Universität Bremen

DFG-SCHWERPUNKTPROGRAMM 1158 ANTARKTISFORSCHUNG mit vergleichenden Untersuchungen in arktischen Eisgebieten

Hochschule Bremerhaven

Limitation by iron and manganese of phytoplankton communities in the Drake Passage.

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Context of study

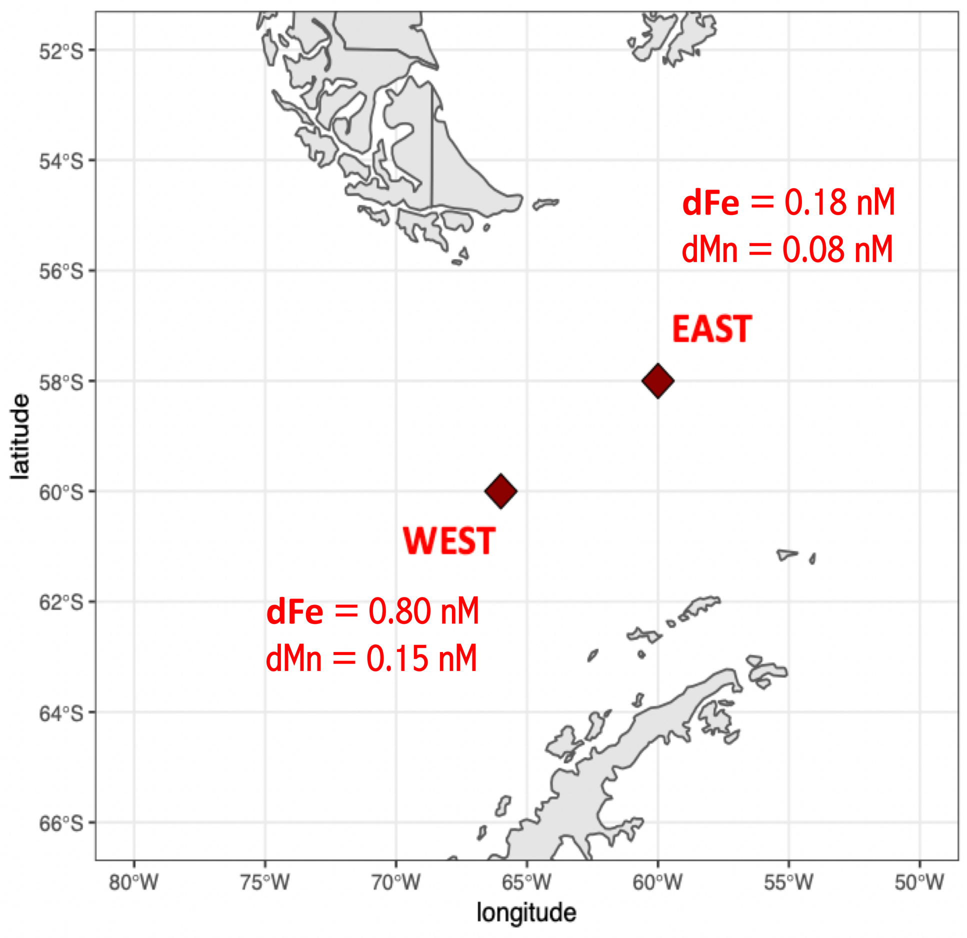
- The Southern Ocean is a High Nutrient Low Chlorophyll **(HNLC)** region
  → Trace metals and especially **Iron (Fe)** availability are the key control for community composition and biomass
  (Martin *et al.*, 1990 ; Boyd *et al.*, 2007 ; Sunda, 2012)
- Co-limitation of **Fe** with **manganese (Mn)** in the Drake Passage was suggested early in1990 (Martin *et al.*, 1990)
- Total dissolved Mn concentrations were found to be very low :
  - North Pacific (Coale, 1991)
  - Southern Ocean : Drake Passage, Scotia and Weddell Sea
    (Martin *et al.*, 1990 ; Buma *et al.*, 1991 ; Middag *et al.*, 2011; Middag *et al.*, 2013)
- Significant stimulation of the photosynthetic activity and biomass buildup after ash additions (including Mn) of phytoplankton assemblages across the Drake Passage were reported (Browning *et al.*, 2014)
- Only supply of Fe and Mn together led to optimal growth, photochemical efficiency and carbon production of the Antarctic diatom *Chaetoceros debilis* (Pausch *et al.*, 2019)

Can Mn act as a limiting factor with Fe ?

