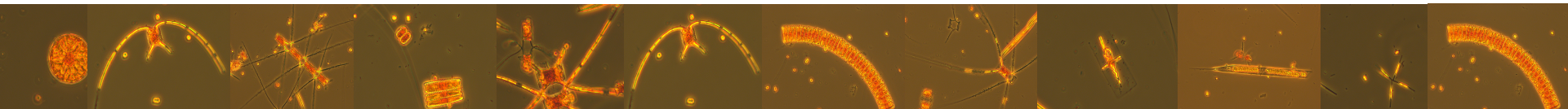
Iron and Manganese co-limitation:

a potential driver of Southern Ocean phytoplankton ecology

Ecological chemistry section
EcoTrace junior group *' The role of trace elements in the Southern Ocean'*
Supervised by: Dr. Scarlett Trimborn

September 2021

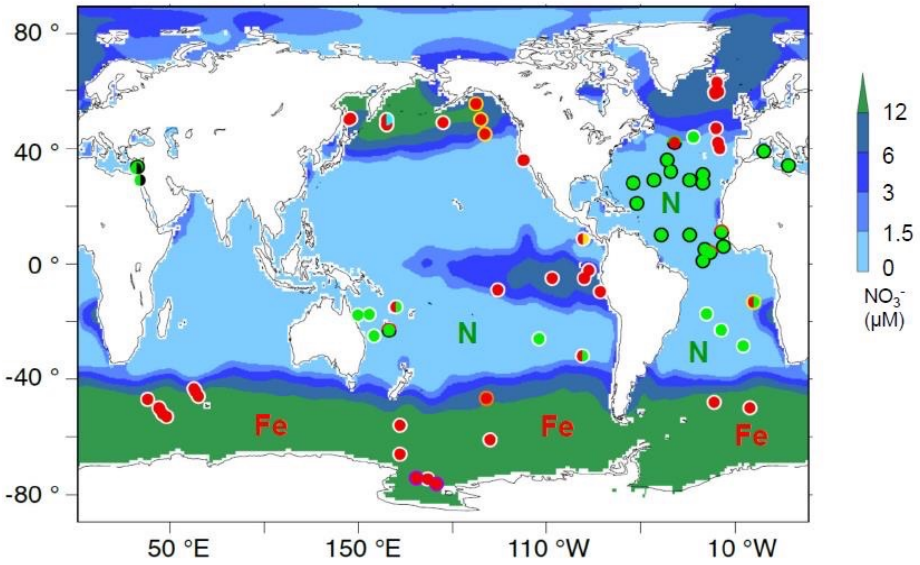
Jenna BALAGUER



The Southern Ocean

- **SO phytoplankton**: 20% of the global annual primary production
  (Arrigo *et al.*, 2008)
- **High Nutrient Low Chlorophyll area**
- **Controlling key factor : Iron (Fe) availability**
  (Martin *et al.*, 1990; Boyd *et al.*, 2007)
- **Why Iron?** Fe is entailed in many pathways of the cells
  - Photosynthesis and respiration processes / Nitrogen fixation / Chlorophyll synthesis

(Behrenfeld et Milligan, 2013; Twinning et Baines, 2012)



Global patterns of nutrient limitation from Moore et al., 2013

Concept of co-limitation

- Nutrient co-limitation: *"conditions where two (or more) nutrients have simultaneously been drawn down to levels where addition of both (or on some usage either) is required to stimulate growth. "*
  (Moore *et al.*, 2013)

- Light or other trace metals (Mn, Co, Zn, Cu…) and vitamins (such as B_{12})

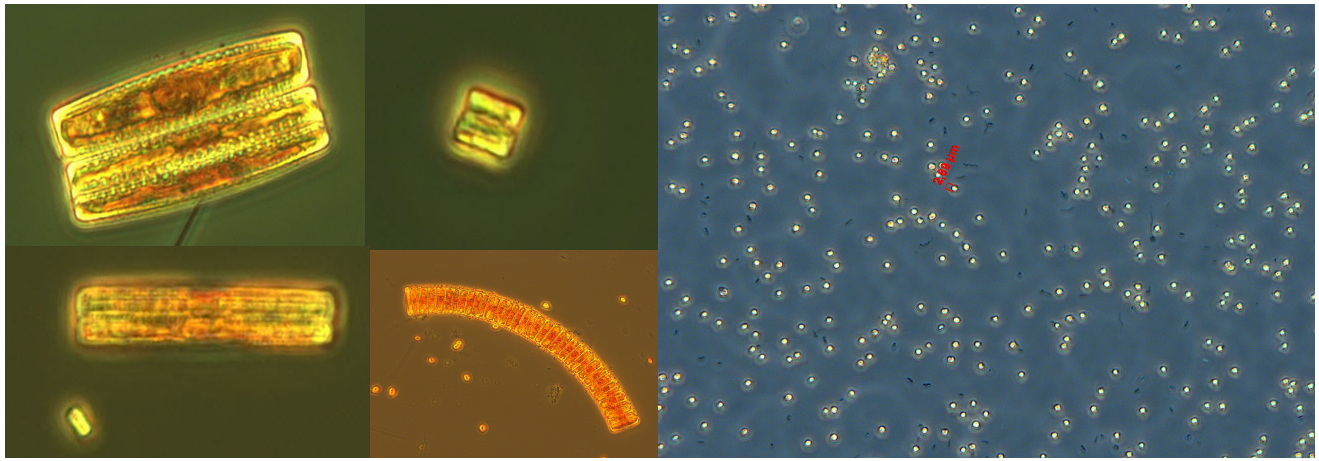
- **Mn: 2nd most abundant** in the thylakoids
  (Wolfe-Simon *et al.*, 2005)

- **Co-limitation by Mn** in Drake Passage was suggested in the early 1990 (Martin *et al.*, 1990)

- **Co-limitation of Fe-Mn** on SO phytoplankton in the field was detected
  (Buma *et al.*, 1991; Browning *et al.,* 2014; Wu *et al.*, 2019; Browning *et al.*,2021)

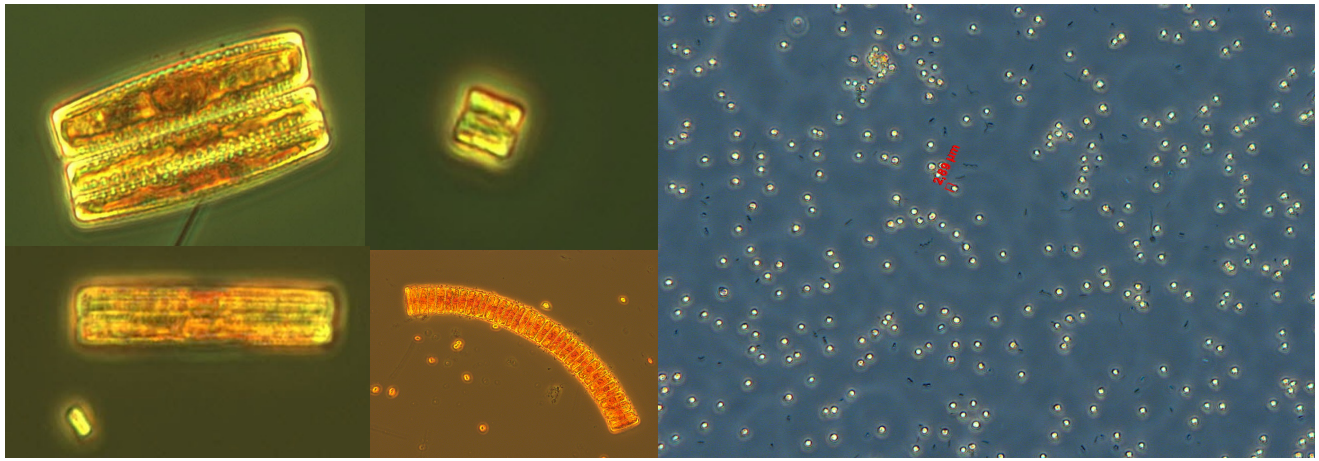
Impact on species composition?

