Effect of Ocean Acidification on Marine Nitrogen Fixation

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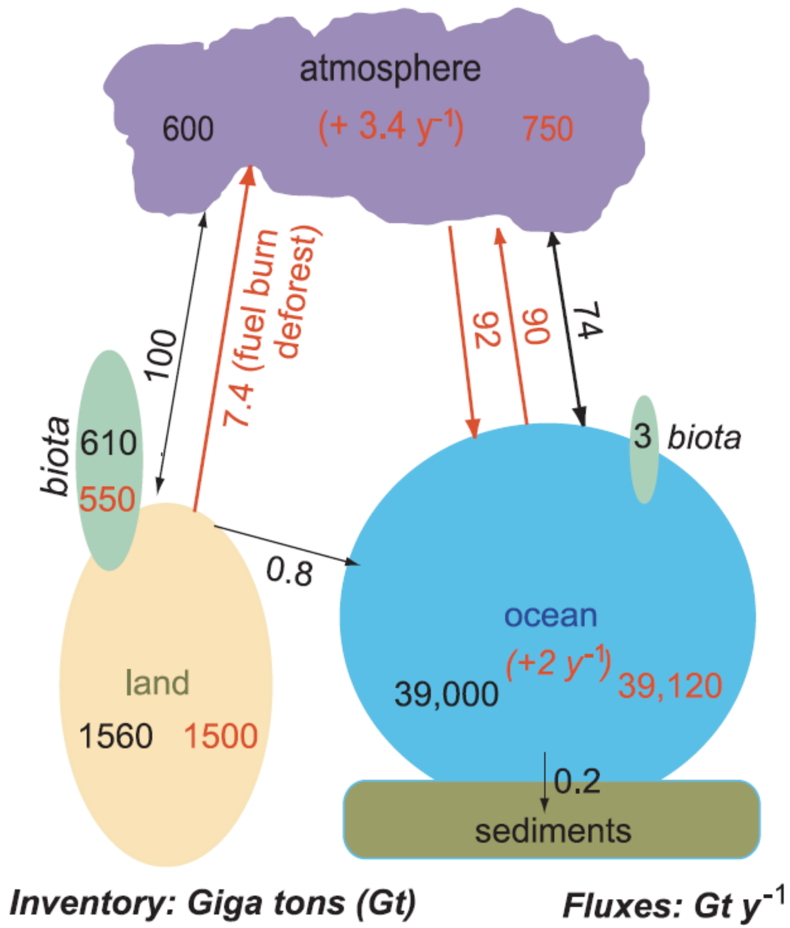
Singh, Bach, Loescher, Paul, Ojha and Riebesell (2021), L&O

