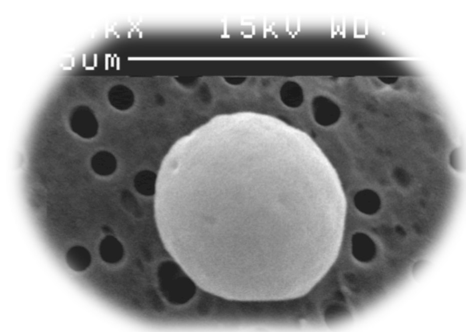
Impact of atmospheric iron from Saharan dust on *Crocosphaera watsonii*

Violaine Jacq

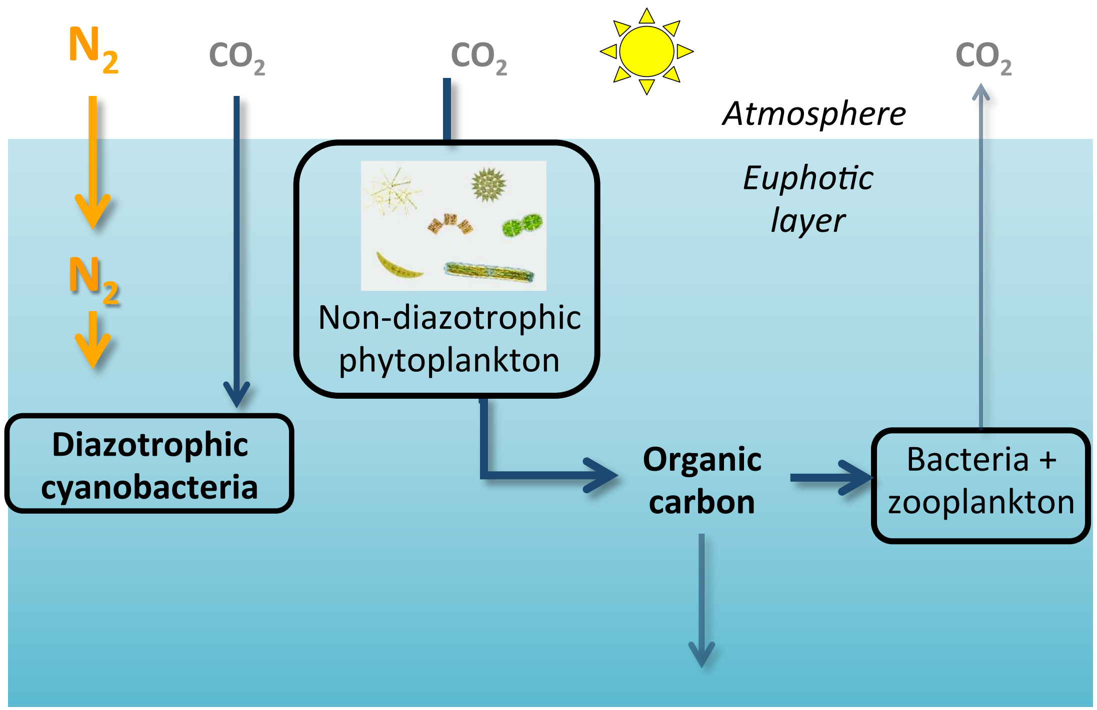
Meeting SOLAS Paris, 29 juin 2015



N_2 fixation

$$N_2 + 8H^+ + 8e^- + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16\ Pi$$

Nitrogenase enzyme complex



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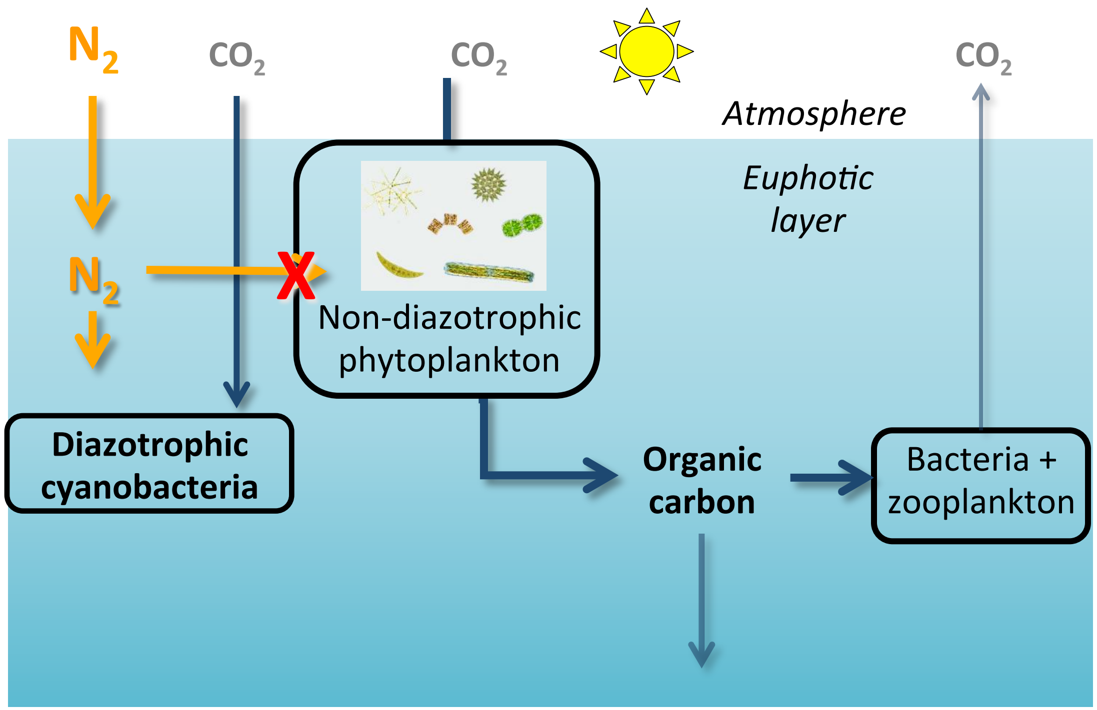

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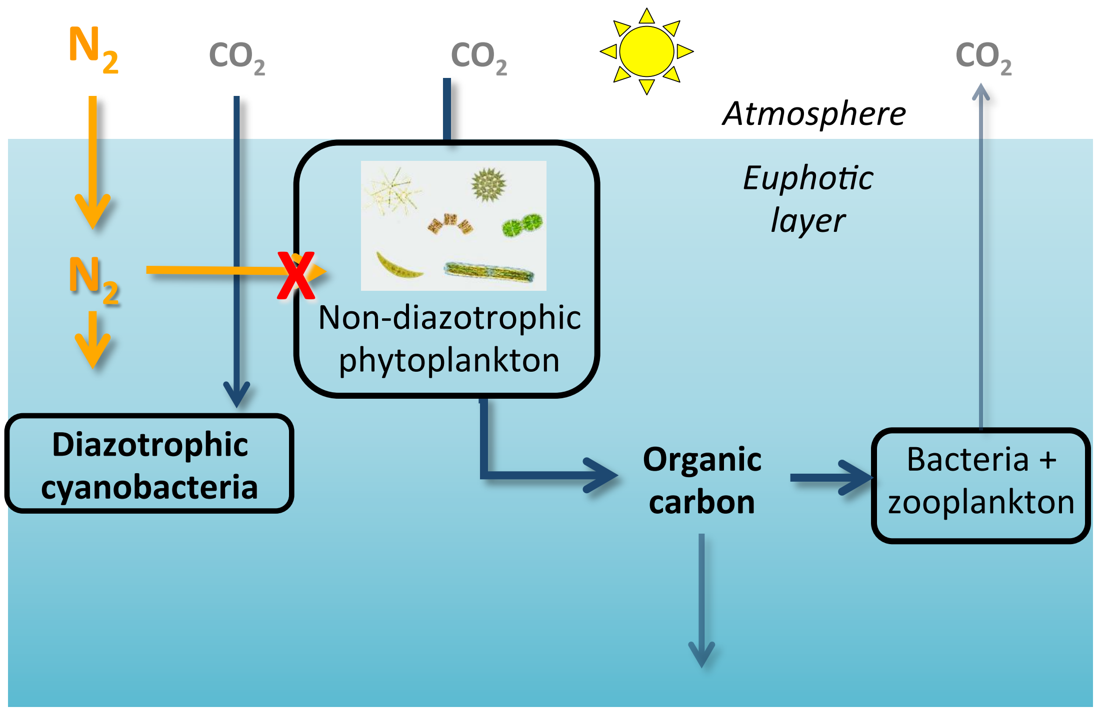

Ecological advantage of diazotrophic cyanobateria in **N-limited areas**

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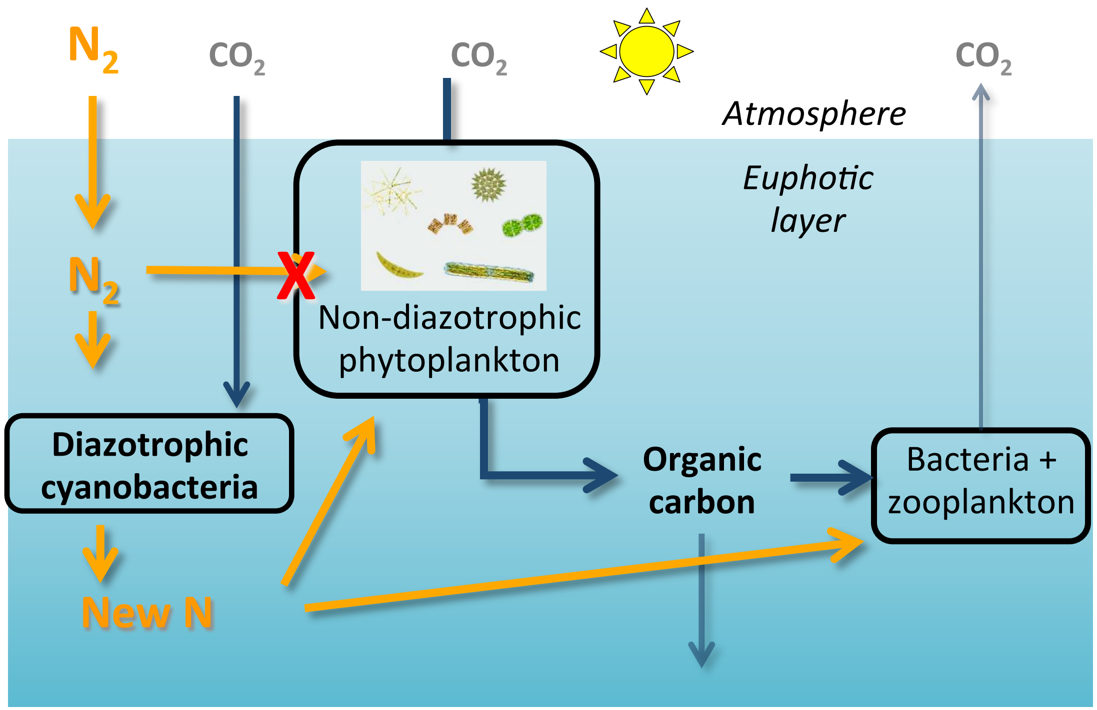

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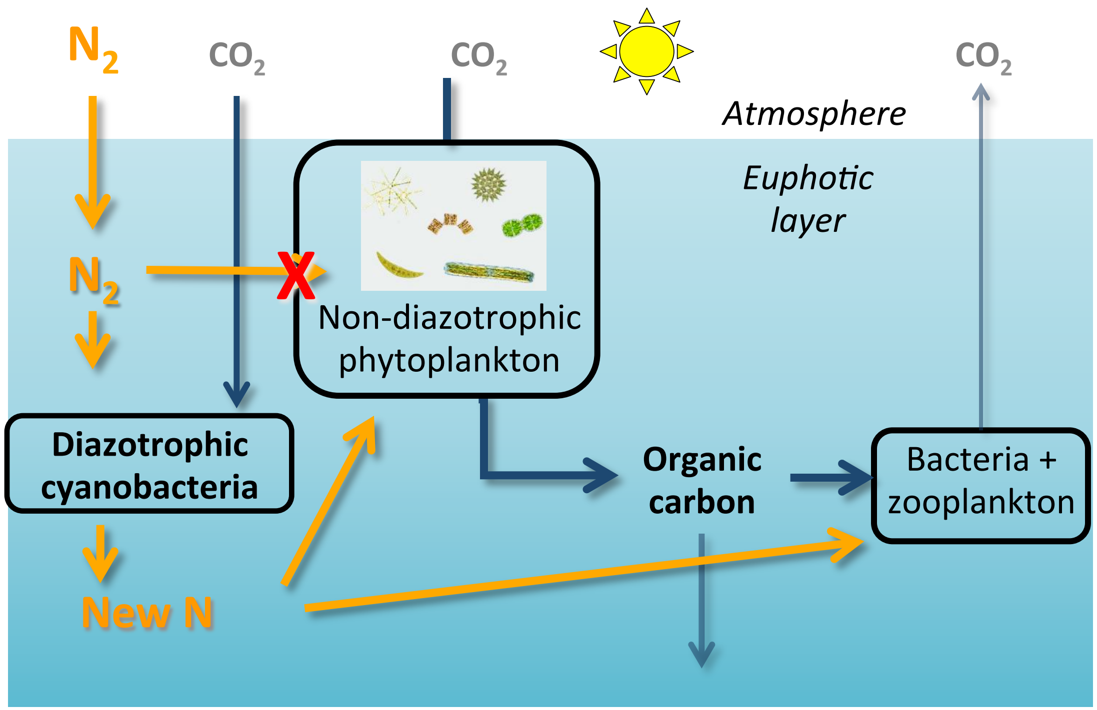

