}

- Compounds that are produced exclusively by either sympagic or pelagic microalgae
- Produced only by very few (not dominant) species in low quantities

$$\text{H-Print}(\%) = \frac{(\text{pelagic HBIs})}{(\text{sea ice HBIs} + \text{pelagic HBIs})}$$

Courtesy of Thomas Brown

Previous work on environmental impact on trophic markers

J. Mar. Sci. Eng. **2020**, *8*, 676; doi:10.3390/jmse8090676

Journal of *Marine Science and Engineering*

MDPI

Article

Spatial and Temporal Variability of Ice Algal Trophic Markers—With Recommendations about Their Application

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Received: 10 July 2020; Accepted: 21 August 2020; Published: 2 September 2020

check for updates

Vol. 411: 49–60, 2010
doi: 10.3354/meps08647

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published July 20

OPEN ACCESS

Increased irradiance reduces food quality of sea ice algae

E. Leu[1,*], J. Wiktor[2], J. E. Søreide[3], J. Berge[3,4], S. Falk-Petersen[1,5]

Organic Geochemistry 141 (2020) 103977

Contents lists available at ScienceDirect

Organic Geochemistry

journal homepage: www.elsevier.com/locate/orggeochem

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Influence of nutrient availability on Arctic sea ice diatom HBI lipid synthesis

Check for updates

T.A. Brown [a,*], C. Rad-Menéndez [a,b], J.L. Ray [c], K.S. Skaar [c], N. Thomas [a,b], C. Ruiz-Gonzalez [a], E. Leu [d]