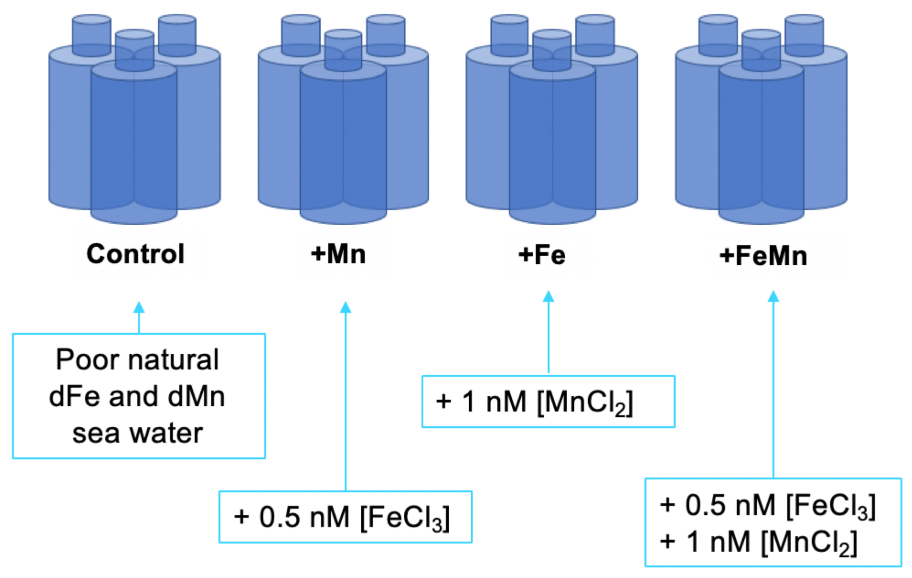
Experiment design

2 indoor trace metals addition experiments conducted for 14 days during Polarstern 97 Expedition in 2016

Goal - Identify Fe-Mn co-limitation and assess phytoplankton sensitivity towards altered trace metal concentrations



Light = 30 µmol photons m^{-2} s^{-1}
Light:dark cycle of 16:8 h
Temperature = 2 °C

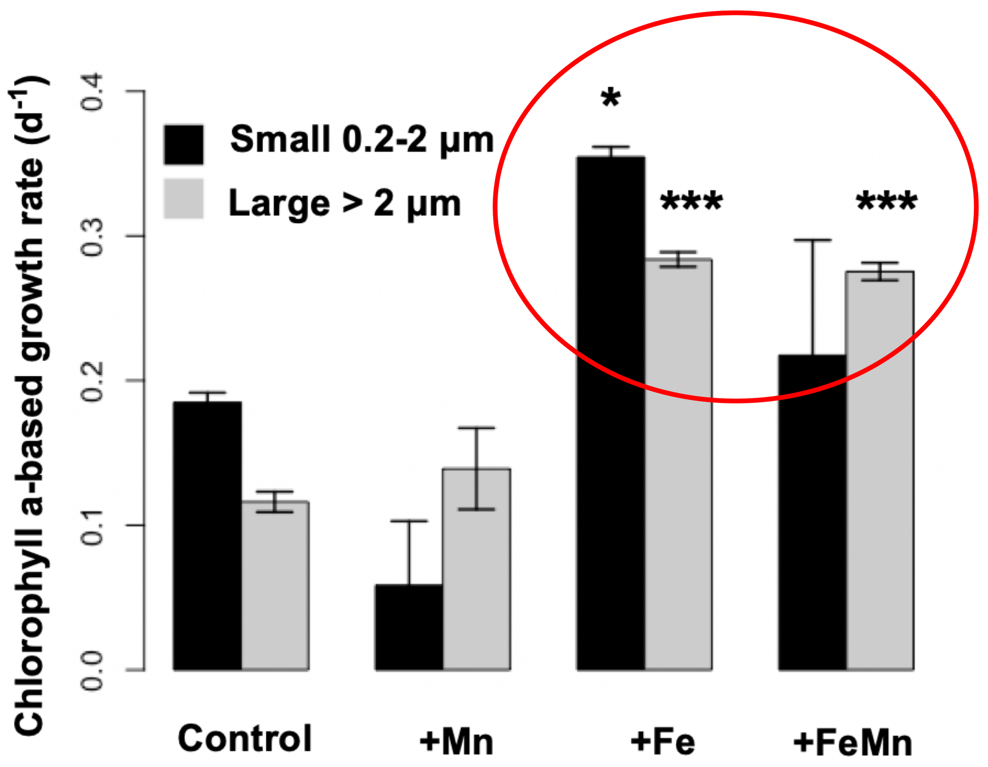


As expected for HNLC region -> High macronutrients concentration
[N] > 23 µmol.L^{-1} // [P] > 1,5 µmol.L^{-1} // [Si] > 16 µmol.L^{-1}