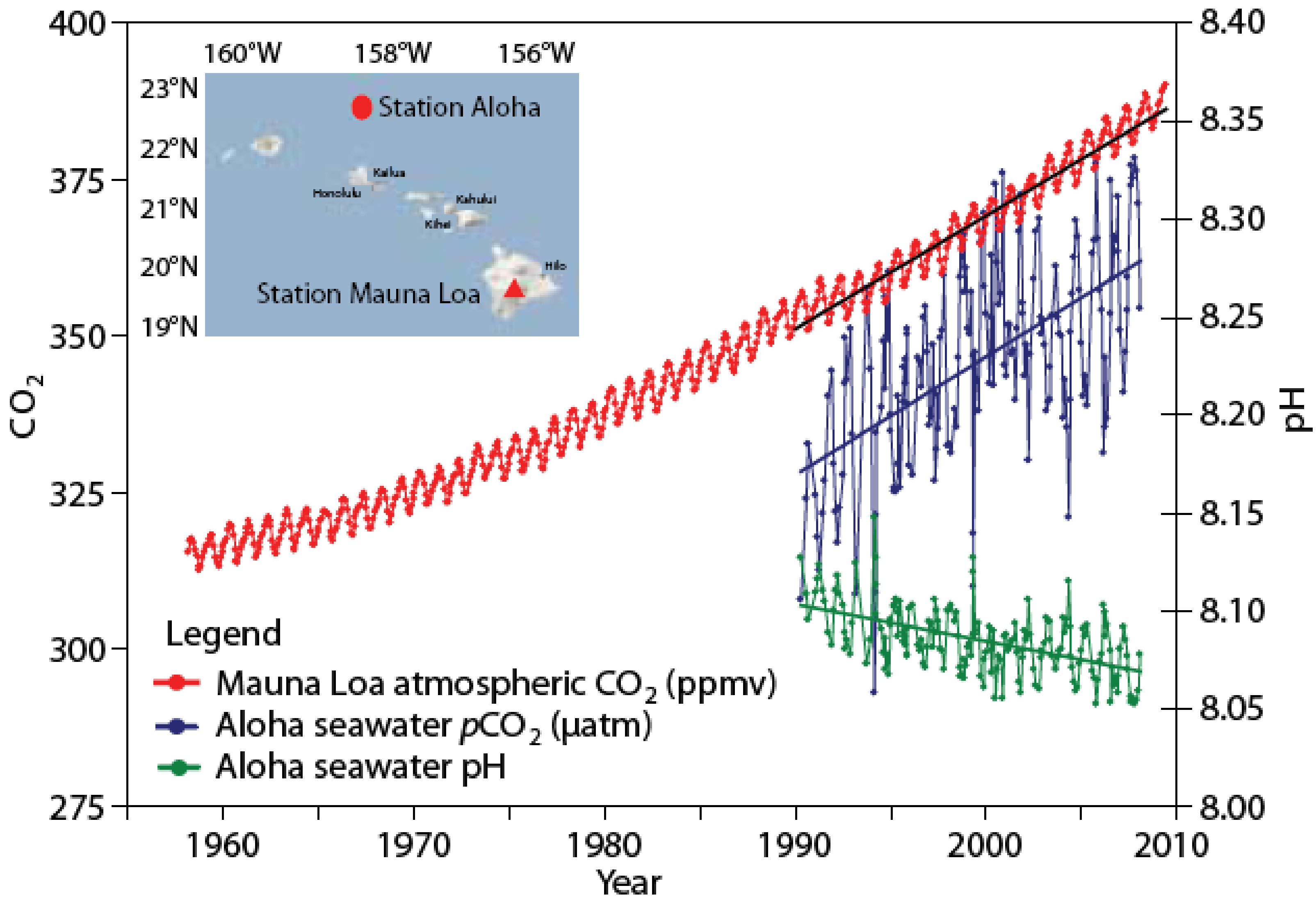
Nano Seminar **29 Oct 2021**

Global Carbon Cycle



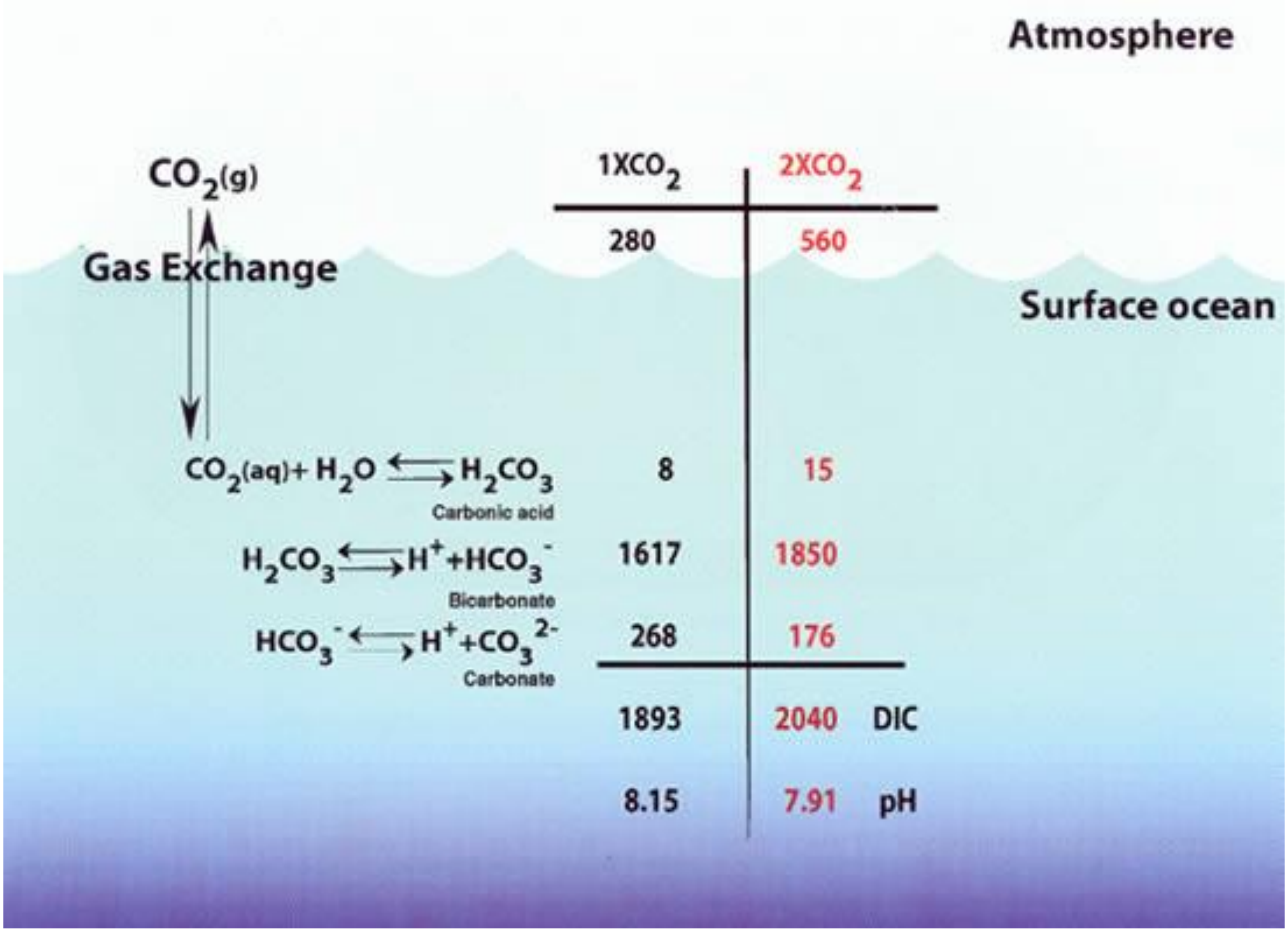
Kumar, IGBP, 2006

CO_2 variation in the atmosphere and ocean



Doney et al., 2009

Effect of adding CO_2 to ocean



Feely et al. (2000)

Impacts of anthropogenic CO_2 on oceans

Increase in atmospheric CO_2 <u>indirectly</u> influences -

- **Sea surface temperature**
- **Sea level rise**
- **Oxygen minimum zone expansion (Hypoxia)**
- **Stratification**
- **Nutrient stoichiometry (also because of N deposition due to human activities)**
- **Sea surface salinity (Increased precipitation?)**
- **Any other parameters?**

and <u>directly</u> influences -

- **pH**
- **Carbon species distribution**

} **Ocean Acidification**

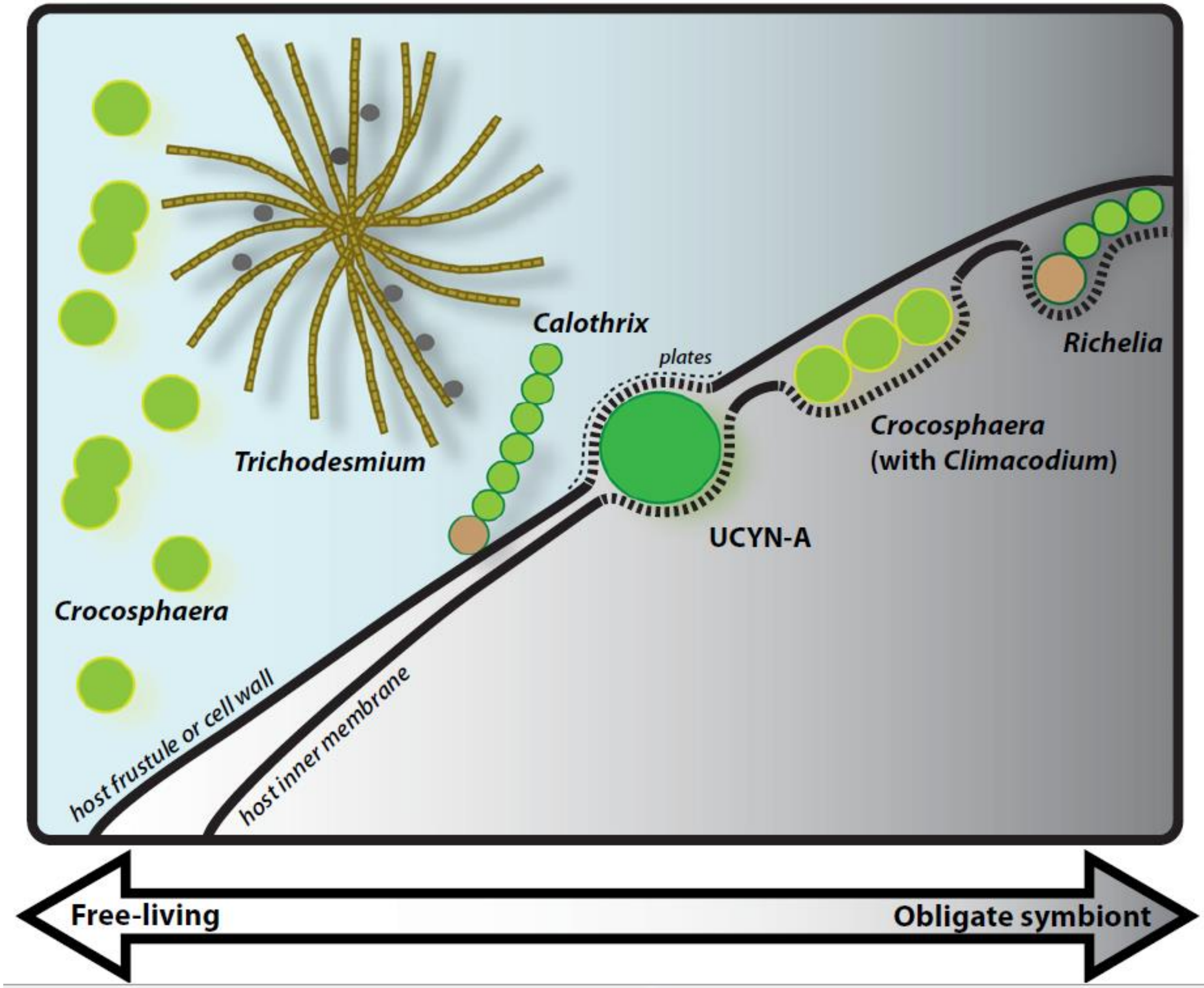
How will ocean acidification affect ocean's nitrogen cycle? And how do we study it?

Who is getting impacted?

Great Barrier Reef

Fig. Source: http://www.sciencemag.org/

N_2 fixers: dinitrogen to ammonium reducers



Thompson and Zehr, 2013

Why is nitrogen important for oceans?

Although Earth's atmosphere is an abundant source of nitrogen, most is relatively unusable by phytoplankton. Hence, limited for ocean productivity.

Nitrogen fixation is major pathway through which oceans receive nitrogen.

REPORTS

Effect of Ocean Acidification on Iron Availability to Marine Phytoplankton

Dalin Shi,* Yan Xu, Brian M. Hopkinson, François M. M. Morel

Global Change Biology

Global Change Biology (2012) 18, 3004–3014, doi: 10.1111/j.1365-2486.2012.02777

No stimulation of nitrogen fi... diazotrophs under elev...

CLIFF S. LAW*, EIKE BRE... W†‡,
REBECCA J. LANGL... AFI¶

PNAS

Ocean acidificati... growth in t... und... ...mium

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[a]State K... ...ent and Ecology, Xiamen University, Xiamen 361005, China;
and [b]Dep...