TWO FIELD STUDIES: CANADA & SVALBARD

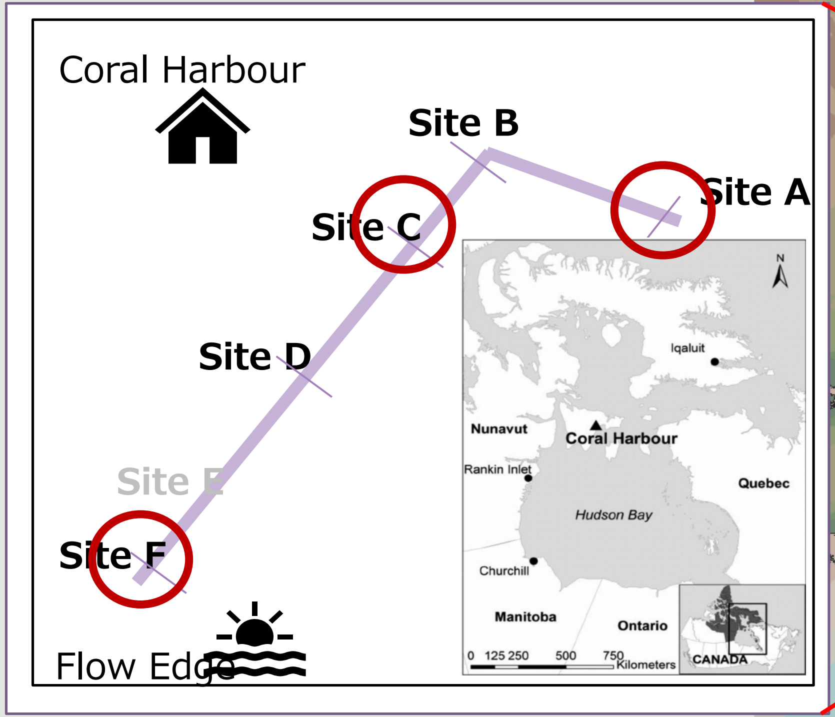
Coral Harbour (Hudson Bay) - 2018

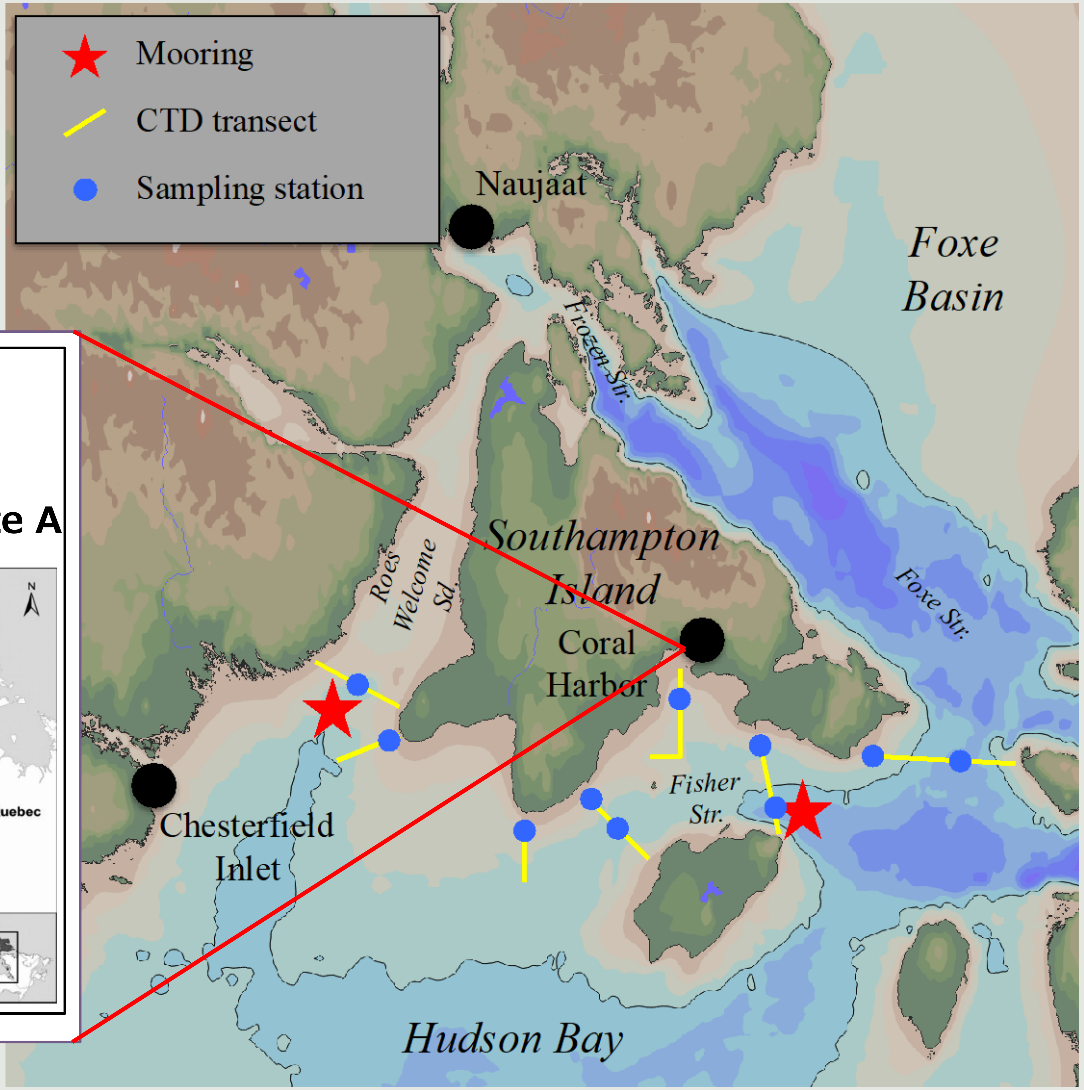
Van Mijenfjorden - 2017

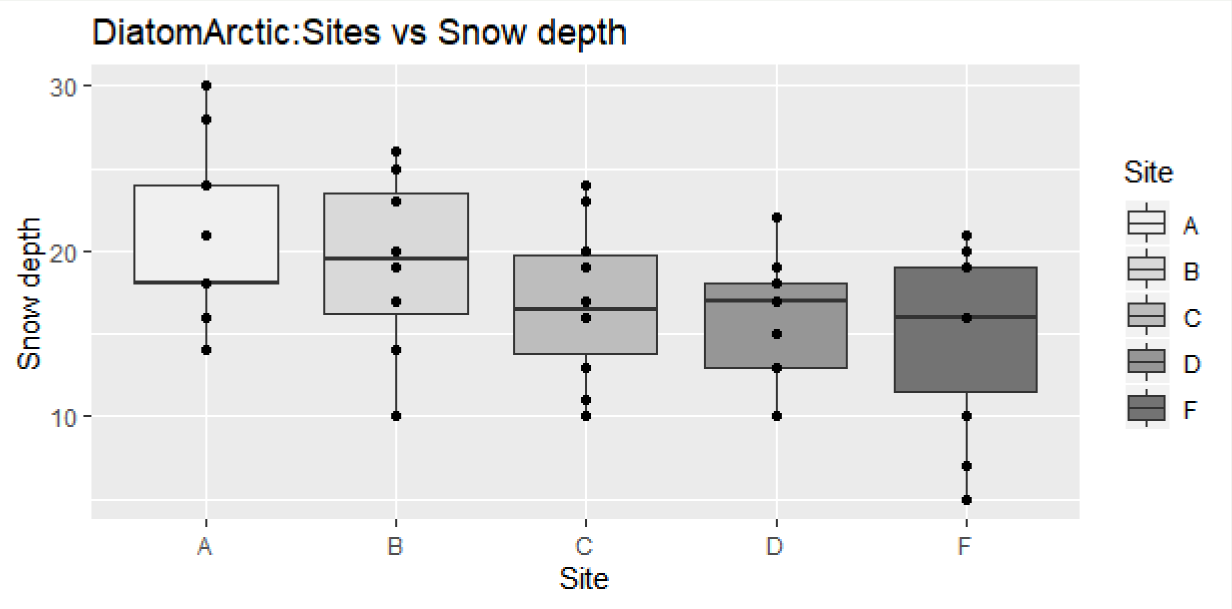
DiatomArctic Field sampling:

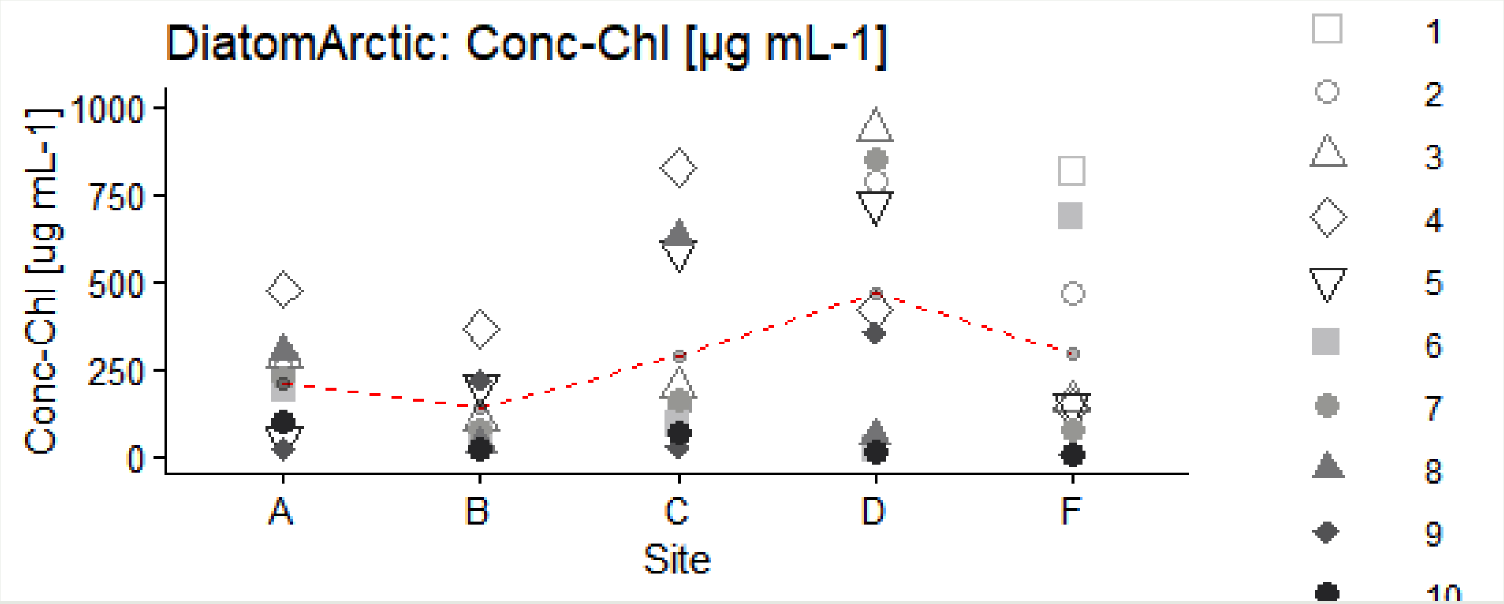
May 4th - June 1st 2018

Coral Habour, Southampton Island, Hudson Bay, Canada



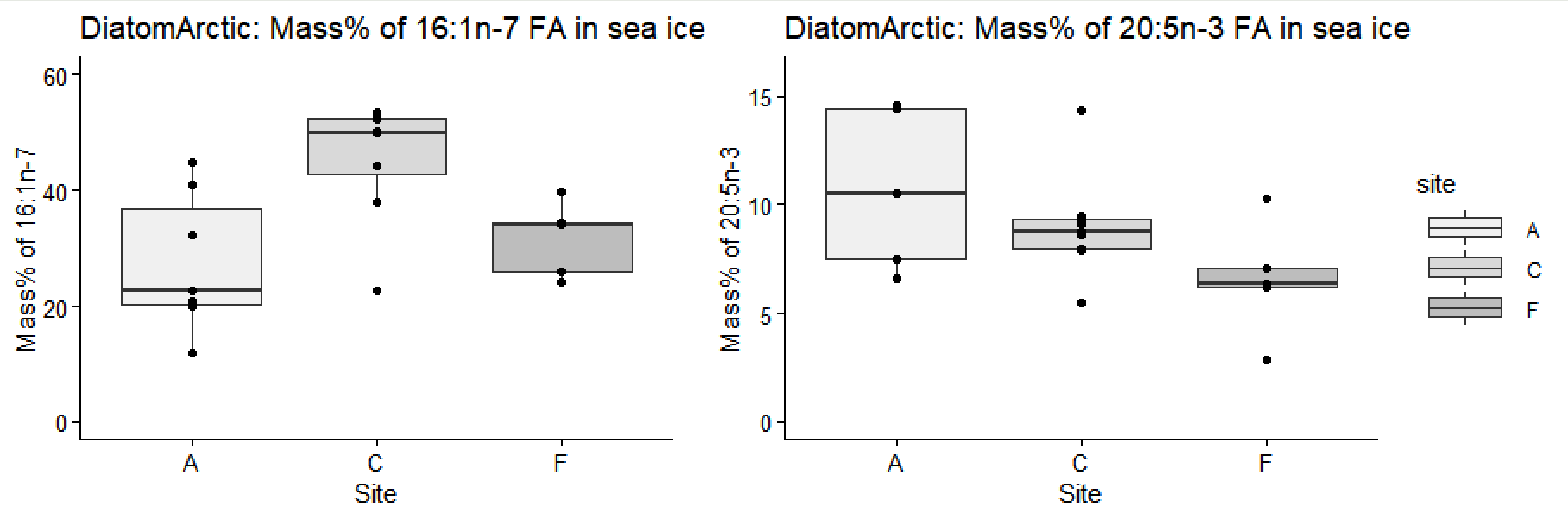



DiatomArctic:Sites vs Snow depth
30
20
10
Snow depth
A
B
C
D
F
Site
Site
A
B
C
D
F

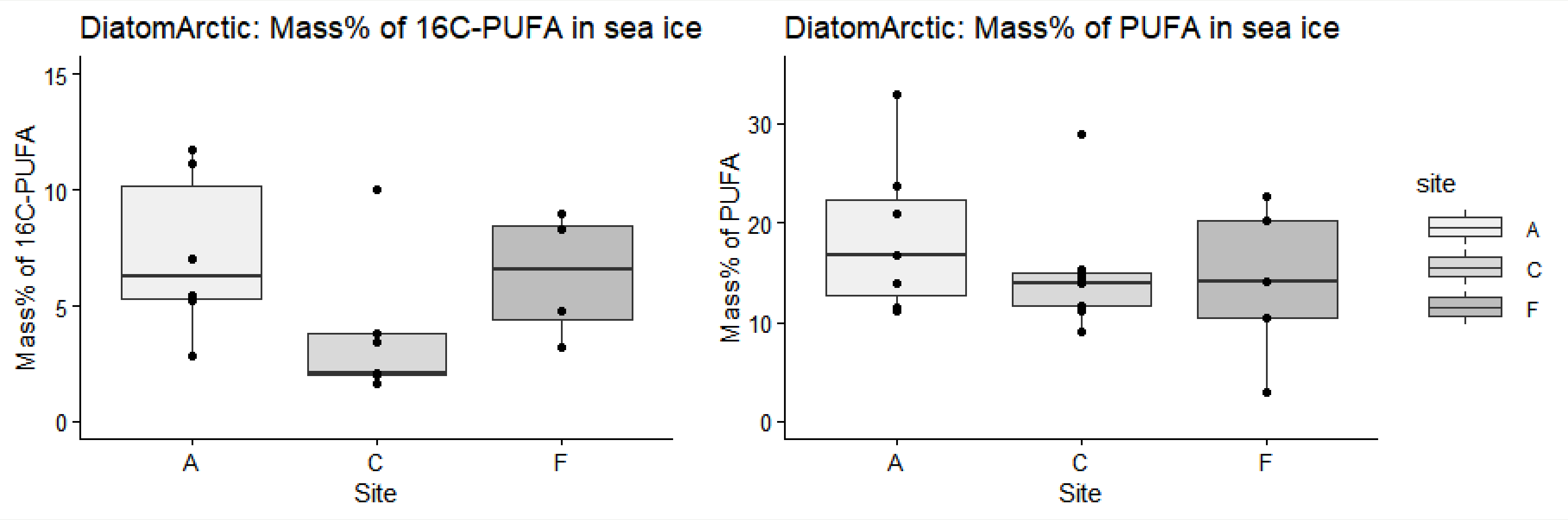

DiatomArctic: Conc-Chl [µg mL-1]
1000
750
500
250
0
Conc-Chl [µg mL-1]
A
B
C
D
F
Site
1
2
3
4
5
6
7
8
9