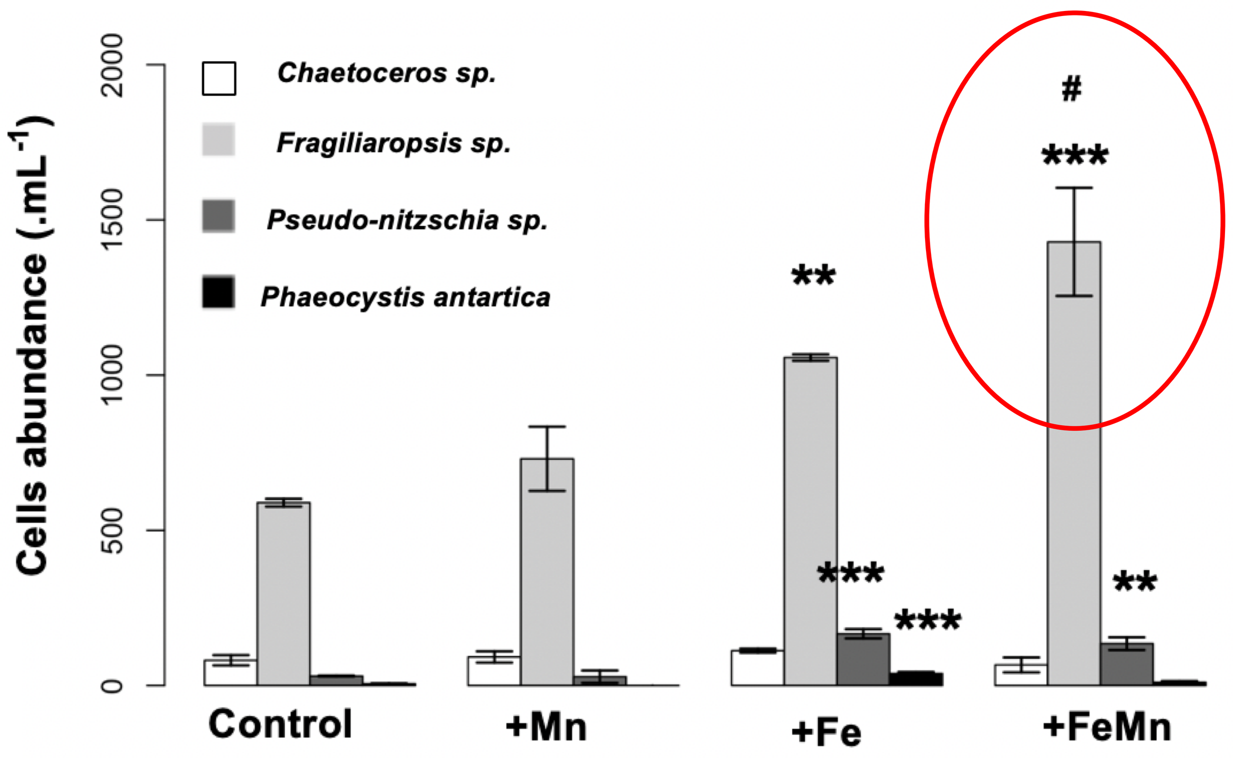
Results

Station East

Day 1 of the experiment
Fv/Fm = 0.27 [rel.unit]
Chl*a* = 0.04 [ug.L^{-1}]

