Effective CO_2 utilization in response to increasing CO_2 levels in natural phytoplankton assemblages from the coastal Bay of Bengal, India

Presented by

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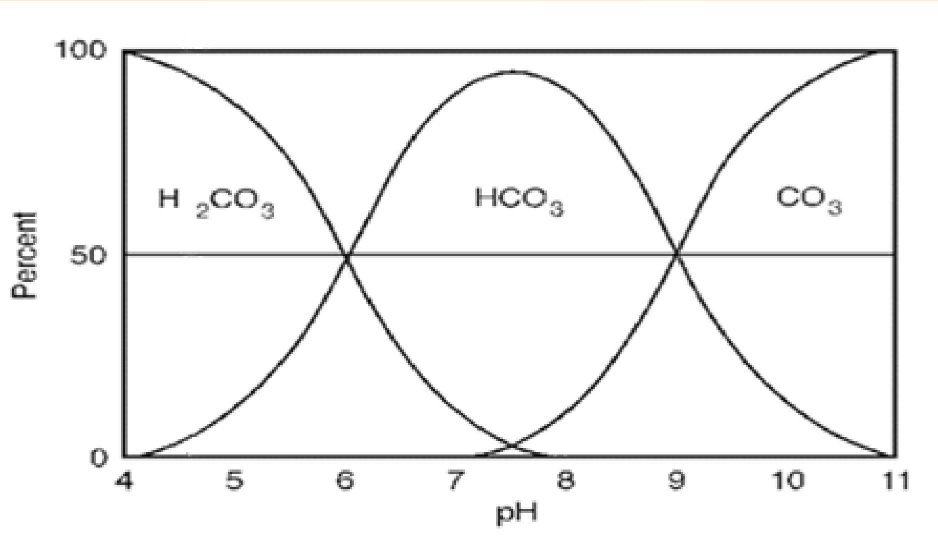
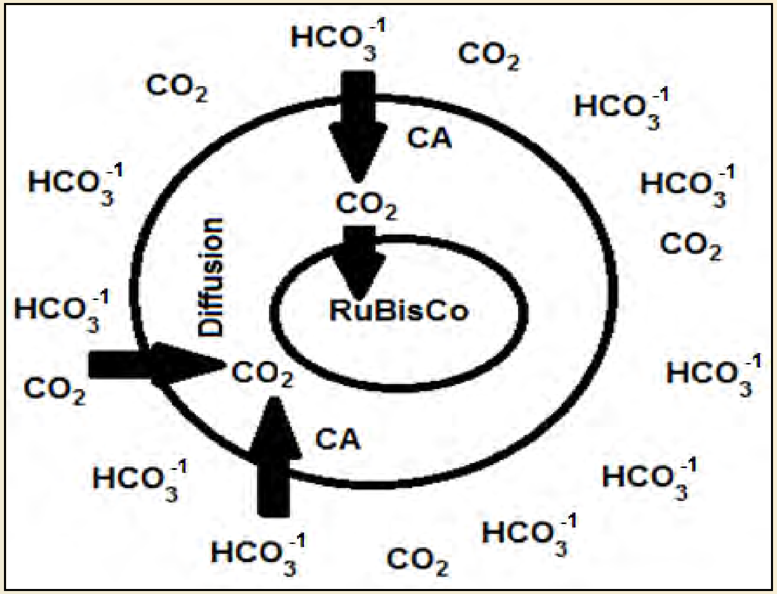
Dissolved Inorganic Carbon (DIC) $= CO_{2\,(aq)} + CO_3^{-2} + HCO_3^{-1}$