Contribute... ...t for review June 21, 2012)

Contradictory results; Reason: conditions and species are different in different experiments, while most were laboratory simulations

nature geoscience

ARTICLES

PUBLISHED ONLINE: 30 JUNE 2013 | DOI:10.1038/NGEO1858

Taxon-specific response of marine nitrogen fixers to elevated carbon dioxide concentrations

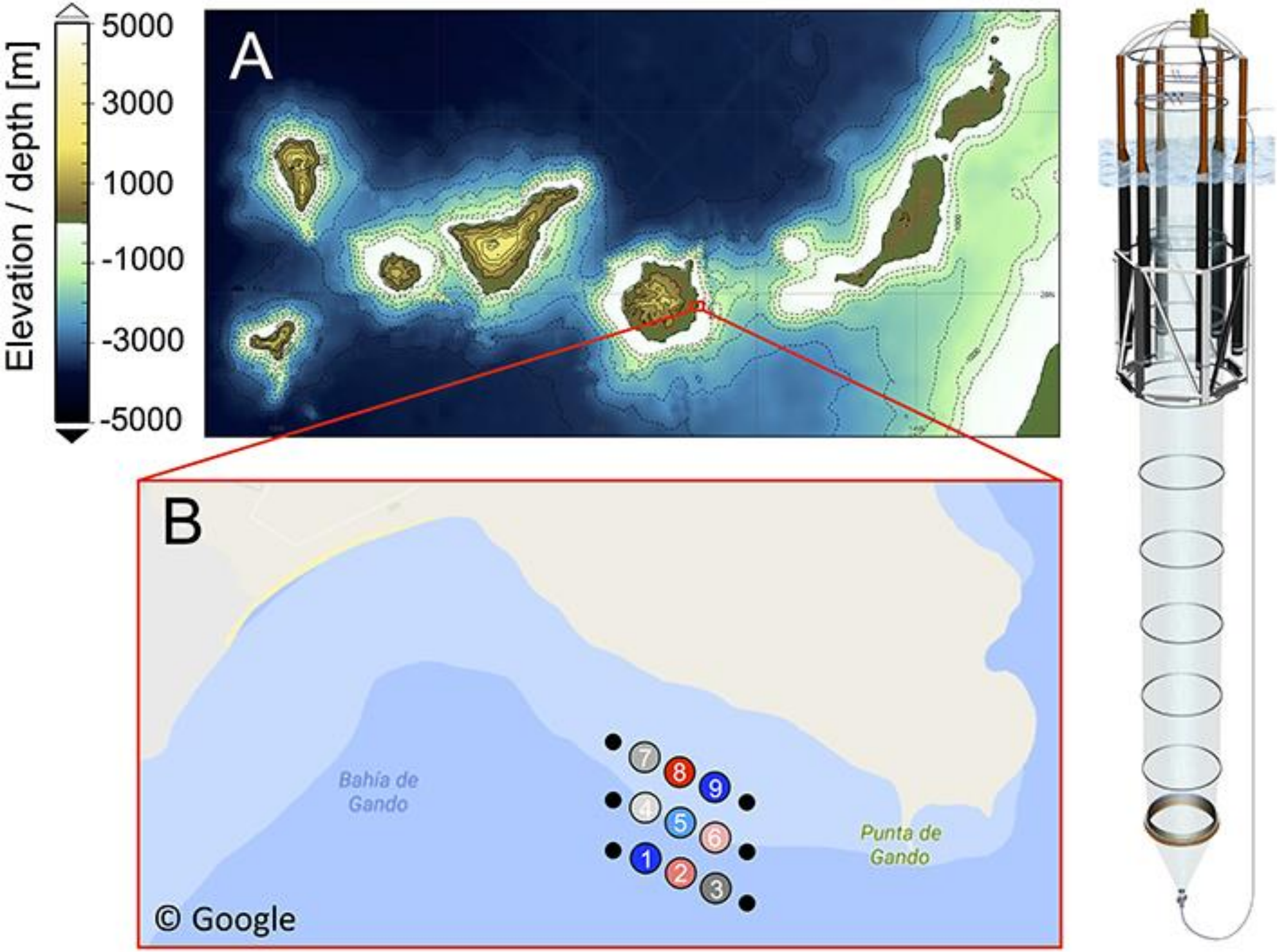
David A. Hutchins[1]*, Fei-Xue Fu[1], Eric A. Webb[1], Nathan Walworth[1] and Alessandro Tagliabue[2]

Hypotheses

1. Future pCO_2 levels will increase N_2 fixation rates.

2. Addition of deep water will decrease N_2 fixation rates.

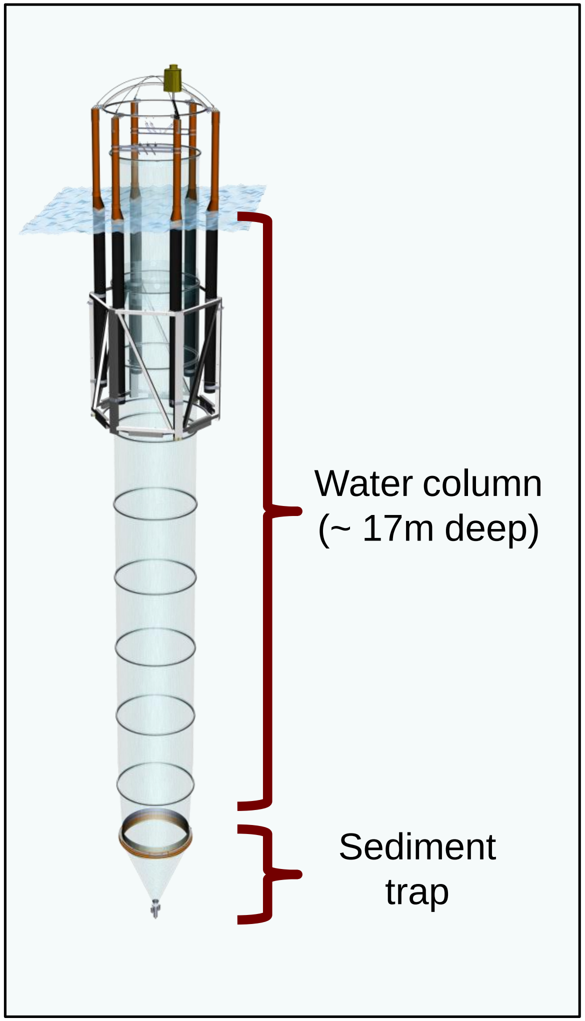
Mesocosm Experiments at Gran Canaria



Taucher et al., 2017

Experimental design

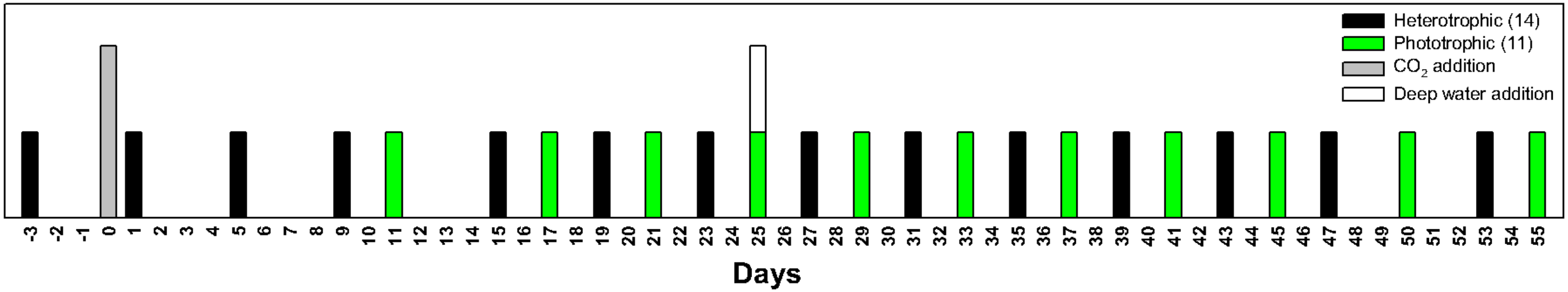
Kiel Off-Shore Mesocosms for future Ocean Simulations (KOSMOS)