SPATIAL PATTERNS of fatty acid composition

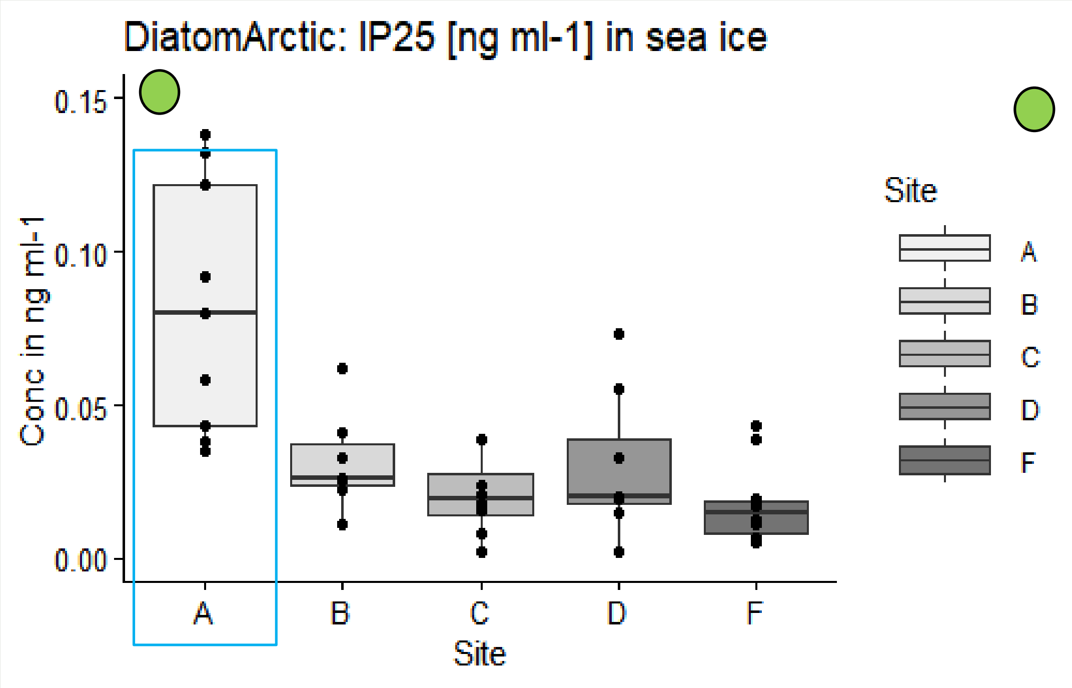
Leu, Graeve et al. unpubl.



Not very clear patterns, less 20:5n3 at the outermost station (least snow, close to open water)



SPATIAL PATTERNS in HBIs

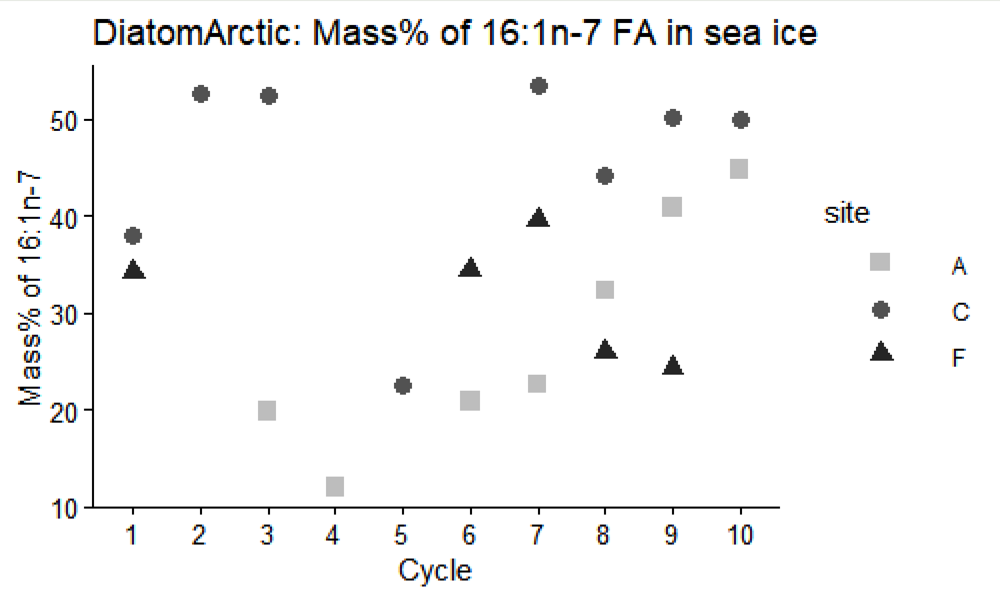


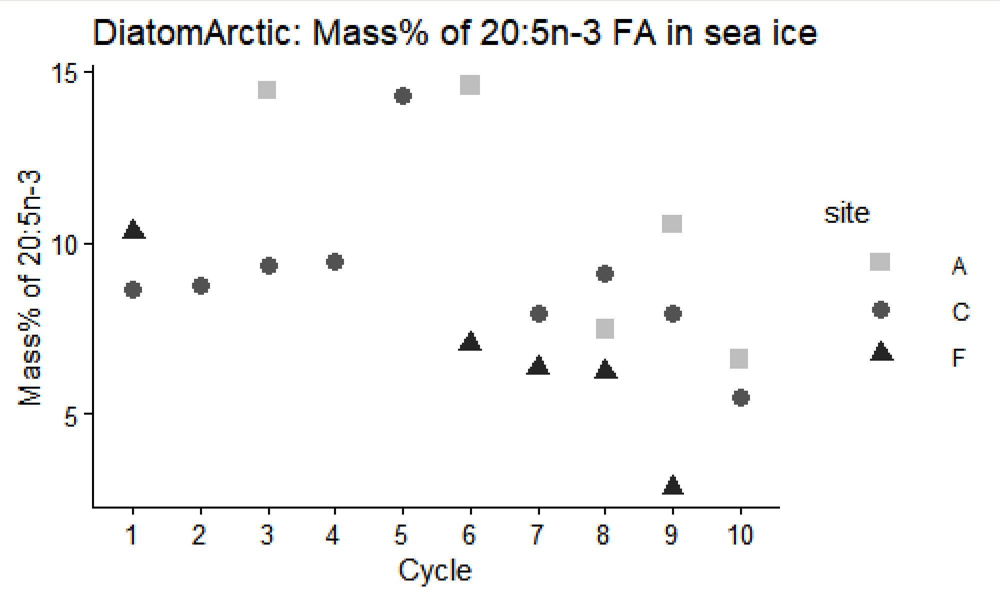
Leu, Graeve et al. unpubl.

