Supplementary material – Hassler and Schoemann

Intracellular and extracellular Fe pool were normalised in an attempt to identify parameters explaining the variability of Fe uptake for Antarctic phytoplankton (Table 1). The least variability was observed when Fe pool was normalised per surface area. The surface to volume, Chl *a* content or volume could not explain the variable Fe uptake for the 4 strains selected in this study. Contrary to what can be calculated for nutrient diffusive supply to phytoplankton (Pahlow et al., 1997), previous studies also showed a weak dependence for the maximal growth rate and Fe requirement for Antarctic phytoplankton on cell size, surface area or shape factor (Sommer 1989, Timmermans et al., 2004). However, Fe biological requirement for growth are usually higher for larger Antarctic diatoms (Timmermans et al., 2004). It is known that variable micro-organisms have different uptake strategies and that Fe uptake can be up-regulated under limiting conditions (e.g. Hutchins et al., 1999, Völker and Wolf-Gladow 1999). In addition, Fe limitation is also known to affect pigments and cellular Chl *a* composition (van Leeuwe and Stefels, 1998), cell size (Sunda and Huntsman, 1995) or Fe biological requirement (e.g. flavodoxin replacement of ferredoxin, e.g. Mc Kay et al., 2005). Fe biological requirement is also very different for variable phytoplankton. Fe half saturation constant for diatom growth in the Southern Ocean were 0.62 nM for a large *Thalassiosira* sp. (A = 12'000 μm^2), 0.19 nM for *Fragilariopsis kerguelensis* and estimated to 0.0006 nM for the small *Chaetoceros brevis* (A = 61 μm^2, Timmermans et al., 2001; 2004). Under these circumstances, it is not surprising that the variability of Fe uptake for the strains selected could not be explained by Chl *a*, surface to volume ratio or volume.

In order to improve existing model used to predict the bioavailability of organically bound iron and associated global impact (Tagliabue and Arrigo, 2006; Tagliabue et al., 2009), one has not only to consider cycling and production pathways of organic ligands reacting with Fe. The variable bioavailabilities of strongly (L1 or Lb) or weakly (L2 or La) bound iron to eukaryotic and bacterioplankton need also to be included, with La being bioavailable to all plankton classes but Lb being mostly available to bacterioplankton only (see Hunter and Boyd, 2007). It is worth mentioning that for organically-complexed Fe to be bioavailable it does not necessarily imply that the complex itself is directly bioavailable, but that the complex is labile or chemically reactive enough to be dissociated before being taken up (see van Leeuwen, 1999 and Morel et al., 2008). Finally, both La and Lb should be

sensitive to light. We have summarised (Fig. 1) the potential impact that such ligands could have on iron bioavailability to bacterio- and phyto-plankton. At present this scheme is simplified as it only considers biological consumption of organic ligands by bacterioplankton but not by mixotrophic phytoplankton or protozoa.

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Table 1. Intracellular Fe uptake rate (amol Fe $cell^{-1}$ h^{-1}) and extracellular Fe pool (amol Fe $cell^{-1}$) normalised against cellular Chl *a* (pg Chl *a* $cell^{-1}$, determined by fluorimetry), surface area (A, μm^2), and cell aspect ratio (surface area to volume ratio, A/V, μm^{-1}) for *Phaeocystis sp.(Phaeo), Chaetoceros sp.(Chaet), Thalasiossira antarctica Comber* (*Thal*) and *Fragilariopsis kerguelensis* (*Frag*). For *Fragilariopsis* Fe/chain was normalised against A and A/V considering the average cells number per chain measured (27.7 cells/chain). The average of two replicates for each strain is shown with its half interval. Minimal and maximal inter-strain variation is shown for each parameter.

	Treatment	**Cellular fraction**	***Phaeo***	***Chaet***	***Thal***	***Frag***	**Min**	**Max**
Fe/cell	CONT	Fe int	0.89 ± 0.01	0.36 ± 0.01	3.27 ± 0.11	1.86 ± 0.05	1.8	9.0
		Fe ext	1.42 ± 0.01	0.58 ± 0.01	4.04 ± 0.23	3.41 ± 0.39	1.2	7.0
	Fe	Fe int	1.22 ± 0.04	0.59 ± 0.13	10.94 ± 0.05	2.22 ± 0.01	2.1	18.5
		Fe ext	4.24 ± 0.02	3.06 ± 0.13	9.76 ± 0.64	15.38 ± 0.36	1.4	5.0
Fe/Chl *a*	CONT	Fe int	1.45 ± 0.02	2.82 ± 0.08	0.03 ± 0.00	0.03 ± 0.00	1.9	88.1
		Fe ext	2.30 ± 0.01	4.49 ± 0.08	0.04 ± 0.00	0.06 ± 0.01	2.3	119.5
	Fe	Fe int	1.98 ± 0.06	4.59 ± 1.01	0.11 ± 0.00	0.04 ± 0.00	1.9	109.5
		Fe ext	6.86 ± 0.03	23.74 ±1.01	0.10 ± 0.01	0.27 ± 0.01	3.5	237.4
Fe/A	CONT ×100	Fe int	1.13 ± 0.02	0.59 ± 0.02	0.41 ± 0.01	0.20 ±0.01	1.4	5.7
		Fe ext	1.80 ± 0.01	0.94 ± 0.02	0.50 ± 0.03	0.37 ±0.05	1.4	4.9
	Fe ×100	Fe int	1.55 ±	0.96 ±	1.37 ±	0.24	1.1	6.5

