Iron and manganese co-limitation - a potential driver of phytoplankton species composition in the Southern Ocean.

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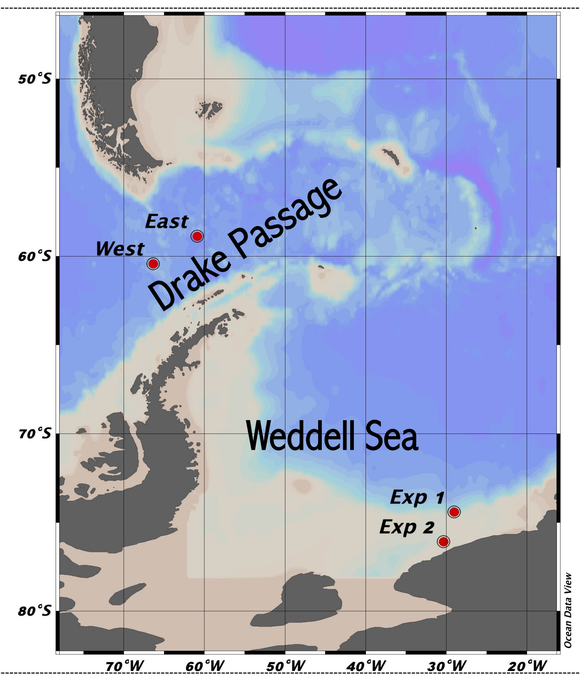
Context of study

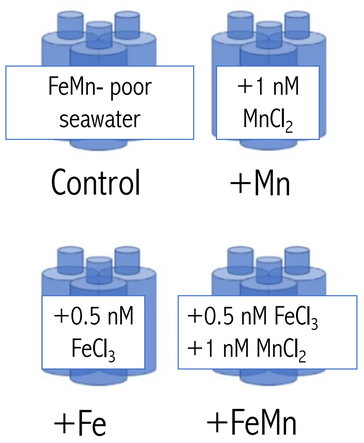
- The Southern Ocean **(SO)** is a High Nutrient Low Chlorophyll **(HNLC)** region
  → Trace metals and especially **iron (Fe)** availability are the key control for biomass buildup
  (Martin *et al.*, 1990; Boyd *et al.*, 2007; Sunda, 2012)
- Co-limitation of **Fe** with **manganese (Mn)** in the Drake Passage was suggested early in1990, but not proven (Martin *et al.*, 1990)
- Total dissolved Mn concentrations were found in the SO to be very low
  (Martin *et al.*, 1990; Buma *et al.*, 1991; Middag *et al.*, 2011; Middag *et al.*, 2013)
- Clear evidence for FeMn co-limitation of phytoplankton biomass in Drake Passage waters (Browning *et al.*, 2014; Browning *et al.*, 2021)

How do Fe and Mn together influence phytoplankton species composition in the SO ?

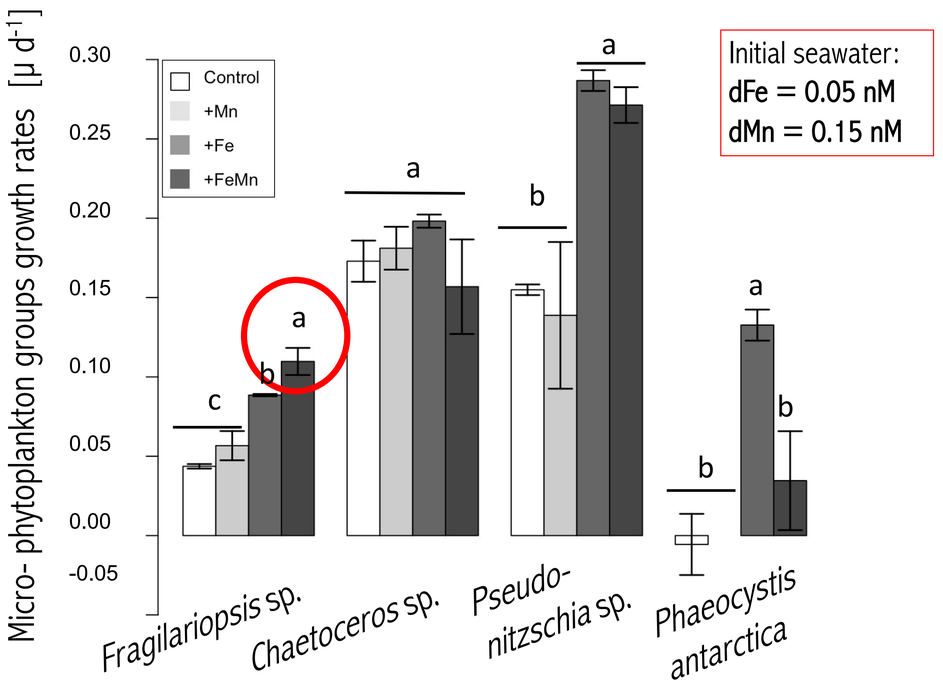


WP1 Field study :

