Effects of Light and Iron on Growth and Physiology of a Polar Diatom, *Fragilariopsis cylindrus:* Implications for Biogeochemcial Cycles

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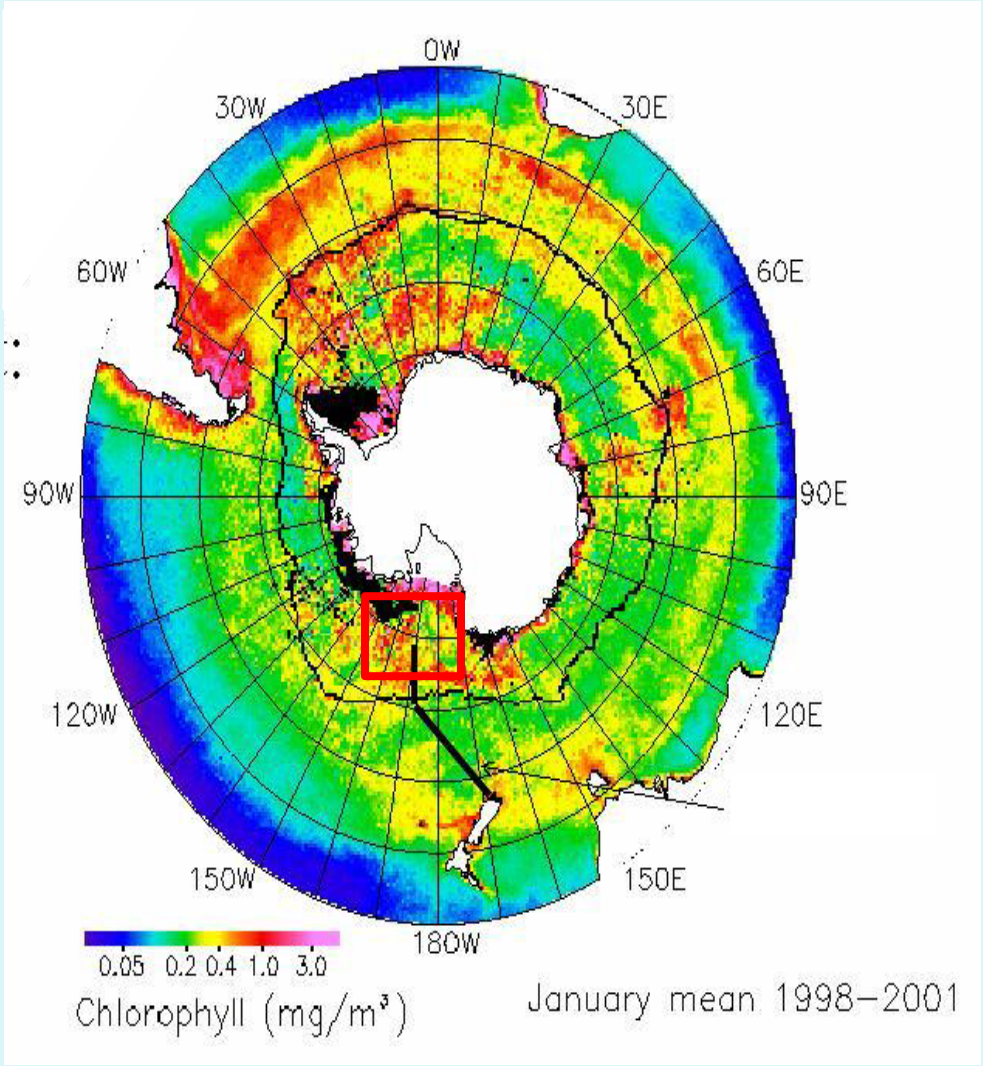
Brown Bag Seminar

May 17th, 2012

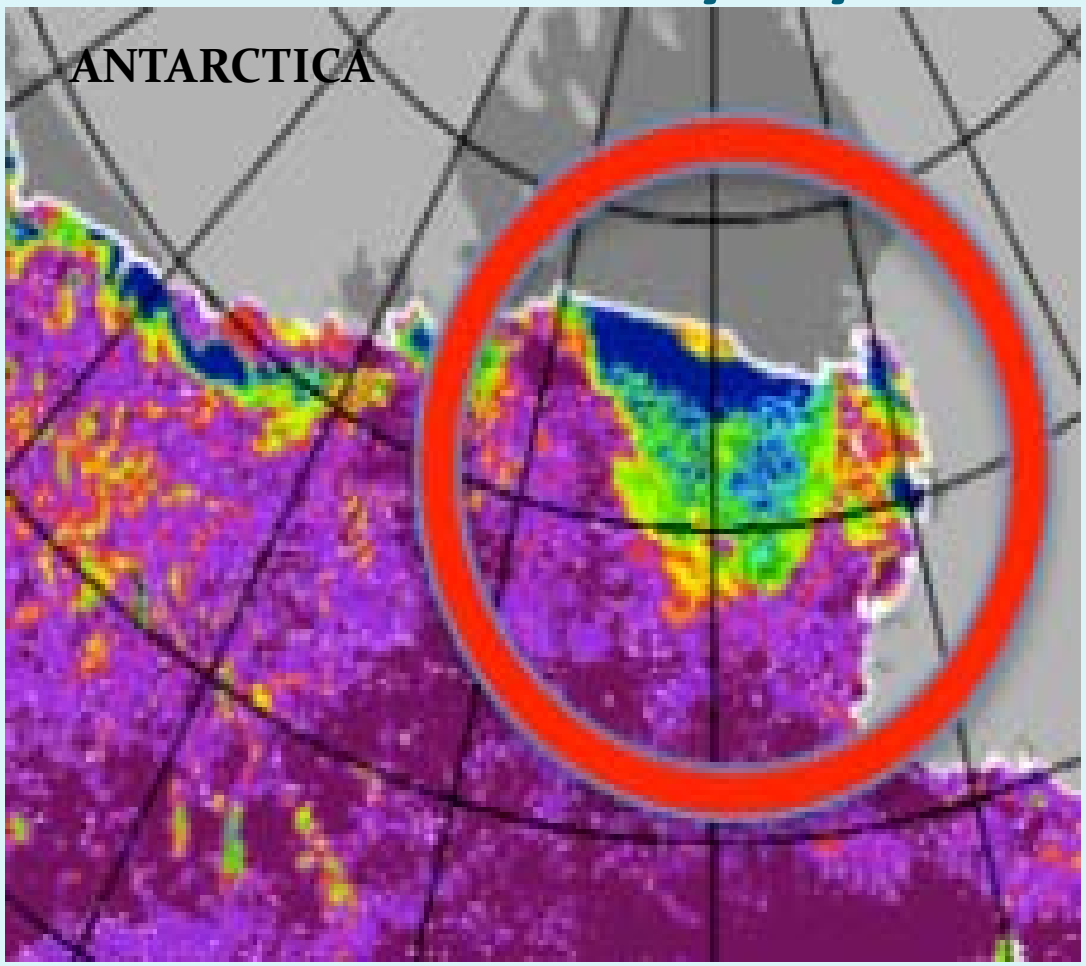
Southern Ocean

- HNLC
  - iron (Fe) limited
  - deep vertical mixing
  - species composition
- ~30% of ocean's primary productivity & C export
- global biogeochemical cycles (C, N, S)
- sensitivity of high latitudes to shifts in climate



SOFeX Adapted from www.mbari.org

Ross Sea Polynya

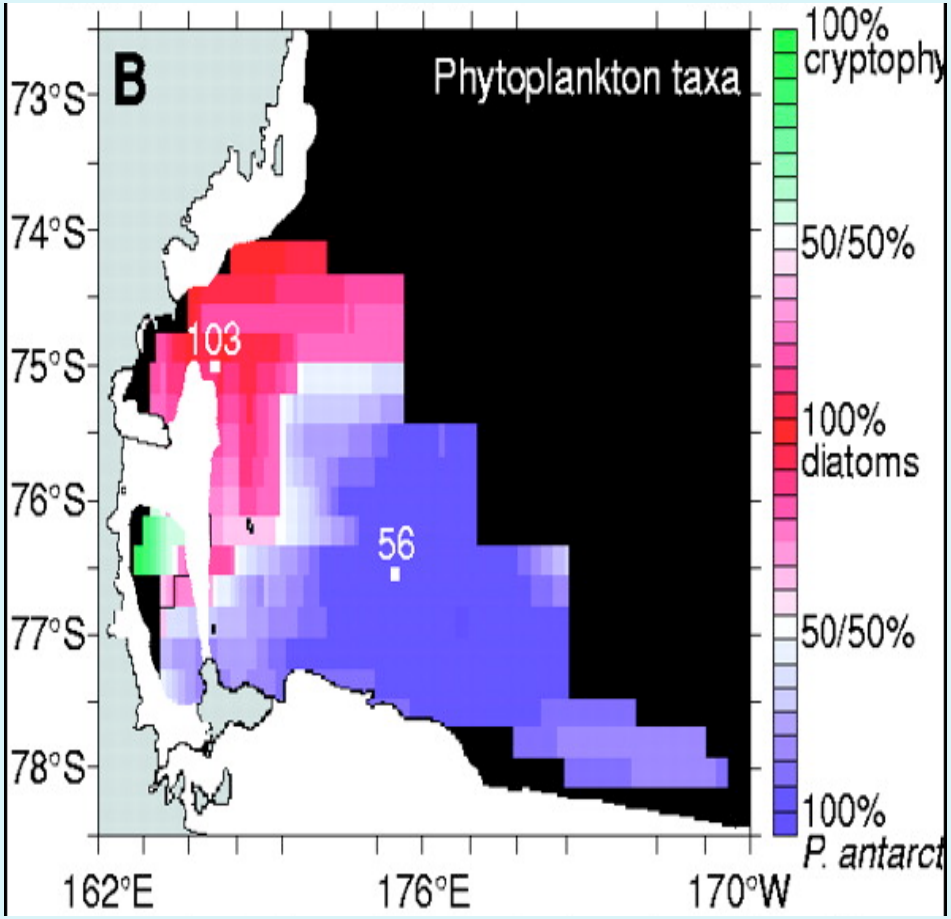


Nov 2010 ice cover, adapted from PolarView Universiat Brenen

- extremely high 1° production
- 27% of C export in Southern Ocean
- dynamic light and nutrient regime
- predicted to change with shifts in climate