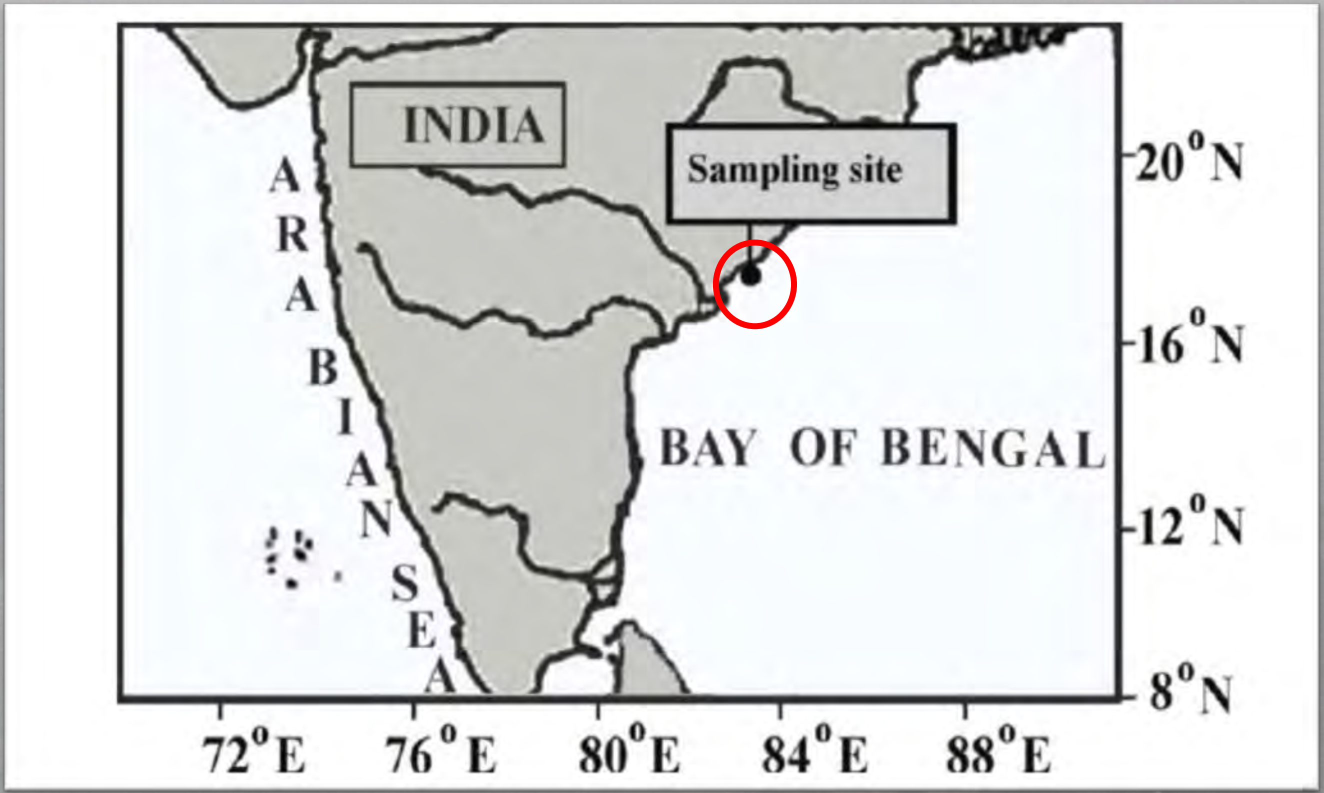


- **The majority of DIC in the modern ocean is in the form of HCO_3^- (≈90%) and dissolved CO_2 is < 1%**
- **Rubisco fixes only dissolved CO_2 and the half-saturation concentration (CO_2 aq) of diatom's Rubisco is much higher**
- **Marine phytoplankton production can be limited by CO_2 concentrations (Riebesell et al., 1993)**



To increase CO_2 level at the site of carboxylation, HCO^-_3 ions are taken up actively (Reinfelder 2011) and converted to CO_2 by the metaloenzyme enzyme Carbonic Anhydrase (CA)

Study area:



Bay of Bengal (BoB)

- A low productive part of the North Indian Ocean
- Often possesses low CO_2 levels in its surface waters
- Diatoms dominate the phytoplankton communities
- Receives huge amount of freshwater discharge and nutrients by the major monsoon fed rivers in the Indian east coast

Objectives:

- Whether phytoplankton community in the coastal Bay of Bengal show any response when external CO_2 levels are increased ?

- Whether low external CO_2 concentrations limit their growth?

- How phytoplankton community overcome CO_2 limitations in this subtropical sea?

Experimental :

Natural coastal water → 200µm mesh

Filtered with GF/F and 0.2µM Polycarbonate filters

Measuring Initial alkalinity, DIC, Nutrients, salinity

4-8L polycarbonate bottles (Nalgene)

Manipulating the targeted CO_2 levels (105 -1500µatm)

CO2 was manipulated following the method of Riebesell et al 2010 (Best practice in Ocean acidification; $NaHCO_3$ addition followed by Acid addition)

Incubation under natural day and night (12:12hrs) in variable time scale (24hrs to 120 hrs) and light

Parameters measured……………….

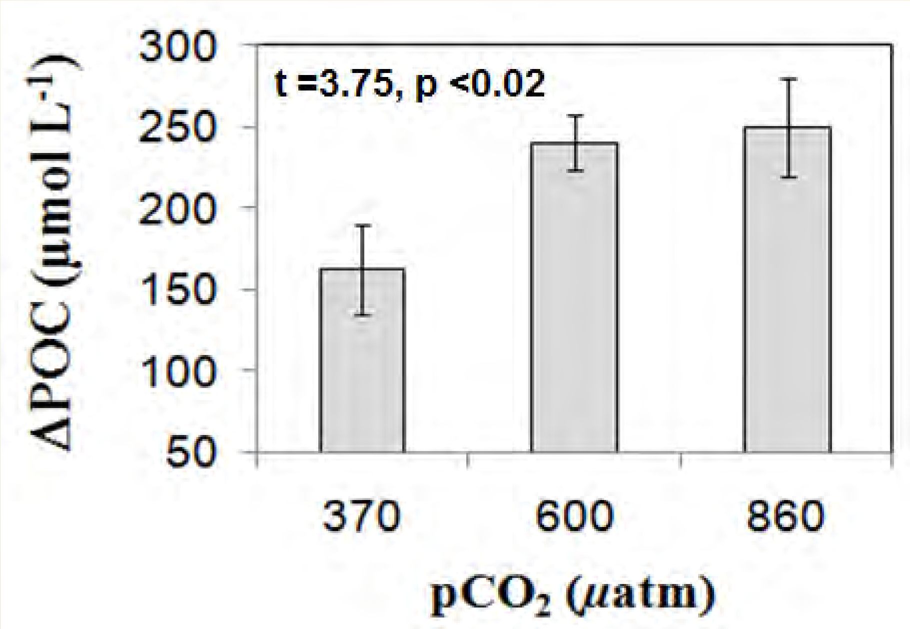
1. Carbon chemistry parameters:
   - Dissolved Inorganic Carbon (DIC)- Coulometer acidification Module (CM5 130), (Dickson et al 1992).
   - Total Alkalinity- 794 Basic Titrino from Metrohm, following (Dickson 2003).
   - pH- Titrino from Metrohm, following (Dickson 2003).
2. Oxygenic photosynthesis by dissolved oxygen method (Winkler et al 1888).
3. Chlorophyll by fluorometer and HPLC
4. POC/PON by elemental analyzer (Sharp et al 1975).
5. δ^{13}C and δ^{15}N by Isotopic Ratio Mass Spectrometry following δ V+ method.
6. Total protein by spectrophotometer method following (Lowry et al 1951).
7. Nutrients by using Spectrophotometer/Autoanalyzer (Strickland and Parsons, 1971).