Source: GEOMAR

- 9 mesocosms (made of 1 mm thick thermoplastic polyurethane, 2 m diameter) containing a natural phytoplankton community
- $p\text{CO}_2$ was manipulated between 400 µatm and 1480 µatm
- Experiment length ~ 8 weeks during Sep – Nov 2014
- Volume = ~ 50000 L

Mesocosm experiment in Gran Canaria (GC 2.0) 2014

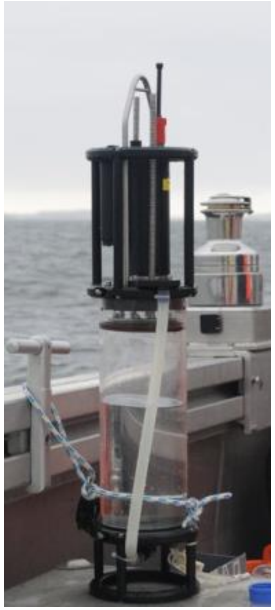


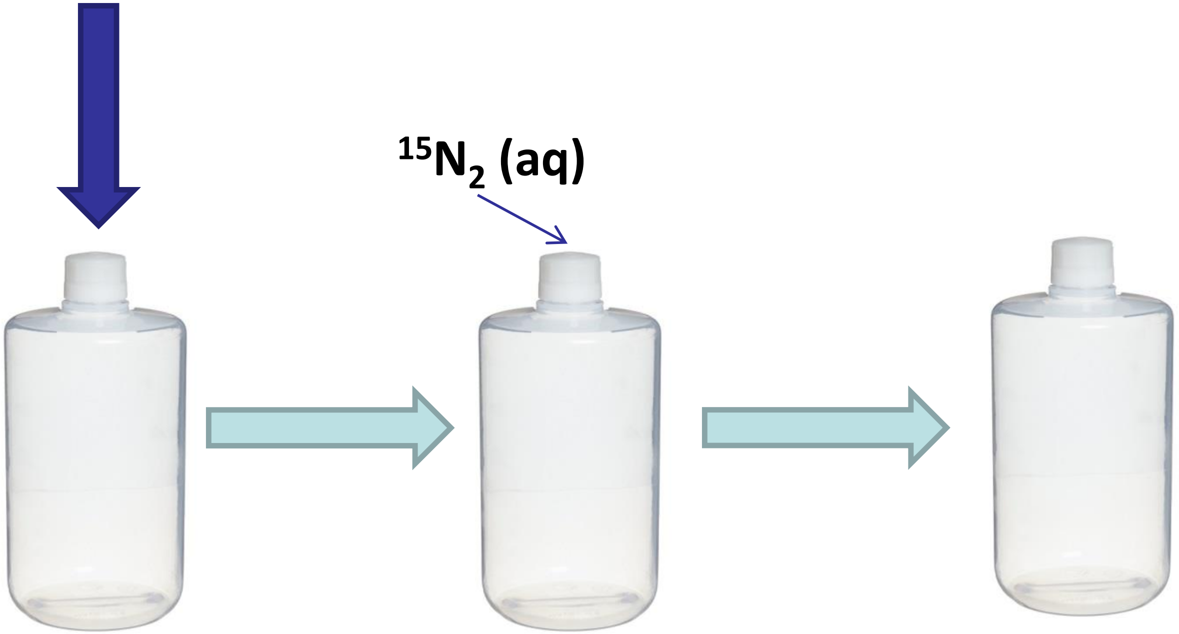
CO_2 levels in Mesocosms

Mesocosm	Symbol	Volume [m^3]	DW addition [m^3]	pCO_2 [μatm]				Comment
				Phase I	Phase II	Phase III	Mean t1–t55	
M1		37.75	8.95	401	374	326	369	
M2		34.18	8.11	1,050	748	830	887	
M3		31.57	7.50	636	493	546	563	
M4		36.93	8.66	800	620	710	716	hole on t11
M5		34.00	8.07	502	404	427	448	
M6		34.03	8.08	976	–	–	–	lost on t27
M7		35.25	8.36	746	571	672	668	
M8		34.95	8.29	1,195	902	944	1,025	
M9		35.21	8.36	406	343	297	352	hole on t13

Note that the control treatment (M1 and M9) did not receive CO_2 enrichment and followed ambient pCO_2 for the entire study.