Species composition, why it is important ?



Carbon export

Species composition, on what it depends?



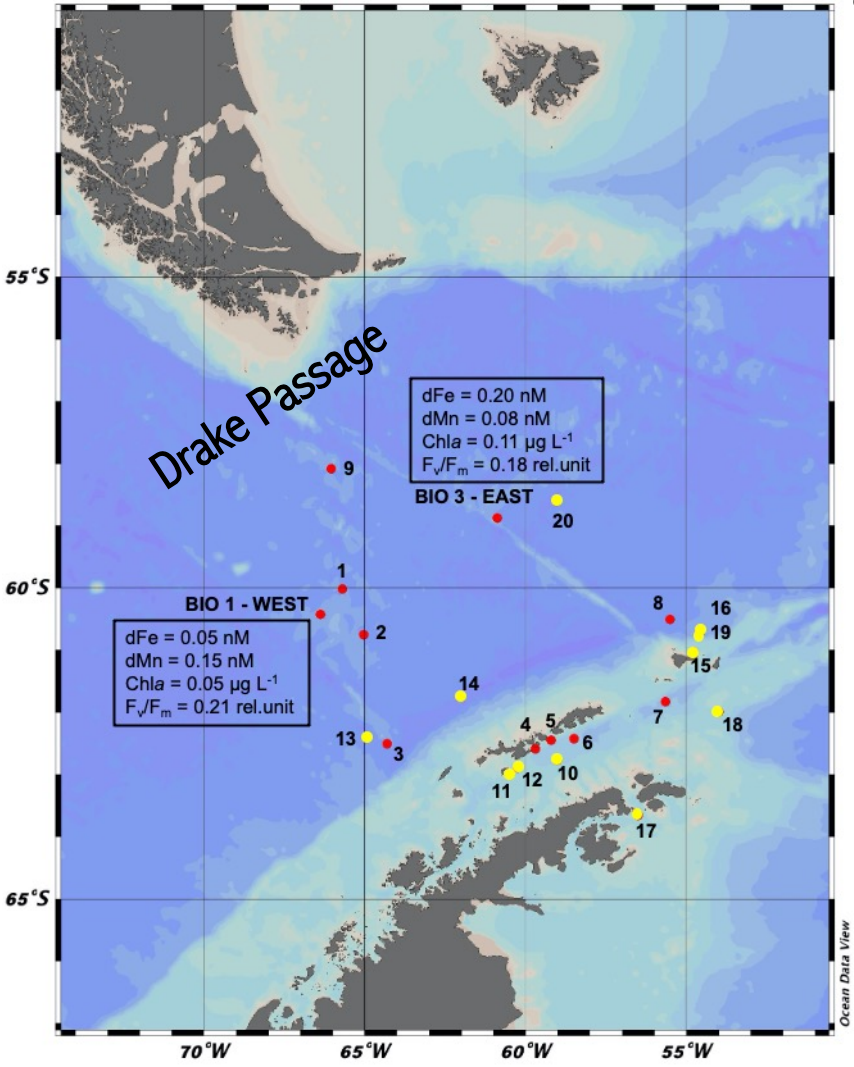
Requirements

Trace metals availability

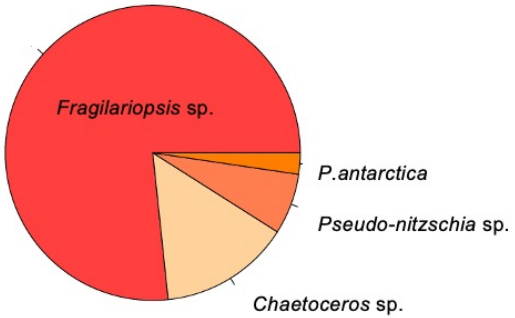
Sources

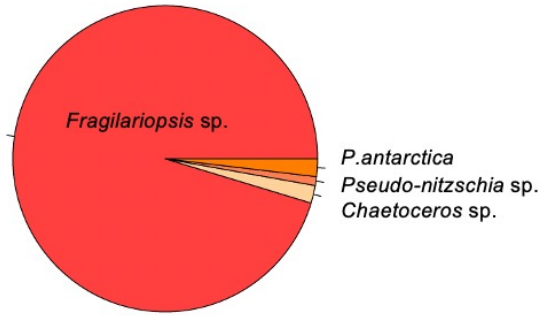
Chapter 1: Detection of FeMn co-limitation in the Drake Passage