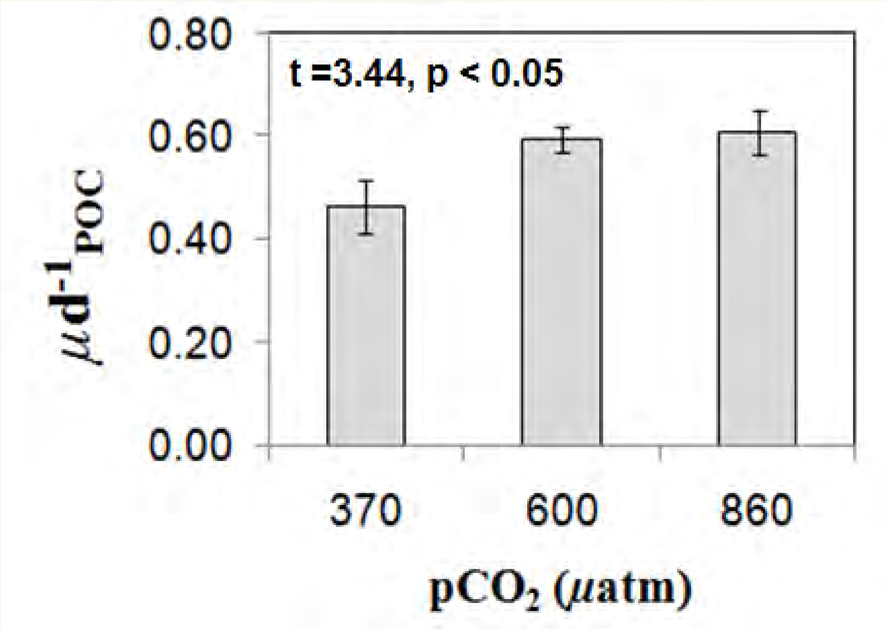
Carbon chemistry parameters from some experiments

pCO_2 (µatm)	Alkalinity (µmol Kg-1)	DIC (µmol Kg-1)	pH
130	2131	1660	8.42
280	2135	1817	8.18
300	2159	1852	8.15
380	2160	1894	8.13
550	2190	1982	7.95
1100	2185	2088	7.67

Salinity varied from 29 -31psu, DIN =13.12±7.32µM;DIP =1.15µM ±0.46µM;Silicate 14.16 ±8.69µM