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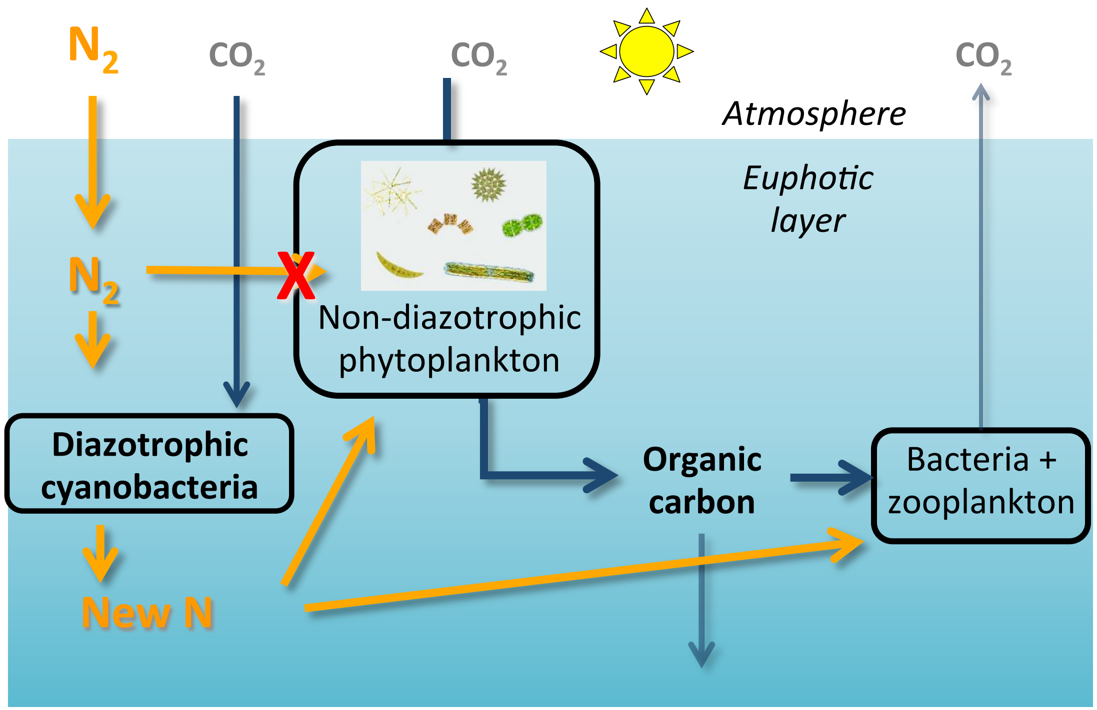

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Key role of N_2 fixation in biogeochemical cycles of C and N

Diazotrophic cyanobacteria: key actors of oceanic N_2 fixation

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Filamentous

Trichodesmium spp.

MIT/WHOI

Has long been considered as dominant

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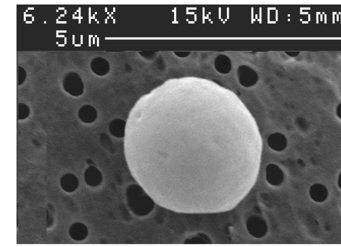
Unicellulars (UCYN)

UCYN-B
Crocosphaera watsonii
WH8501



(Jacq et al. 2014)

Diazotrophic cyanobacteria: key actors of oceanic N_2 fixation

F

Trichodesmiu

Has long be

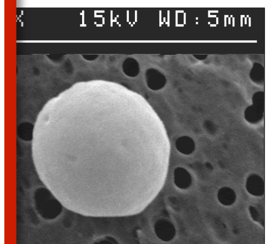
UCYN:

~50% of global N_2 fixation *(model, Monteiro et al. 2010)*

Diazotrophes < 10µm:

≤ 75% of N_2 fixation in equatorial Pacific

(Bonnet et al. 2009)



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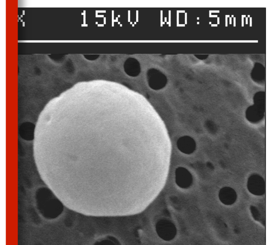

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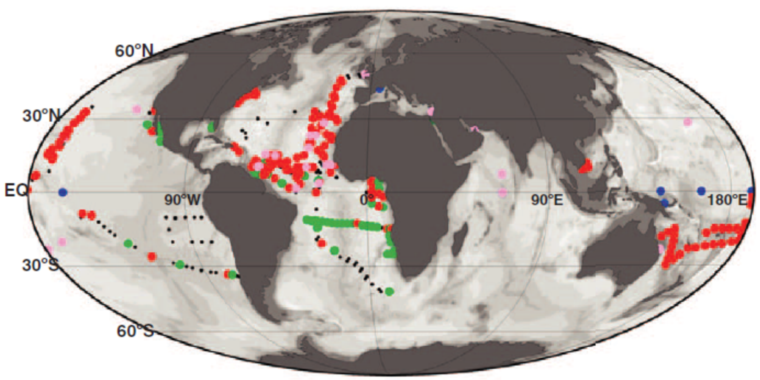

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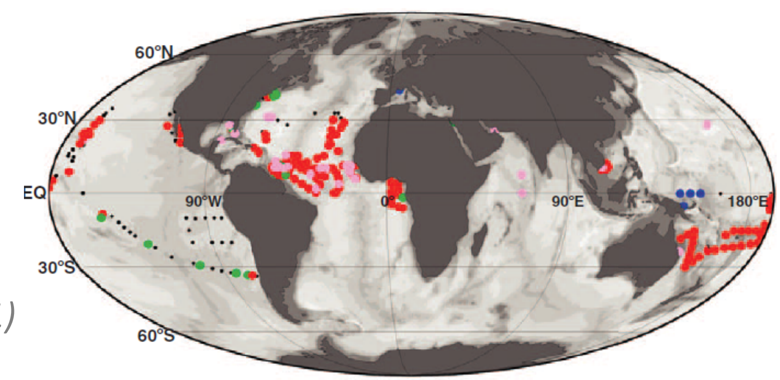

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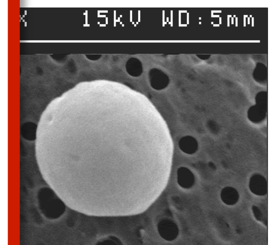

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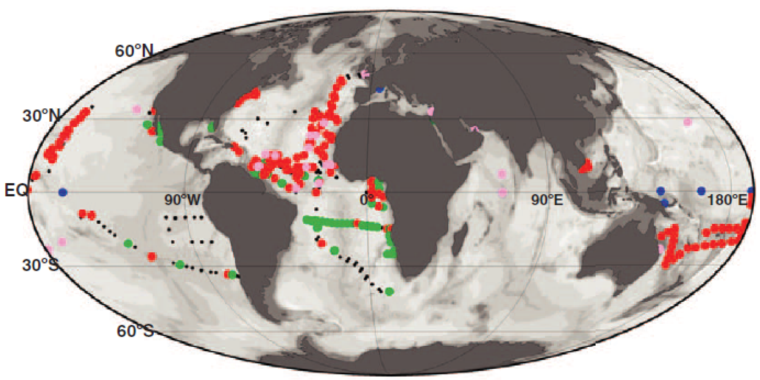

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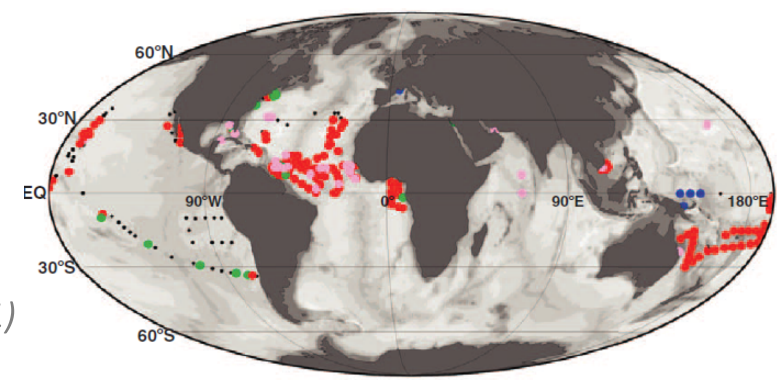

(Zehr 2011)

Coexistence of 2 types
Mainly in (sub)tropical areas

Fe limitation of oceanic N_2 fixation

- N_2 fixation = high bioenergetic cost ➔ increase in photosynthesis
- Fe = cofactor of several photosynthetic enzymes

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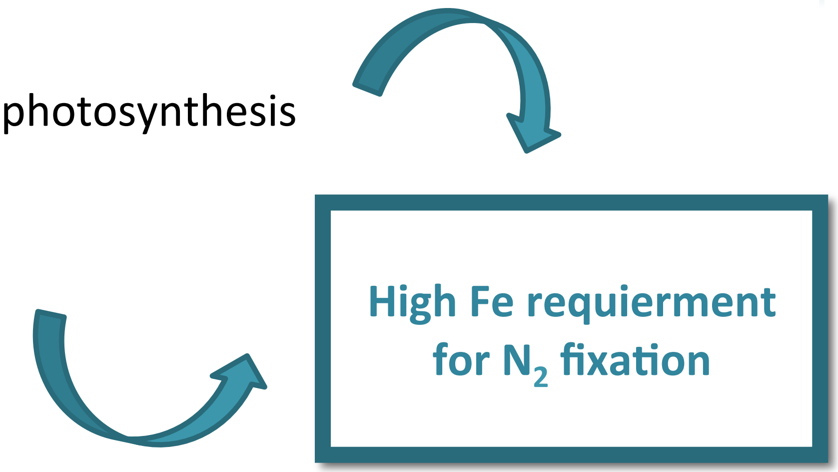

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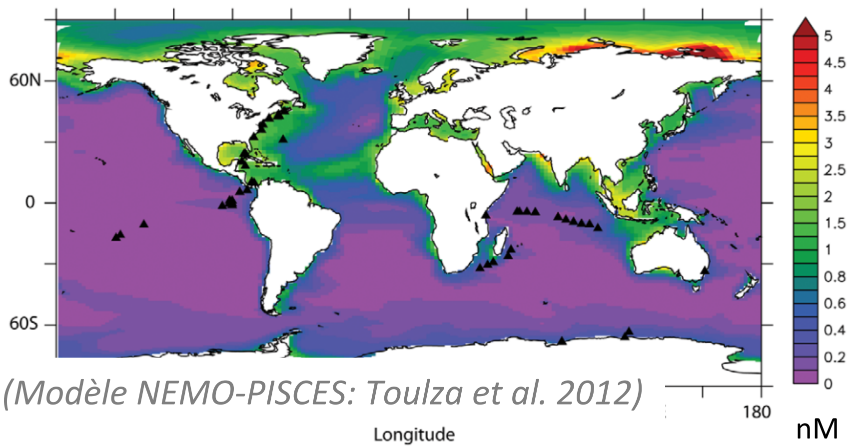

(Modèle NEMO-PISCES: Toulza et al. 2012)

Very low [dFe] in surface open ocean

(< ~1 nM)

➔ **potential Fe limitation of N_2 fixation.**

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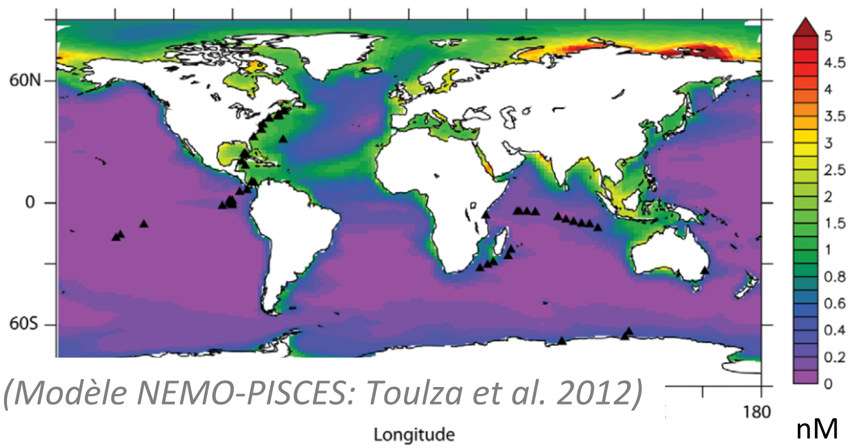