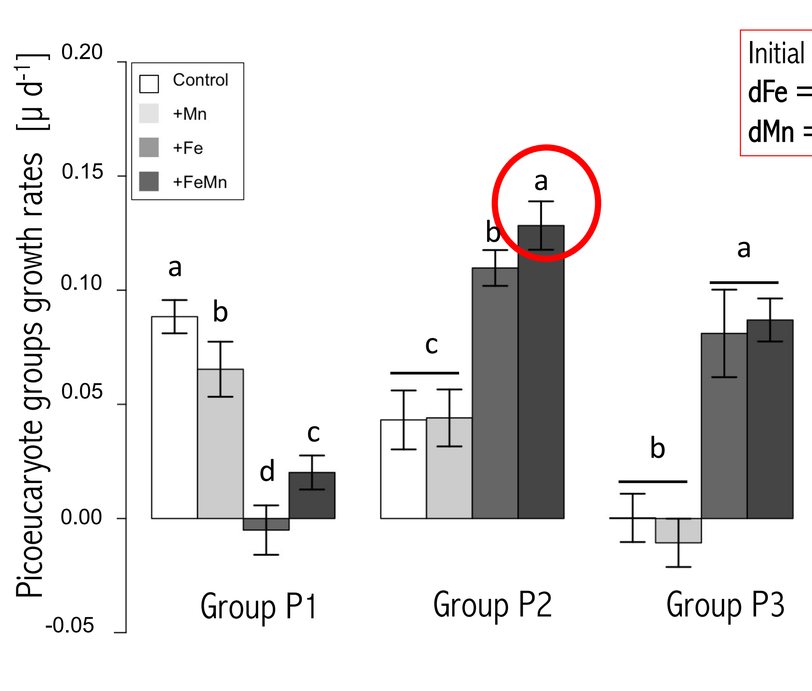
2 shipboard Fe-Mn addition experiments were conducted at the stations West and East in the Drake Passage during: **Polarstern cruise 97 (March – April 2016)**



West Drake Passage: Growth of *Fragilariopsis* sp. was FeMn co-limited

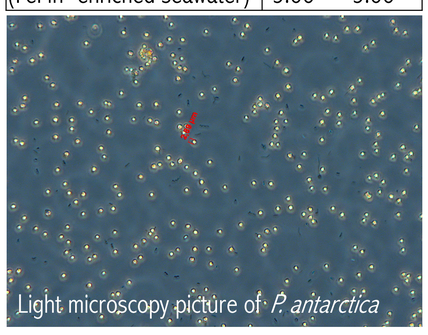


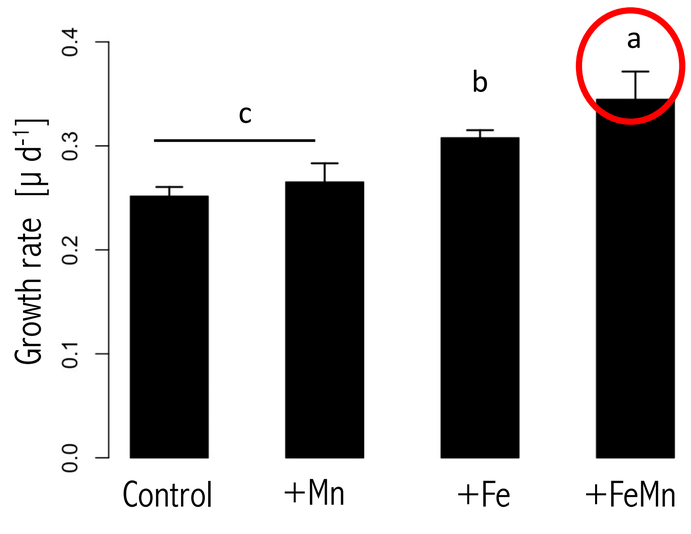
East Drake Passage: Growth of Pico-group P2 was FeMn co-limited



WP2 Laboratory FeMn experiment performed with *Phaeocystis antarctica* :

	dFe [nM]	dMn [nM]
Control (FeMn- poor seawater)	0.16	0.15
+Mn (Fe- poor seawater)	0.16	3.00
+Fe (Mn- poor seawater)	3.00	0.15
+FeMn (FeMn- enriched seawater)	3.00	3.00



