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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&

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3rd International symposium on Climate change 23$^{rd}$-27$^{th}$ March 2015, Brazil.
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 metalloenzyme 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 $\text{CO}_2$ levels are increased?

- Whether low external $\text{CO}_2$ concentrations limit their growth?

- How phytoplankton community overcome $\text{CO}_2$ limitations in this subtropical sea?
Experimental:

- Natural coastal water
- 200µm mesh
- Measuring Initial alkalinity, DIC, Nutrients, salinity
- Filtered with GF/F and 0.2µM Polycarbonate filters
- Manipulating the targeted CO₂ levels (105-1500µatm)
- 4-8L polycarbonate bottles (Nalgene)
- CO₂ was manipulated following the method of Riebesell et al 2010 (Best practice in Ocean acidification; NaHCO₃ 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. $\delta^{13}$C and $\delta^{15}$N by Isotopic Ratio Mass Spectrometry following $\delta$ 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

<table>
<thead>
<tr>
<th>pCO₂ (μatm)</th>
<th>Alkalinity (μmol Kg⁻¹)</th>
<th>DIC (μmol Kg⁻¹)</th>
<th>pH</th>
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<tbody>
<tr>
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<td>1660</td>
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<tr>
<td>1100</td>
<td>2185</td>
<td>2088</td>
<td>7.67</td>
</tr>
</tbody>
</table>

Salinity varied from 29 -31psu, DIN =13.12±7.32μM; DIP =1.15μM ±0.46μM; Silicate 14.16 ±8.69μM
Results: 48 hours incubation

1.5 times CO\(_2\) enhancement led to
- 48% net increase in POC
- \(\approx 30\%\) increased POC based growth rate
- Depleted \(\delta^{13}C_{\text{POC}}(\%)\) values: higher diffusive influx of CO\(_2\) inside the cells

DIN: 19.94\(\pm\)2.24; SiO\(_4\) : 16.08\(\pm\)0.8; DIP: 6.81\(\pm\)0.06
An increase of pCO₂ from 390 to 800 µatm 34% increase in POC based growth rate
From an enhancement of 170 µatm to 390 µatm increase in pCO₂ almost 50% growth enhancement
Depleted values of δ¹³C_POC ‰ under elevated CO₂ levels clearly suggests dissolved CO₂ uptake
Total protein content increased linearly with increasing CO₂ levels
Carbon Concentration Mechanisms (CCMs)

Carbonic Anhydrase (CA)

\((\text{HCO}_3^-) \rightleftharpoons (\text{CO}_2)\)

A generalized model for the marine phytoplankton CCM.
Effects of Zn addition: 24 hours incubation

- Increased supply of CO₂ and Zn revealed similar results with different magnitude
- Presumably Zn containing carbinic anhydrase is involved in CCM operation
- Hence Zn treated samples showed higher biomass production relative to the control
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 downregulated 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.
Ecological implications of microalgal and cyanobacterial CO₂ concentrating mechanisms, and their regulation

John Beardall⁷ and Mario Giordano⁸

Living in a high CO₂ world: impacts of global climate change on marine phytoplankton

John Beardall⁷*, Slobodanka Stojkovic²,³ and Stuart Larsen⁷
Acknowledgement

I express my sincere gratitude to

- My PhD Guide Dr. Haimanti Biswas and my colleague Ms. Debasmita bandyopadhyay for their active contribution to this research.
- IAEA/OA-ICC and PICES for their generous financial support.
- Director and Scientist-In-Charge NIO for support and cooperation and Mr. NPC Reddy and Ch. Jawahar Kumar, NIO for partial travel support.
- Conveners of PICES for providing me this opportunity to deliver this talk.