Bloom Dynamics

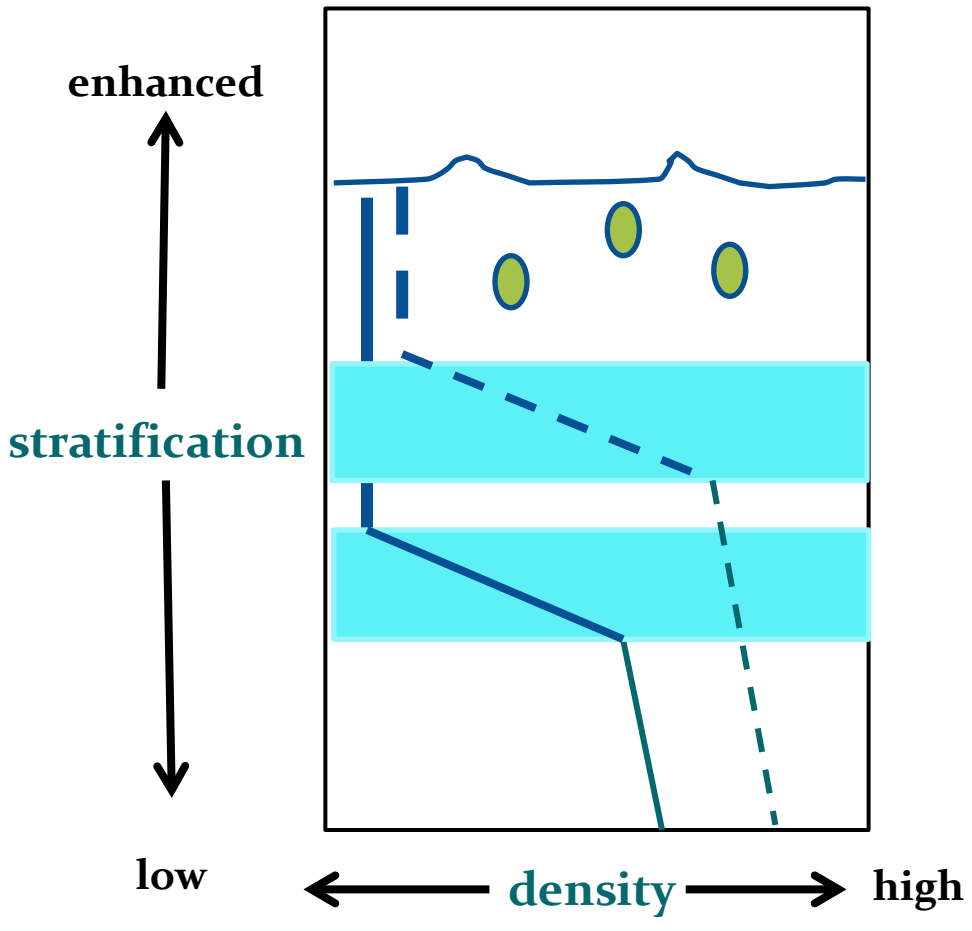
- 2 taxa
  - *Phaeocystis antarctica*
    - Prymnesiophyceae
    - deep mixed layer (DML)
      - lower irradiance regime
  - diatoms
    - Bacillariophyceae
    - shallow mixed layer (SML)
      - higher irradiance regime
  - spatio-temporal trends
    - driven by Fe and light



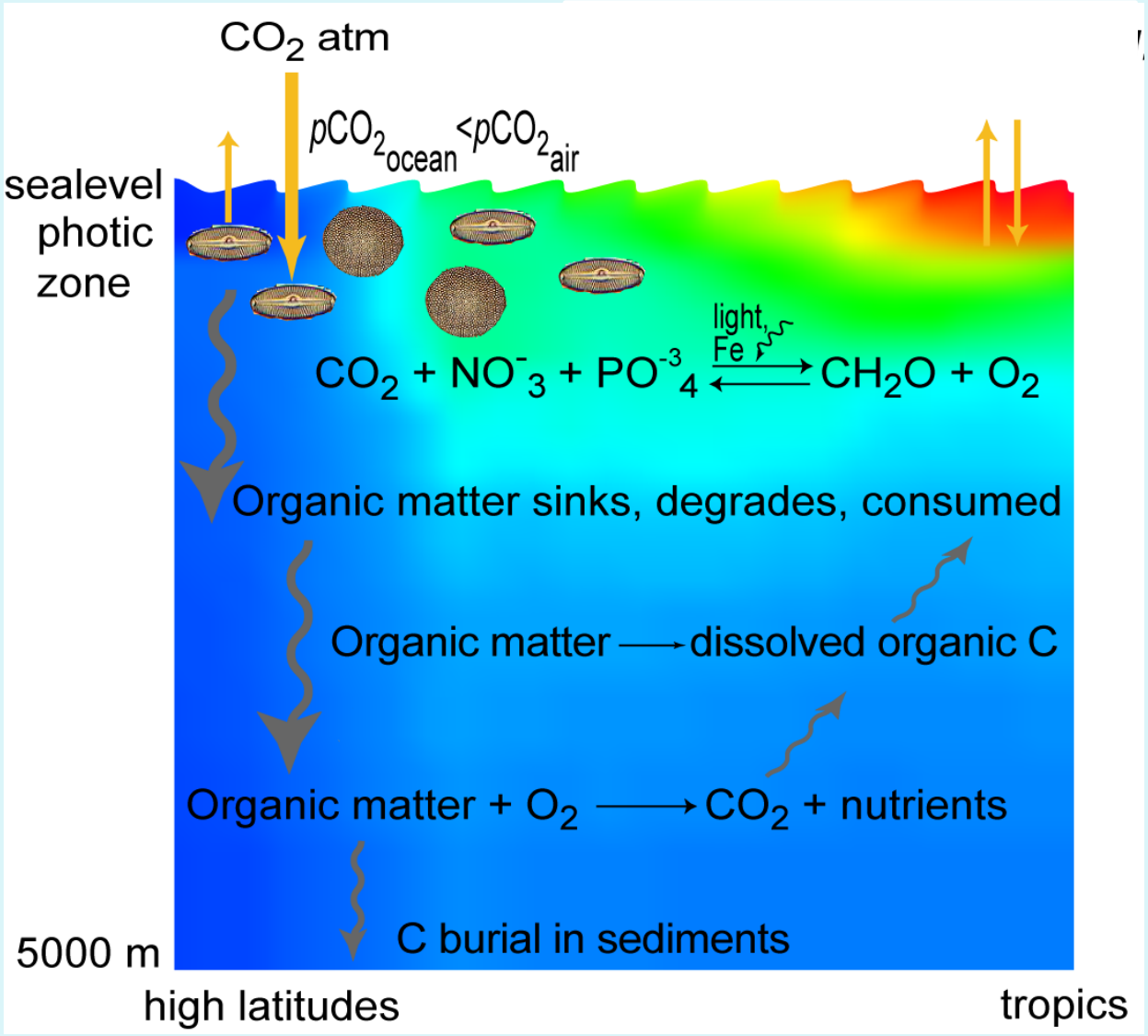
Adapted from Arrigo et al. 1999

Predicted changes in light and iron

- increased temperature
- increased rainfall
  (Sarmiento et al. 1998)
- increased pycnocline
  - irradiance
  - decrease flux of Fe across pycnocline
- stratification effects on species composition?