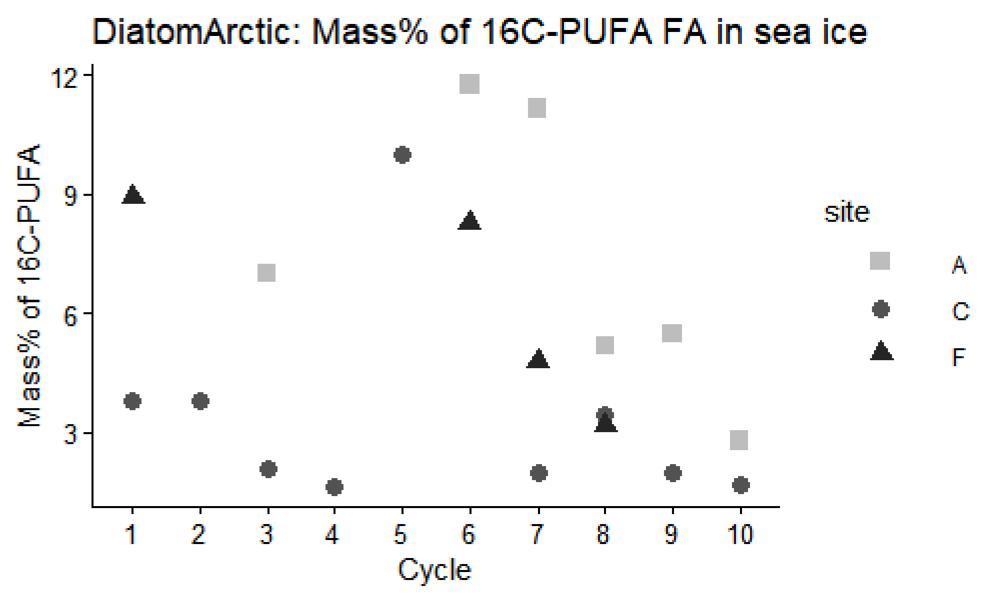
Highest concentrations of IP25 (ice algal biomarker) at the shallowest station – Potentially strong benthic-sympagic coupling; easy colonisation for heavy silicified IP25 producing species that spend the ice-free months in the sediment.
(found as well in Svalbard, see later)

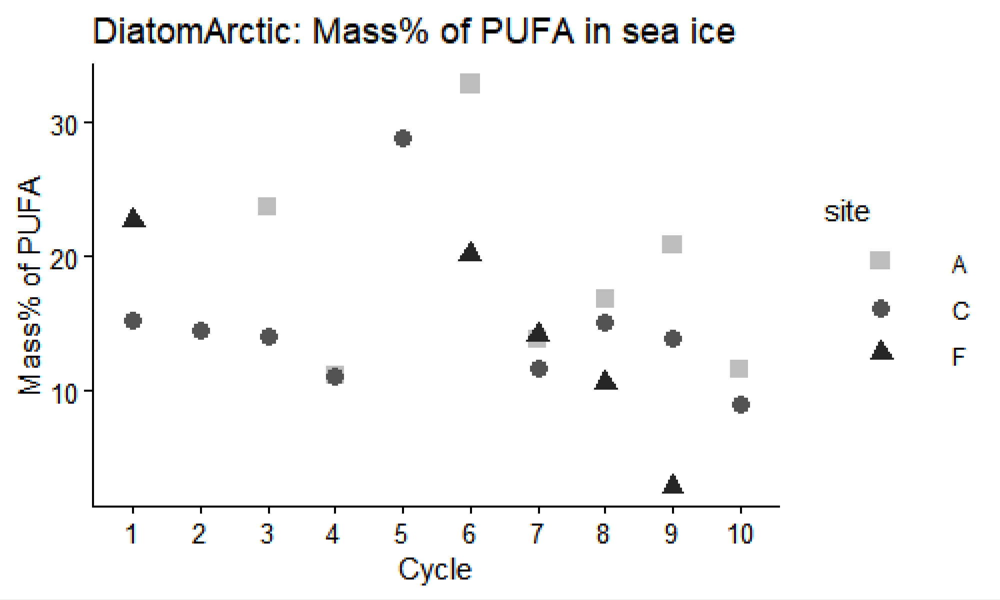
TEMPORAL PATTERNS of fatty acid composition

Leu, Graeve et al. unpubl.









Temporal patterns of fatty acid composition

(Coral Harbour)