Results: 48 hours incubation



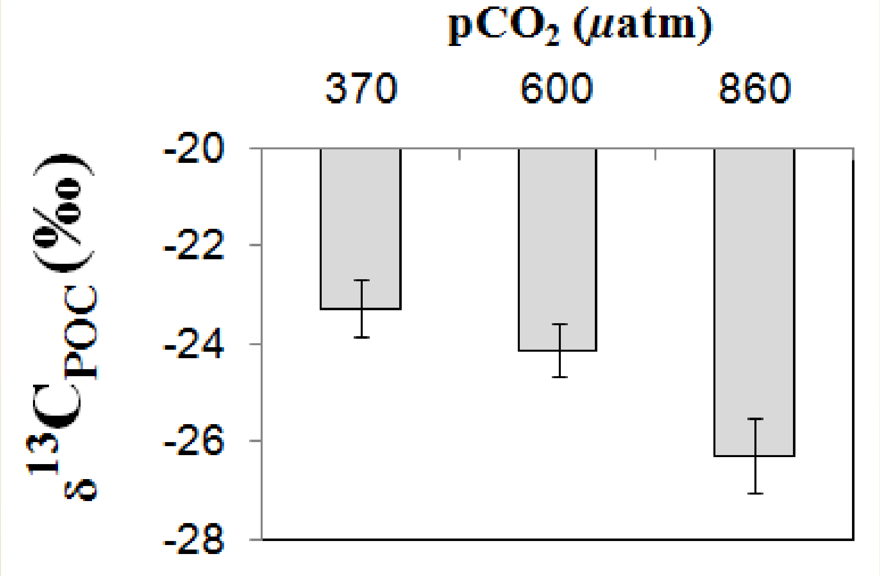


1.5times CO_2 enhancement led to

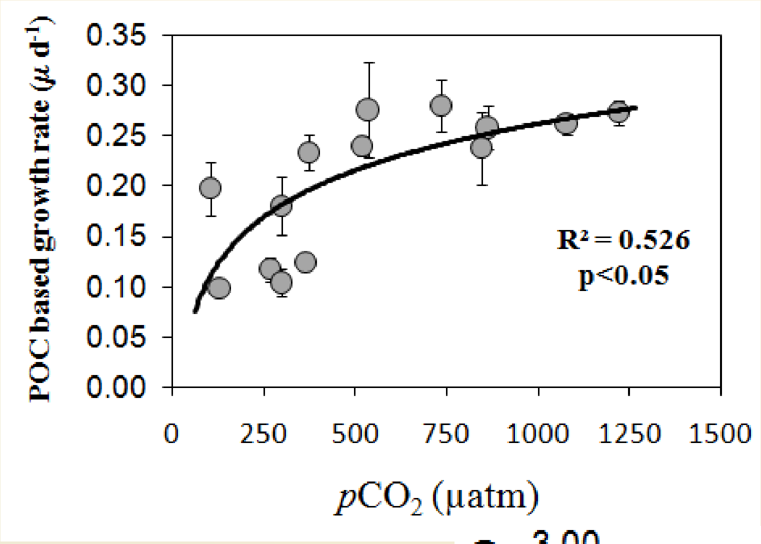
- 48% net increase in POC

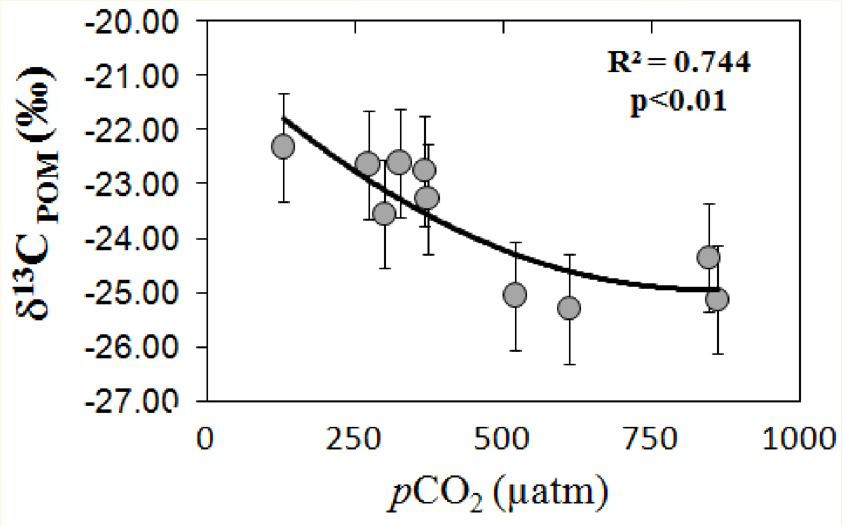
•≈30% increased POC based growth rate

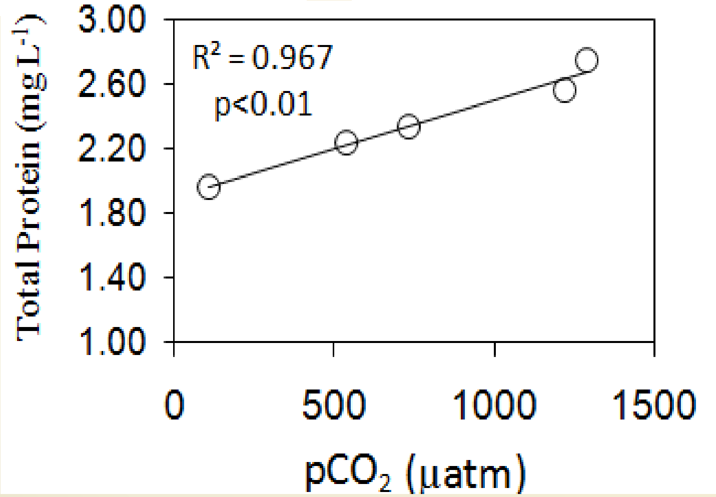
•Depleted $\delta^{13}C_{POC}$(‰) values: higher diffusive influx of CO_2 inside the cells