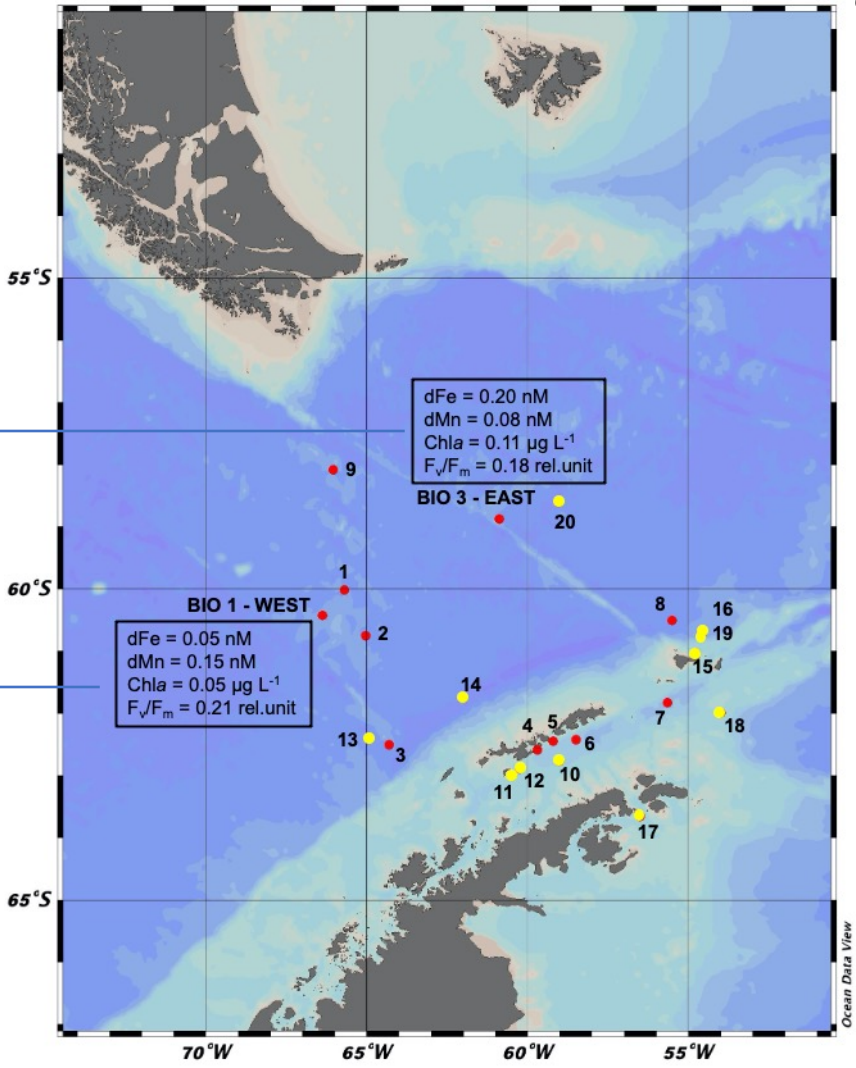
Polarstern cruise PS97



Chapter 1: Detection of FeMn co-limitation in the Drake Passage

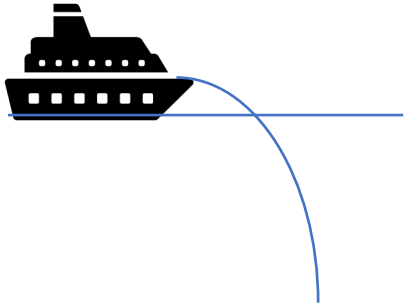




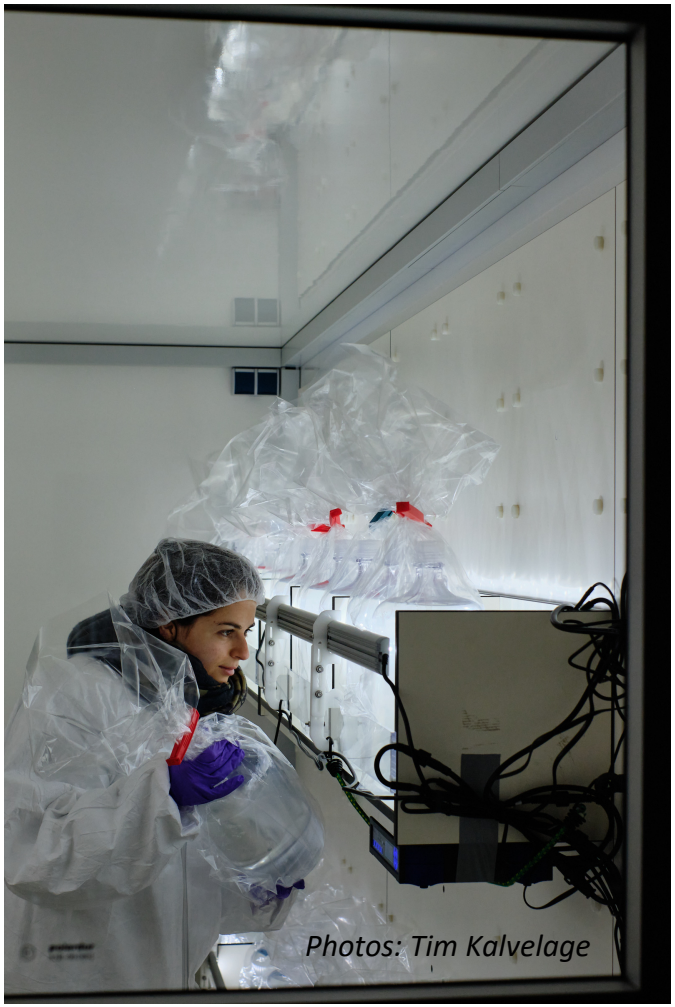


Chapter 1: Detection of FeMn co-limitation in the Drake Passage

Polarstern cruise PS97

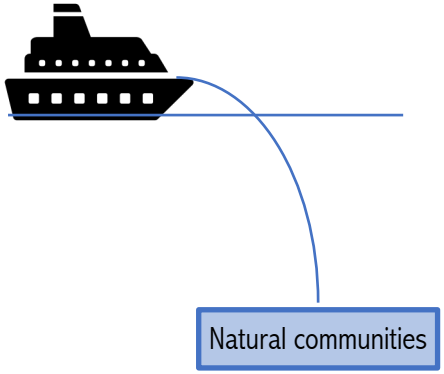


2 stations:
West Drake Passage
East Drake Passage



Chapter 1: Detection of FeMn co-limitation in the Drake Passage

Polarstern cruise PS97



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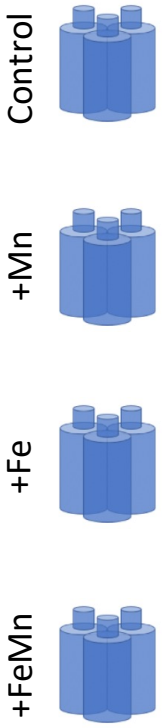


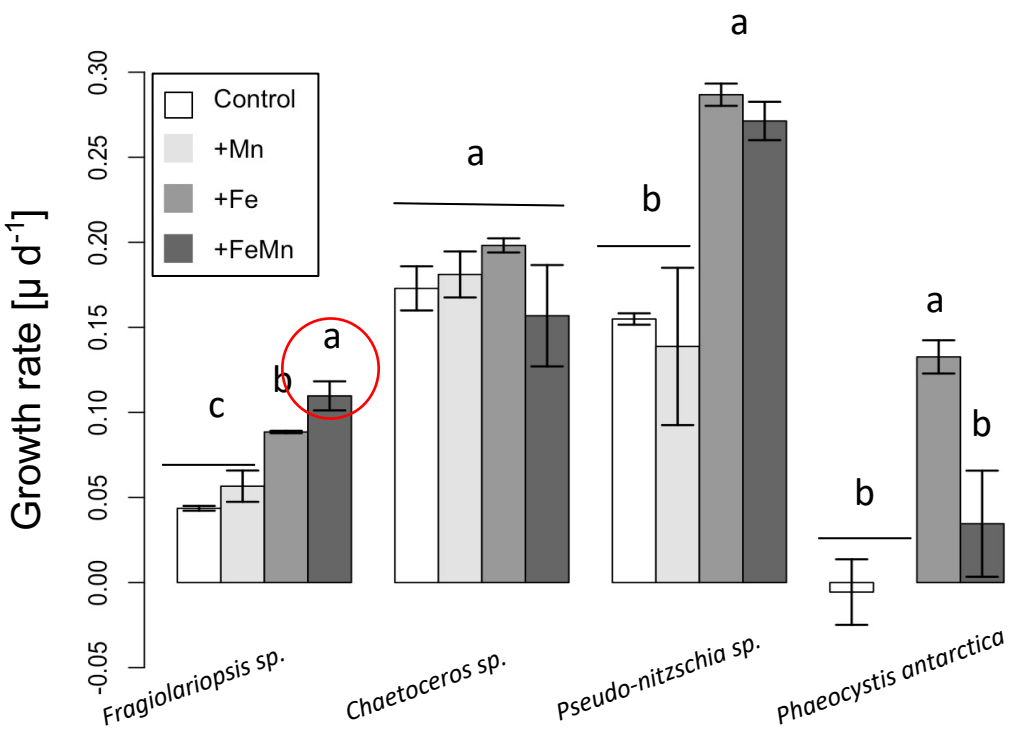
Determination of bulk parameters
Pigments
Nutrients drawdown
Particulate organic carbon

Determination of species composition
Microscopy
Flow cytometry

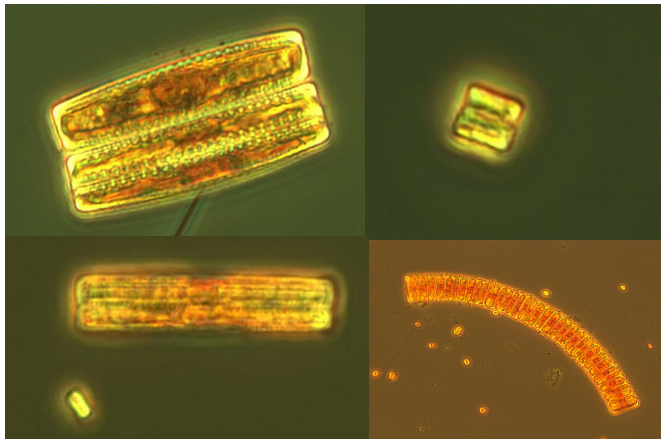
Photophysiology:
Photosynthetic efficiency

Chapter 1.