			0.05	0.21	0.01	±0.001		
		Fe ext	5.37 ± 0.02	4.94 ± 0.13	1.22 ± 0.08	1.65 ±0.04	1.1	4.4
Fe/ (A/V)	CONT	Fe int	0.72 ± 0.01	0.18 ±0.000	6.95 ± 0.22	429.4 ± 11.5	3.9	2394
		Fe ext	1.14 ± 0.01	0.29 ± 0.003	8.60 ± 0.49	787.9 ± 114.0	3.9	2717
	Fe	Fe int	0.98 ± 0.03	0.30 ± 0.04	23.28 ± 0.10	512.4 ± 2.31	3.3	1708
		Fe ext	3.39 ± 0.02	1.53 ± 0.004	20.77 ± 1.36	3550 ± 83.1	2.2	2320
Fe/V	CONT ×100	Fe int	1.30 ± 0.02	1.18 ± 0.03	0.19 ± 0.01	0.02 ± 0.00	1.1	57
		Fe ext	2.06 ± 0.01	1.87 ± 0.03	0.23 ± 0.01	0.04 ± 0.01	1.1	49.2
	Fe ×100	Fe int	1.77 ± 0.05	1.91 ± 0.42	0.63 ± 0.00	0.03 ± 0.00	1.1	70.2
		Fe ext	6.15 ± 0.03	9.88 ± 0.51	0.56 ± 0.04	0.19 ± 0.00	1.6	52.3

Table 2. Short-term (2h) cellular carbon uptake rate (C_{int}, fmol C $cell^{-1}$ h^{-1}) in the control treatment (filtered Antarctic seawater) normalised against cellular Chl *a* (pg Chl *a* $cell^{-1}$), biovolume (V), surface area (A, μm^2 $cell^{-1}$), and surface to volume ratio (A/V, μm^{-1}) for *Phaeocystis sp. (Phaeo)*, *Chaetoceros sp.(Chaet)*, *Thalasiossira antarctica Comber (Thal)* and *Fragilariopsis kerguelensis (Frag).* For *Fragilariopsis* Fe/chain was normalised against A and A/V considering the average cells number per chain measured (27.7 cells/chain).The average of two replicates for each strain is shown with its half interval. Minimal and maximal inter-strain variation is shown for each parameter.

	Phaeo	***Chaet***	***Thal***	***Frag***	**Min**	**Max**
C/cell	61.2 ± 3.50	19.1 ± 0.39	937.6 ± 20.6	2417 ± 127	2.6	126.4
C/ Chl *a*	99.0 ± 5.66	148 ± 3.04	9.59 ± 0.21	41.8 ± 2.19	1.5	15.5
C/A	0.77 ± 0.04	0.31 ± 0.01	1.17 ± 0.03	2.59 ± 0.14	1.5	8.4
C/(A/V)	76.5 ± 4.37	9.51 ± 0.19	1995 ± 43.7	557991 ± 29218	8.0	58674
C/V	0.89 ± 0.05	0.62 ± 0.01	0.54 ± 0.01	0.31 ± 0.02	1.1	2.9

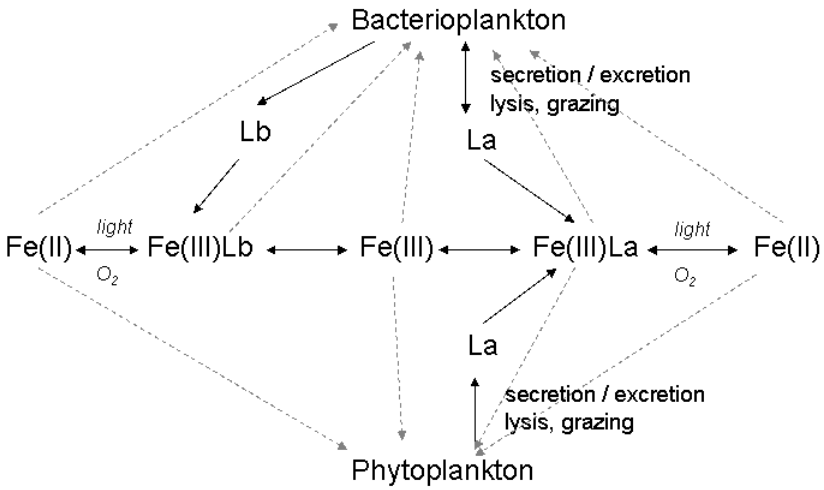

Figure 1. Schematic representation of the release and cycling of organic ligands and subsequent effect on the chemistry and the bioavailability of iron for planktonic organisms. La and Lb were respectively the weak and strong ligands used in the Fe marine cycle model developed by Tagliabue et al. (Tagliabue and Arrigo, 2006; Tagliabue et al., 2009). Dashed arrows represent iron forms that are potentially bioavailable to primary producers. Note that bacterioplankton can produce and consume La ligands. Activity of mixotrophic phytoplankton (not considered here) could also lead to a consumption of La.