DIN: 19.94±2.24; SiO4 : 16.08±0.8; DIP: 6.81±0.06





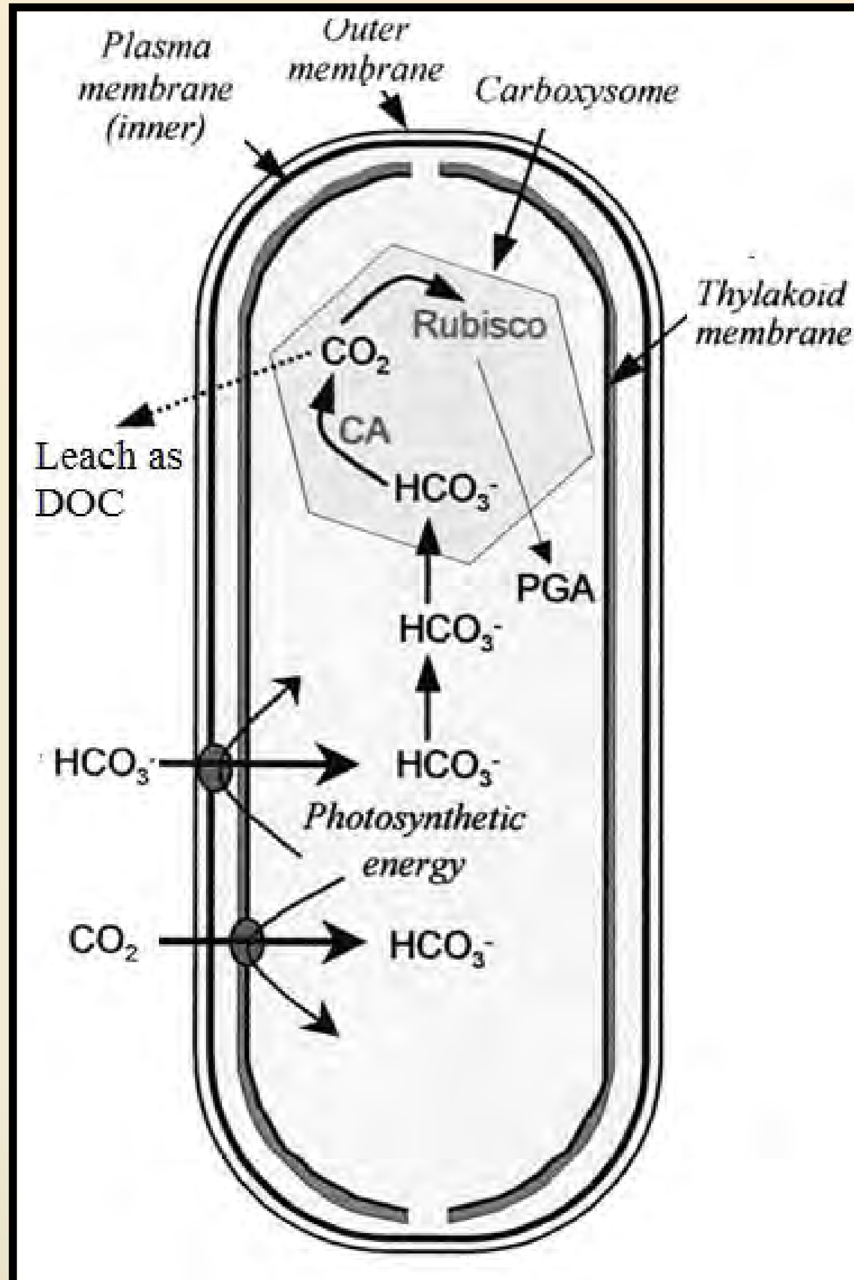


- An increase of pCO_2 from 390 to 800µatm 34% increase in POC based growth rate
- From an enhancement of 170µatm to 390µatm increase in pCO_2 almost 50% growth enhancement
- Depleted values of $\delta^{13}C_{POC}$ ‰ under elevated CO_2 levels clearly suggests dissolved CO_2 uptake
- Total protein content increased linearly with increasing CO_2 levels

Carbon Concentration Mechanisms (CCMs)

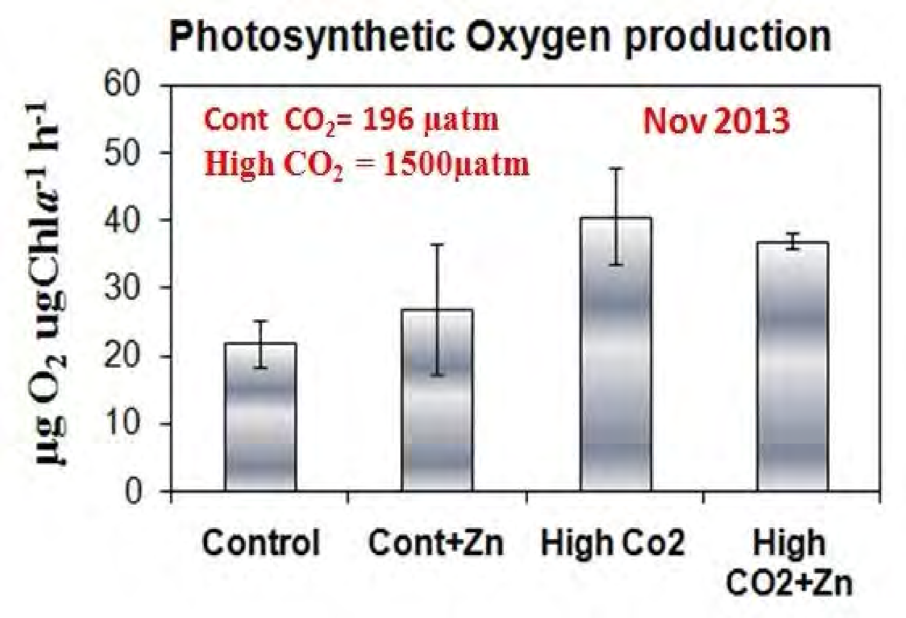
Carbonic Andydrase (CA)