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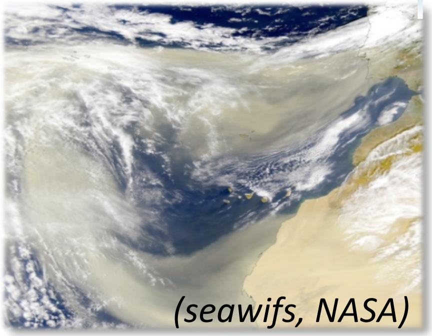
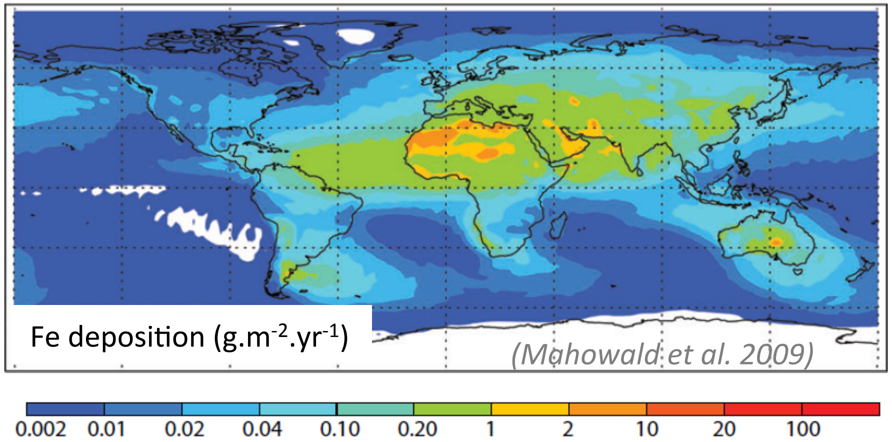
Growth and activity of cultured *C. watsonii* are controlled by Fe concentration

(Jacq et al. 2014)

Atmospheric Fe deposition to the ocean

- Main Fe source to the surface open ocean
- Sahara: main atmospheric Fe source





Atmospheric Fe deposition to the ocean

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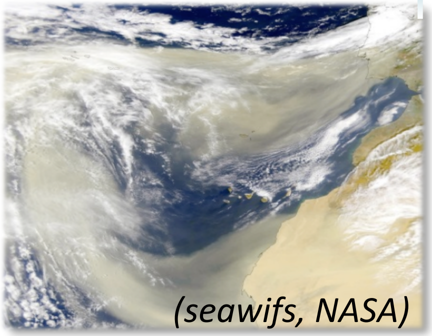
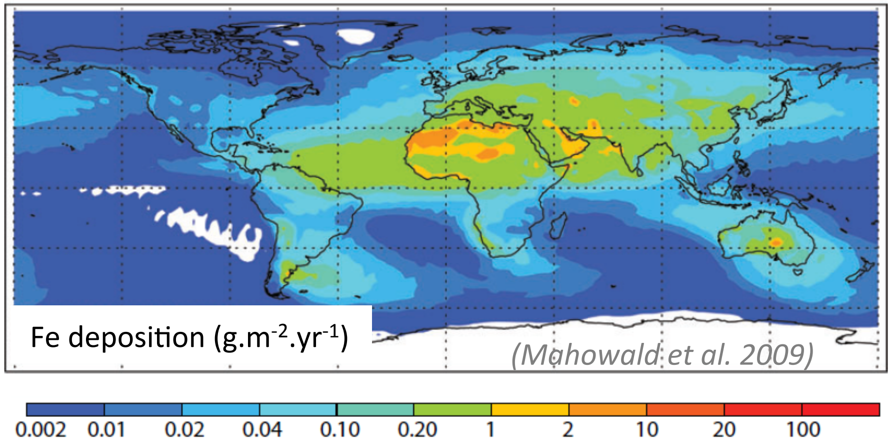
Impact of atmospheric Fe on N_2 fixation still poorly known





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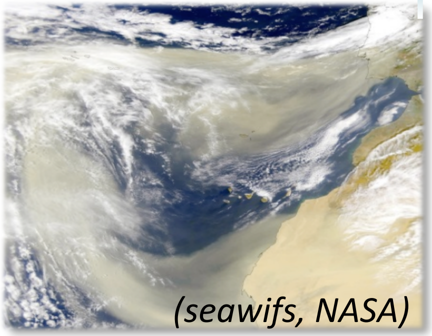

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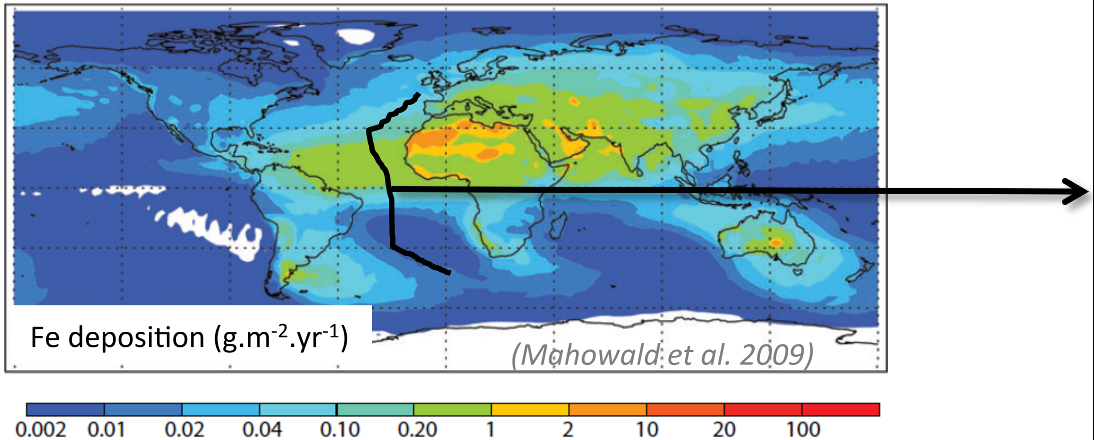

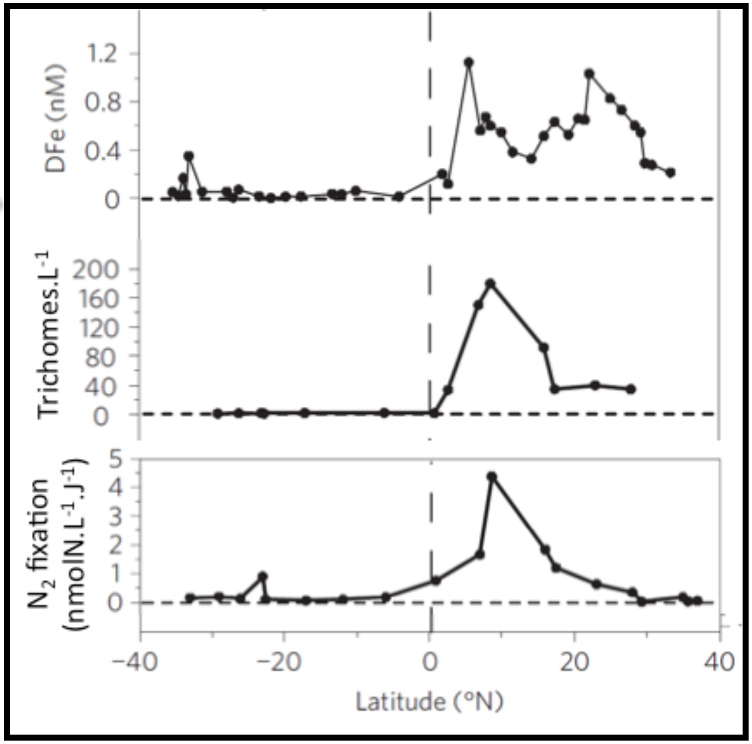

(Moore et al. 2009)

Impact of atmospheric deposition on N_2 fixation:

Atlantic ocean:

surface [dFe] concentrations, *Trichodesmium* abundance and N_2 fixation rates correlated

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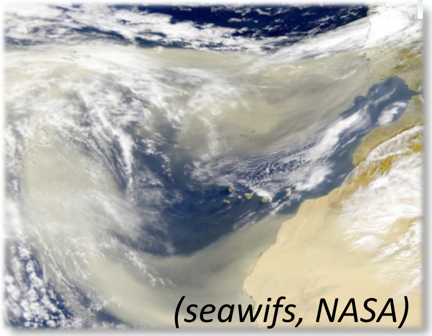
(seawifs, NASA)

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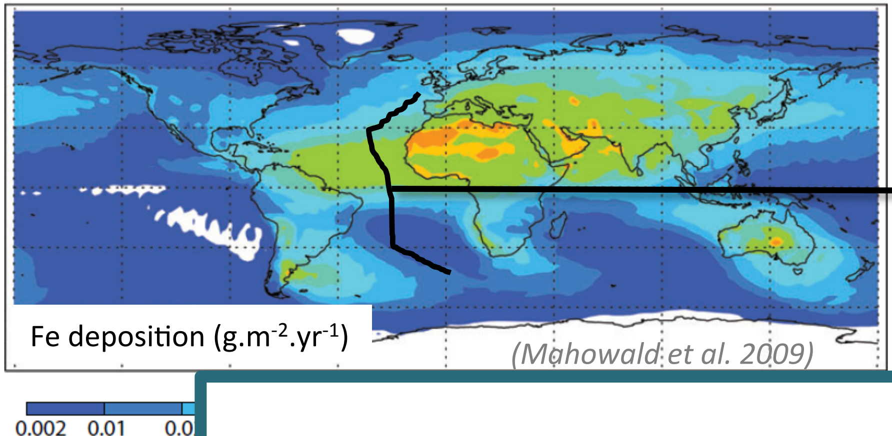

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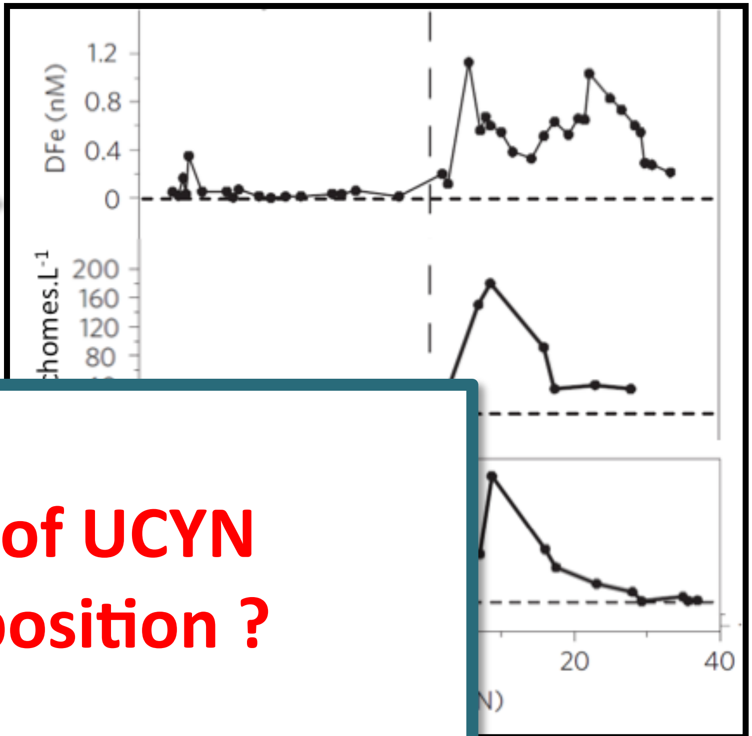

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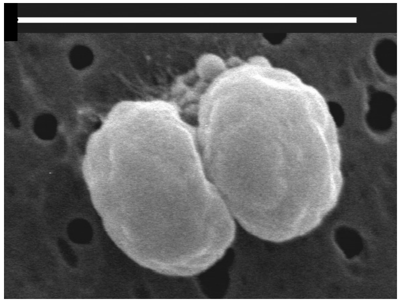
What is the response of UCYN to atmospheric Fe deposition ?

Experimental pan

Is Fe releasing by saharan dust abble to stimulate growth and activity of *C. watsonii* ?