Sampling for N_2 fixation

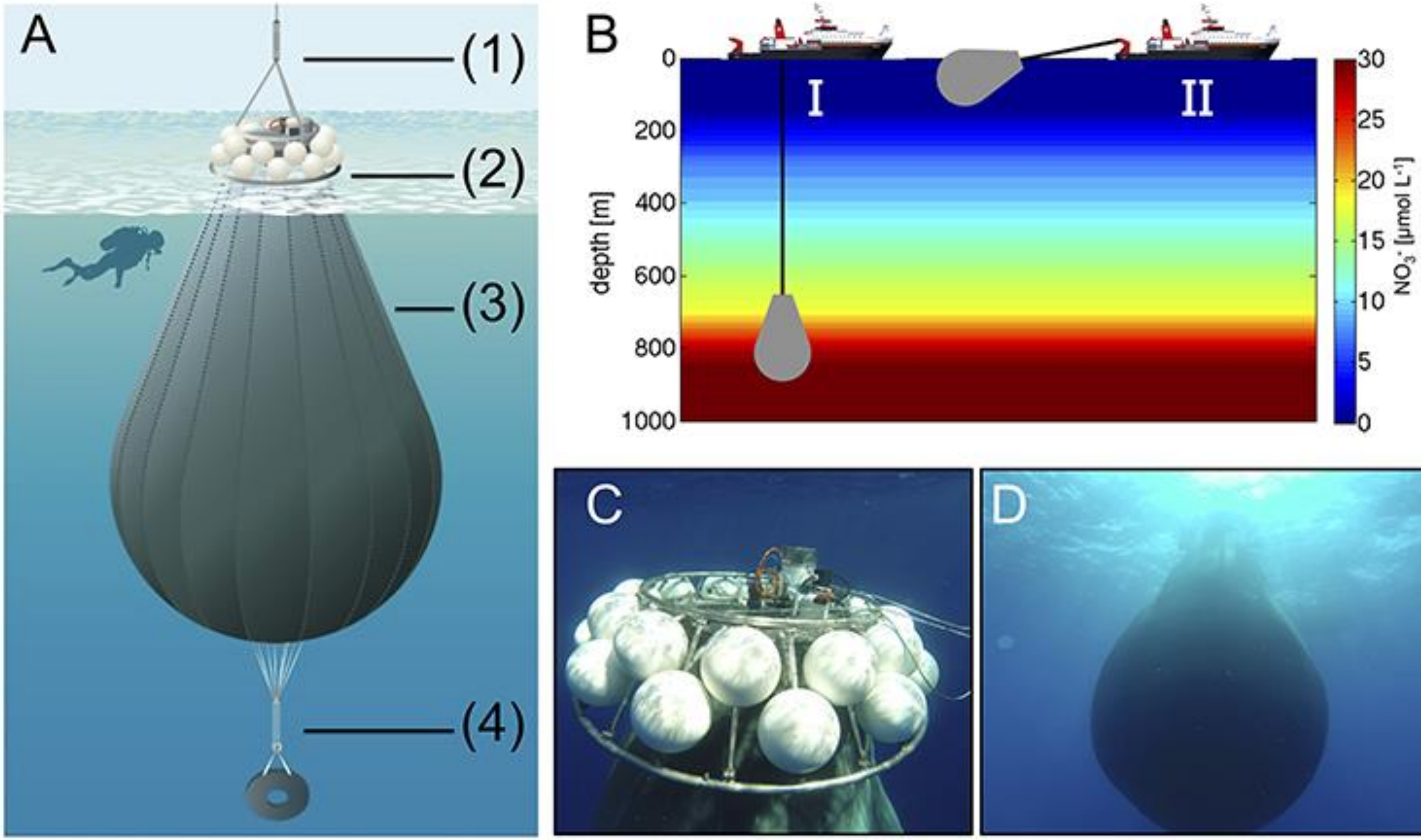




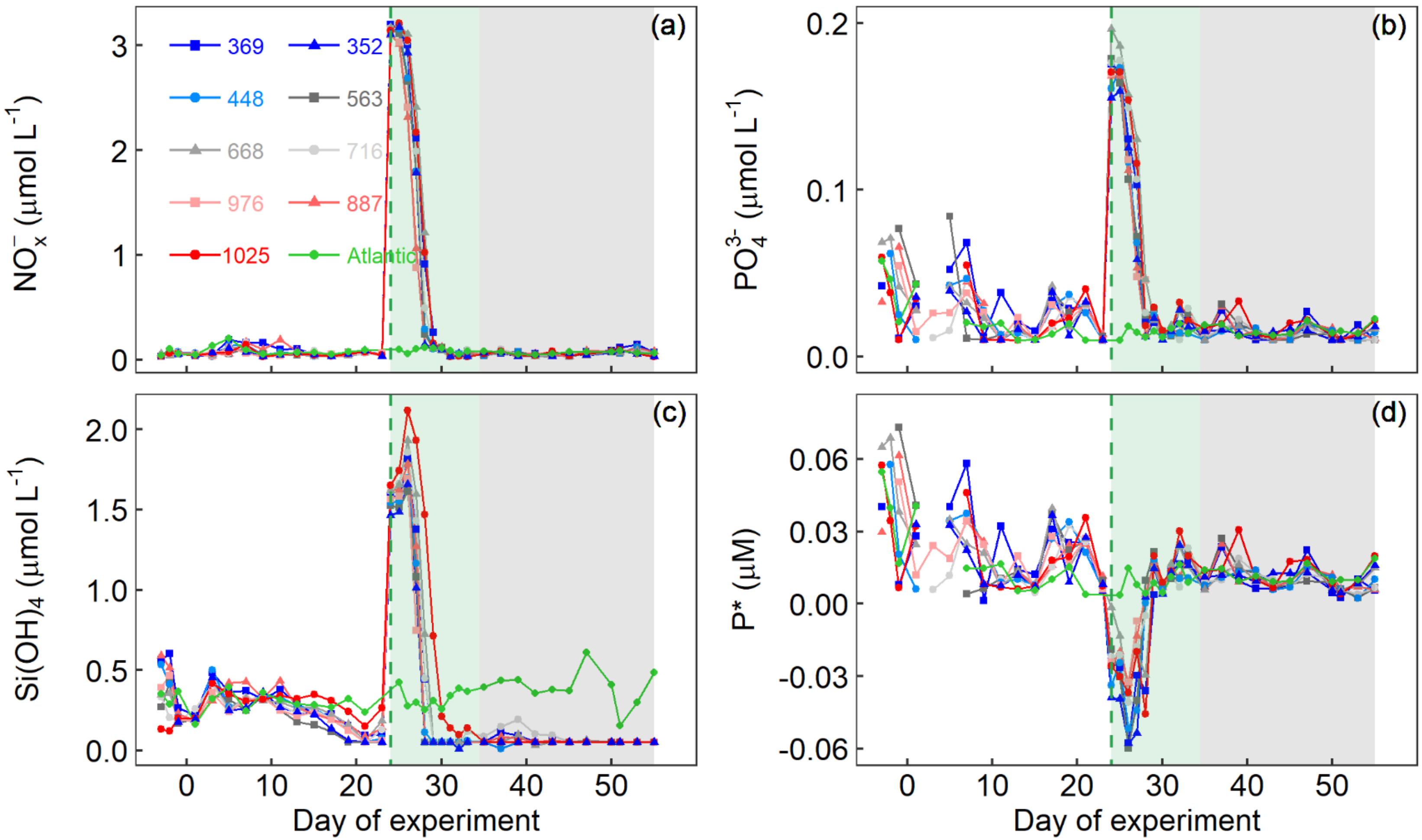
Mohr et al. (2010) method followed

24 hrs dark for heterotrophic or 12:12 (L:D) incubation for Phototrophic

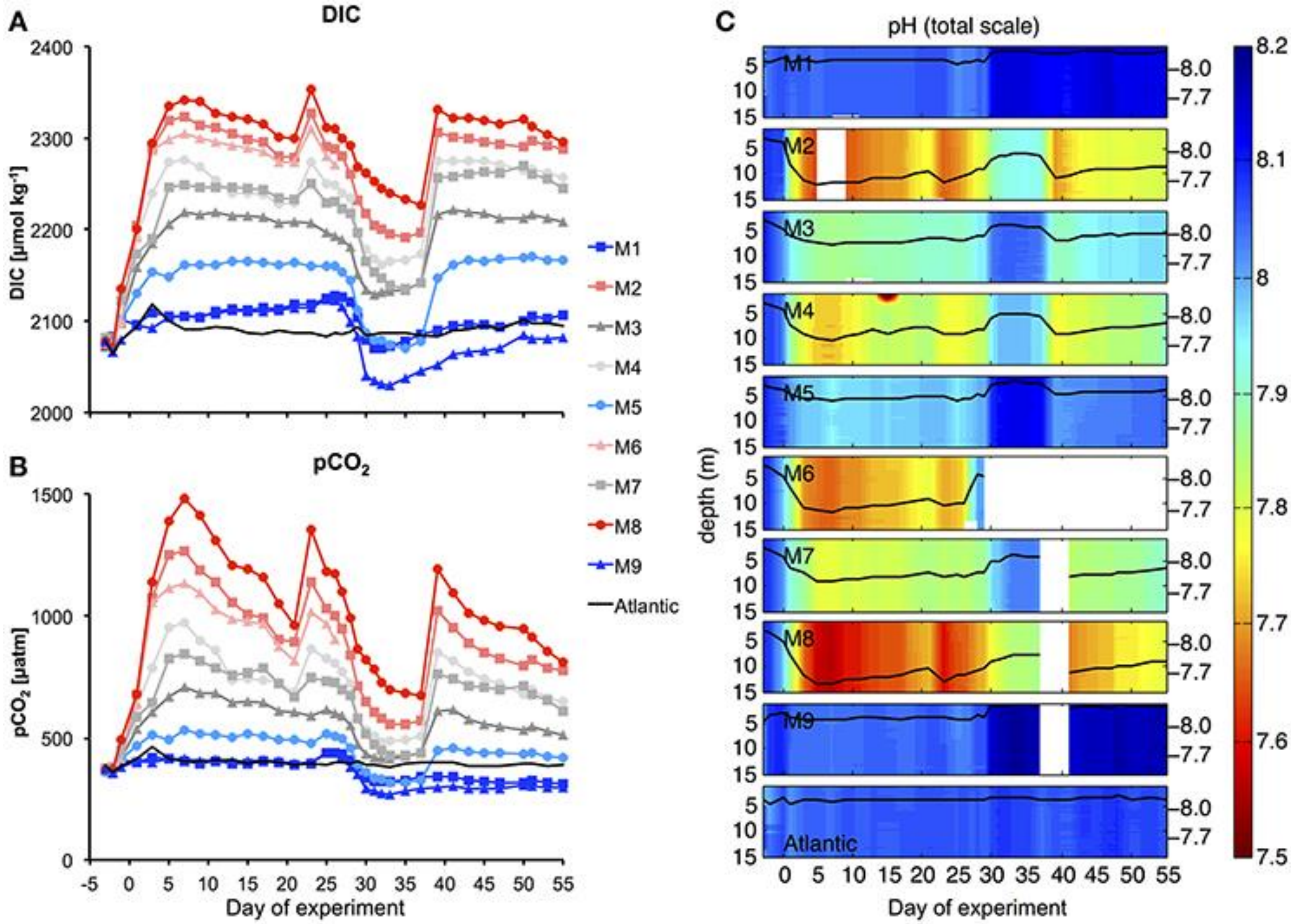
Deep water collection



Nutrients concentrations after deep water addition

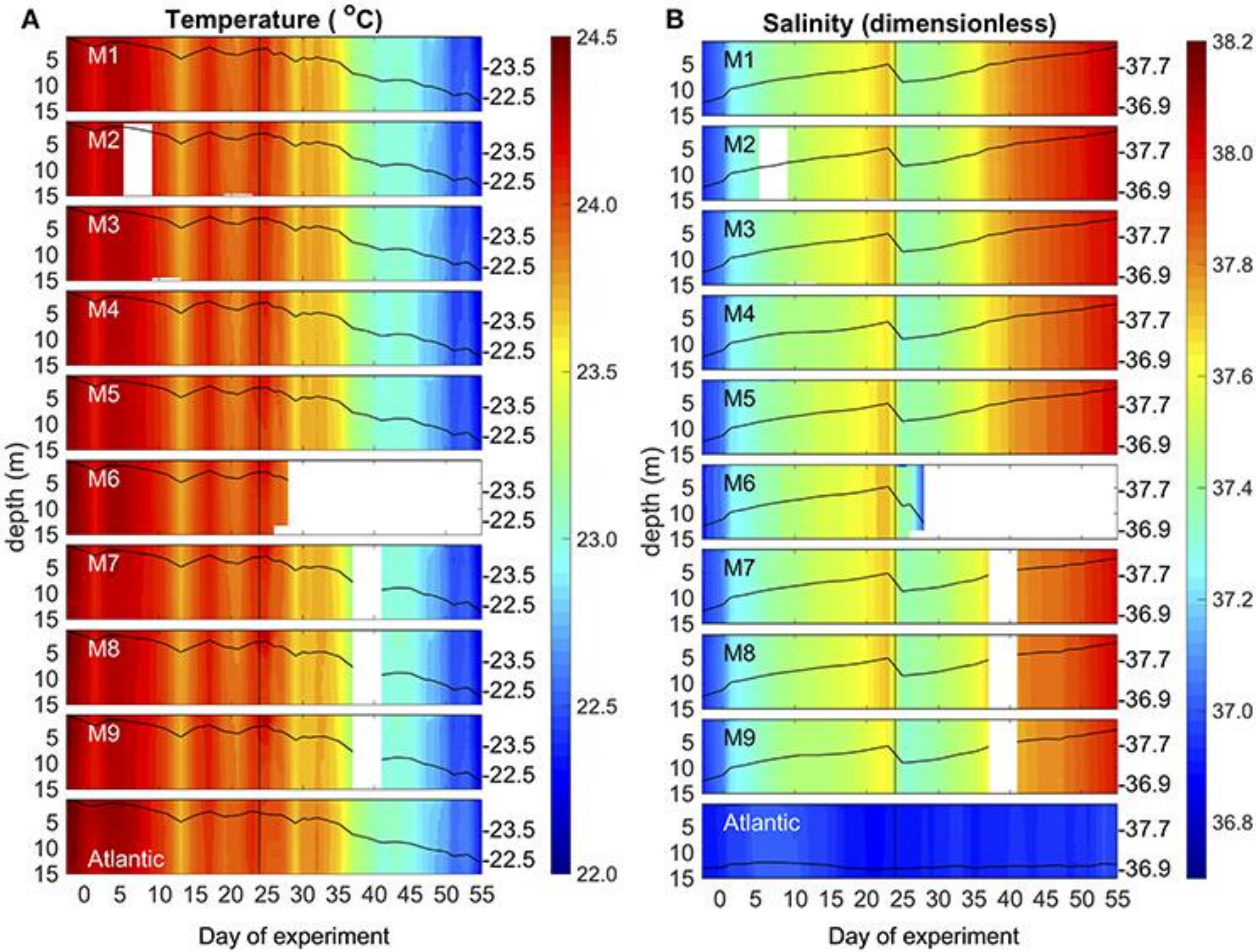