Relief of FeMn on some members of the community at WEST



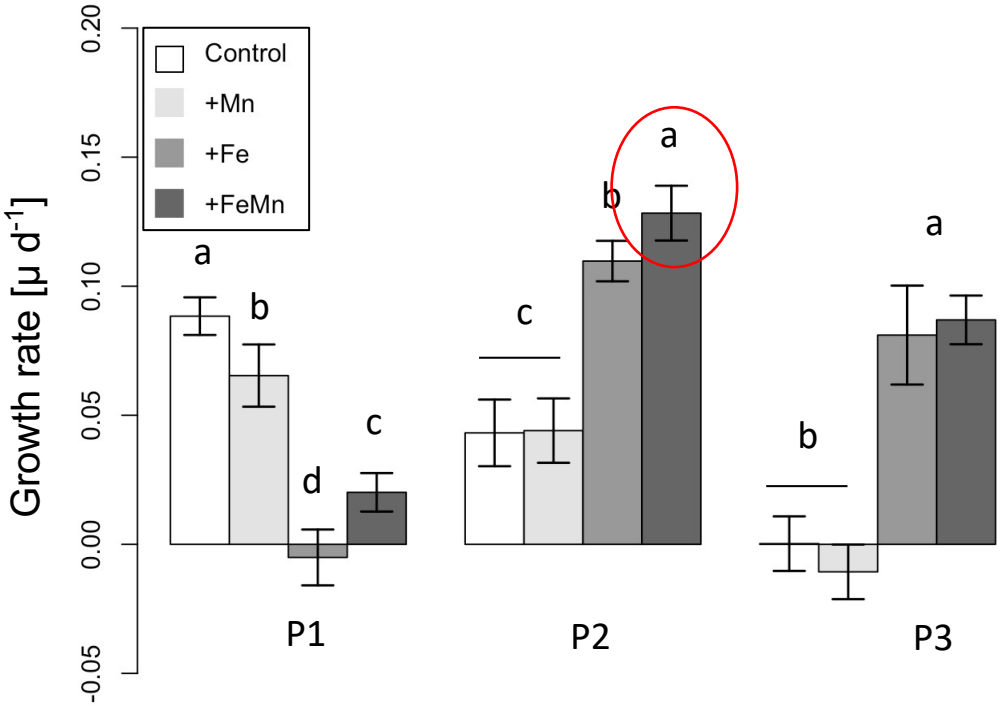
Initial seawater:
dFe = 0.05 nM
dMn = 0.15 nM
dZn = 3.21 nM
dCo = 0.03 nM



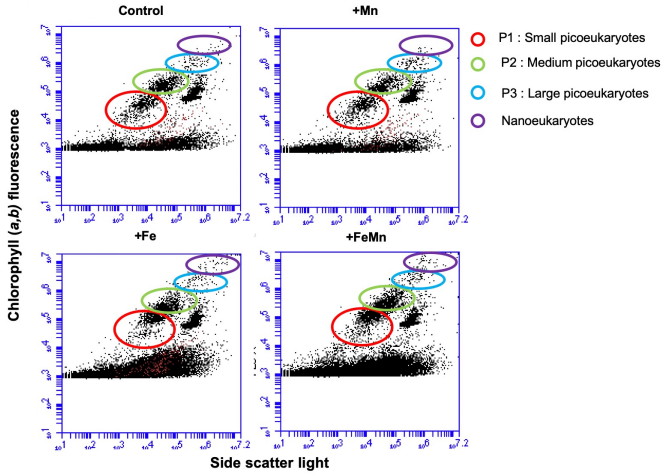
Different letters indicate significant differences between treatments ($p < 0.05$).

Chapter 1.

Relief of FeMn on some members of the community at EAST



Initial seawater:
dFe = 0.20 nM
dMn = 0.08 nM
dZn = 1.71 nM
dCo = 0.02 nM



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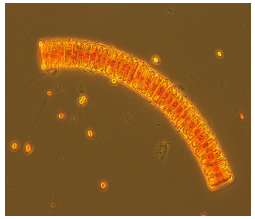
Chapter 1.



Ecological implications

- **Only some members were FeMn co-limited**: *Fragilariospsis* sp. and P2 group
- Results **not mirrored** at both location, **why?**

Initial seawater West:	Initial seawater East:
dFe = 0.05 nM	dFe = 0.20 nM
dMn = 0.15 nM	dMn = 0.08 nM
dZn = 3.21 nM	dZn = 1.71 nM
dCo = 0.03 nM	dCo = 0.02 nM

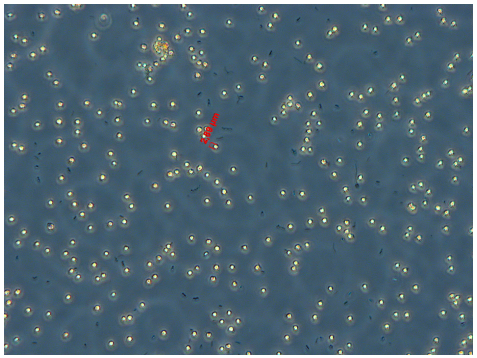
- Need to perform single species experiments to understand mechanistic mechanisms

Balaguer et al. (*in review* Communications Biology)

Chapter 2: Mechanistic understanding of FeMn co-limitation for photophysiology

Case of study: *Phaeocystis antarctica*

Acclimated for 6 months



Control — FeMn- Antarctic poor seawater
0.16 nM dFe
0.15 nM dMn

+Mn — 0.16 nM dFe
3 nM dMn

+Fe — 3 nM dFe
0.15 nM dMn

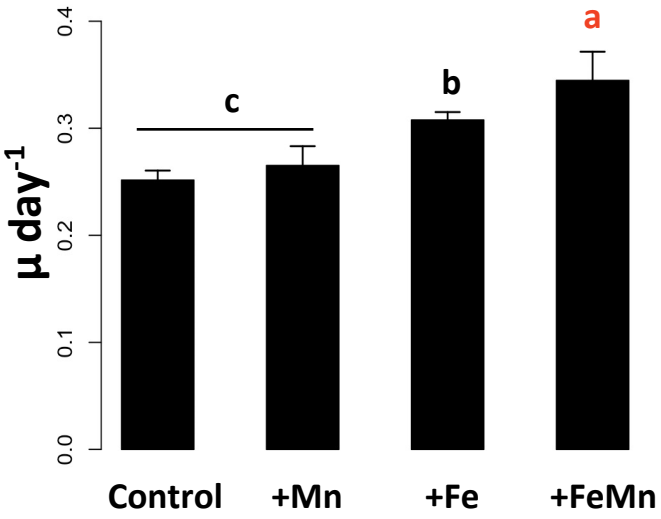
+FeMn — 3 nM dFe
3 nM dMn

Determination of bulk parameters
Pigments
Nutrients drawdown
Particulate organic carbon

Photophysiology:
Photosynthetic efficiency

Chapter 2.

Growth of *P. antarctica* was co-limited



The photosynthetic effiency of *P. antarctica* was driven by Mn availabilty

	F_v/F_m rel. unit	σ_{PSII} nm^2
Control	0.29 ± 0.03 ^{c}	9.3 ± 2.8 ^{b}
+Mn	0.31 ± 0.01 ^{b}	8.3 ± 0.7 ^{b}
+Fe	0.29 ± 0.02 ^{c}	6.6 ± 0.7 ^{a}
+FeMn	0.36 ± 0.01 ^{a}	6.2 ± 0.6 ^{a}