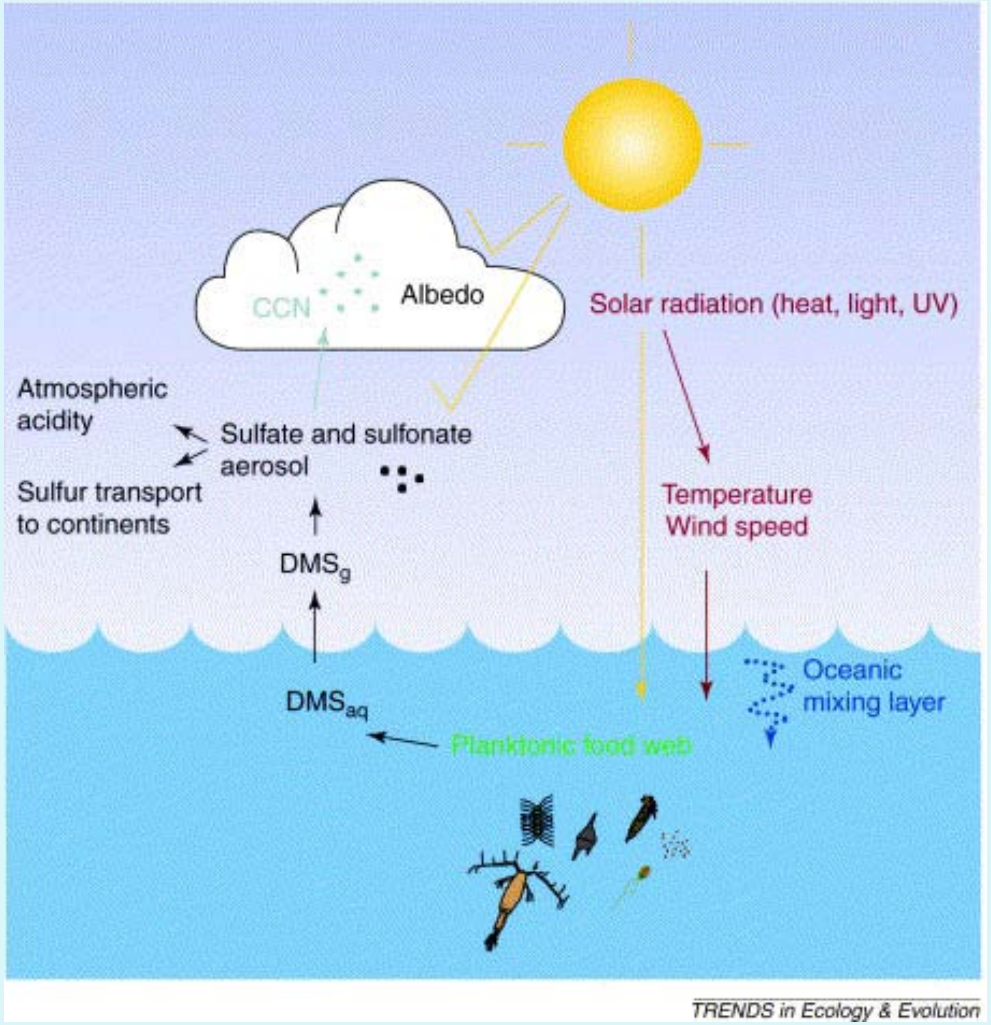
"Biological Pump"



- C fixed by photosynthetic organisms
- *P. antarctica* vs. diatoms
  - C fixation rates
  - sinking rates
  - grazing pressure
    - DMS/P
- impacts on global C (and S) cycles?

DMSP

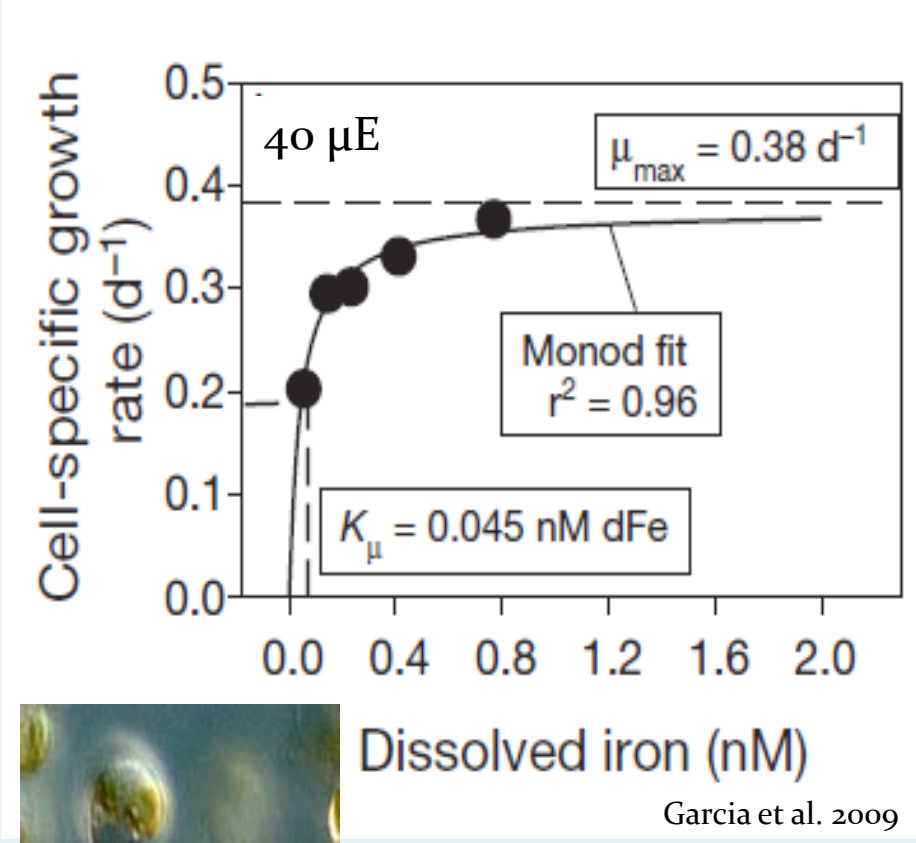
- Dimethyl-sulfoniopropionate
- many proposed functions within the cell
  - cryoprotectant
  - osmolyte
  - defense deterrent
  - anti-oxidant
- sulfur cycles and climate feedback
- *P. antarctica* major contributor
  - diatom contribution



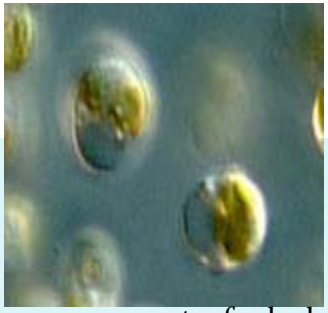
Simo et al. 2001

P. antarctica

- DMSP
  - 125-350 mM
- grazing
- dynamic iron requirement as a function of irradiance
  - dFe
  - Fe'- free inorganic Fe
    - Bioavailable

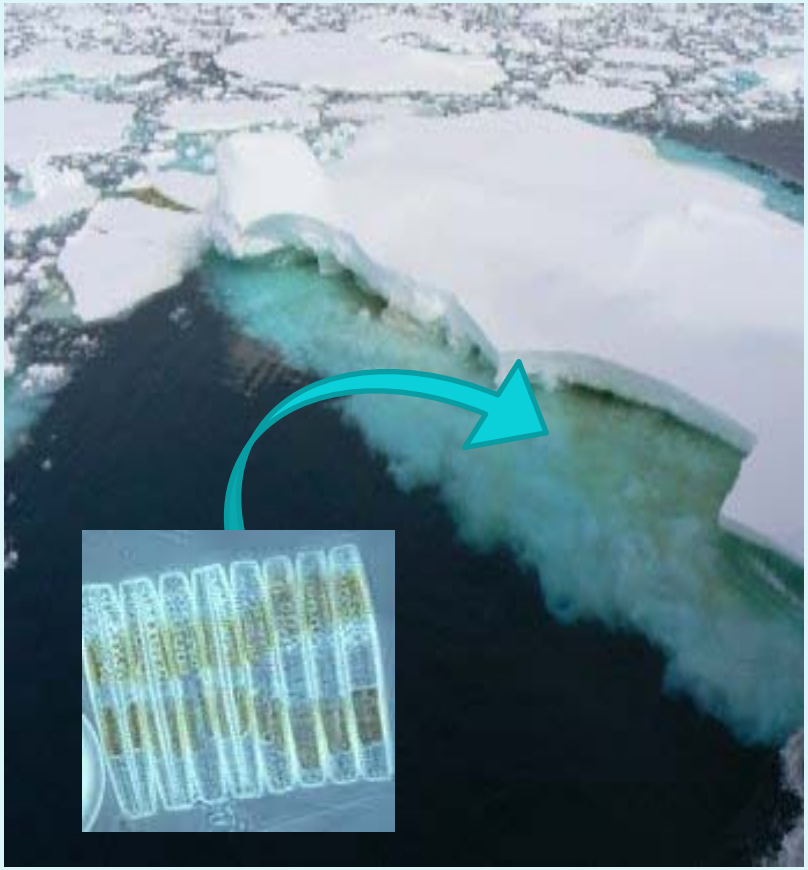


Garcia et al. 2009



ocean.stanford.edu

Fragilariopsis cylindrus (Grunow 1883)



- dominant diatom in this region
- inhabits various habitats
  - sea-ice
  - near-shore waters
- acclimates to variable conditions
  - temperature
  - salinity
  - light
  - Micro-nutrients (i.e. Fe)

Pigments

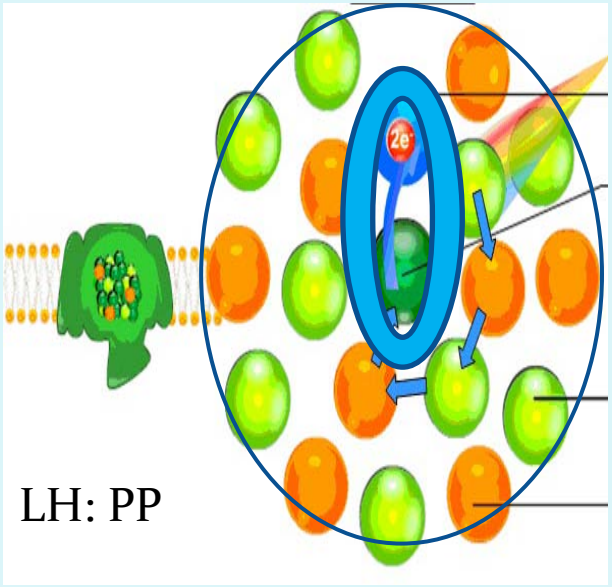
Light harvesting pigments

- chlorophylls
- transferred excitation energy is utilized to transfer electrons to the acceptor in the reaction center

Photoprotective pigments

- carotenoids
- transfer of excitation energy OR potentially remove excitation energy from chlorophyll