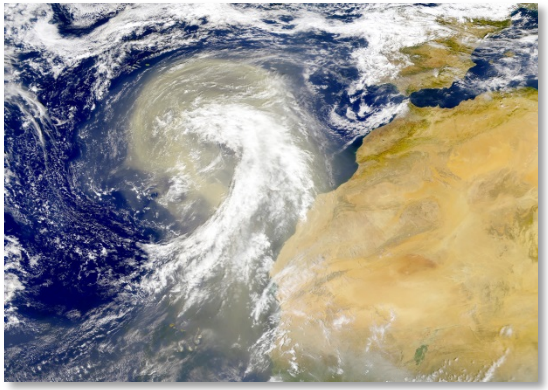
Fe limited

C. watsonii WH8501 cultures



C. watsonii

Addition of an artificial saharan rain



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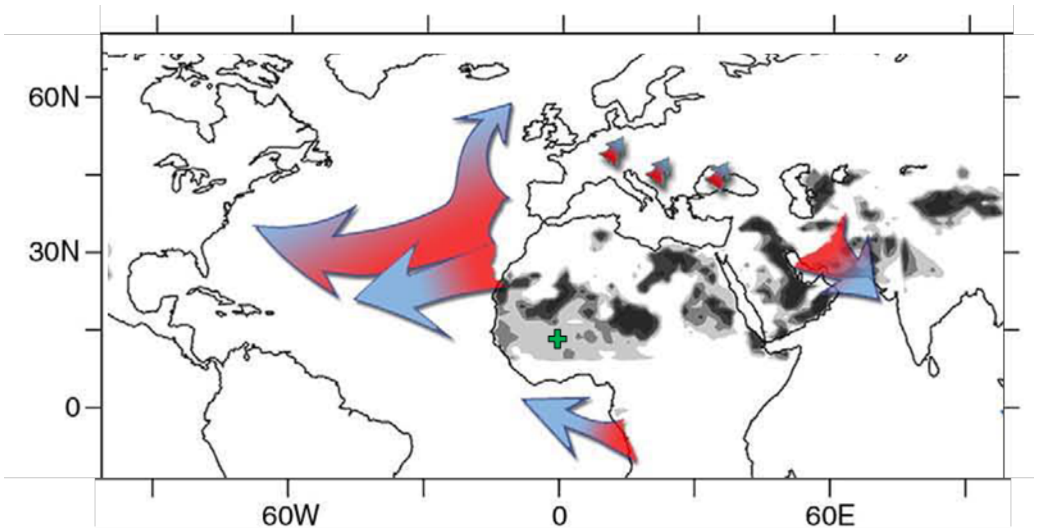
The Saharan dust



(Maher et al. 2010)

- Fine fraction (< 20 µm) of Saharan soils (Niger)
- Représentative of collected aerosols in (sub)tropical North Atlantic
- Fe content: **3.1** ± 0.2 **%**

(Paris et al. 2011)

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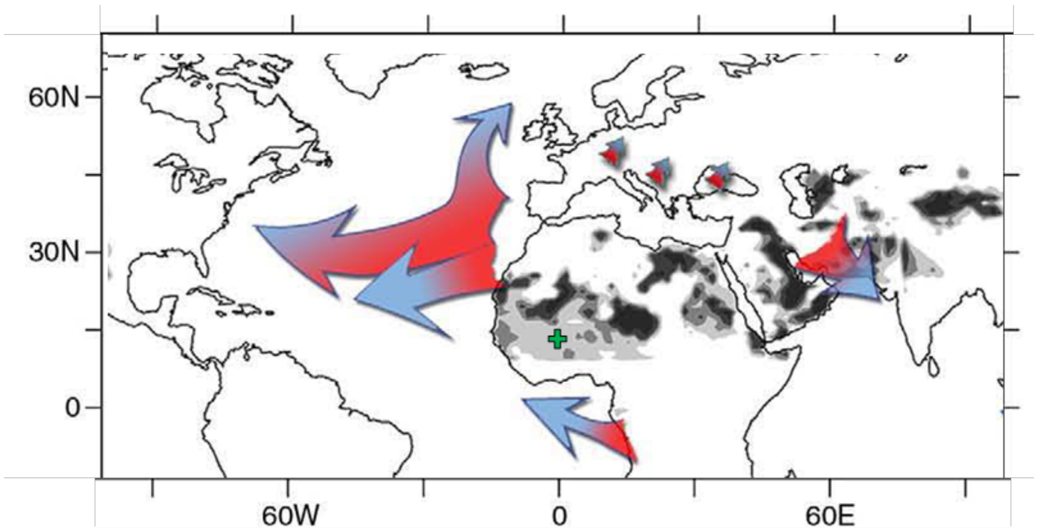

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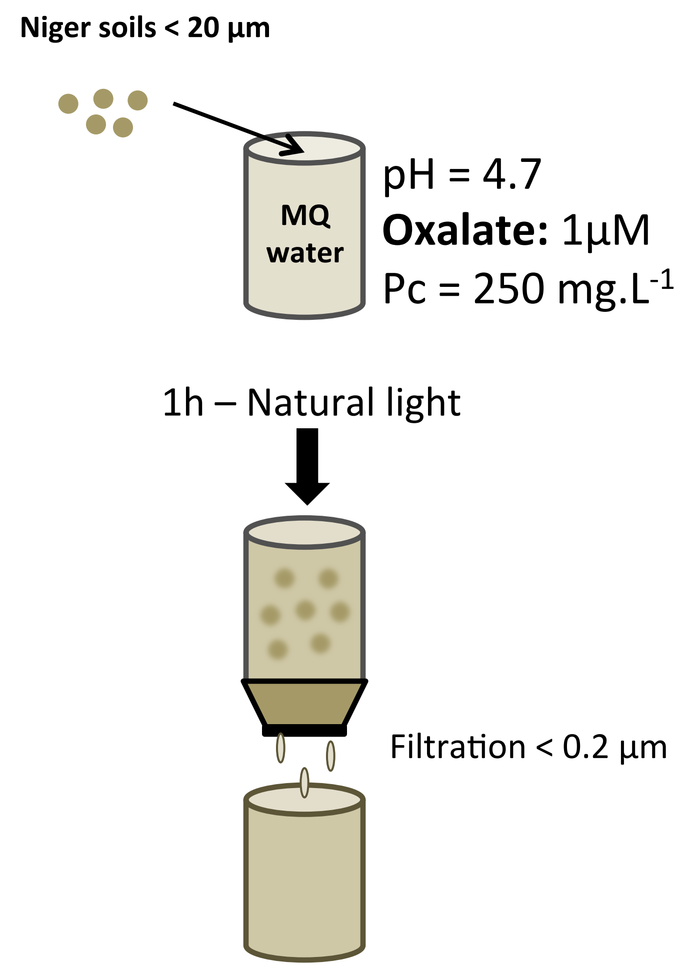
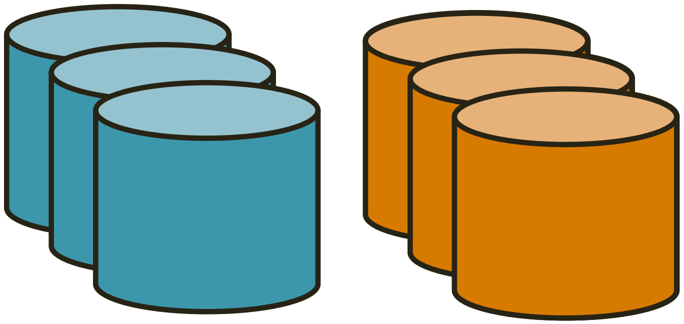


dFe = 138 nM → 0.10 %

Experimental protocol



Control
Ox = 200 nM
dFe = 2nM

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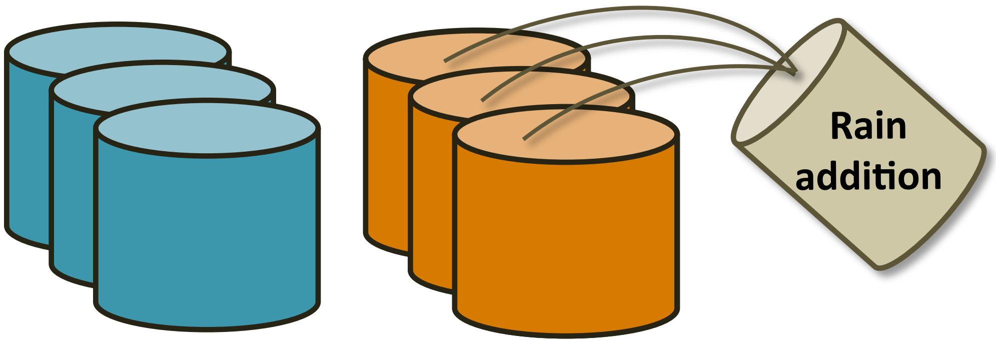

Control
Ox = 200 nM
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+ Rain
Ox = 200 nM + 20 nM
dFe = 2 **+ 2.7 nM**

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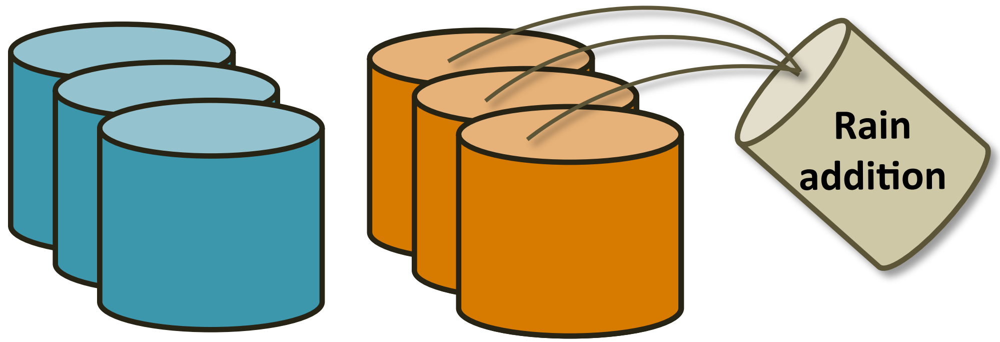

Control	**+ Rain**
Ox = 200 nM	Ox = 200 nM + 20 nM
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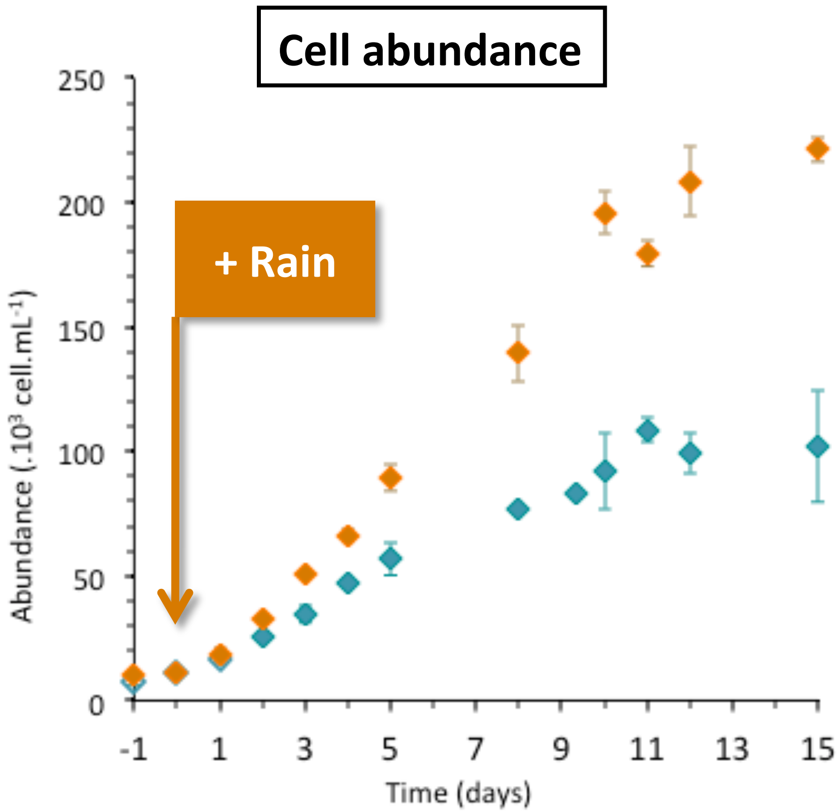
- Cell abudance
- C, N and Chl *a* cellular contents
- N_2 fixation rates
- CO_2 fixation rates
- Cell volume

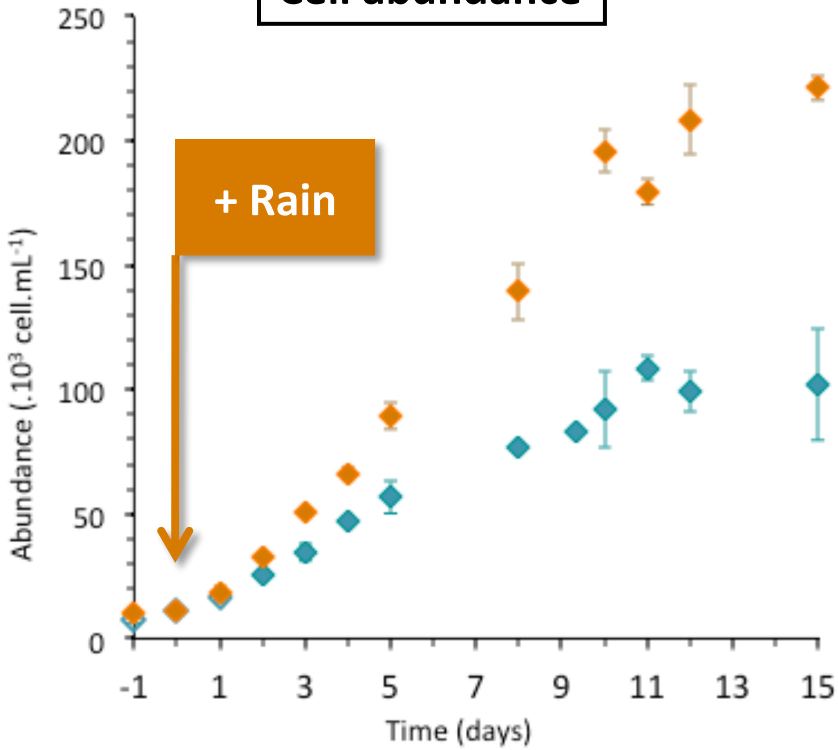
Triplicate measurement during exponential growht phase