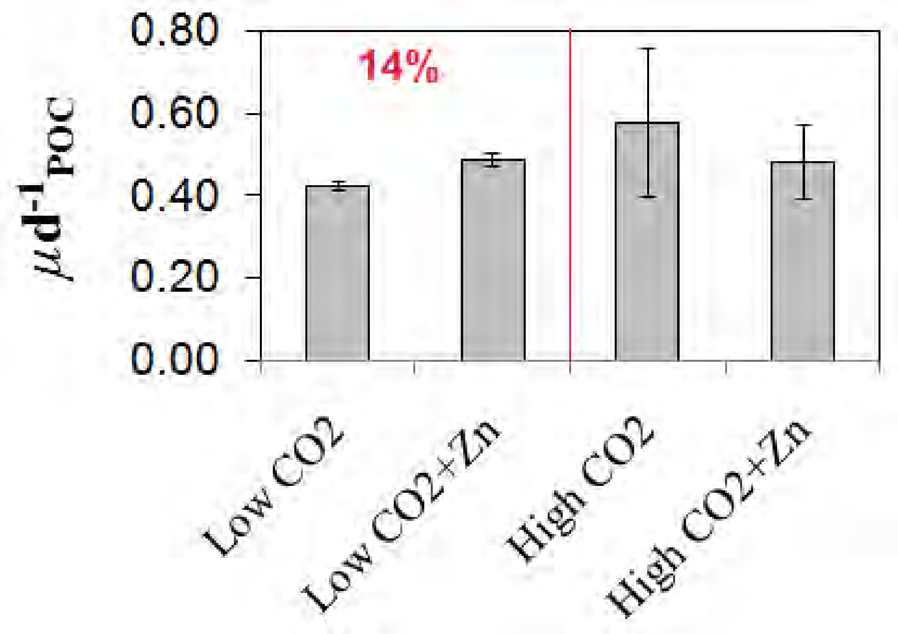
$$(HCO_3^-) \rightleftarrows (CO_2)$$

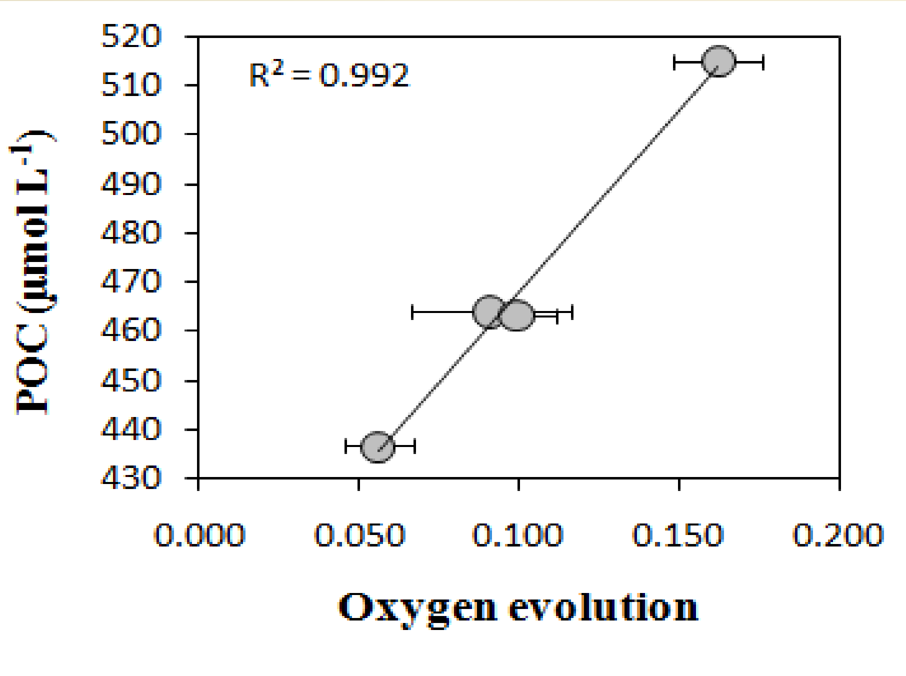


A generalized model for the marine phytoplankton CCM.

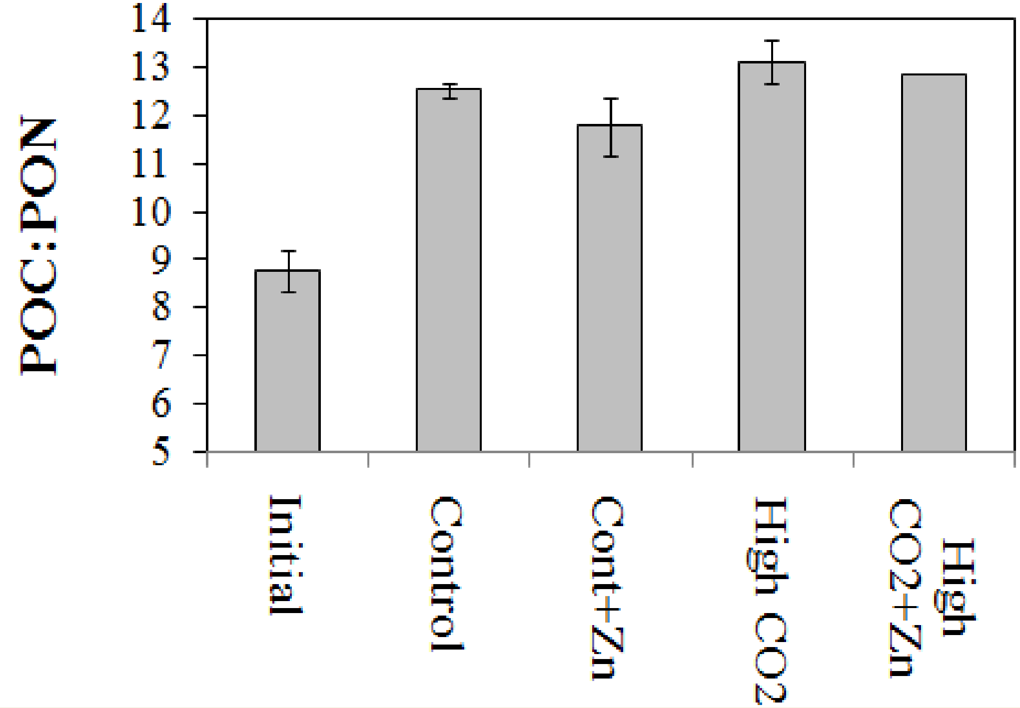
Effects of Zn addition:24 hours incubation