- Fe drives the **efficiency of the electron transport**

→ Enhanced growth and particulate organic carbon production

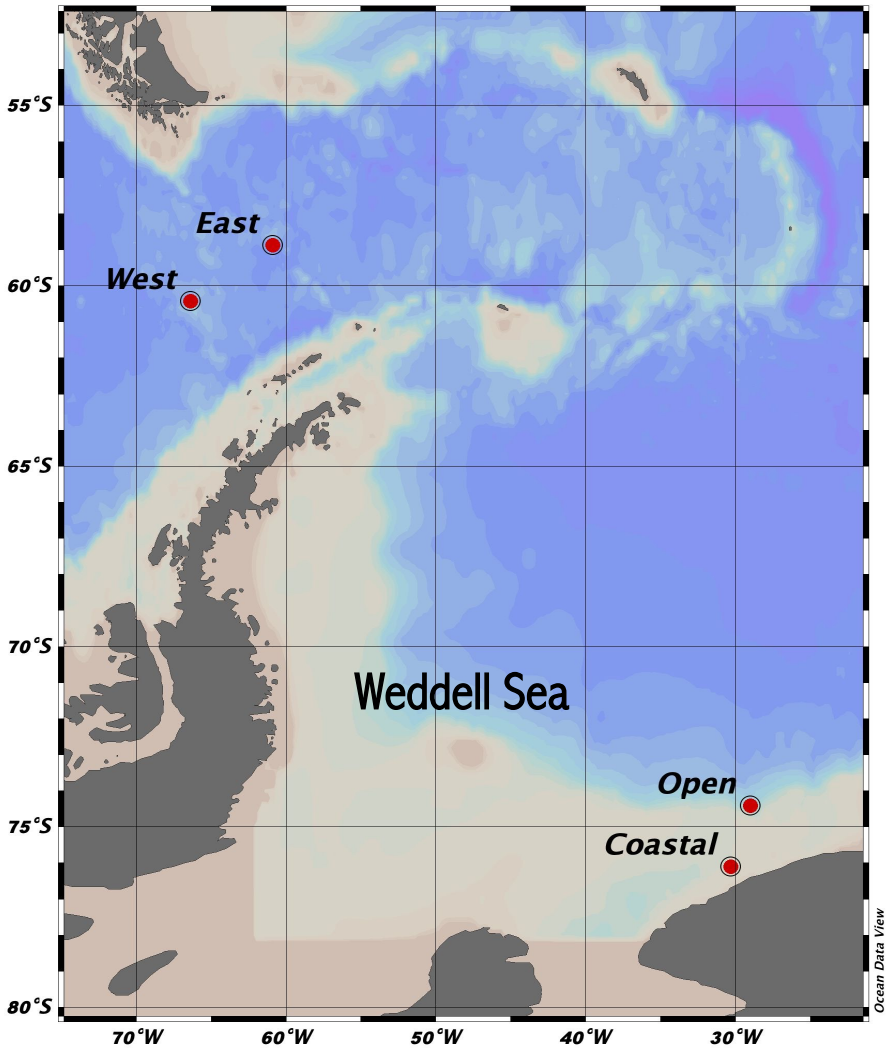
- Mn supply increase ROS scavenging also increased under Fe limitation

- Only supply of both enable: growth and maximum efficiency for photosynthesis

Balaguer et al. (*in prep*)

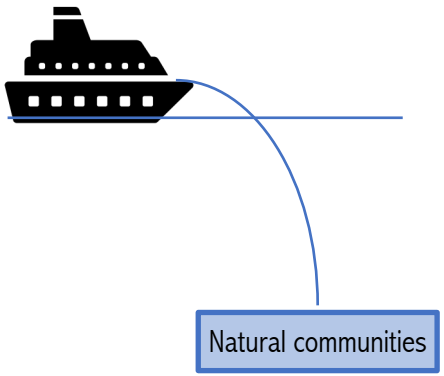
Chapter 3: Detection of multi co-limitation in the Weddell Sea

Polarstern cruise PS124
February - March 2021

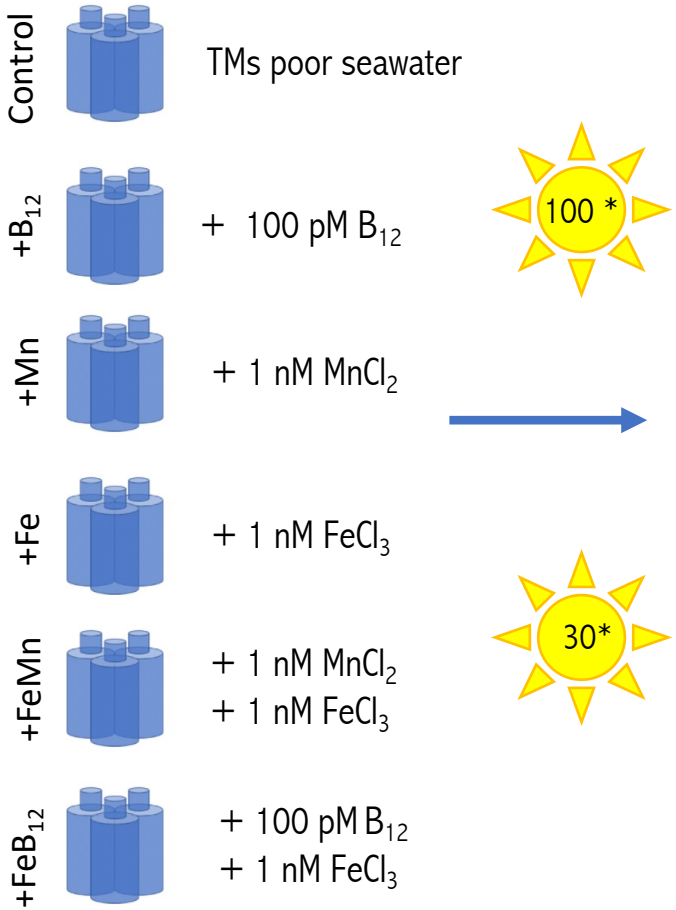


Chapter 3: Detection of multi co-limitation in the Weddell Sea

Polarstern cruise PS124



2 contrasted stations:
Open Ocean
Coastal



Determination of bulk parameters
Pigments
Nutrients drawdown
Particulate organic carbon

Determination of species composition
Microscopy
Flow cytometry

Photophysiology:
Photosynthetic efficiency

* $\mu E\ m^{-2}\ s^{-1}$

Chapter 3: Detection of multi co-limitation in the Weddell Sea

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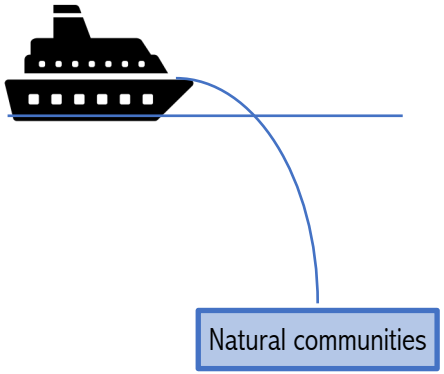
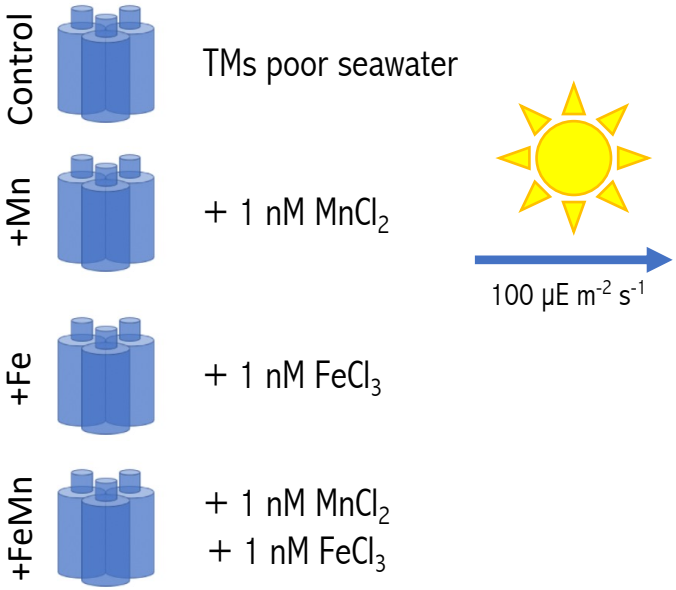
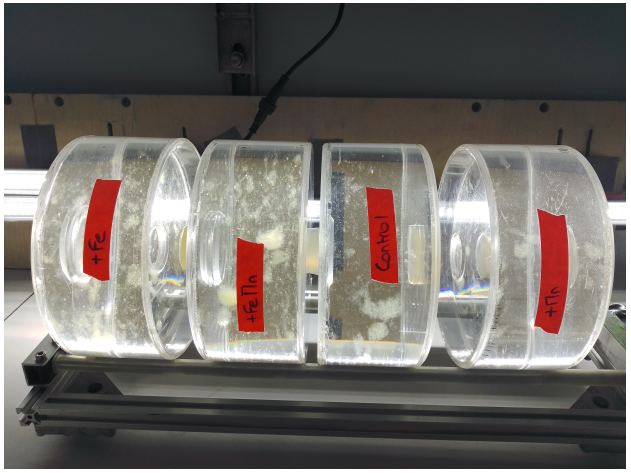