Site A: Increase of 16:1n7 over time

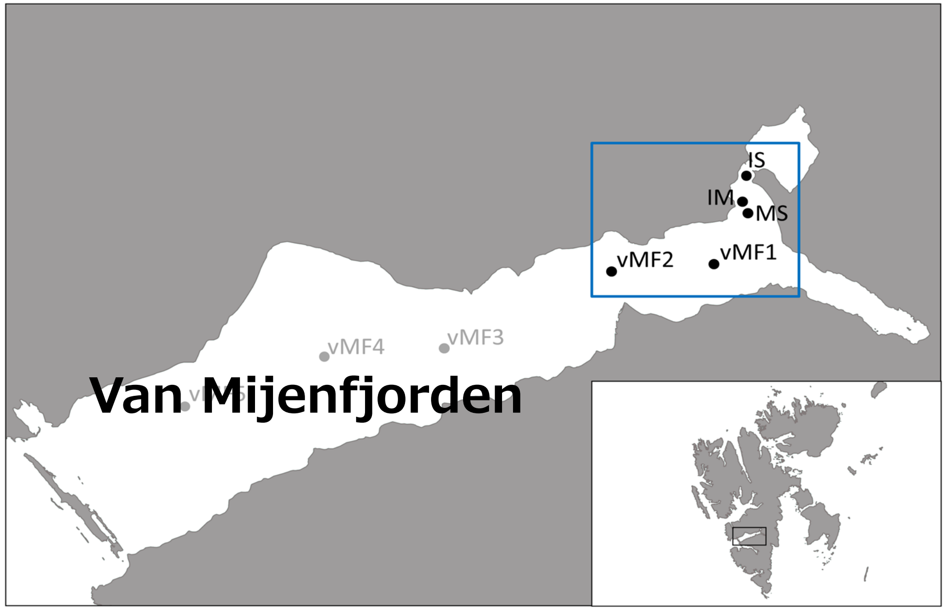
Decrease of all PUFAs

Site C: Very little changes

Sample cycle 5: higher PUFAs

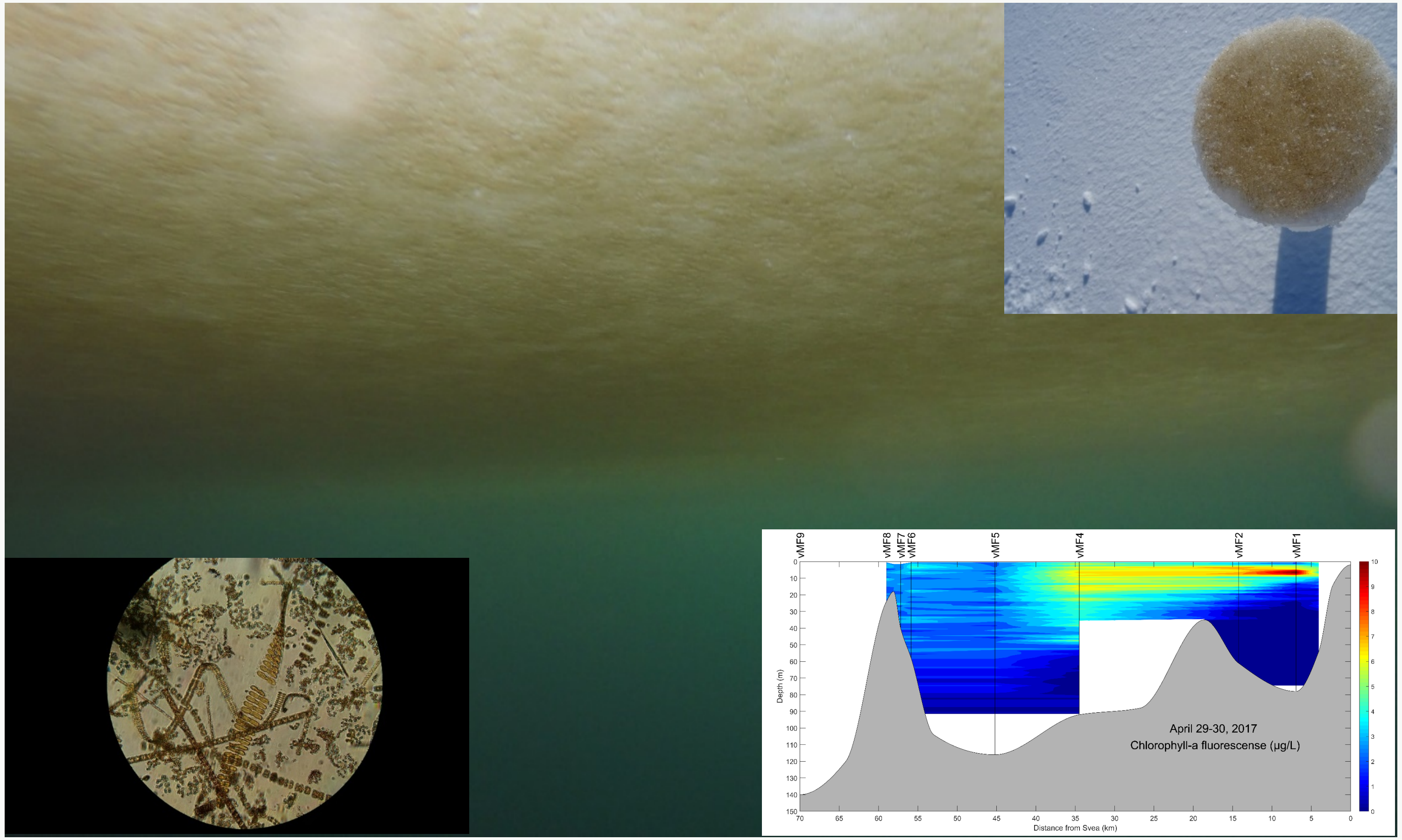
Site F: No clear increase of 16:1n7

Decrease of all PUFAs



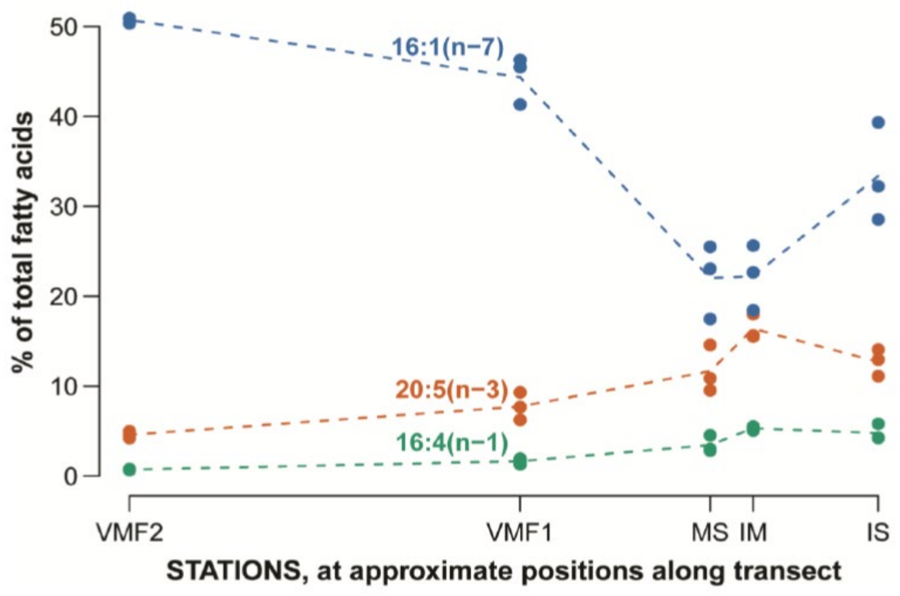
Ice algae transect: from shallow to midfjord (70 m)