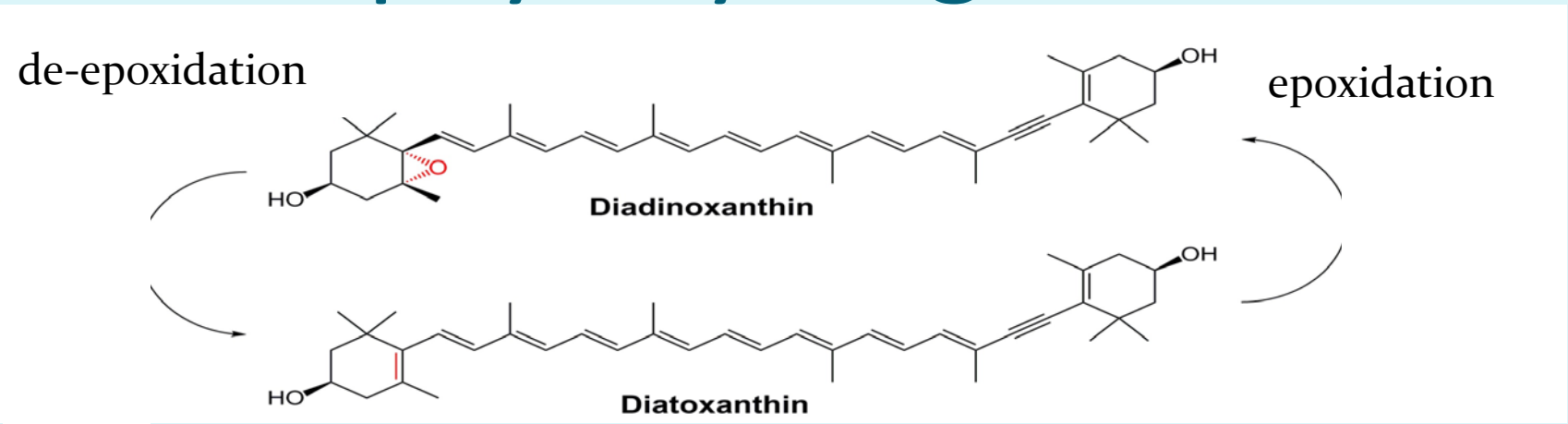
- chl-a
- chl-c
- fucoxanthin



diadinoxanthin(DD)

diatoxanthin (DT)

Xanthophyll Cycling



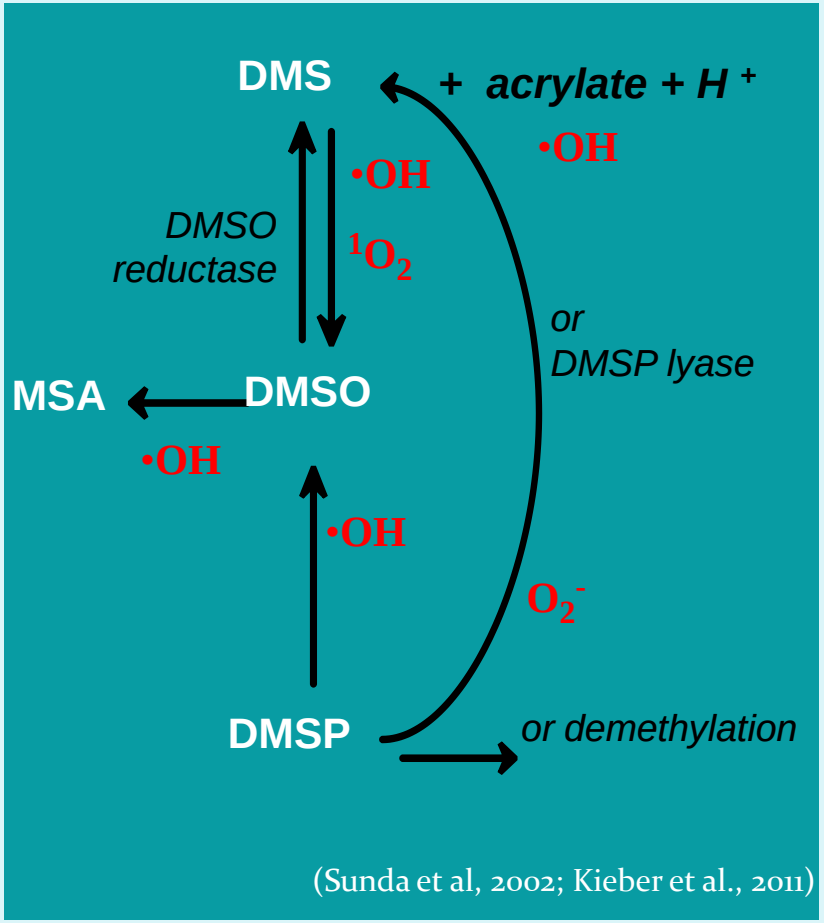
- photoprotective pigments
  - carotenoids
    - diadinoxanthin (DD)

    & diatoxanthin (DT)

- photoprotective role
  - non-photochemical quenching (NPQ)
  - expressed as DT:DD+DT
    - ↑ DT = ↑ xanthophyll cycling

DMSP and ROS

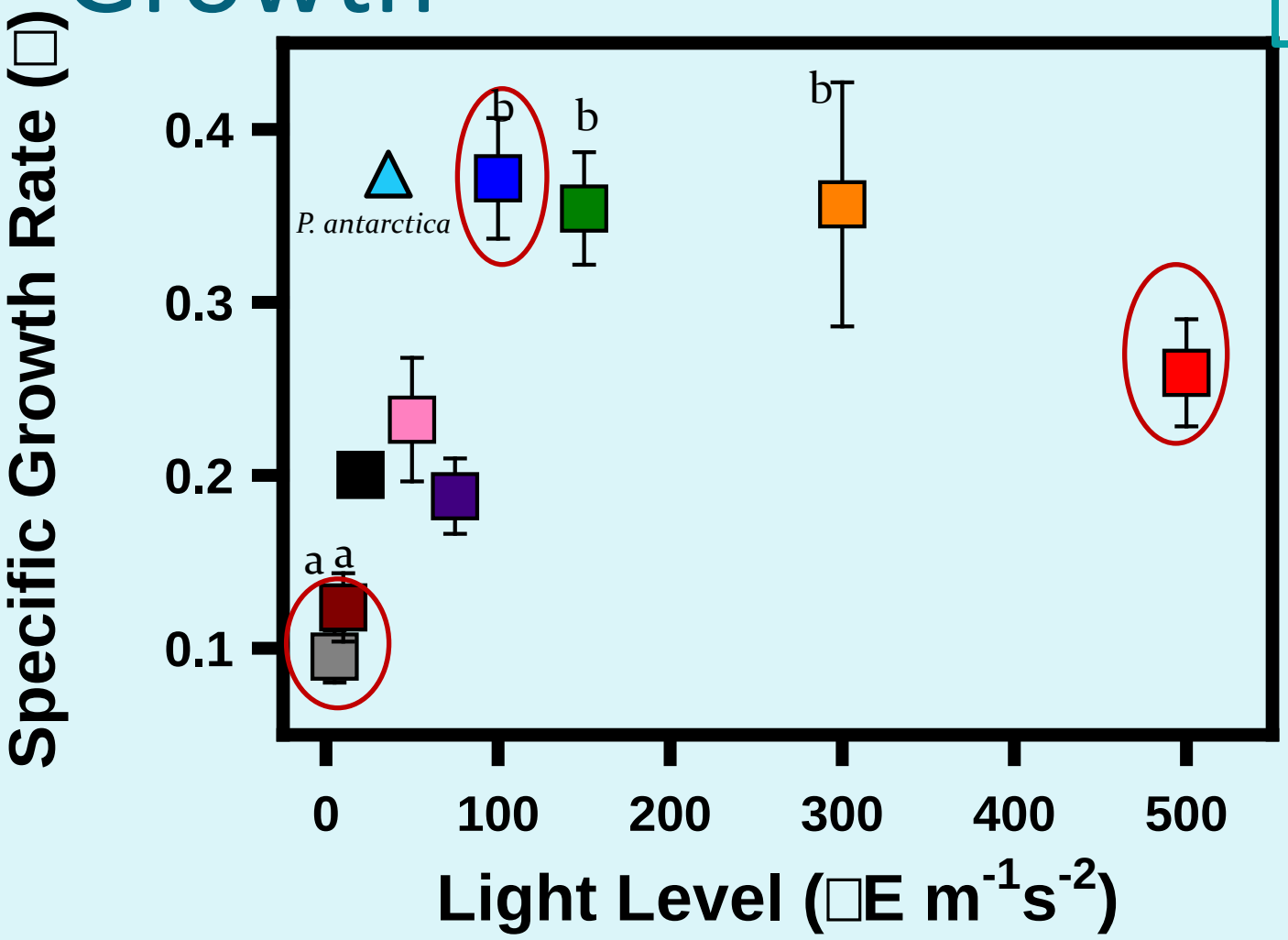
- reactive oxygen species (ROS)
  - i.e. ·OH, · O_2-, H_2O_2
  - byproduct of metabolism
  - increases under stressful conditions→ oxidative stress
- DMSP & its derivatives



(Sunda et al, 2002; Kieber et al., 2011)