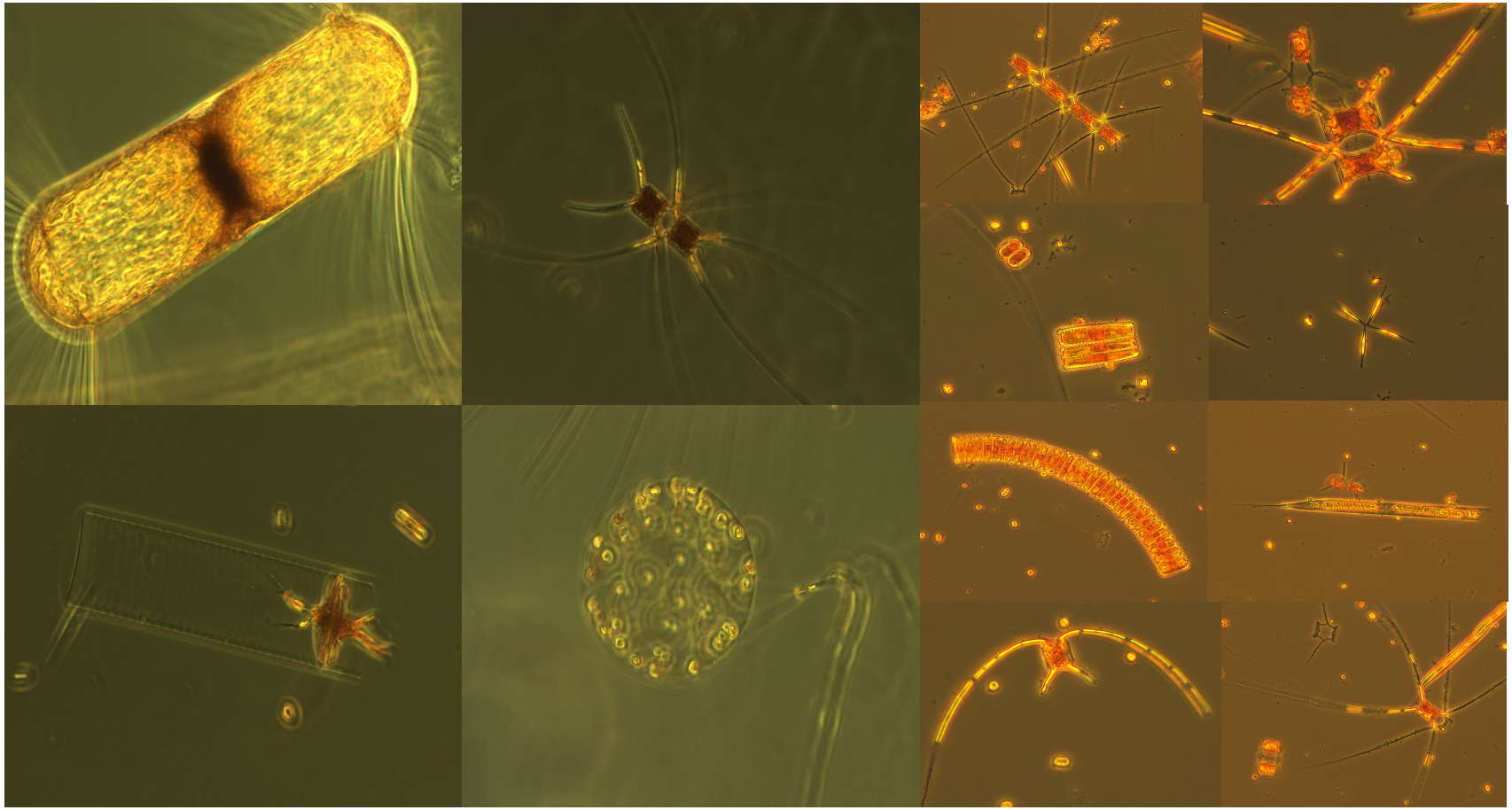




2 contrasted stations:
Open Ocean
Coastal

Aggregation experiments
→ Estimation of carbon export

Take home message



Thanks! Questions?

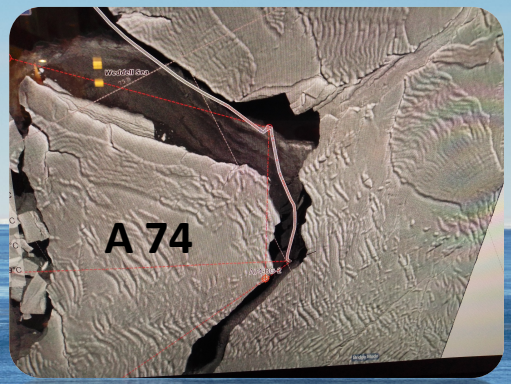
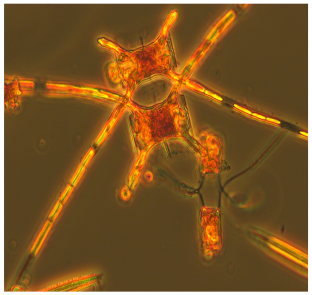


Photo: Tim Kalvelage

Impact on species composition?

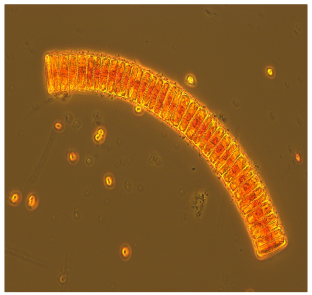
#1



- Identify **Fe-Mn co-limitation** and elucidate the impact on phytoplankton species composition

Incubation experiments from
PS97 expedition

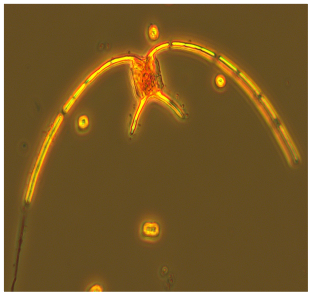
#2



- Provide a detailed physiological characterization of a key species in response to different Fe and Mn concentrations