Physiological response

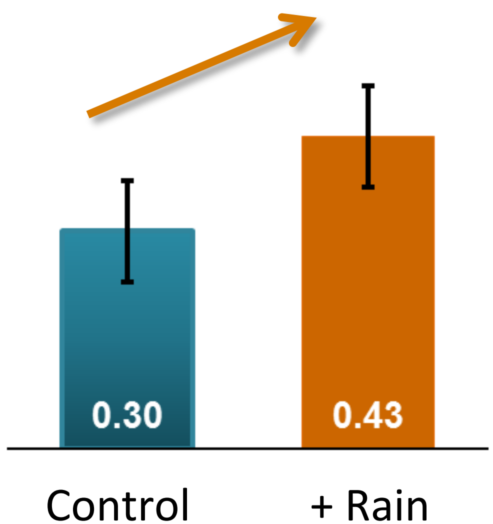


Physiological response

Cell abundance

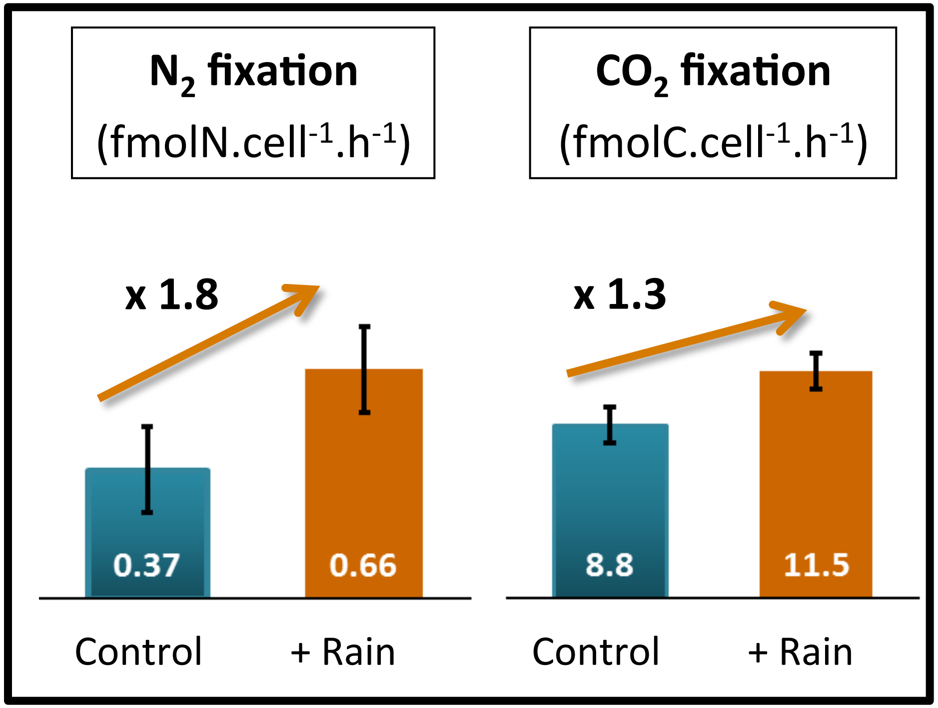


Growth rate (d^{-1})



Dust realesed bioavailable Fe for *C. watsonii*

Physiological response

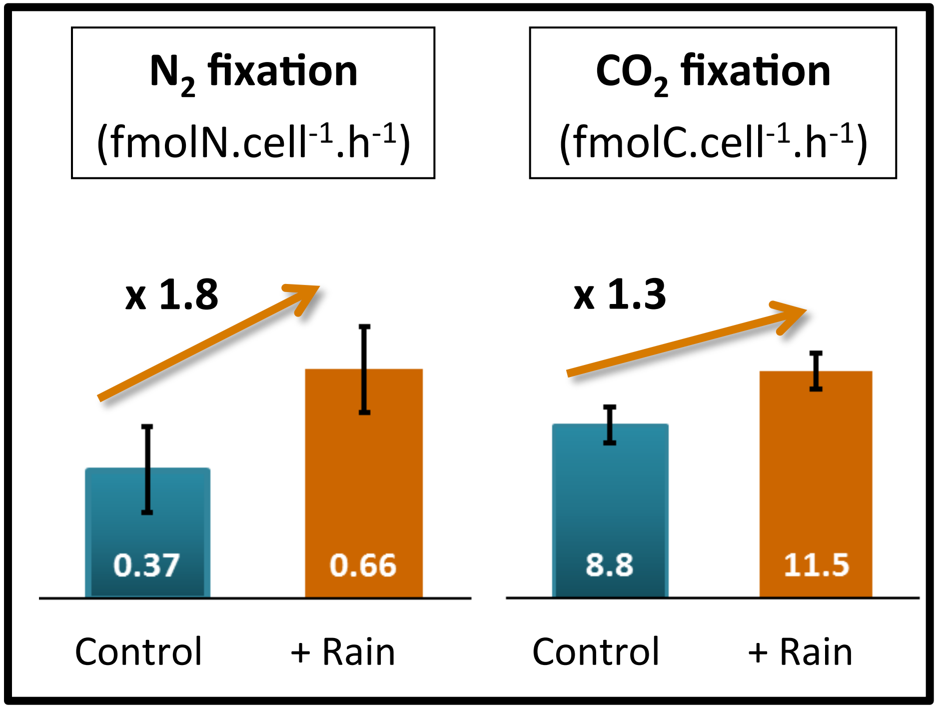


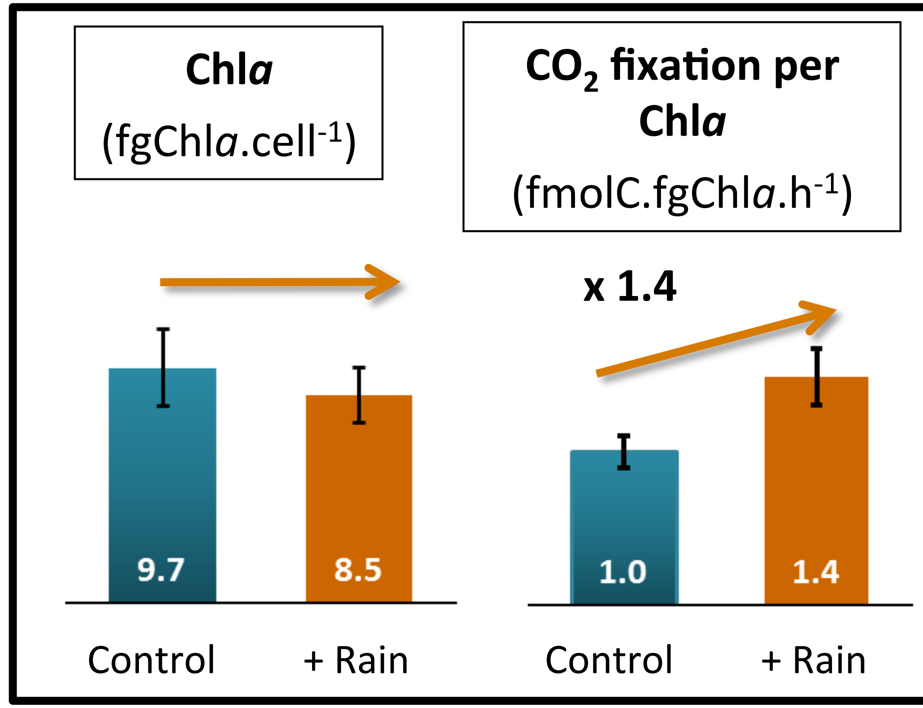
Increase in synhesis of enzymes

Involved in N_2 fixation and phtosynthesis

Higher impact on N_2 fixation than CO_2 fixation

Physiological response





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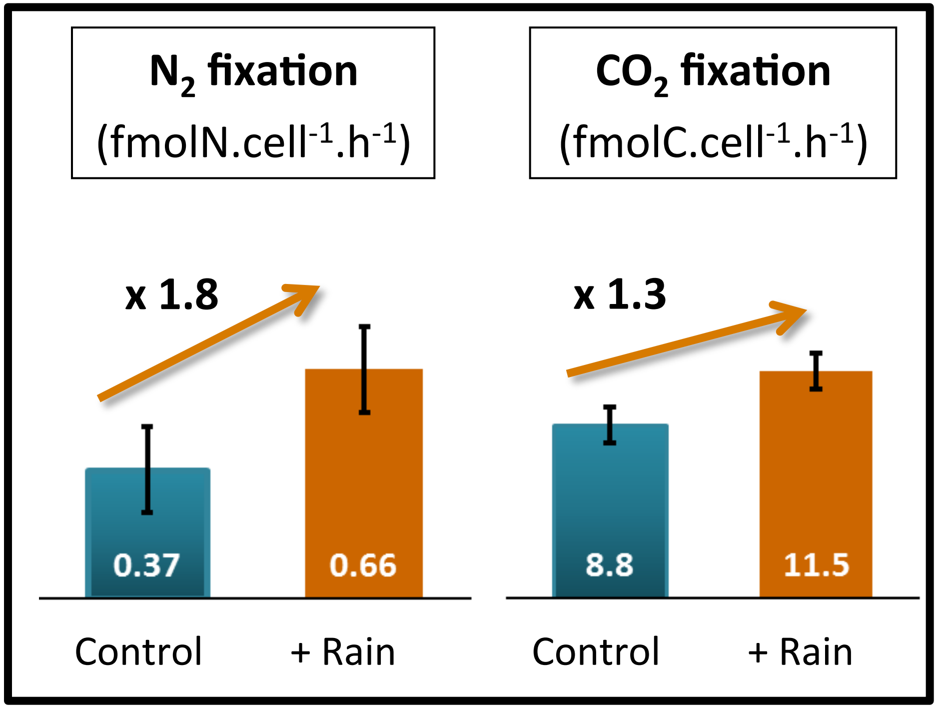

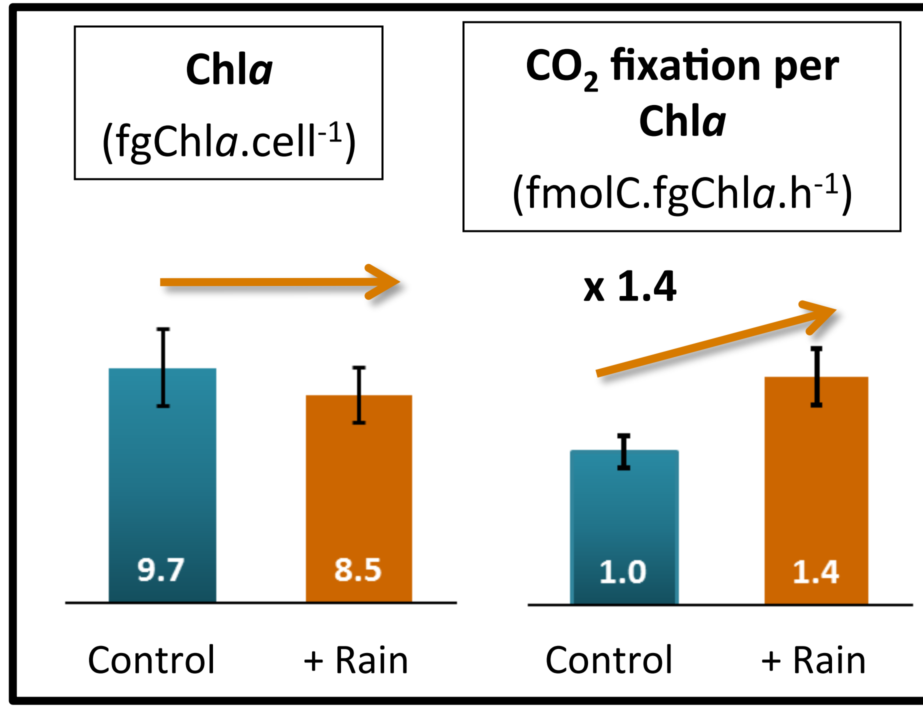

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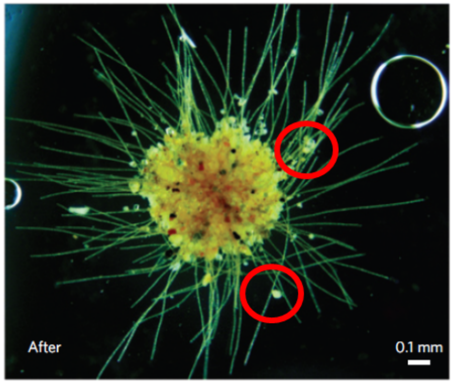
➔ More efficient photosynthesis

Increase in cytochromes synthesis?

C. watsonii versus *T. erythraeum*

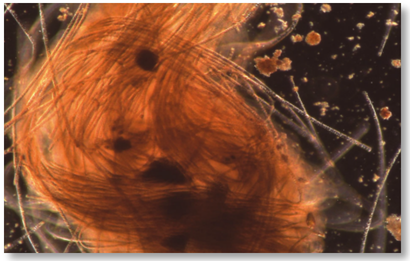
Cultured T. *erythraeum*:

- *Rubin et al. (2011):* Colonies → use directly particulate tanks to adsorption-dissolution mechanisms



(Rubin et al. 2011)

- *Langlois et al. (2012)*: Formation of colonies following dust deposition and increase in cell abondance



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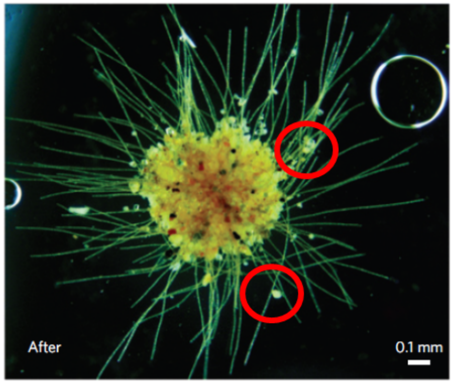

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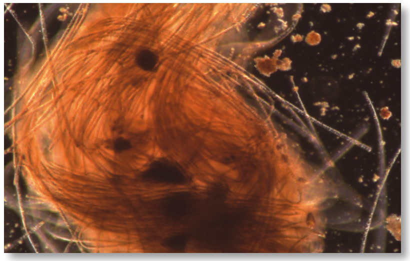


(Langlois et al. 2012)

Positive response of 2 types of diazotrophic cyanobacteria

→Which would be favored in the ocean?