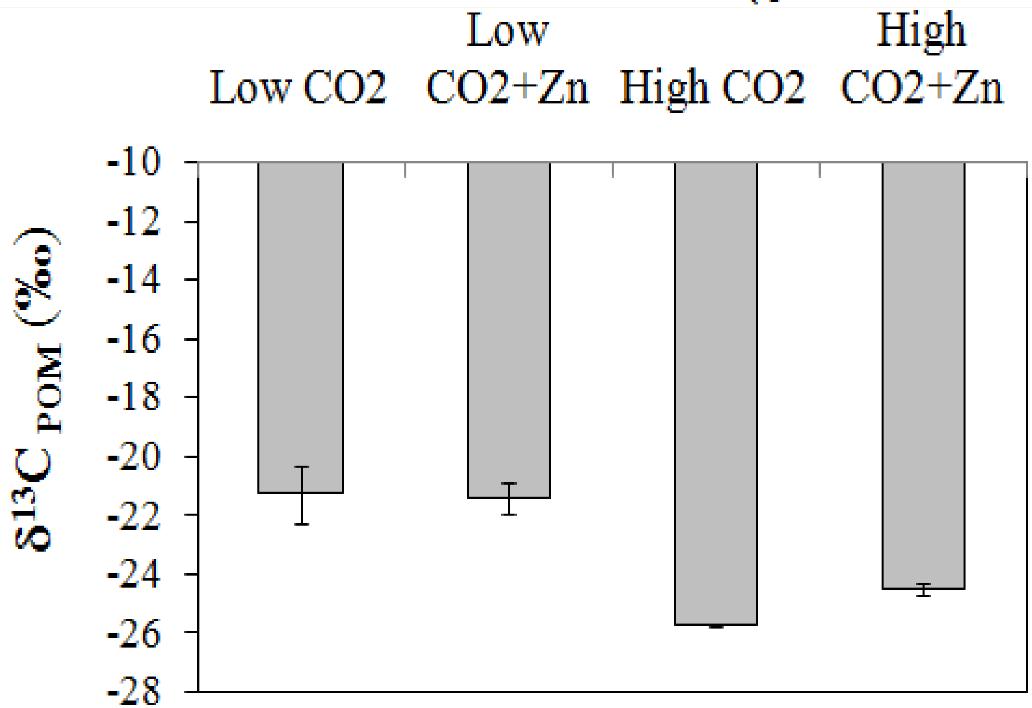


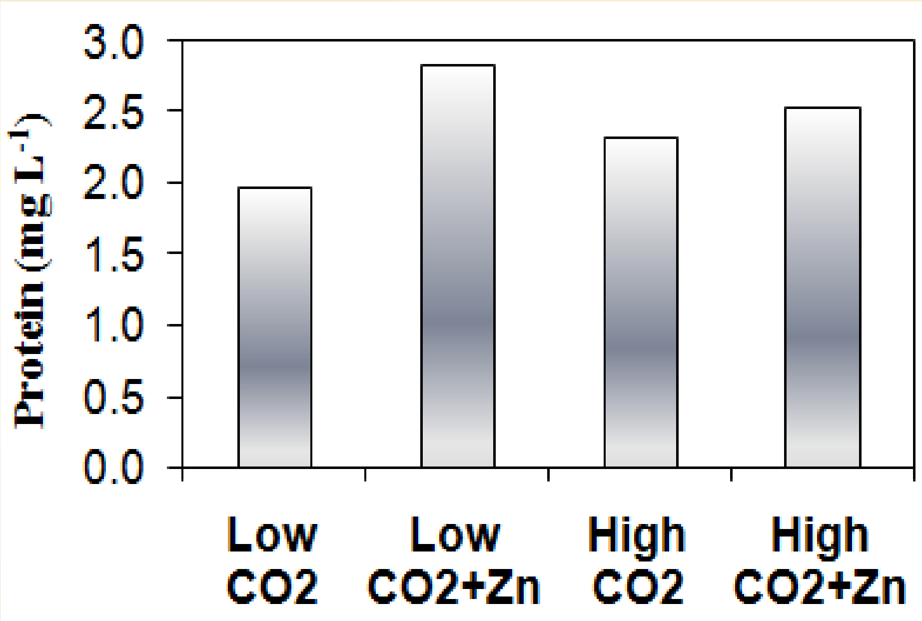


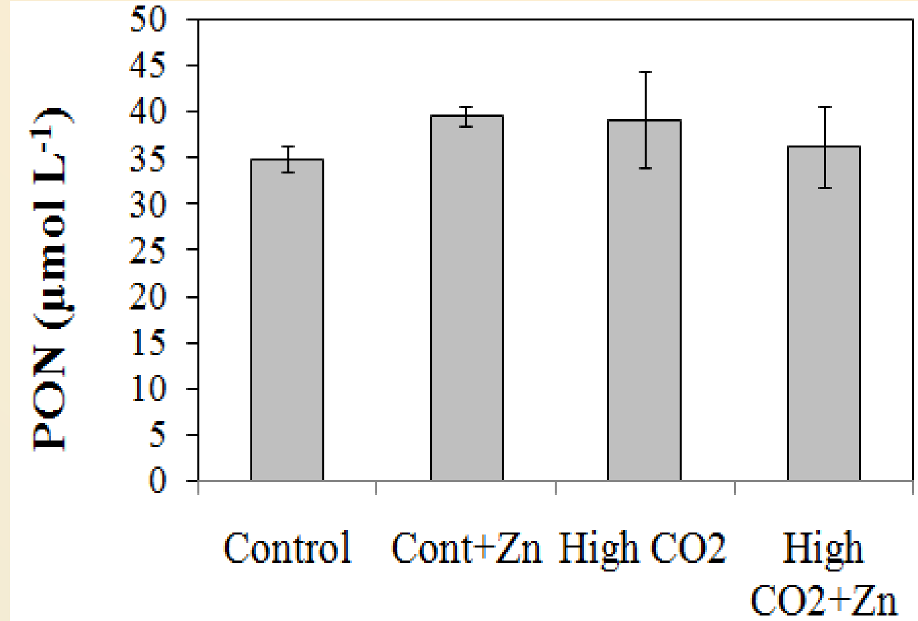


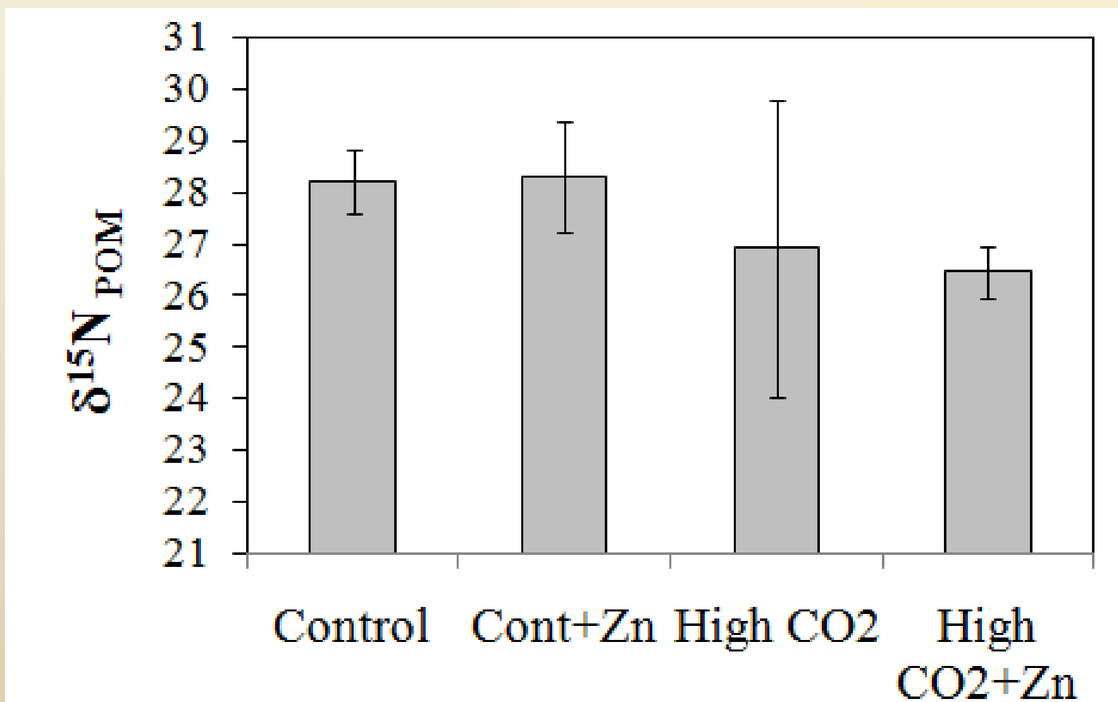
- Increased supply of CO_2 and Zn revealed similar results with different magnitude
- Presumably Zn containing carbnic anhydrase is involved in CCM operation
- Hence Zn treated samples showed higher biomass production relative to the control


POC:PON
14
13
12
11
10
9
8
7
6
5
Initial
Control
Cont+Zn
High CO2
High CO2+Zn


Low CO2
Low CO2+Zn
High CO2
High CO2+Zn
δ13C POM (‰)
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28


Protein (mg L-1)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Low CO2
Low CO2+Zn
High CO2
High CO2+Zn


PON (µmol L-1)
50
45
40
35
30
25
20
15
10
5
0
Control
Cont+Zn
High CO2
High CO2+Zn


δ15N POM
31
30
29
28
27
26
25
24
23
22
21
Control
Cont+Zn
High CO2
High CO2+Zn

Conclusions

- Our results clearly indicated that the coastal phytoplankton benefits from the increasing CO_2 levels
- Under low CO_2 conditions the diatom dominated communities from BOB possibly perform CCM and can be down regulated upon increasing levels of CO_2
- Thus in future any increase in CO_2 levels may potentially impact growth and biomass production in the phytoplankton communities from this bay.
- Hence, these features may exert a huge biogeochemical influence on carbon fixation and its metabolism in marine phytoplankton from this basin.

Long term experiment is required to be conducted with a pre-acclimation time to get a better picture of their responses

Funct. Plant Biol., 2002, **29**, 335–347

Ecological implications of microalgal and cyanobacterial CO_2 concentrating mechanisms, and their regulation

John Beardall[A] and Mario Giordano[B]

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Living in a high CO_2 world: impacts of global climate change on marine phytoplankton

John Beardall[a*], Slobodanka Stojkovic[a,b] and Stuart Larsen[a]

THANK YOU

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