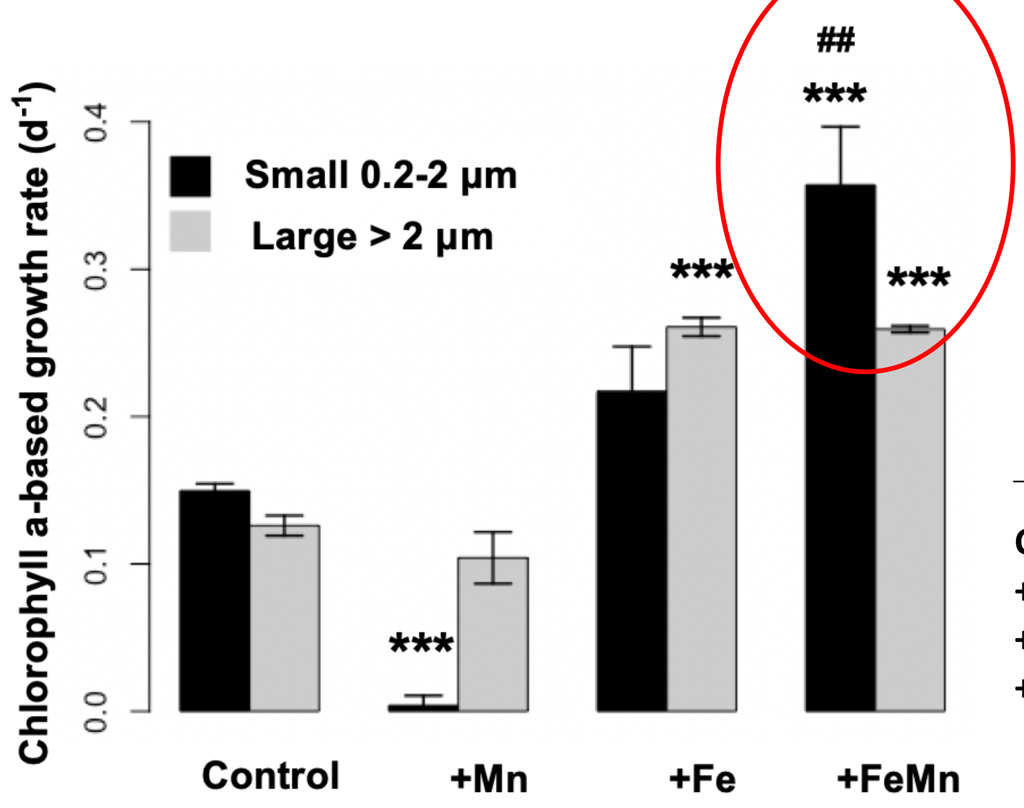


	F_v/F_m rel.unit	σ_{PSII} nm^2
Control	0.26 ± 0.04	4.46 ± 1.01
+Mn	0.25 ± 0.04	4.20 ± 0.73
+Fe	0.44 ± 0.05 ***	4.26 ± 1.51
+FeMn	0.51 ± 0.04 *** ###	2.80 ± 1.24 ***