Thank you for your attention

and thanks to…

Céline Ridame
and
Alain Saliot

Karine Desboeufs

Fanny Kaczmar

Stéphane L'Heleguen

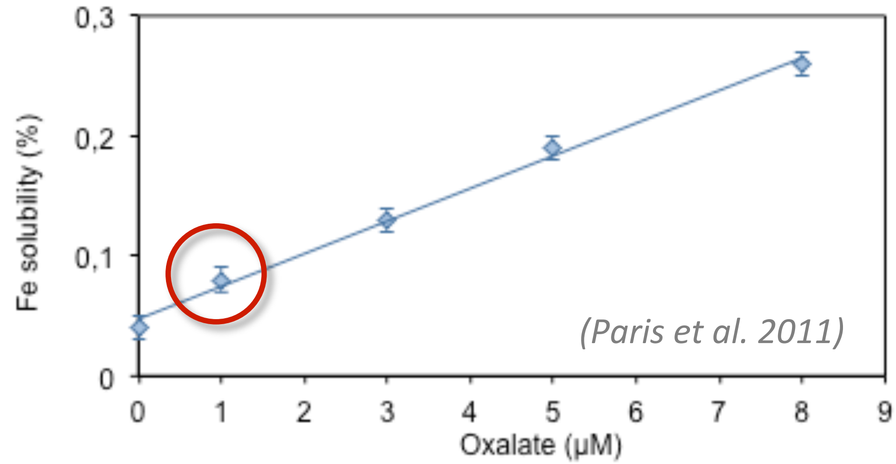
Hervé Rybarczyk

Annexes

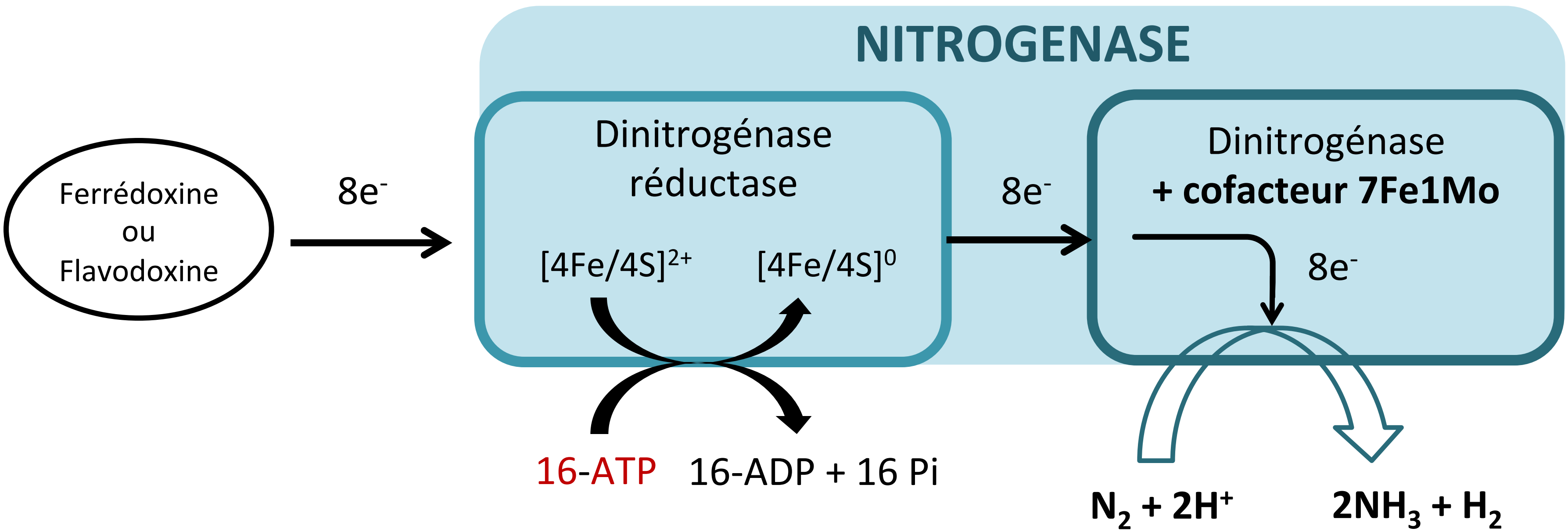
Fe organic chelator

- **Oxalate:** the most abondant in rainwater and aerosols
- Increase Fe solubility
- Concentration in artificial rainwater: **1 µM**

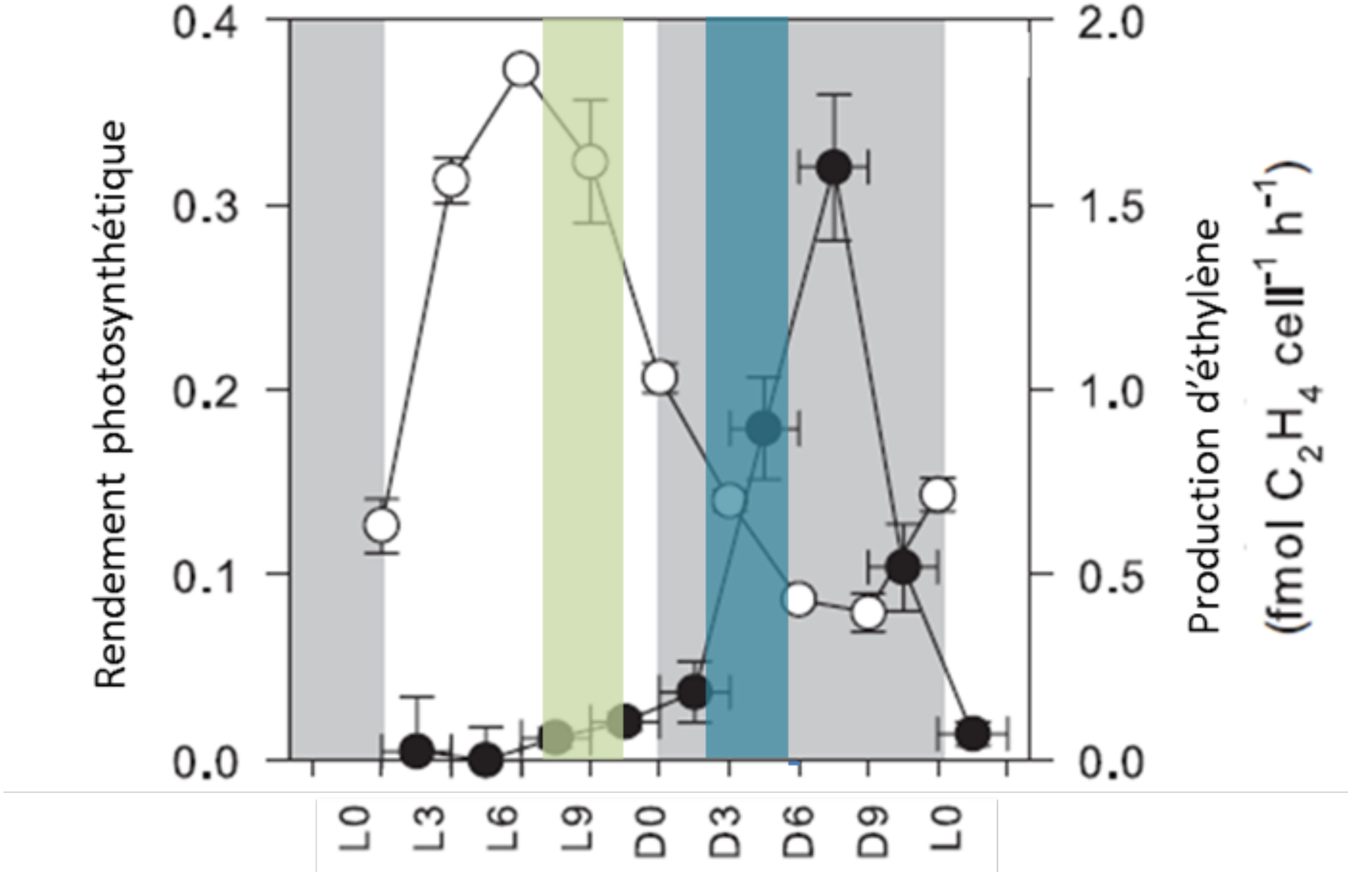
➔ Theoritical Fe solubility: **0.08** ± 0.01 **%**