Co-occuring ice algae and phytoplankton bloom



Field study II: Van Mijenfjorden, spring 2017

Fatty acid trophic markers



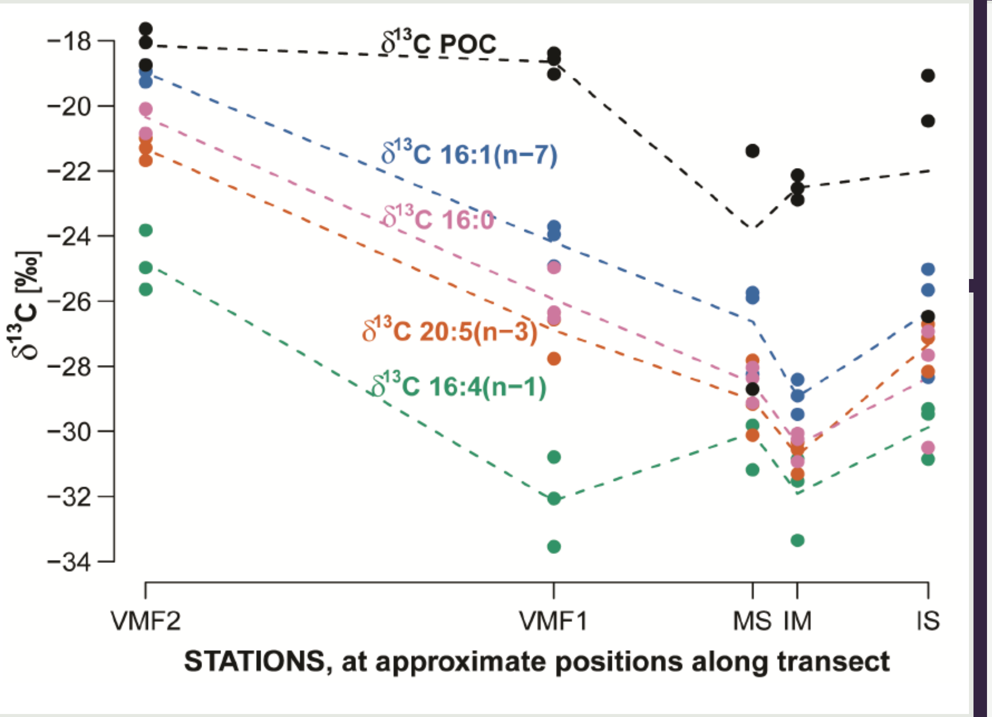
Large differences in % diatom marker fatty acids

Highest PUFA content at IM: 20:5n3 (long-term membrane lipids)

Highest 16:1n7 at VMF2 (short-term storage lipids)

Leu et al. JMSE (2020)

Stable isotope ratios



Large differences

Highest values at VMF2

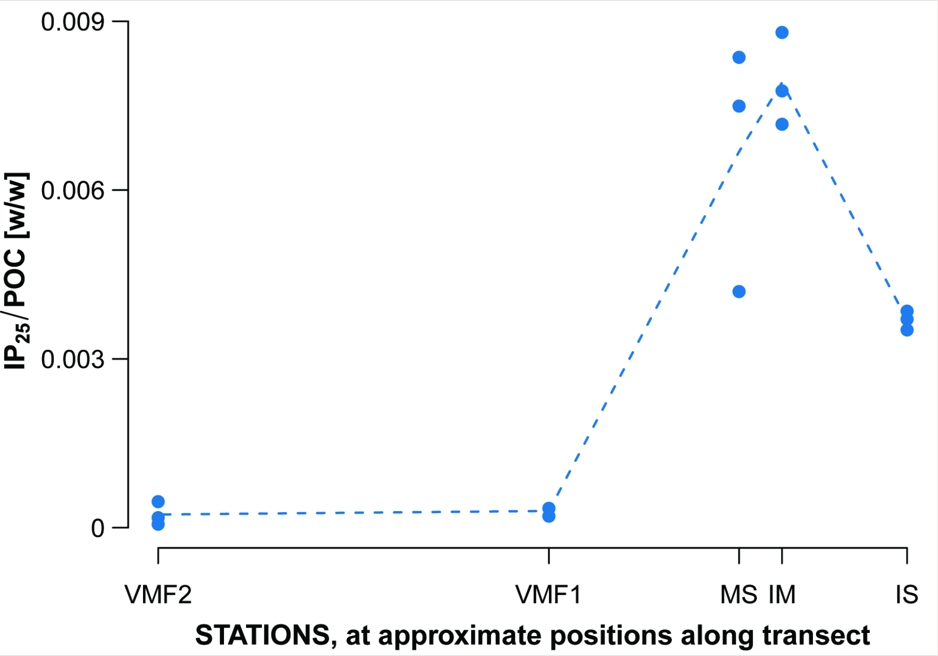
Lowest at IM

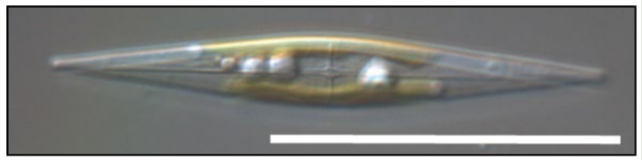
Patterns not uniform for all fatty acids

=> Based on these results: most ice-algae dominated community at VMF2

Leu et al. JMSE (2020)

HBI markers: IP_{25}





Haslea crucigeroides, IP_{25} producer

- **Large differences**
- **Lowest values at VMF2**
- **Highest at IM**

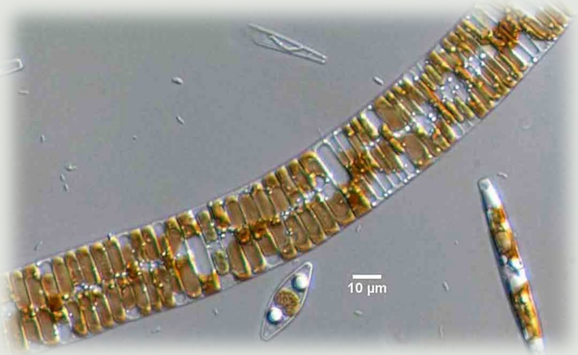
=> Based on these results: most ice-algae dominated community at IM (contradicts the CSIA data, previous slide!)