Laboratory experiment AWI

#3

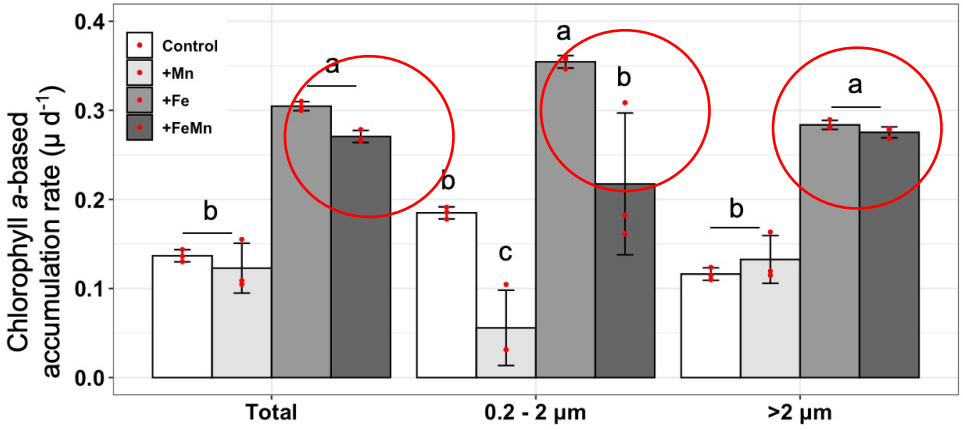


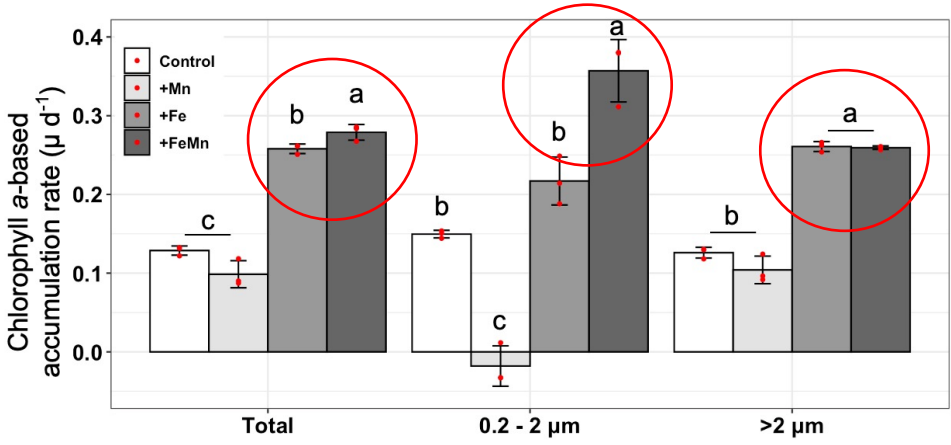
- Assess how different light and trace metal input scenarios affect natural phytoplankton assemblages

Incubation experiments from
PS124 expedition

Chapter 1.

→ All the groups responded to **Fe addition:** meaning that a relief of Fe limitation occured at both locations





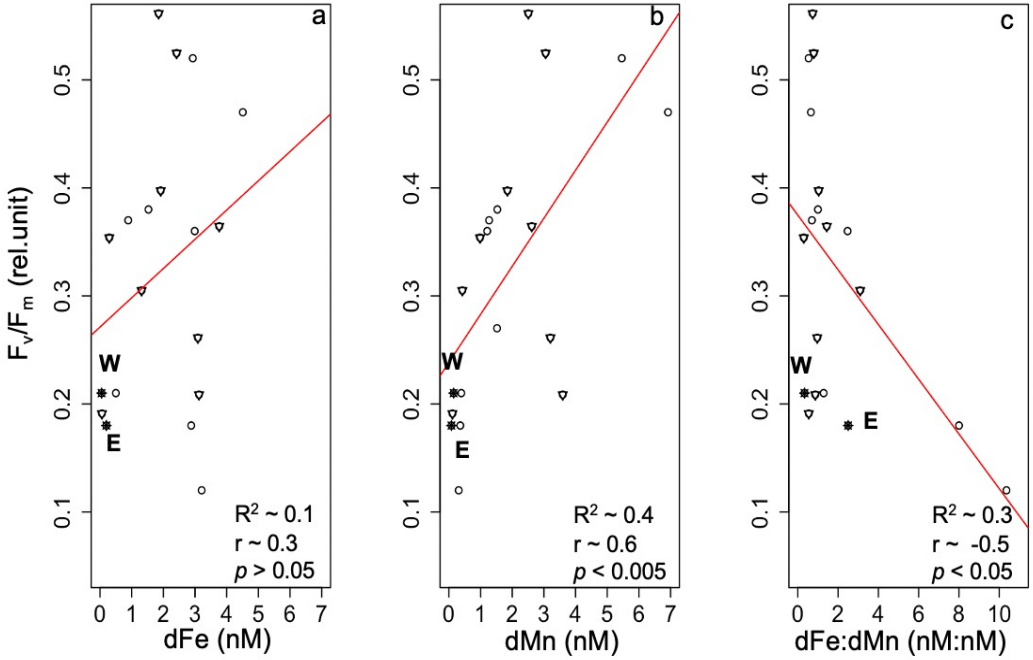
Different letters indicate significant differences between treatments ($p < 0.05$).

Balaguer et al. (*in review* Communications Biology)

Chapter 1.

Photosynthetic efficiency of the cells a potential proxy for FeMn limitation?

- F_v/F_m was used a proxy to detect **Fe limitation** in the field
- dMn contribute as well
- F_v/F_m to detect multi limitation in the field?

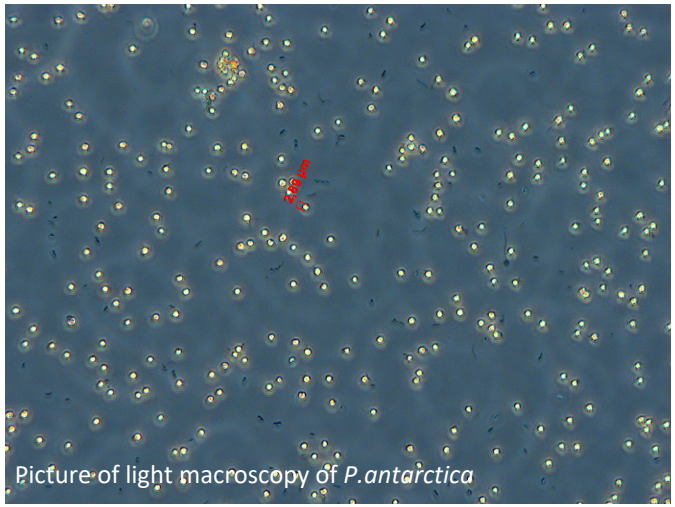


Balaguer et al. (*in review* Communications Biology)

Chapter 2: Mechanistic understanding of FeMn co-limitation for photophysiology

Case of study

Laboratory experiment on single specie : ***Phaeocystis antarctica***


Picture of light macroscopy of *P.antarctica*

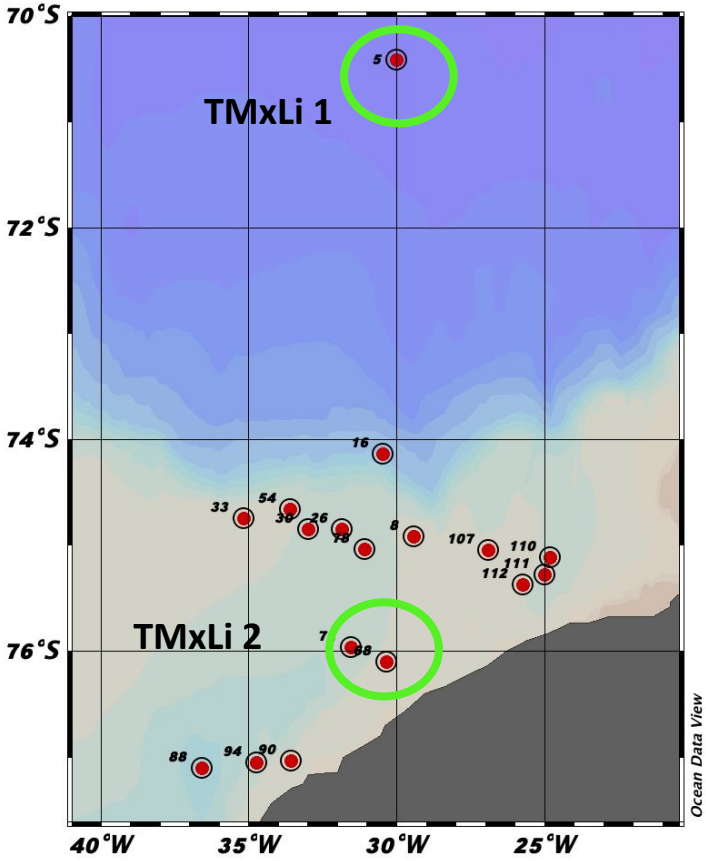
- *P.antarctica* usually dominate blooms in the SO
  (Arrigo *et al.*, 1999)
- Major actor in carbon export from ocean to atmosphere (~ 30%)
  (DiTullio *et al.*, 2000; Wang et Moore, 2011)
- Important role in ocean biogeochemistry and climate regulation: Ideal candidate to study
  (Schoemann *et al.*, 2005)