La nitrogénase

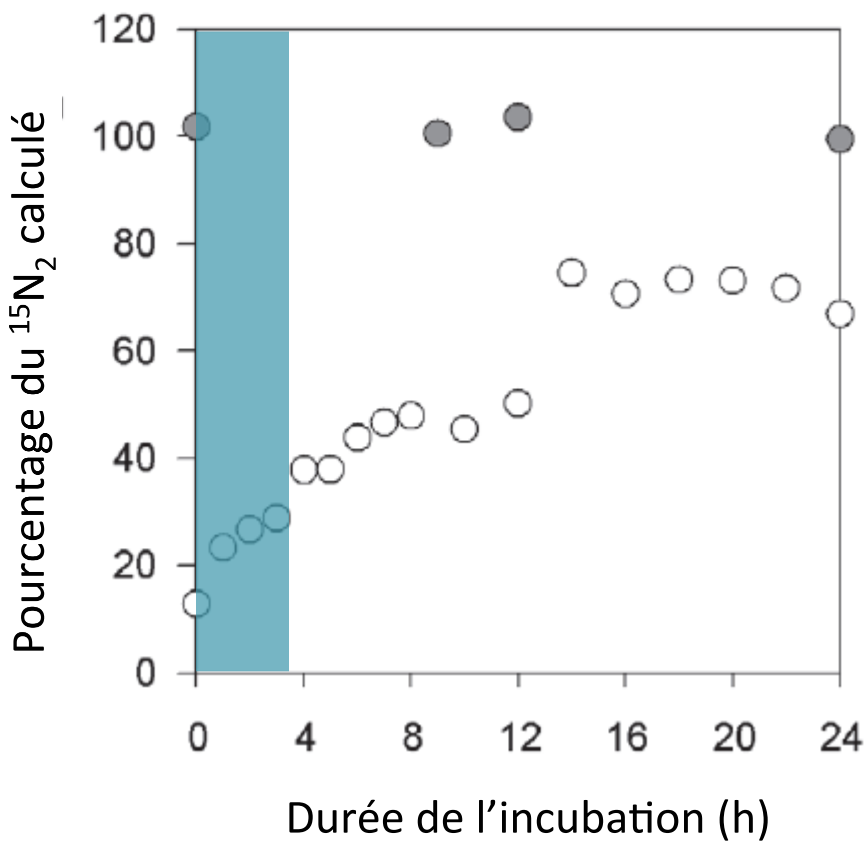


Prélèvements cultures: Fixation de CO_2 et N_2



Mohr et al. 2010a

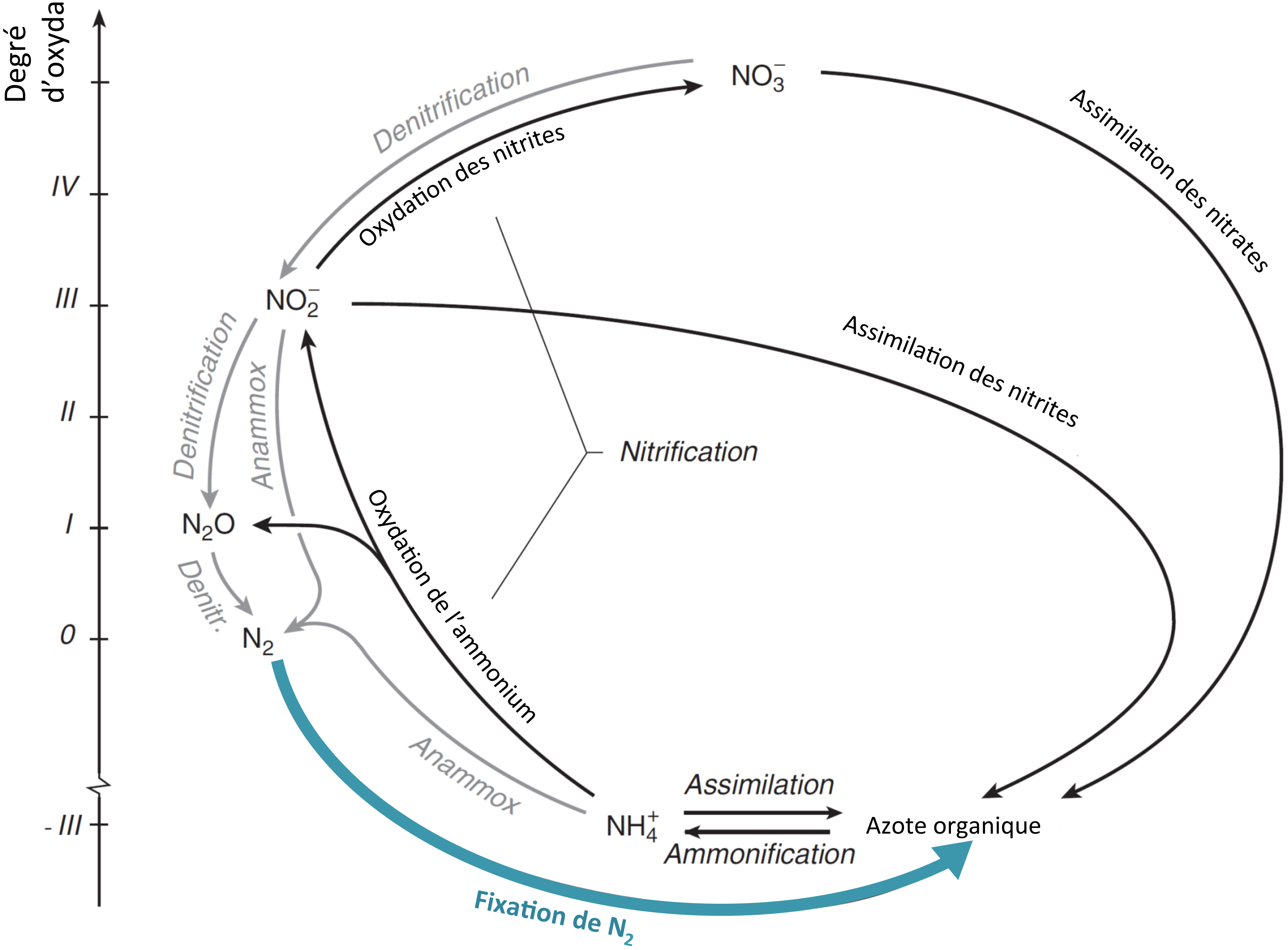
Sous estimation des taux de fixation de N_2



24%

Mohr et al. 2010b

Le cycle de l'azote



Chélation du fer

pFe > dFe car peu soluble dans l' eau de mer

dFe = Fe-L + Fe'

99% du dFe sous forme complexée

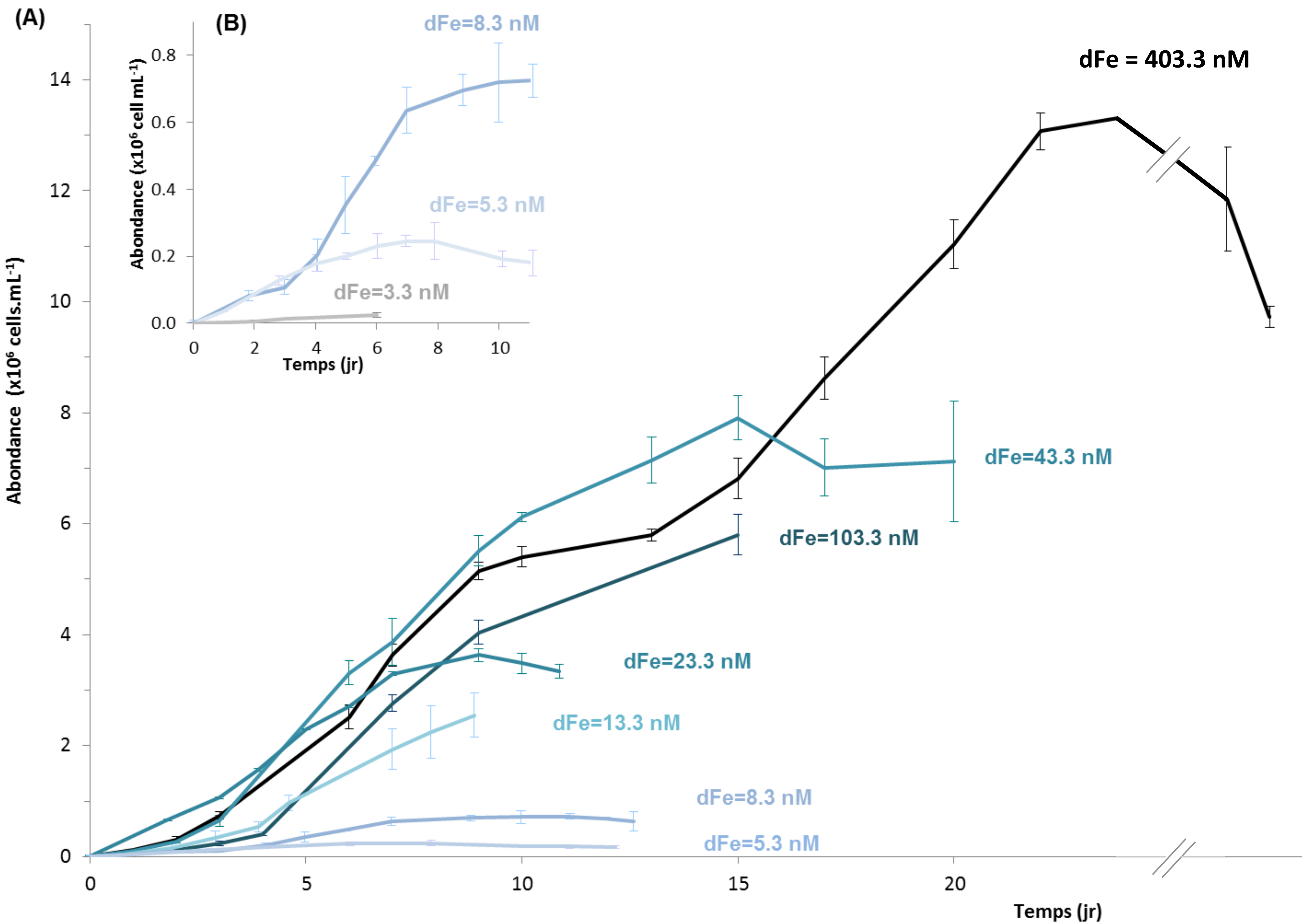
(Gledhill et Van Den Berg 1994)

Fer organique dissous

Fe^{3+}, Fe^{2+}, $Fe(OH)_n^m$

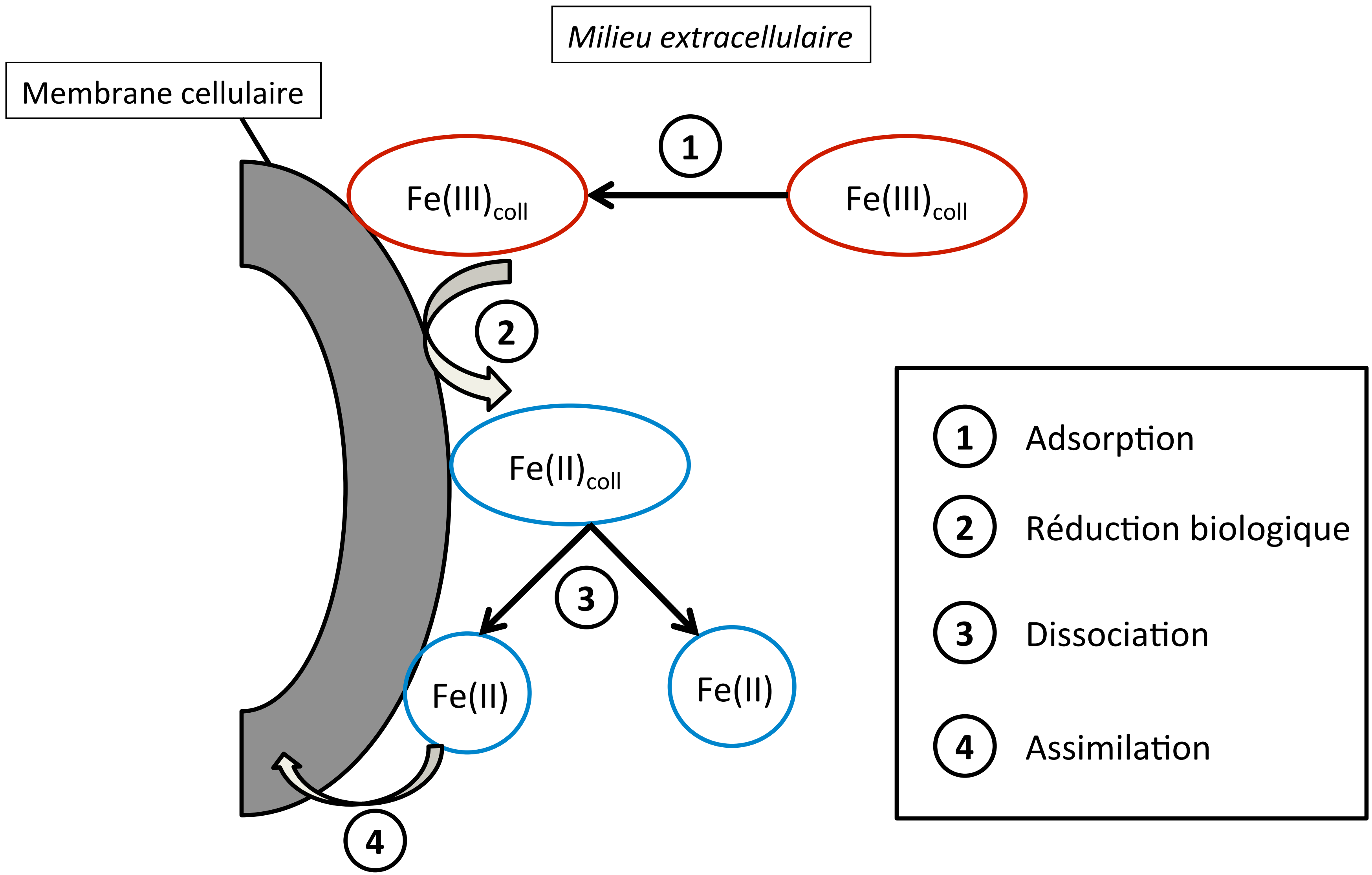
Très faible solubilité

(Millero, 1998)



(A)
(B)
dFe=8.3 nM
dFe=5.3 nM
dFe=3.3 nM
Abondance (x10^6 cell mL^-1)
Temps (jr)
dFe = 403.3 nM
dFe=43.3 nM
dFe=103.3 nM
dFe=23.3 nM
dFe=13.3 nM
dFe=8.3 nM
dFe=5.3 nM
Abondance (x10^6 cells.mL^-1)
Temps (jr)

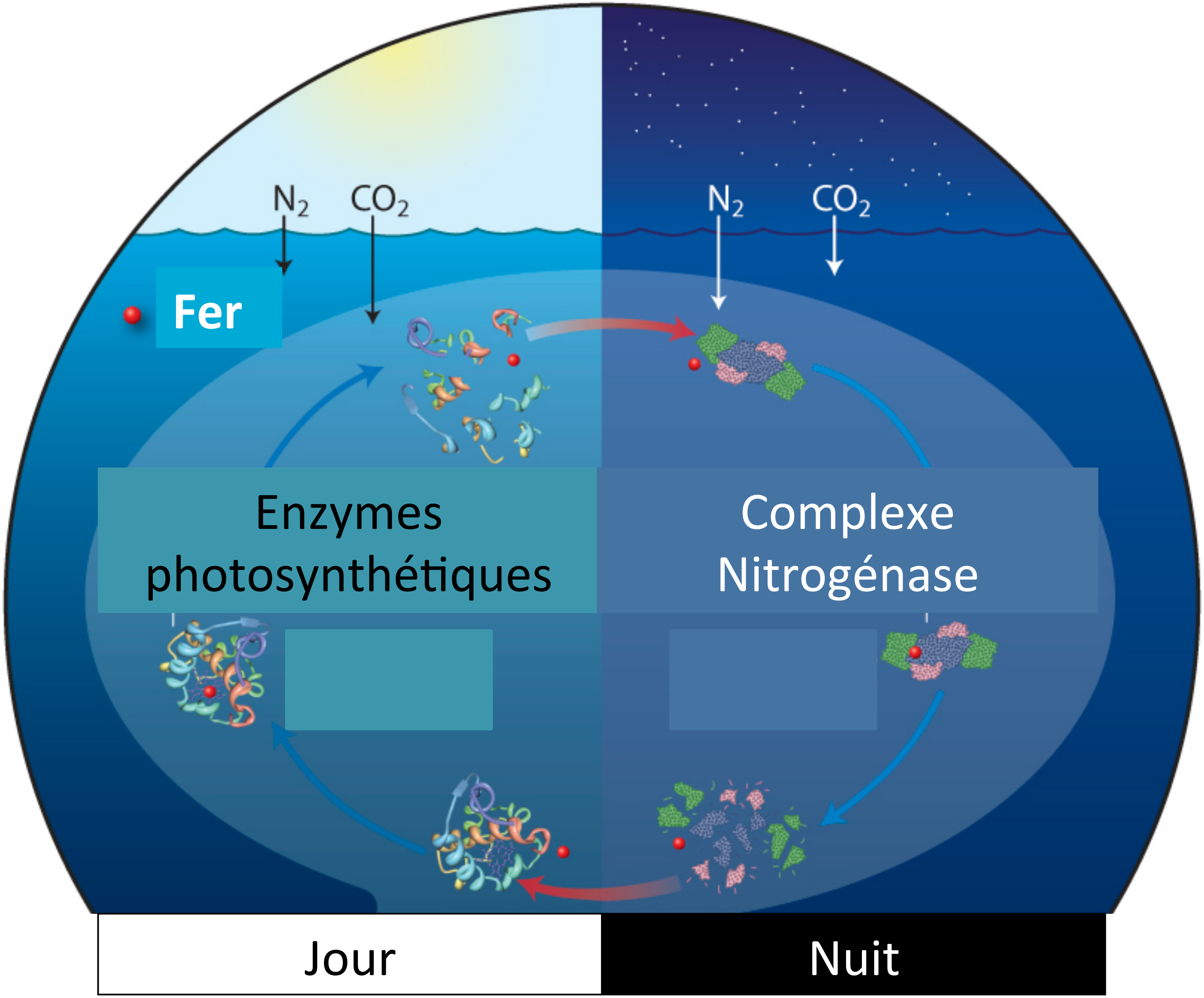
Mécanisme d'assimilation du fer colloïdal



Sunda, comm. pers.