Akvaplan niva

faabulous Future Arctic Algae Blooms

Leu et al. JMSE (2020)

Who was there???



Large dominance of pennate diatoms at all stations

More pelagic influence on community visible at VMF1/2

Probably highest frequencies of IP25 producers at shallow stations (but minor contribution to overall biomass)

Nutrient and carbon availability (and light?) control trophic marker signals!

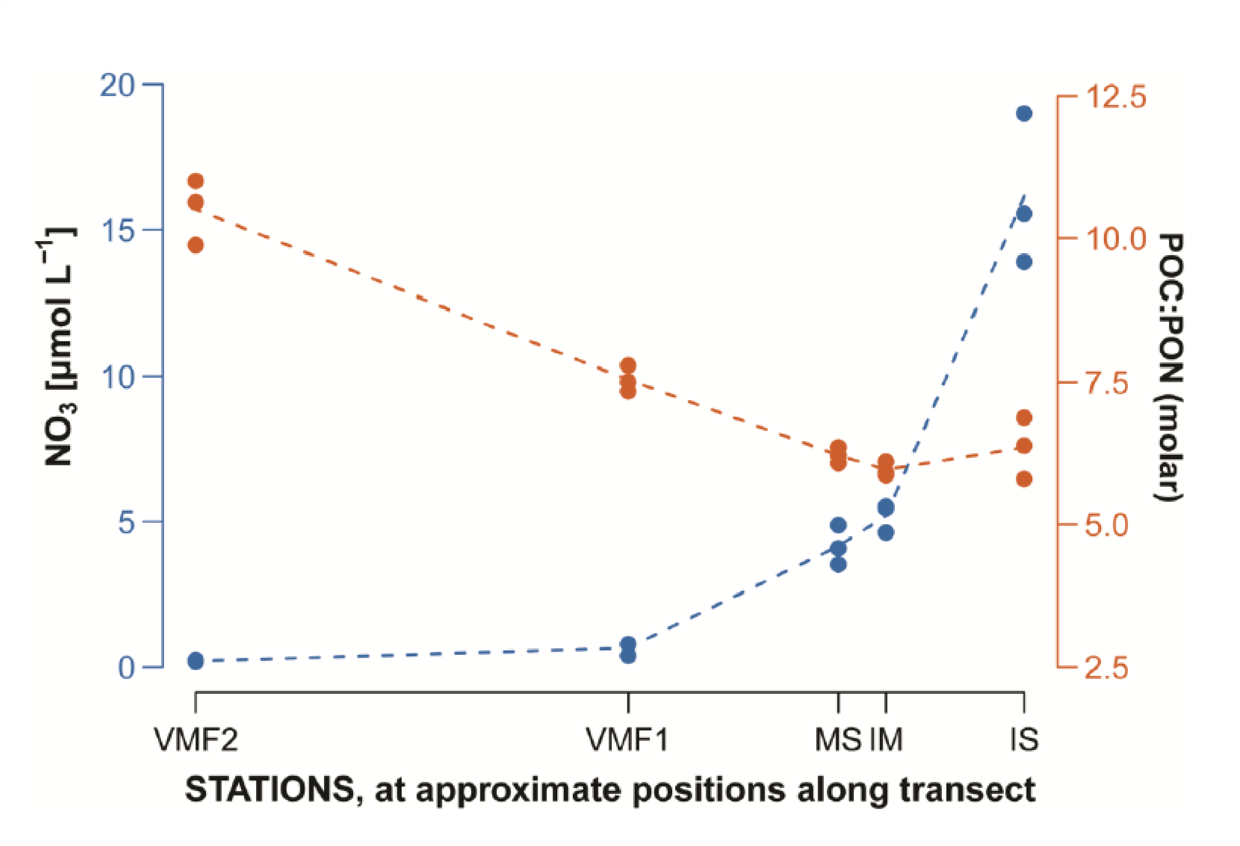
Explanation for variability

Strong nutrient (nitrate) gradient

Result of temporal differences in succession

Nitrate limitation in algae reflected in molar C:N ratio of >10 at VMF2

Metabolic changes affect trophic markers!



Leu et al. JMSE (2020)

Correlations of trophic markers and nutrients

Biomarkers	NO_3 [μmol L^{-1}]	SiO_2 [μmol L^{-1}]	C:N [molar]
IP_{25}/ POC	0.770*	0.802**	–0.782*
16:1(n-7)	–0.794**	–0.261	0.903**
16:4(n-1)	0.758*	0.462	–0.939**
20:5(n-3)	0.709	0.669	–0.782*
$\delta^{13}C$ POC	–0.673	–0.438	0.891**
$\delta^{13}C$ 16:1(n-7)	–0.733*	–0.498	0.818**
$\delta^{13}C$ 16:4(n-1)	0.006	–0.486	–0.188
$\delta^{13}C$ 20:5(n-3)	–0.370	–0.608	0.418

Interpretation of data

Transect: space for time replacement

Shallowest stations represent earliest succession status

Midfjord stations: more mature/ late bloom status:

Low nutrient status

High C:N ratios

(presumbly) depleted in DIC

Low PUFA content

High 16:1n7 – indication for storage lipid formation!

Physiology/growth state more important than taxonomic differences (in this dataset)

Key findings and implications

- Lipid and stable isotope trophic markers in sea ice algae show a remarkable spatial and temporal variabiliy on short scales
- Nutrient, inorganic carbon (DIC) and light availability are key factors controlling their changes
- For stable isotopes: 'Typical' sea ice algal signals are only found under limiting conditions (nutrients and/or DIC)
- **Using ice algal trophic marker signals in food web analysis requires caution and a sound understanding of ancillary data**