DIC and pCO_2 variation

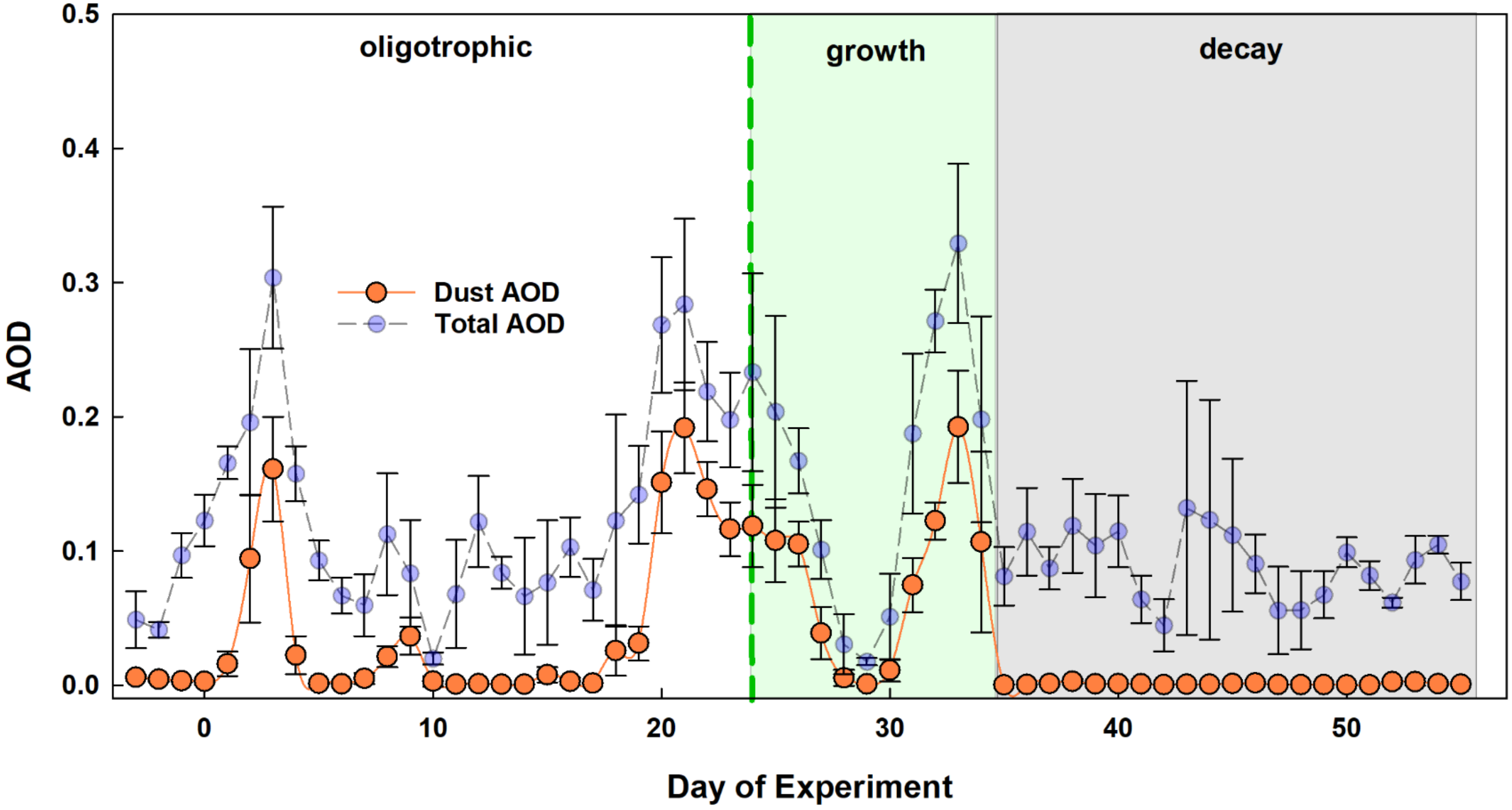


Taucher et al., 2019

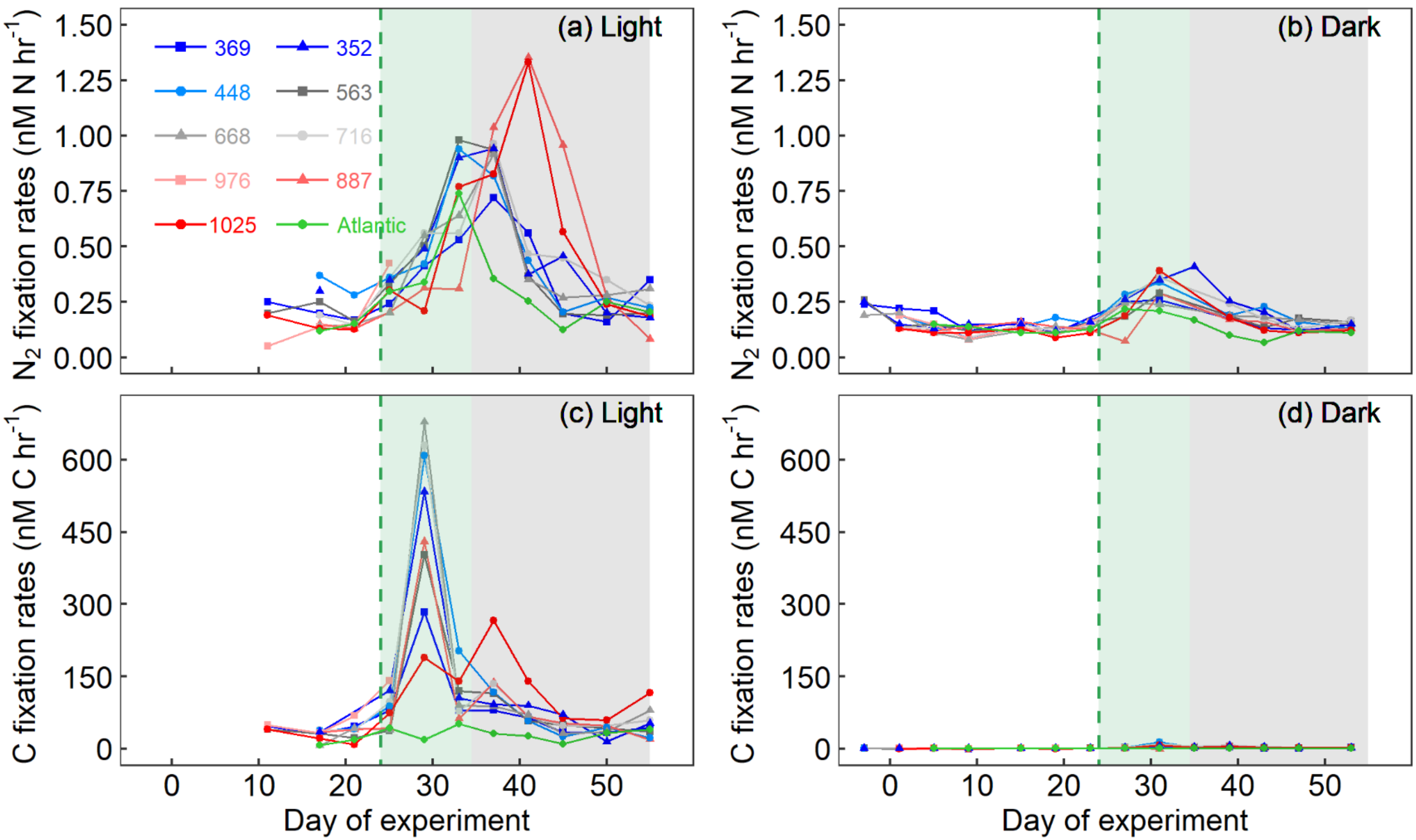
T and S variation in the mesocosms



AOD (dust) variation during the sampling period

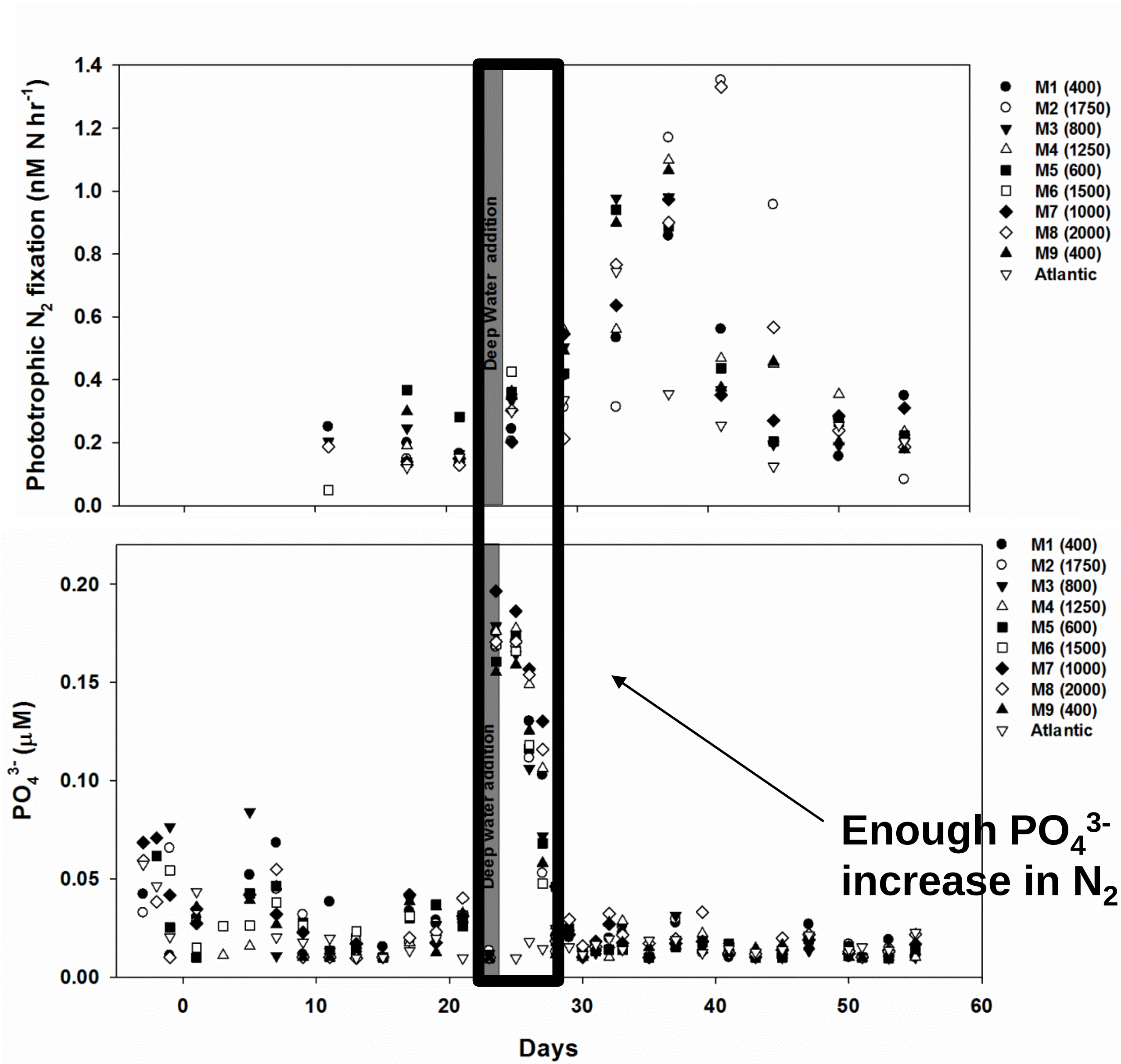


C and N_2 fixation



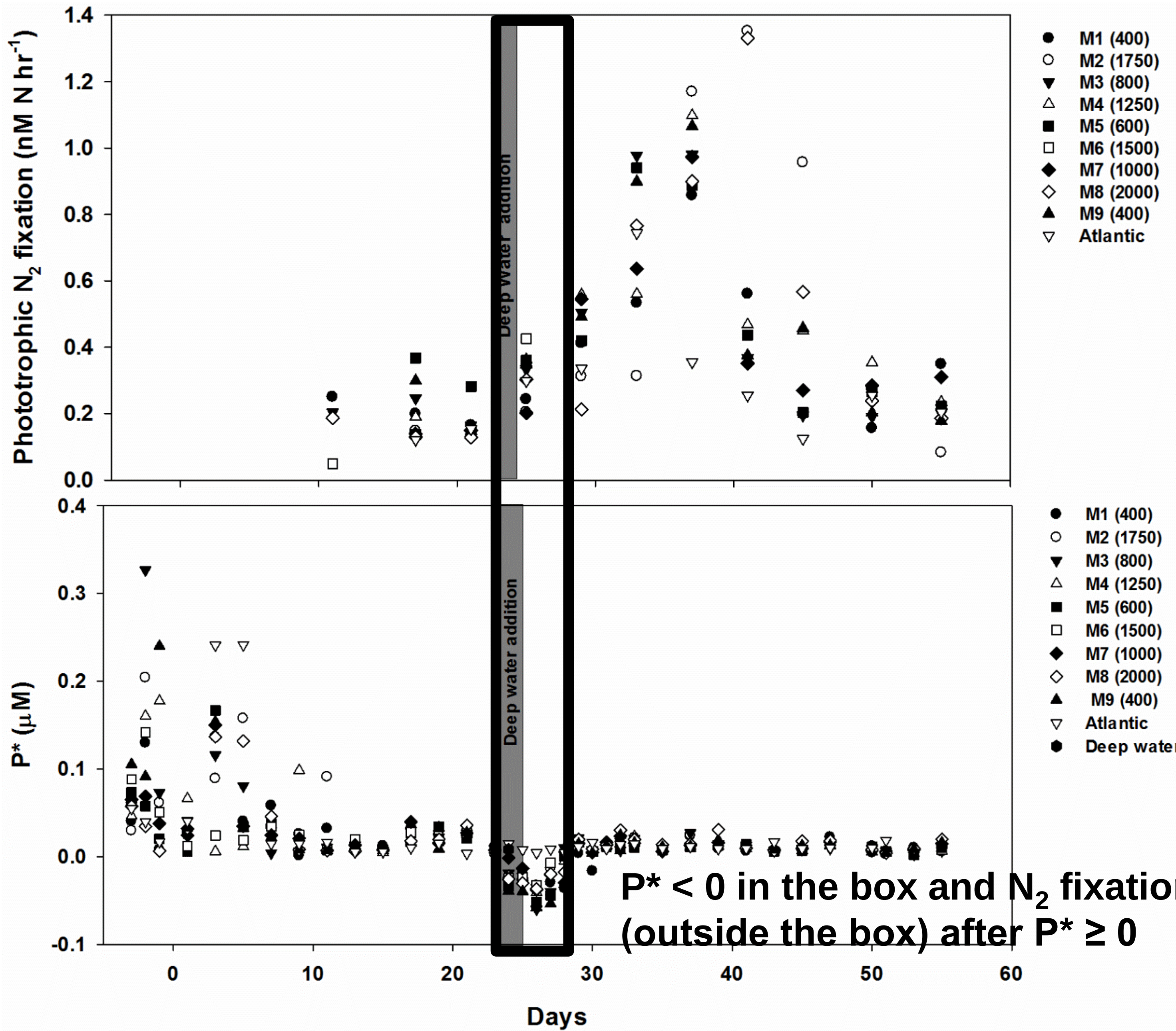
Deepwater addition enhanced C and N_2 (?) fixation rates