Growth

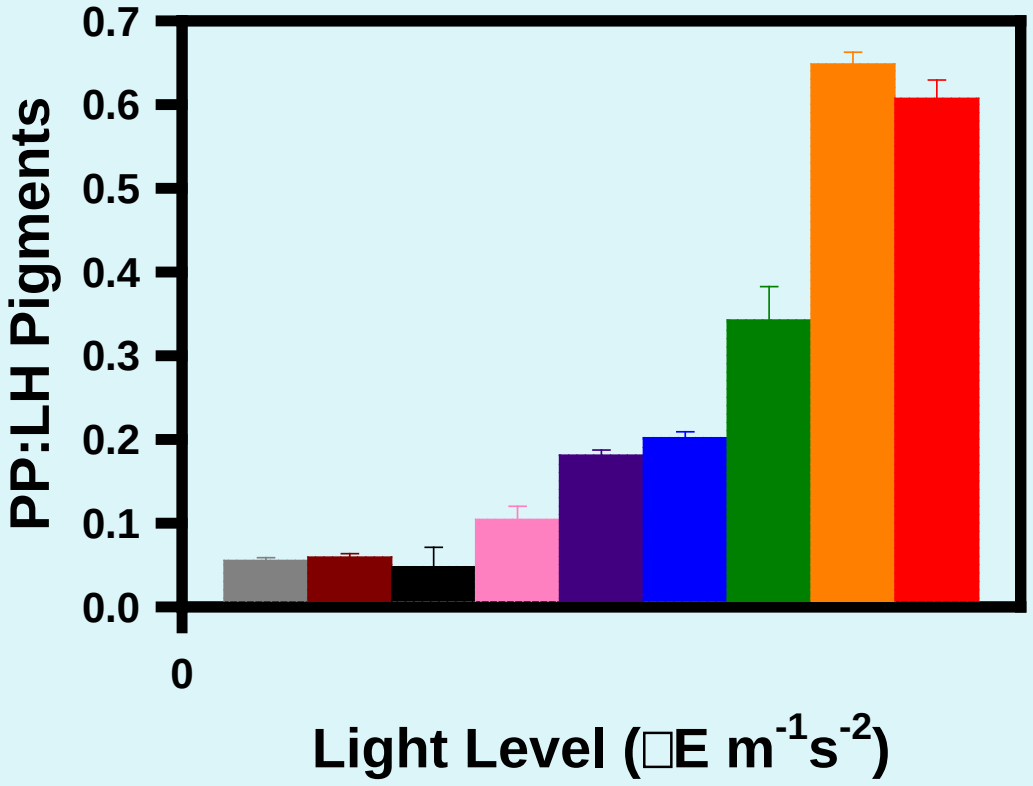
LIGHT ACCLIMATION



ANOVA, p≤ 0.001- 0.005 significant diff. between “a” and “b”

LIGHT ACCLIMATION

PP:LH Pigments

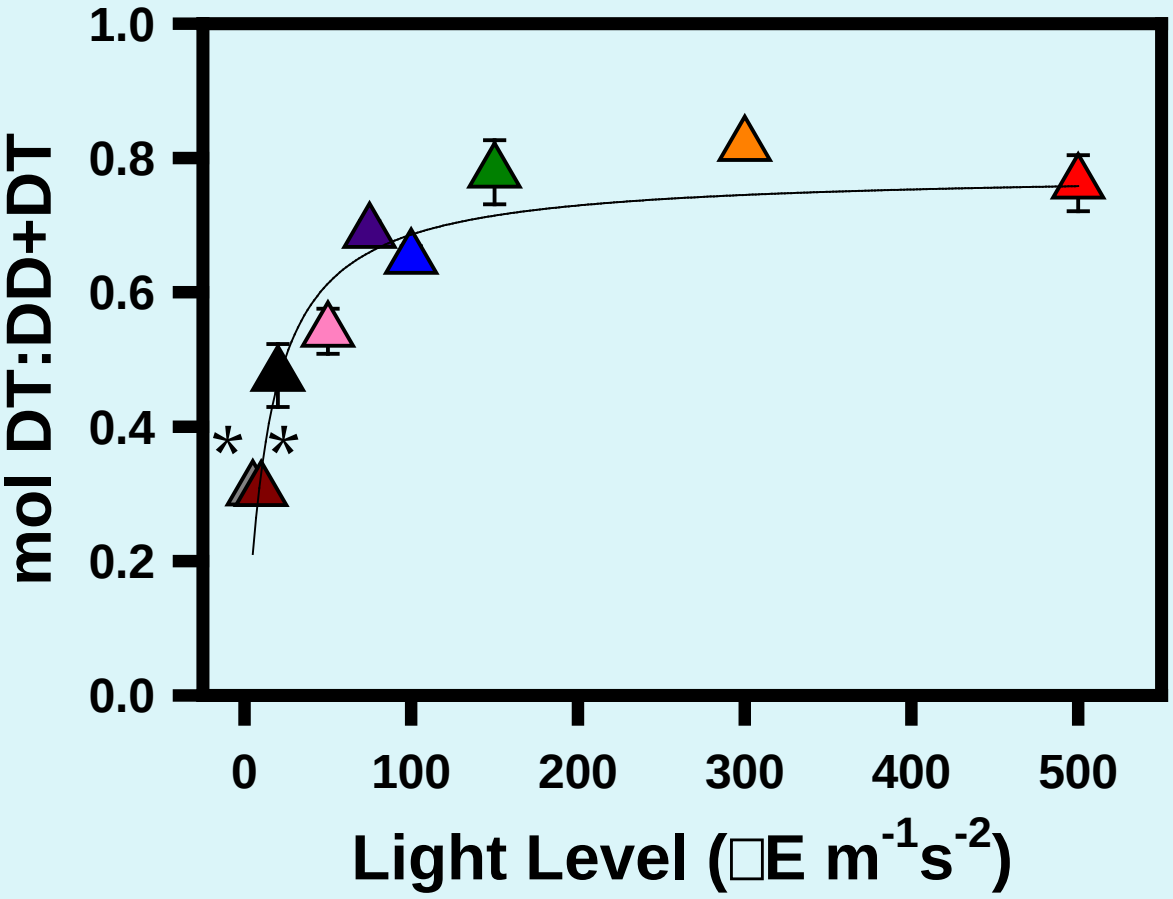


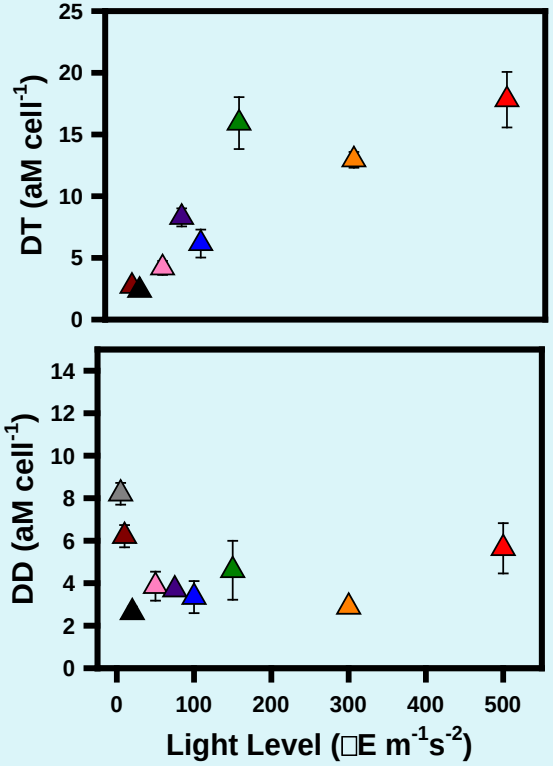
PP:photoprotective pigments(DD+DT)
LH: light harversting pigments (chl-a, chl-c, fuco)