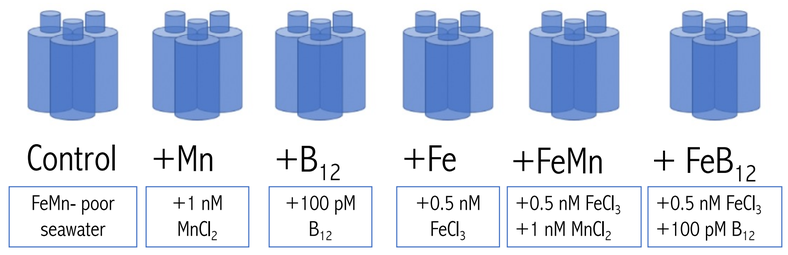


	Particulate organic carbon (pgC $cell^{-1}$ day^{-1})	Photosynthetic efficiency (rel. unit)	Functional absorption cross section of PSII (nm^2)
	POC production	F_v/F_m	σ_{PSII}
Control	1.04 ± 0.06 [b]	0.29 ± 0.03 [c]	9.3 ± 2.8 [b]
+Mn	1.07 ± 0.06 [b]	0.31 ± 0.01 [b]	8.3 ± 0.7 [b]
+Fe	1.40 ± 0.16 [a]	0.29 ± 0.02 [c]	6.6 ± 0.7 [a]
+FeMn	1.41 ± 0.03 [a]	0.36 ± 0.01 [a]	6.2 ± 0.6 [a]

WP3 Light-Fe-Mn-B_{12} experiments in the Weddell Sea :

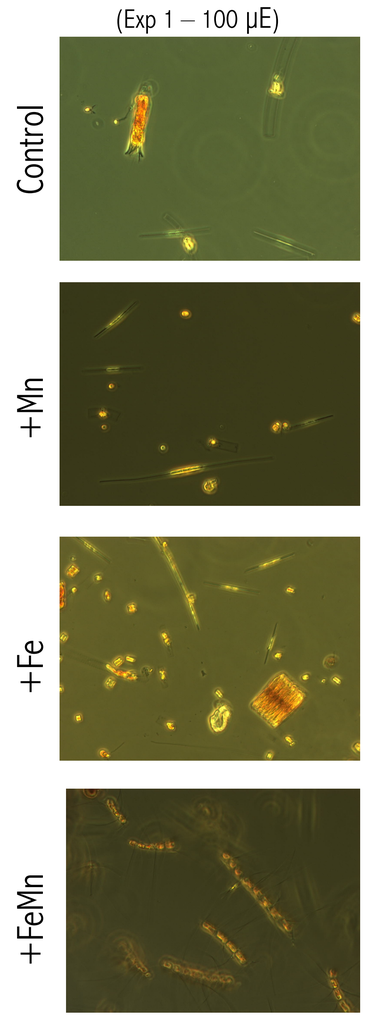
2 shipboard Fe-Mn-B_{12} addition experiments were conducted at 2 stations (**Exp 1 and 2**) during: **Polarstern cruise 124 (February – March 2021)**

The sensitivity of two different phytoplankton communities of the Weddell Sea was assessed towards altered trace metal and light availability



All incubation were either grown at 30 or 100 μE m^{-2} s^{-1} with a light:dark cycle of 20:4h

Example of community changes with altered Fe and Mn (Exp 1 – 100 μE)



Highlights

WP1: Our Fe-Mn addition experiments with two natural phytoplankton communities clearly show that the ecologically and biogeochemical important diatom group *Fragilariopsis* and one subgroup of picoeukaryotes were Fe-Mn co-limited. **Status:** Paper *in review* - **Balaguer** J, Koch F, Hassler C, Trimborn S. Phytoplankton species composition is governed by both iron and manganese in the Drake Passage. In review. Communications Biology -

WP2: Growth of *Phaeocysis antarctica* was FeMn co-limited and Mn seemed to control the photosynthetic efficiency - **Status**: Paper *in preparation*

WP3: Preminelary results showed a relief of Fe and light limitation at both locations and potential FeMn co-limitation on certain diatom species- **Status**: Samples analysis *still ongoing*

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.
Browning, T. J., Achterberg, E. P., Engel, A., & Mawji, E. (2021). Manganese co-limitation of phytoplankton growth and major nutrient drawdown in the Southern Ocean. *Nature communications*, *12*(1), 1-9.
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 aluminium and manganese to the Weddell Sea and indications for manganese co-limitation. Limnology and Oceanography, 58(1), 287-300.
Sunda, W. G. (2012). Feedback interactions between trace metal nutrients and phytoplankton in the ocean. *Front. Microbiol.* 3:204.