Addition of deep water decreases N_2 fixation rates?



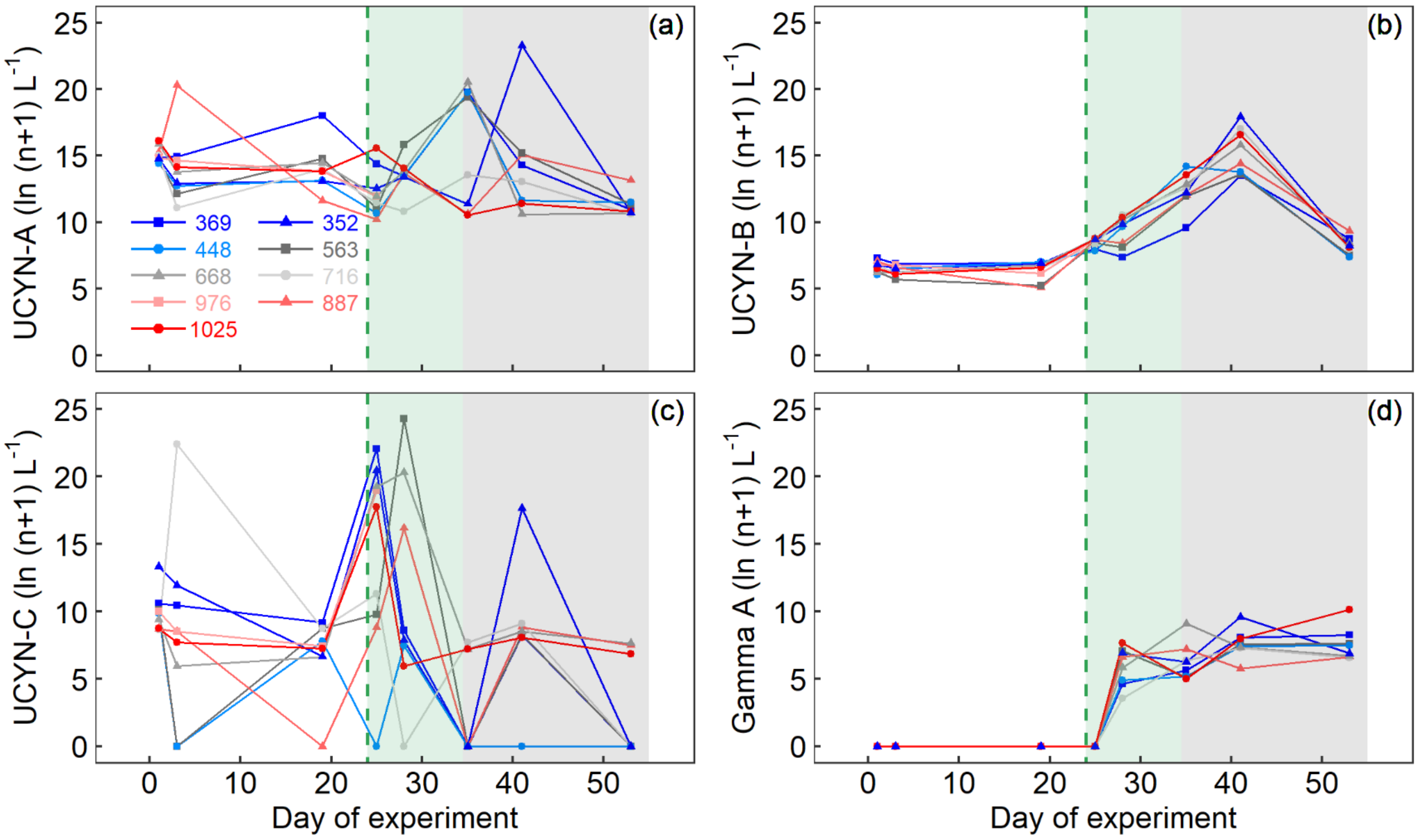
Enough PO_4^{3-} but no increase in N_2 fixation yet

Nutrient stoichiometry plays a role?



P* < 0 in the box and N_2 fixation peaked (outside the box) after P* ≥ 0

Diazotrophic abundance



Summary

1. Future pCO_2 levels will increase N_2 fixation rates provided there is sufficient phosphorous and iron.

2. Addition of deep water (future upwelling events) will decrease N_2 fixation rates => disproved.

3. It is not the absolute PO_4^{3-} but excess PO_4^{3-} ($P^* \geq 0$) that increases N_2 fixation rates.

Acknowledgements

KOSMOS team and GC 2.0 participants

PLOCAN, Gran Canaria

Future Ocean

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