Irradiance μEm⁻²s⁻¹	5	10	20	50	75	100	150	300	500

Xanthophyll Cycling

LIGHT ACCLIMATION

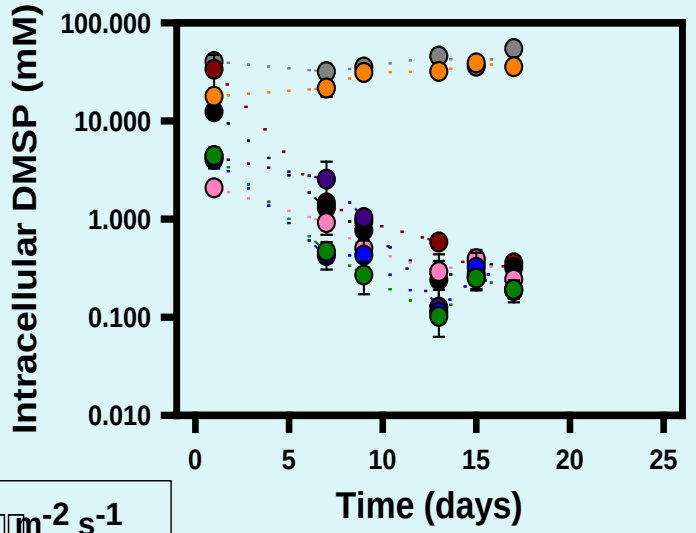


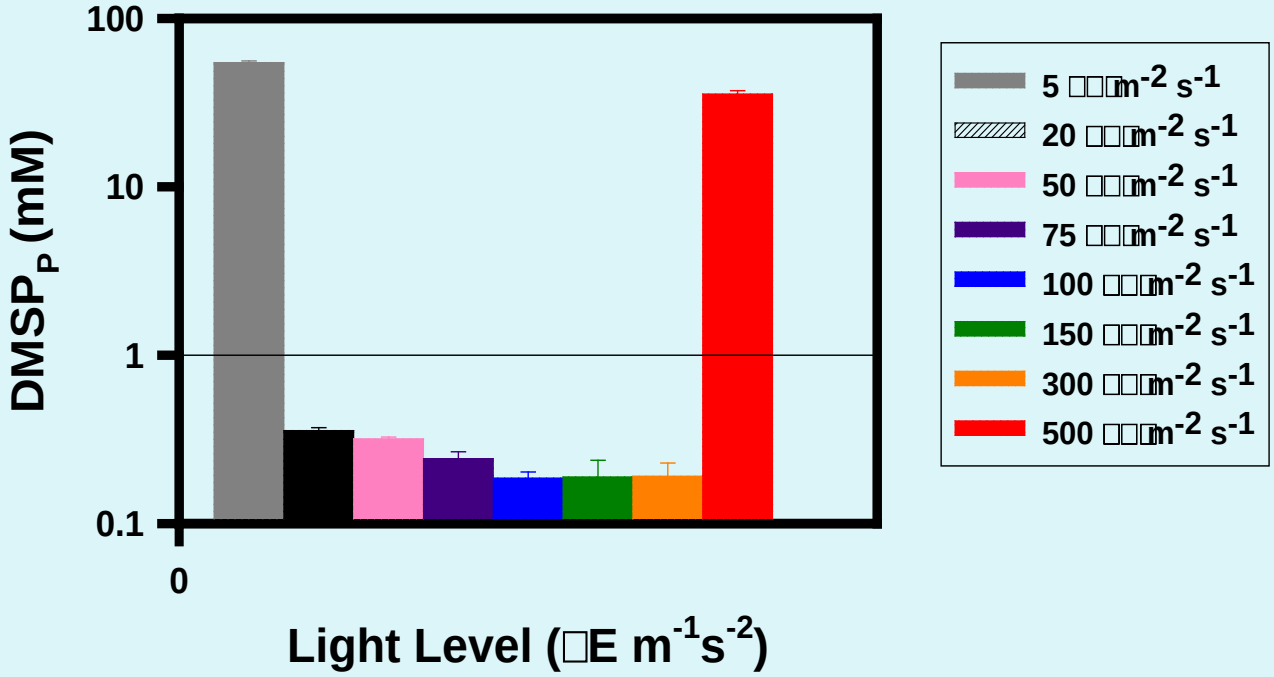


ANOVA, p≤ 0.001- 0.032

$DMSP_P$

LIGHT ACCLIMATION





Light Summary

2. POST ACCLIMATION

Irradiance ($\mu E\ m^{-2}\ s^{-1}$)	$DMSP_P$ (mM)	max μ	PP:LH	DT:DD+DT
5	54.6 (± 1.9) *	0.10	0.06 (± 0.02) *	0.31 (± 0.01) *
20	0.36 (± 0.15)	0.20	0.05 (± 0.01)	0.48 (± 0.05)
100	0.19 (± 0.09)	0.38	0.20 (± 0.06)	0.65 (± 0.02)
300	0.20 (± 0.10)	0.36	0.65 (± 0.02)	0.82 (± 0.01)
500	35.6 (± 1.5) *	0.26	0.61 (± 0.07)	0.77 (± 0.04)

ANOVA, $p \leq 0.001$- 0.034

Light and Iron

Fe MANIPULATION

Light

- energy source

↑ rxn centers
↑ accessory pigments

↓ rxn centers
↓ accessory pigments
↑ ROS

Iron

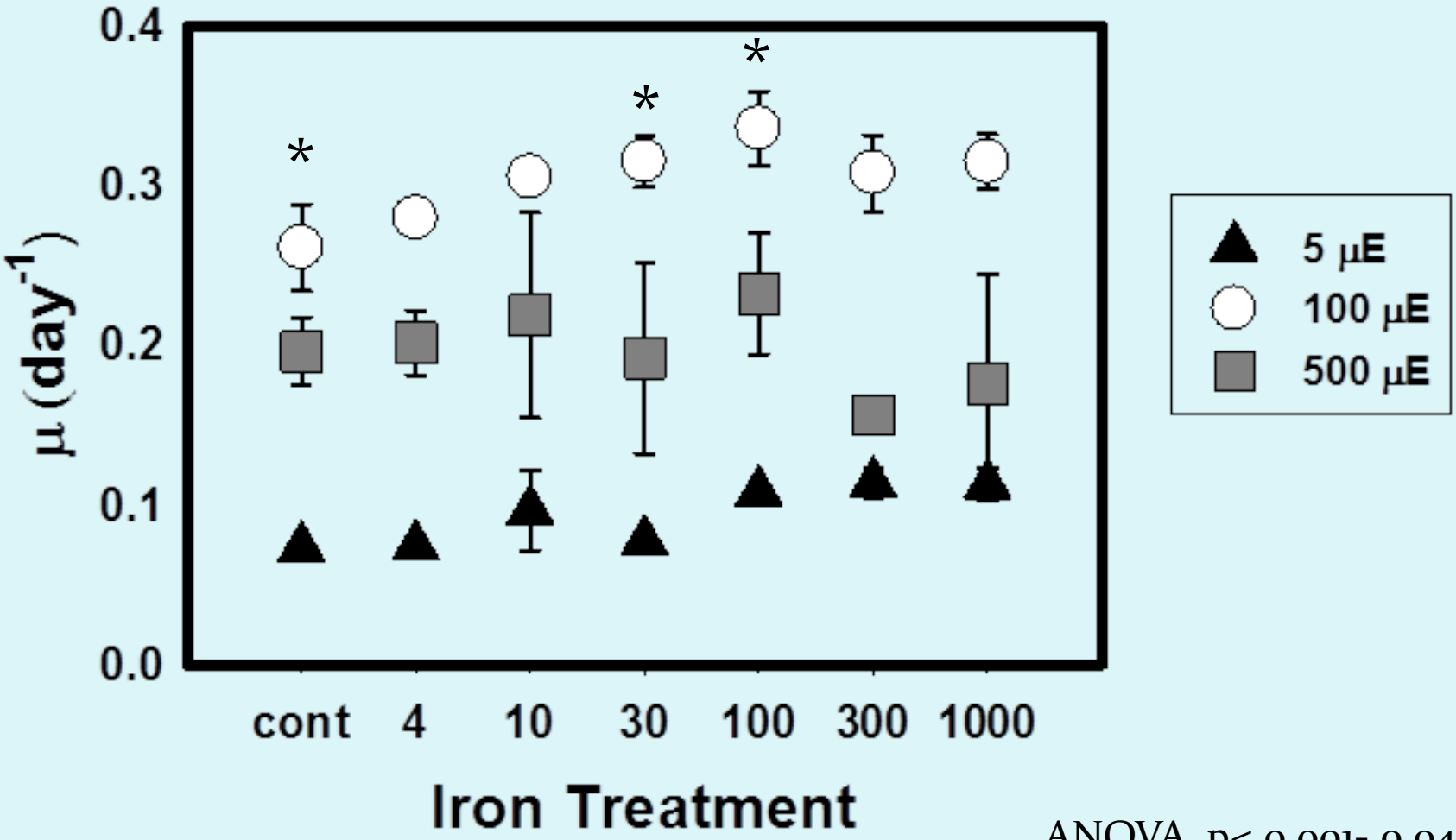
- electron transport
  - Fe-sulfur molecules,cytochrome b_6f, PSI, SOD