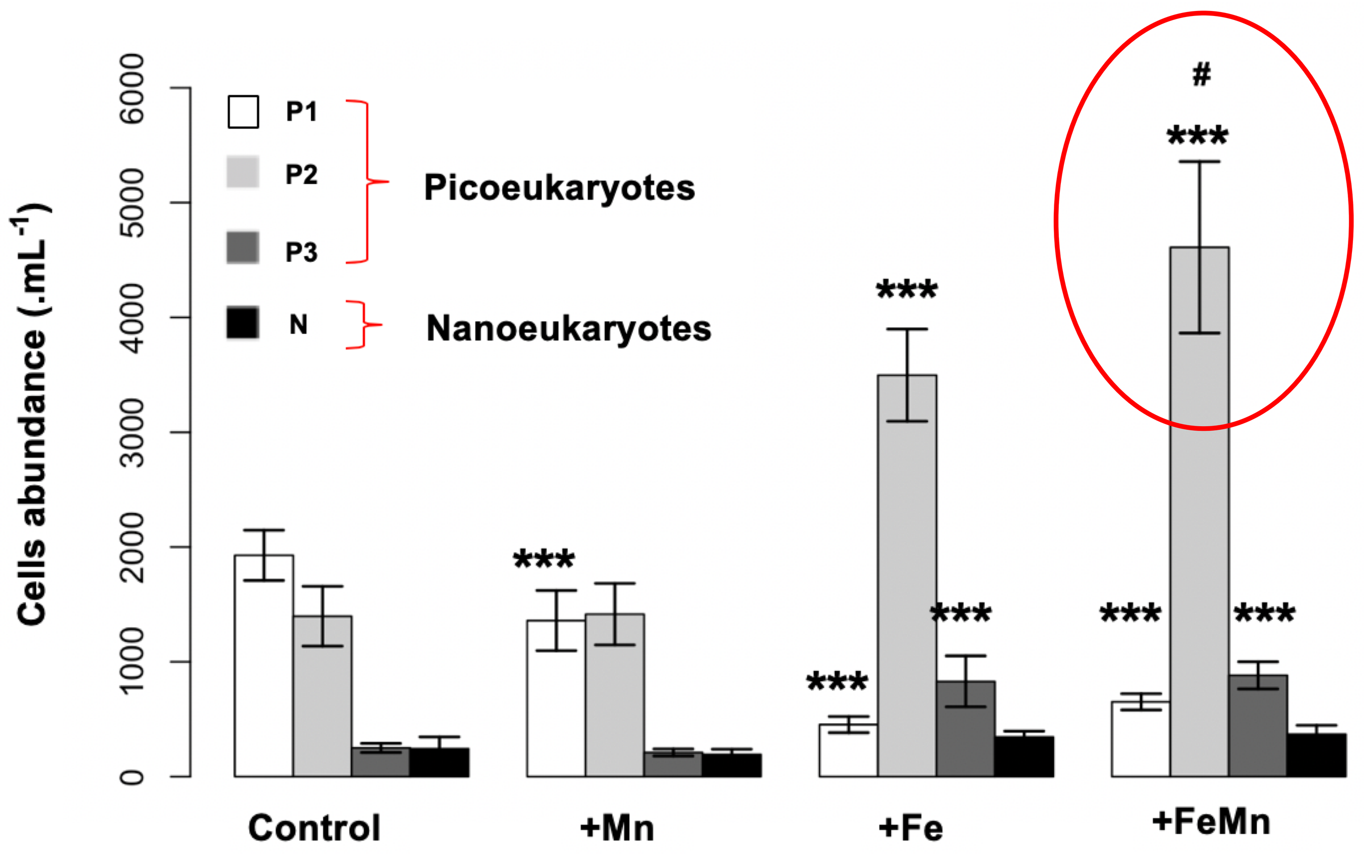


Station West

Day 1 of the experiment
Fv/Fm = 0.18 [rel.unit]
Chl*a* = 0.09 [ug.L^{-1}]



	F_v/F_m rel.unit	σ_{PSII} nm^2
Control	0.25 ± 0.07	3.42 ± 1.15
+Mn	0.27 ± 0.01	4.68 ± 0.52 **
+Fe	0.43 ± 0.05 ***	3.22 ± 1.52
+FeMn	0.47 ± 0.02 *** ##	3.41 ± 1.16



Values represent the mean ± SD (n=3). Statistical differences (ANOVA) for each parameter relative to the Control (*) and between +Fe and +FeMn treatment (#) are denoted by */# p < 0.01, **/## p < 0.001 and */## p < 0.0001.*

Ecological implications

- **Observe changes are not only explained by Fe** → Addition of both trace elements together promoted a shift in the species composition
- **Maximum photosynthetic efficiency** reached only when Fe and Mn were added together
- **On the basis of the photophysiological signature of F_v/F_m and σ_{PSII}** → Fe limitation cannot be differentiated from a Fe-Mn co-limitation
- **To go further** → Species identified in field will be tested under altered trace metal concentrations for a better understanding of their requirements

Boyd PW, Jickells T, Law CS, Blain S et al. 2007. Mesoscale iron enrichment experiments 1993- 2005: Synthesis and future directions. Science 315: 612-617.
Browning TJ, Bouman HA, Henderson GM, Mather TA, et al. 2014. Strong responses of Southern Ocean phytoplankton communities to volcanic ash. Geophys. Res. Lett., 41: 2851-2857.
Buma, A. G., De Baar, H. J., Nolting, R. F., & Van Bennekom, A. J. (1991). Metal enrichment experiments in the Weddell-Scotia Seas: Effects of iron and manganese on various plankton communities. Limnology and Oceanography, 36(8), 1865-1878.
Coale, K.H., 1991. Effects of iron, manganese, copper, and zinc enrichments on productivity and biomass in the subarctic Pacific. Limonology And Oceanography, 36(8), pp.1851– 1864.
Martin, J. H., Gordon, R. M., & Fitzwater, S. E. (1990). Iron in Antarctic waters. Nature, 345(6271), 156.
Martin, J. H., Fitzwater, S. E., & Gordon, R. M. (1990). Iron deficiency limits phytoplankton growth in Antarctic waters. Global Biogeochemical Cycles, 4(1), 5-12.
Middag, R. D., De Baar, H. J. W., Laan, P., Cai, P. V., & Van Ooijen, J. C. (2011). Dissolved manganese in the Atlantic sector of the Southern Ocean. Deep Sea Research Part II: Topical Studies in Oceanography, 58(25-26), 2661-2677.s
Middag, R., de Baar, H. J., Klunder, M. B., & Laan, P. (2013). Fluxes of dissolved aluminum and manganese to the Weddell Sea and indications for manganese co-limitation. Limnology and Oceanography, 58(1), 287-300.
Pausch, F., Bischof, K., Trimborn, S (2019) Iron and manganese co-limit growth of the Southern Ocean diatom Chaetoceros debilis. PLoS ONE
Sunda, W. G. (2012). Feedback interactions between trace metal nutrients and phytoplankton in the ocean. *Front. Microbiol.* 3:204.