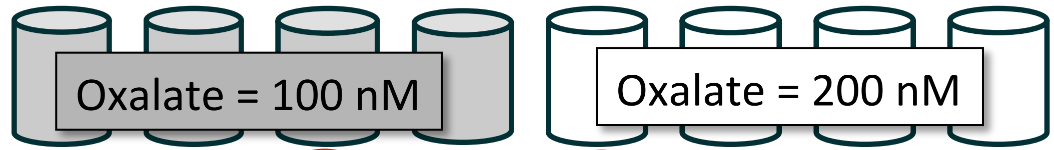
Stratégie de recyclage du fer

Saito et al. 2011

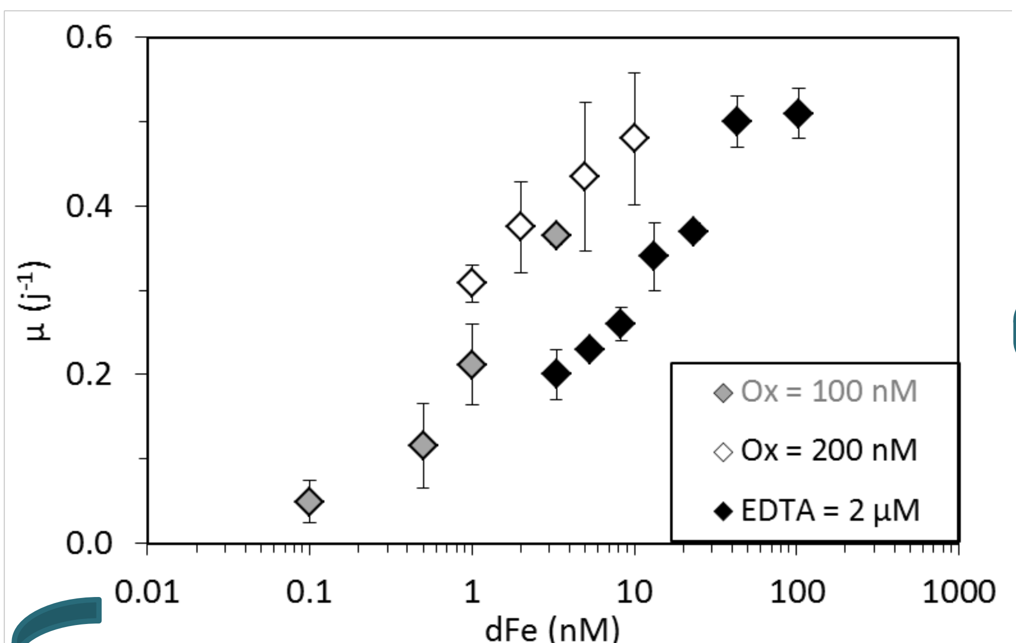


L'impact de l'oxalate $(C_2O_4)^{2-}$ comme agent chélateur du fer sur la croissance de *C. watsonii*

C. Watsonii
Milieu YBCII modifié
Conditions
« trace metal clean »



dFe (nM)	0.1	0.5	1	3.3	1	2	5	10
Fe' (nM)	0.04	0.11	0.26	0.80	0.52	0.68	0.63	1.50



- Oxalate vs. EDTA:
Taux de croissance plus élevés

- Oxalate 100 nM vs. Oxalate 200 nM:
Taux de croissance plus élevé

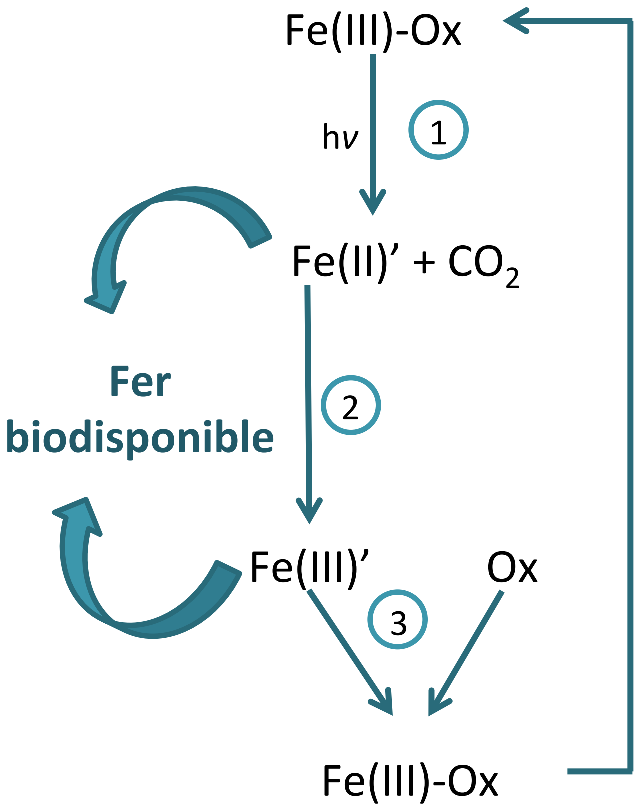
- Utilisation de l'équation de Monod pour déterminer Fe':

$$[Fe'] = K_{\mu Fe'} \times \frac{\mu}{\mu_{max} - \mu}$$

Augmentation des concentrations en Fe' ?

$K_{\mu Fe'}$ **= 0.38 ± 0.11 nM**

L'oxalate comme agent chélateur du fer dans l'eau de mer: *(Bill Sunda, com. pers.)*



Dans l'eau douce:

constantes de complexation Fe-oxalate < Fe-EDTA

➔ **De même dans l'eau de mer?**

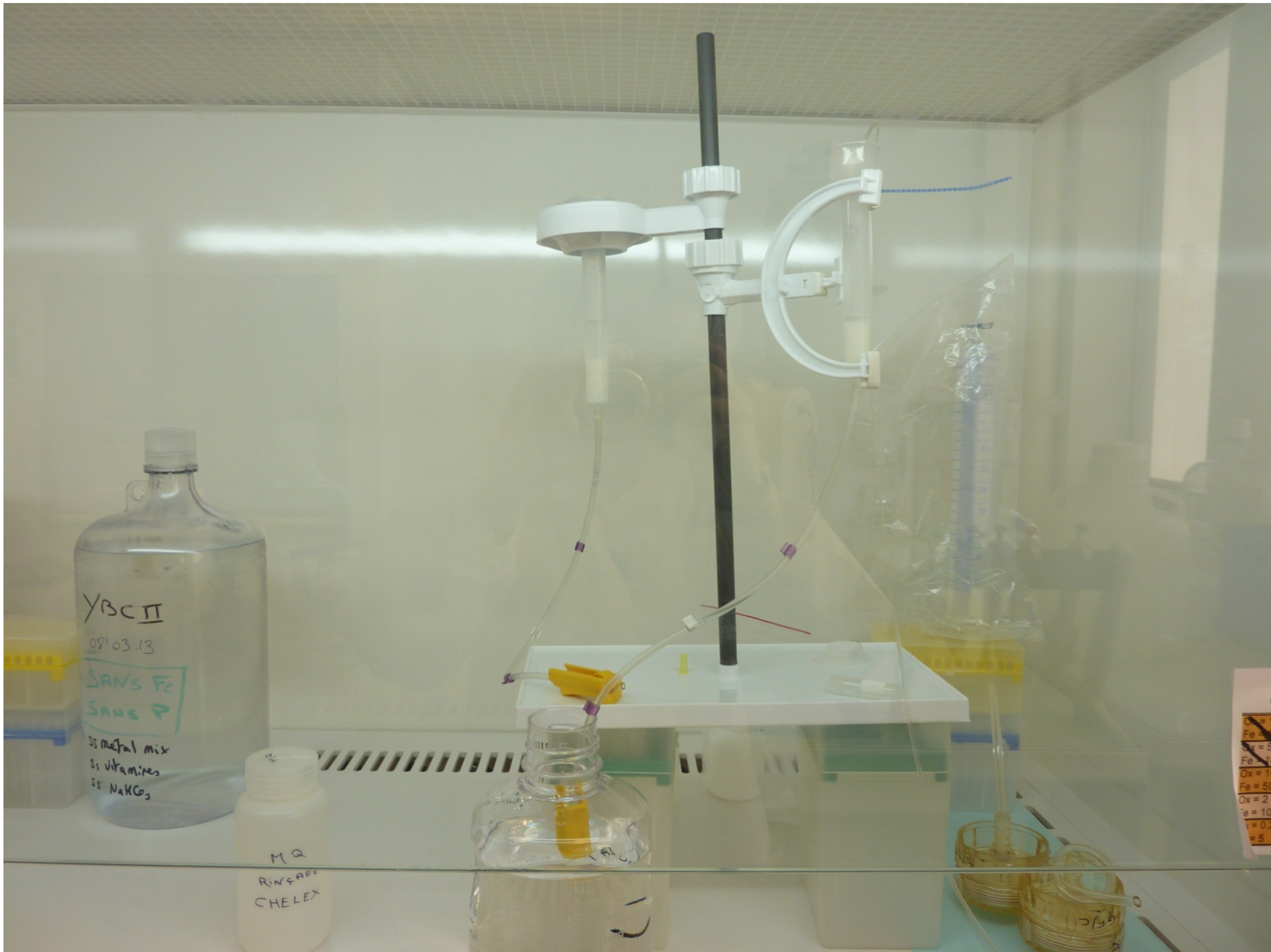
1 Oxydo-réduction photochimique

2 Oxydation

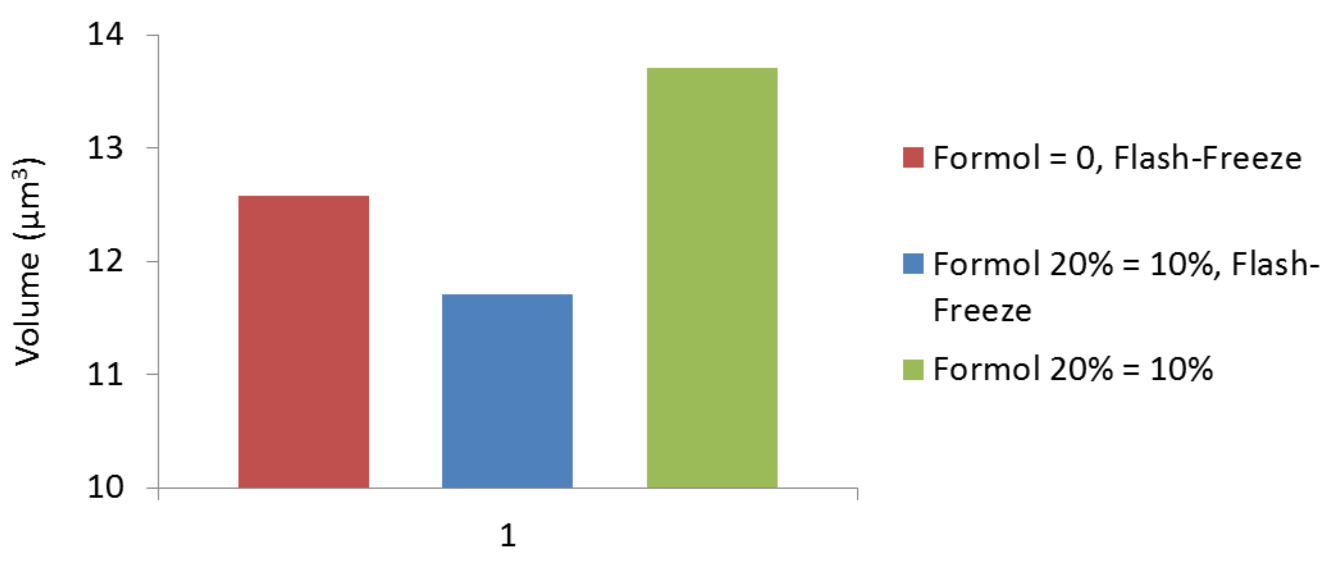
3 Complexation

- Biodisponibilité, au moins partielle, du complexe fer-oxalate?

Montage CHELEX LOCEAN



Influence du fixateur



Biogeochemical relevance