↓ rxn centers
↑ accessory pigments
↑ ROS

↑ rxn centers
↑ accessory pigments

Specific Growth Rate

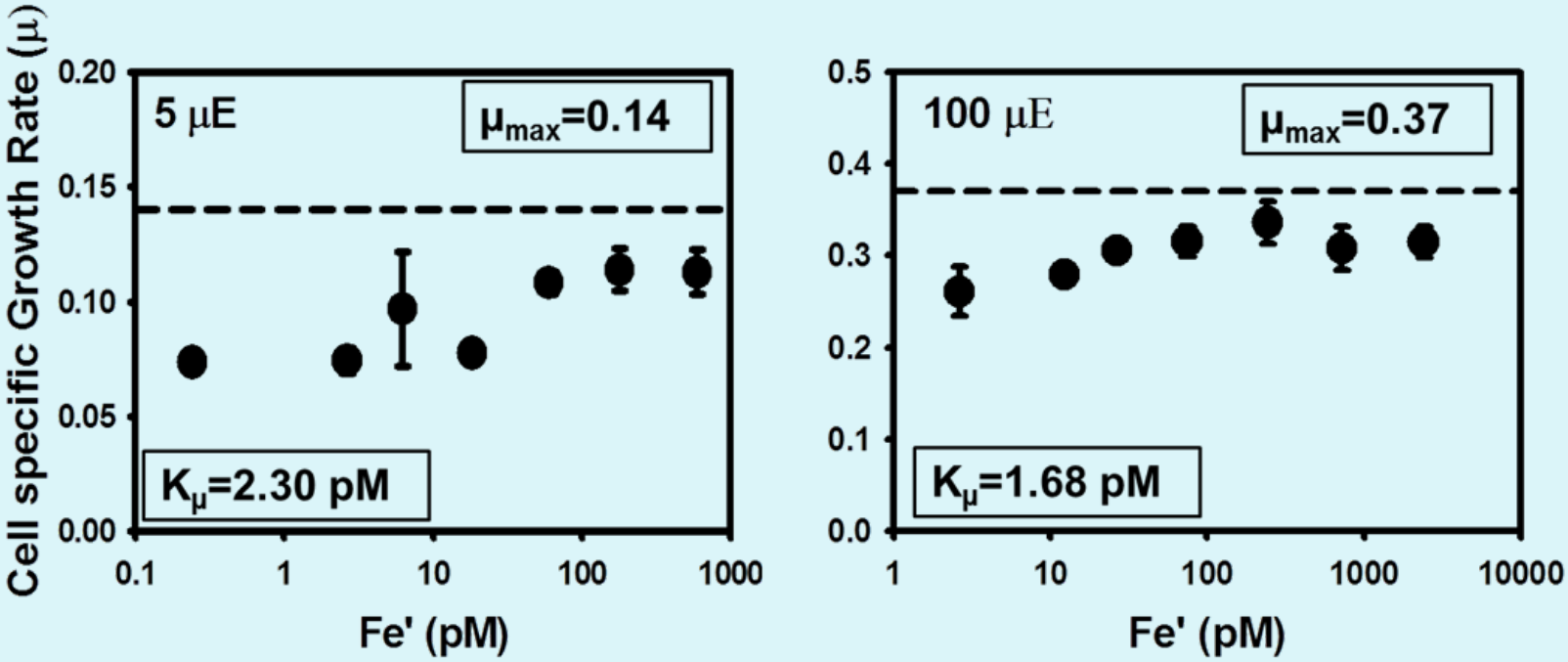
Fe MANIPULATION



ANOVA, $p \leq 0.001$- 0.047

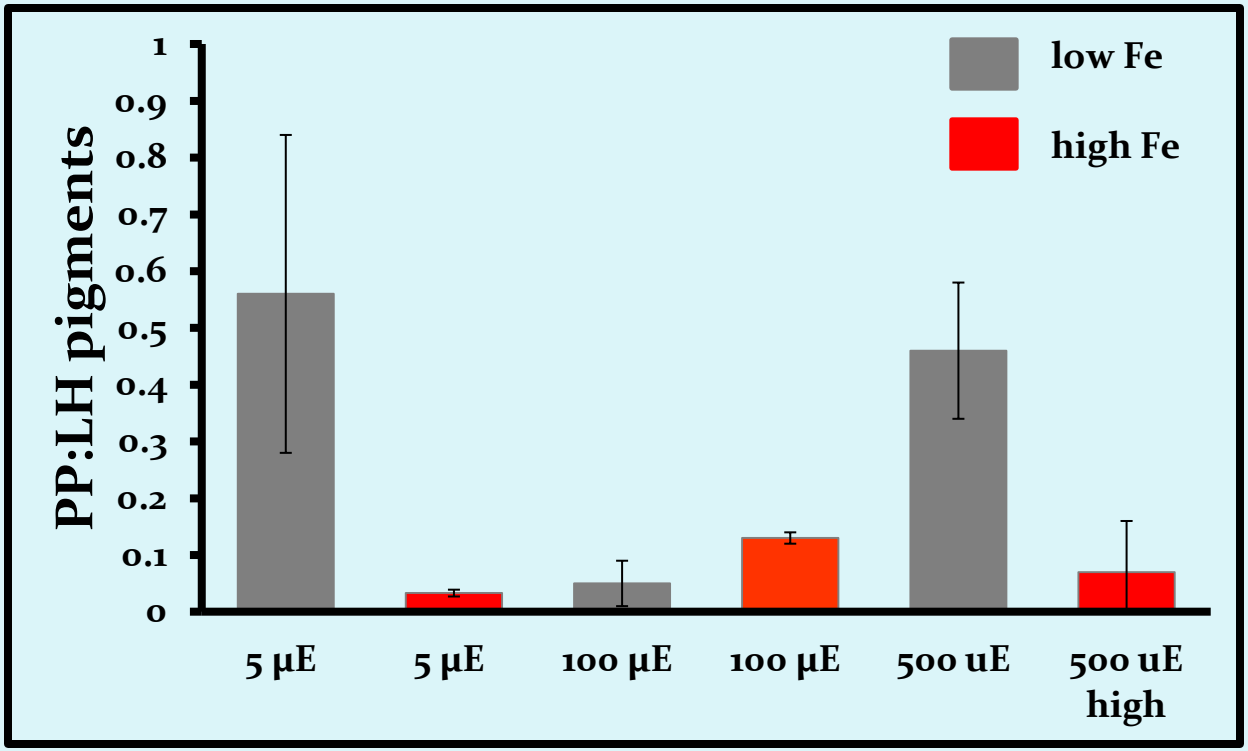
Fe
MANIPULATION

Growth as A Function of Iron



Fe
MANIPULATION

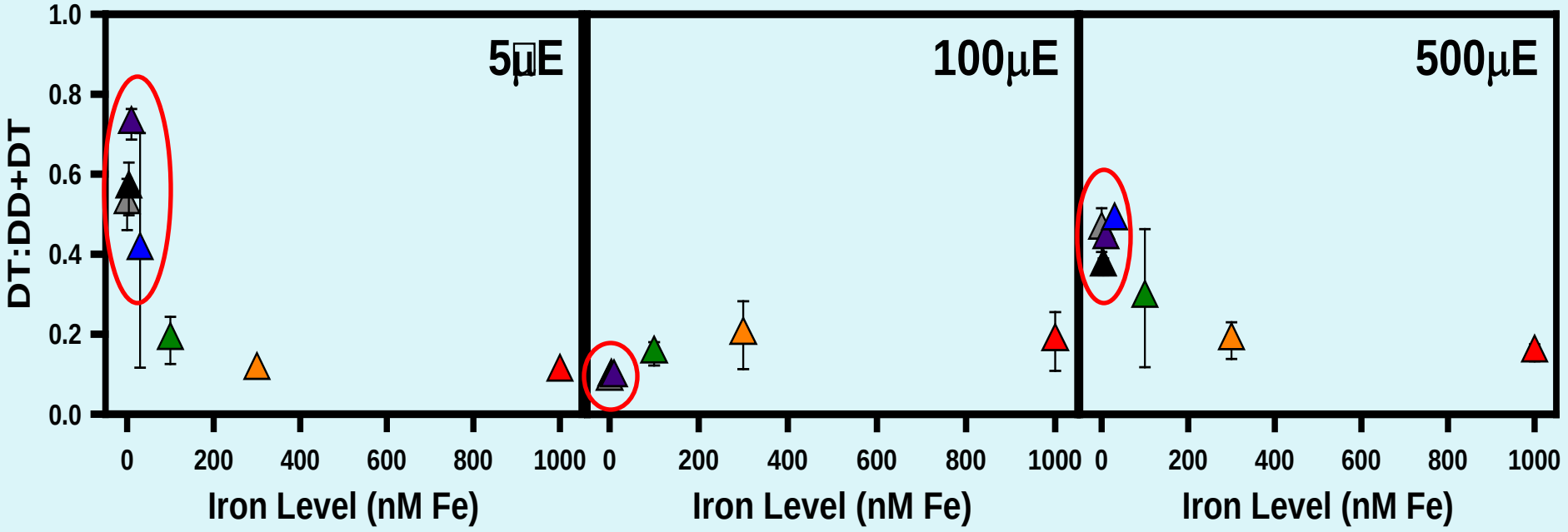
LH:PP Pigments



PP:photoprotective pigments(DD+DT)
LH: light harversting pigments (chl-a, chl-c, fuco)
low Fe: 0,4,10,30 nM treatments
high Fe: 100,300, 1000 nM treatments