Chapter 3: Detection of multi co-limitation in the Weddell Sea

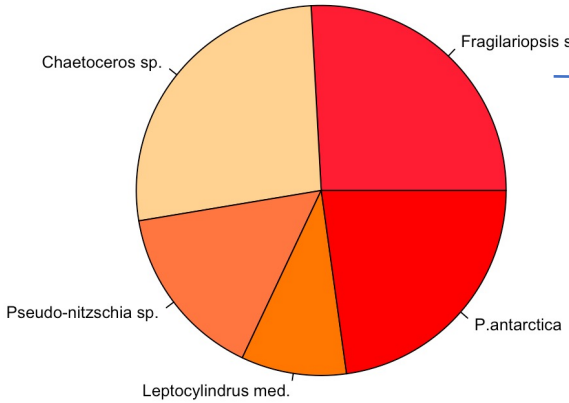
Polarstern cruise PS124

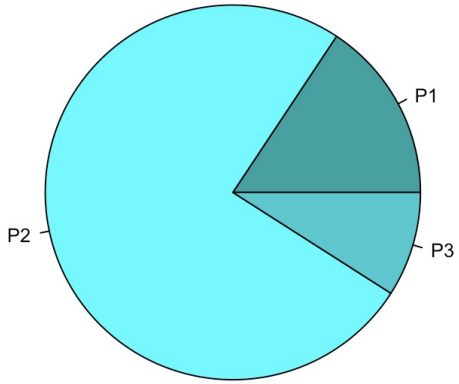
Chl*a* = **0.13** µg L^{-1}
F_v/F_m = **0.28** rel.unit

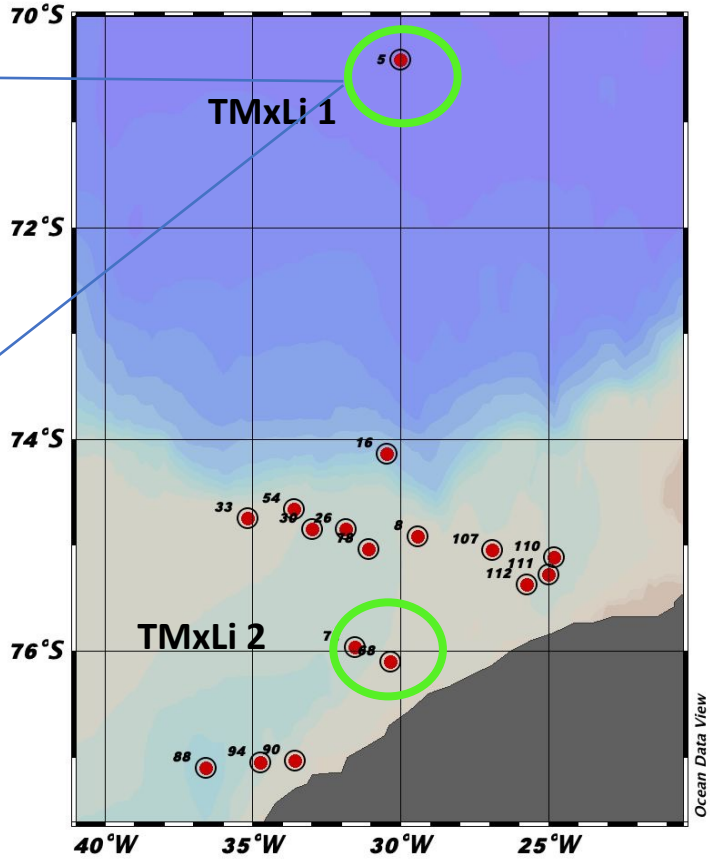
Chl*a* = **0.47** µg L^{-1}
F_v/F_m = 0.26 rel.unit



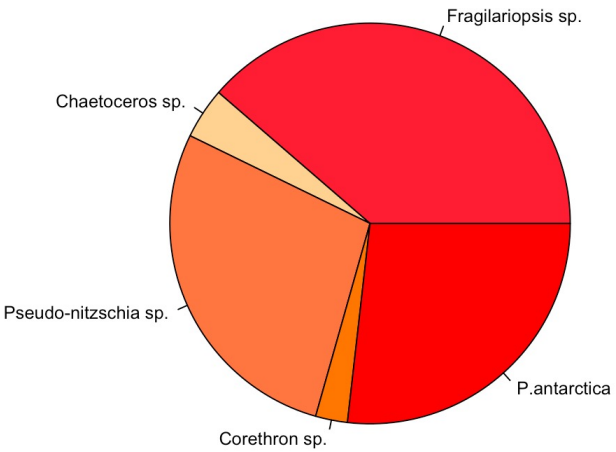
Chapter 3: Detection of multi co-limitation in the Weddell Sea

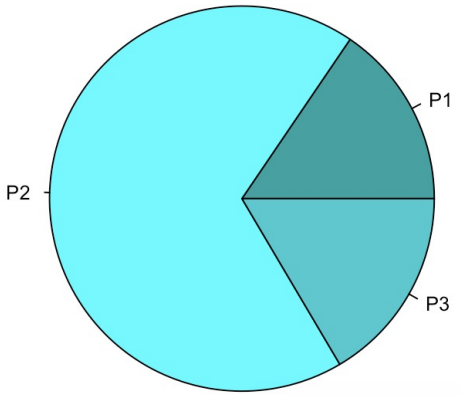


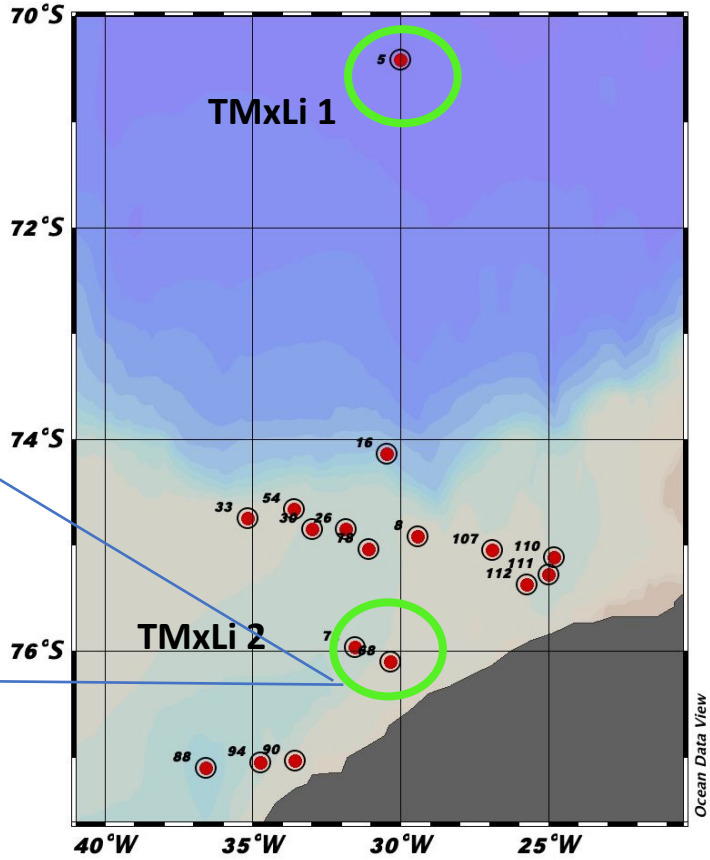




Chapter 3: Detection of multi co-limitation in the Weddell Sea







Chapter 3.

- Data analysis *in process*
- First results showed:
  - Strong relief of Fe and light limitation at both limitation
  - Co-limitation on P2 group at both locations
  - Potential shifts on certain diatoms species with FeMn addition