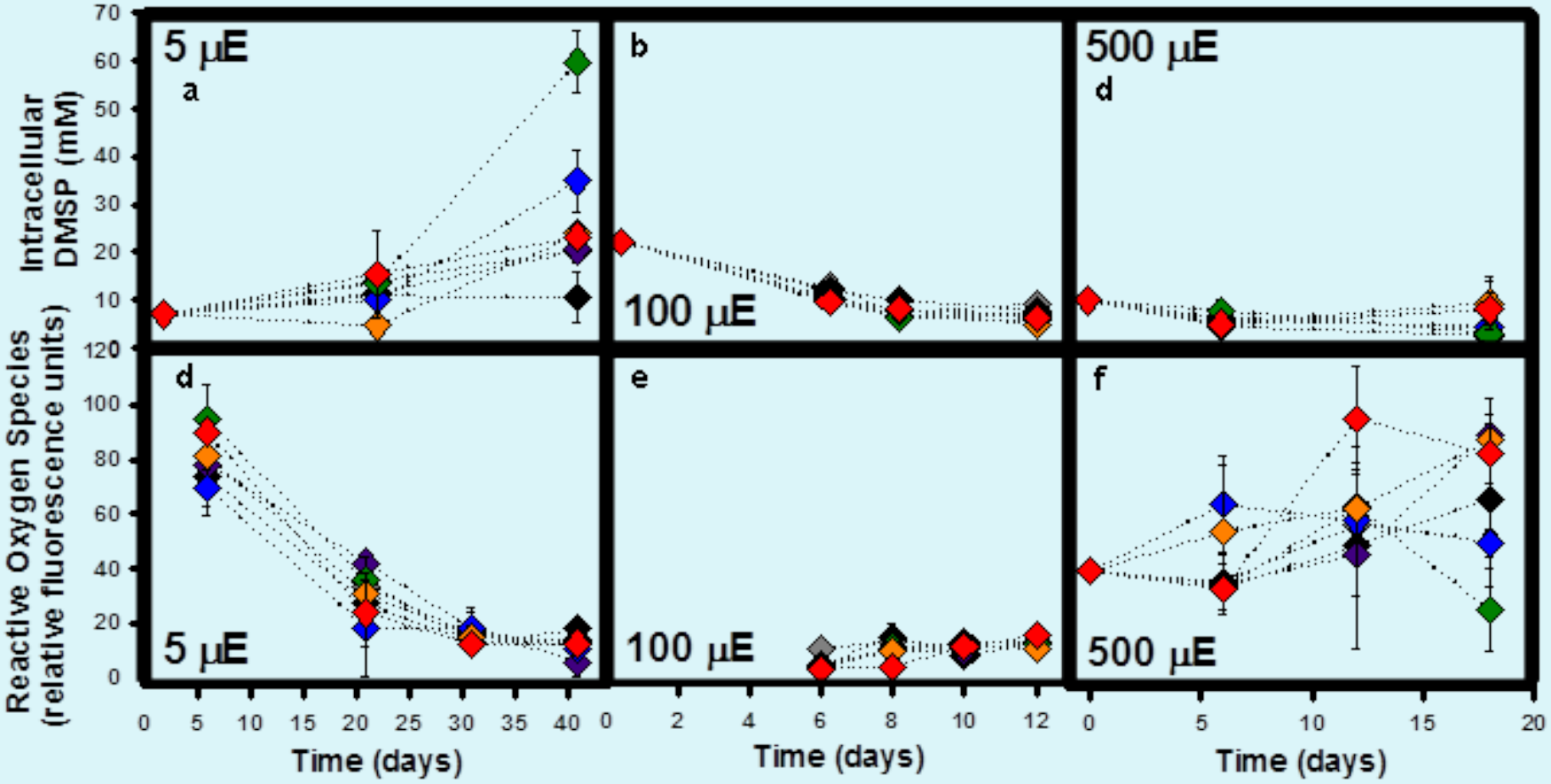
Xanthophyll Cycling

Fe
MANIPULATION

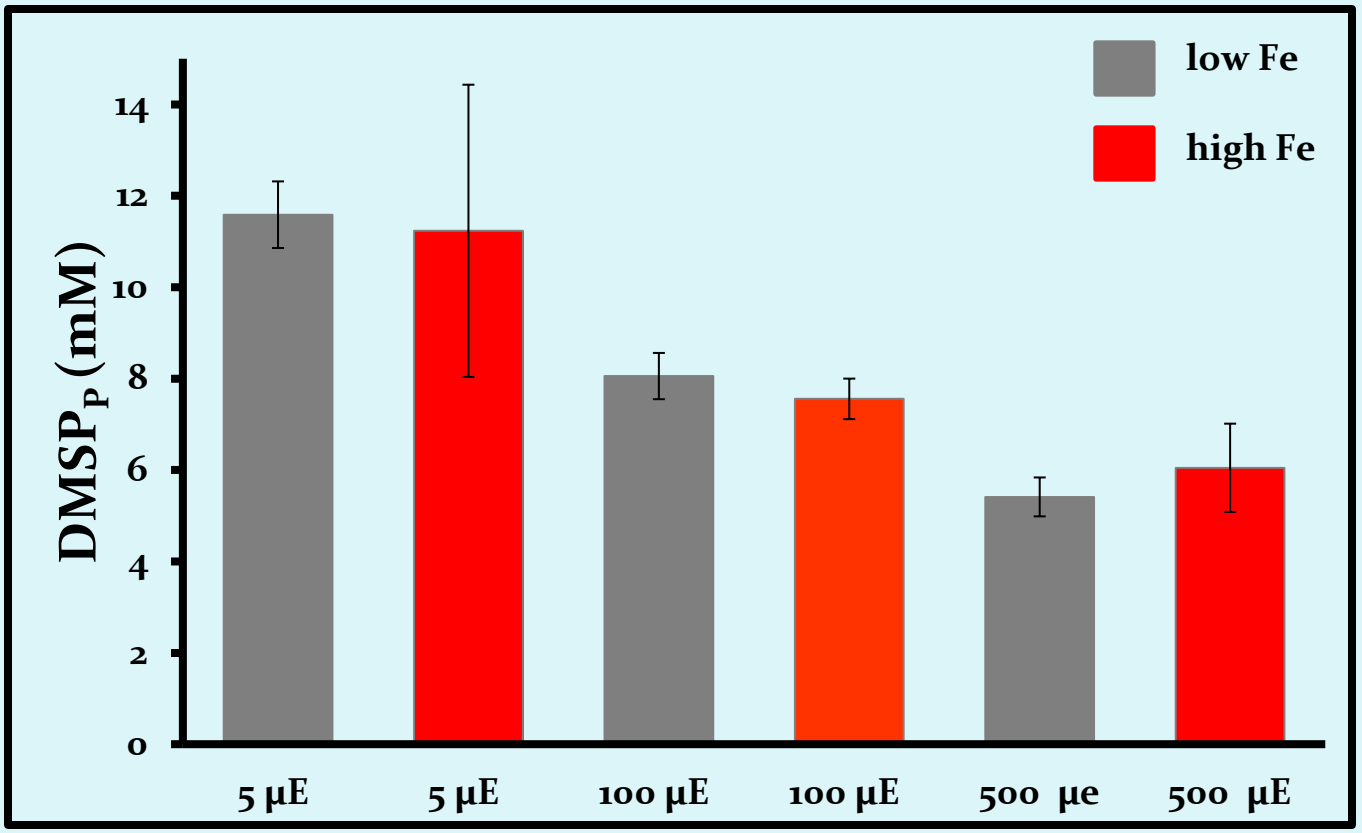


Fe-EDTA treatment (nM)	0	4	10	30	100	300	1000

$DMSP_p$ and ROS



$DMSP_P$



low Fe: 0,4,10,30 nM treatments
high Fe: 100,300, 1000 nM treatments

Fe Summary

Fe MANIPULATION

		5 µE $m^{-2}s^{-1}$	100 µE $m^{-2}s^{-1}$	500 µE $m^{-2}s^{-1}$
F_v/F_m	low	0.21	0.14	0.15
	high	0.45	0.38*	0.22
PP: LH	low	0.56	0.05	0.46
	high	0.03	0.13	0.07
DT:DT+DD	low	0.71	0.05	0.41
	high	0.11	0.19	0.11
DMSP (mM)	low	11.6	8.06	5.41
	high	11.2	7.56	6.05

Growth and Physiology

- *F. cylindrus* is able to grow in a wide range of irradiances
  - 100 fold
- Fe and light interactions are complex
  - alteration of photosynthetic apparatus
    - PP:LH pigments, xanthophyll cycling, DMSP
    - pigments –induced by low Fe as opposed to irradiance
    - DMSP – under light and Fe stress
      - higher utilization, higher turnover, or in derivative forms?

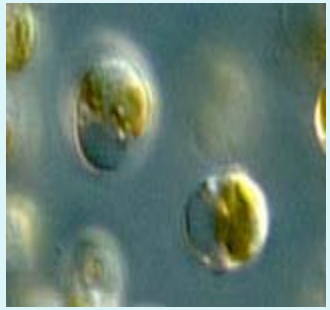
Bloom composition

F. cylindrus

- optimal irradiance for growth = 100 µE $m^{-2}s^{-1}$
  - SML, well stratified
- u_{max} = 0.37 at 100 µE $m^{-2}s^{-1}$
- xanthophyll pool large at low irradiance
  - Photoprotection
- DMSP: ≤ 60 mM

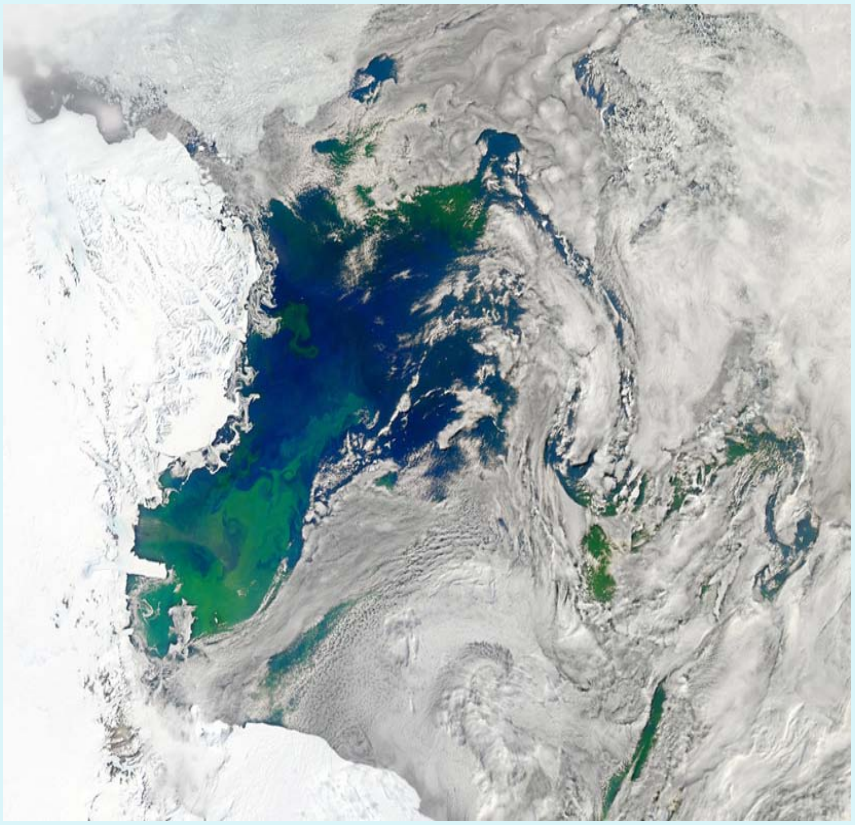
P. antarctica

- optimal irradiance for growth = 40 µE $m^{-2}s^{-1}$
  - DML, lower irradiance
- u_{max} = 0.38 at 40 µE $m^{-2}s^{-1}$
- photo-repair
  - Kropuenske et al. 2009
- DMSP: 125 mM- 350 mM



Ecological Relevance of Findings

- interaction of light and iron affect growth of this species
  - iron requirements are dynamic
  - species specific
- complexities in predicted bloom formation and resulting changes in C export
  - S input greater than previously predicted
  - impacted by flux rates, grazing, etc.



Many thanks!

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Lab mates: Tyler Cyronak, Dr. Jenny Davis, Dr. Peter Lee, Dr. Bobbie Lyon, Amanda McLenon, Sarah Riseman

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GRADUATE PROGRAM IN MARINE BIOLOGY

Questions???