Habitat dependent carbon production in the coral reef ecosystem in Okinawa, Japan

This study was a part of the research project of International Summer Program 2008 “Landscape ecology and biogeochemical cycles in seagrass bed and coral reefs “ conducted as part of the 21st century COE program.
Ninomiya et al. (2006) suggested there is a “Symbiotic Relationship” between Coral and SG in physically. The vertical and horizontal entwining of seagrass stems and coral branches both on and under the surface of seafloor gives stability to seagrass beds.

Coral and Seagrass live together. With this symbiosis, Seagrass can create a dense community, and Fragmented Corals are less affected by wave motion. Coral fragments are usually tumbled by waves and hardly survive. How about Chemical Benefit?

Fig.3 Breeding style of Thalassia hemprichii and Montipora digitata

Mitani's symbiosis (2006) suggested that Seagrass “Symbiotic Relationship” between Coral and SG in physically. Fragmented Corals are less affected by wave action. Coral branches and seagrass stems grow by waves and under the surface.
Study Site

Bise area

Northern part of Okinawa, Japan
Chamber Experiment

Measurement
pH, Total alkalinity
Salinity

- **Triities sample**
- 2-hour incubation
  - 08/01: 12-14:00
  - 08/04: 16-18:00, 19-21:00
- Final sample
  - 08/04: 16-18:00, 20-22:00

- **Day/ Night**
  - 08/05: 7-9:00, 10-12:00, 13-15:00
  - 08/06: 3-5:00, 6-8:00, 9-11:00

- **Sampling dates:**
  - 08/01, 4, 5, 6, 2008
  - Ishikawa et al. (2007)

n=3, each
Low tide sampling

High tide sampling
Sampling of Sandy area water \( (n=30) \)

Ground water at Low tide

Ground water can affect seawater?!
“Ground water” affect “Total Alkalinity” in Bise area, e.g. when salinity changes 1 ‰, TA changes about 100 µmol/kg.

Ground water in Bise

If S=0, ALK=5600 (SW=2300)

Bise: Carbonate Rock Area

Because of dissolution of CaCO₃

Fig. Relationship between Alkalinity and Salinity in sandy area water at Bise
Variation of Salinity on Aug. 1

During Chamber Exp., Salinity was changed slightly from initial to final.
Adjusted TA_{final} = TA_{final} + (Sal._{initial} - Sal._{final}) \times (-93.779)

Adjusted TA was used for calculation of carbon production.
Calculation of inorganic carbon production (IP) & organic carbon production (OP)

\[
\text{IP} = -\frac{(\text{TA}_{\text{final}} - \text{TA}_{\text{initial}}) \cdot V}{2 \cdot A \cdot t}
\]

\[
\text{OP} = -\frac{\left(\text{TIC}_{\text{final}} - \text{TIC}_{\text{initial}}\right) \cdot V}{A \cdot t} - \text{IP}
\]

\[
\text{TIC} = \frac{a_{H^+}^2 + K'_1 a_{H^+} + K'_1 K'_2}{K'_1 (a_{H^+} + 2K'_2)} \cdot \left(\frac{\text{TA} - K'_B \cdot 1.212 \times 10^{-5} \cdot S}{a_{H^+} + K'_B}\right)
\]

\[a_{H^+} = 10^{-\text{pH}}\]
\[K'_1 = 9.914 \times 10^{-7} \text{ at } 25^\circ C\]
\[K'_2 = 7.718 \times 10^{-10} \text{ at } 25^\circ C\]
\[K'_B = 2.020 \times 10^{-9} \text{ at } 25^\circ C\]

\[S = \text{salinity}\]

TA = total alkalinity
A = bottom area of chamber
V = Volume of chamber
t = incubation time (2h)
TIC = total dissolved inorganic carbon

pH

Orion 4star (Thermo)

Total alkalinity Titrator
ATT-05 (Kimoto)
Results

Organic carbon production

Fig. Variation of Organic carbon production

<table>
<thead>
<tr>
<th>Sample</th>
<th>Data Points</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>I = Sand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II = Sea grass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III = SG + CR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV = Coral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V = Acorn worm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Net photosynthesis (+)

Respiration (-)
Daily cycle of OP

I=Sand

II=SG

III=SG+CR

IV=Coral

V=AC worm

Net photosynthesis (+)

Respiration (-)
**OP × Photon flux**

- **I = Sand**
- **II = Seagrass**
- **III = SG+C**
- **IV = Coral**
- **V = AC worm**

### Equations

\[ y = 2.3535x - 1717.4 \quad R^2 = 0.499 \]

\[ y = 11.759x - 6814.9 \quad R^2 = 0.6877 \]

\[ y = 10.859x - 7298.2 \quad R^2 = 0.8456 \]

\[ y = 1.7984x - 2533.4 \quad R^2 = 0.3197 \]

\[ y = 13.15x - 7327.3 \quad R^2 = 0.6964 \]
Daily cycle of IP

Calcification (+)
Dissolution (-)

I=Sand
II=SG
III=SG+CR
IV=Coral
V=AC worm

Inorganic Carbon production (µmol/m²/h)
Photon flux

Time (o'clock)

0 4 8 12 16 20 24

-10000 -5000 0 5000 10000 15000 20000
The graph shows the relationship between photon flux (µmol/m²/s) and IP (µmol/m²/h) for different environments labeled I-V:

- **I = Sand**
  - Equation: \( y = 0.0716x + 45.463 \)
  - \( R^2 = 0.0159 \)

- **II = Sea grass**
  - Equation: \( y = 0.5417x - 808.36 \)
  - \( R^2 = 0.1761 \)

- **III = SG+C**
  - Equation: \( y = 2.3269x - 168.44 \)
  - \( R^2 = 0.6905 \)

- **IV = Coral**
  - Equation: \( y = 5.0793x - 250.13 \)
  - \( R^2 = 0.7608 \)

- **V = AC worm**
  - Equation: \( y = 0.2108x - 608.66 \)
  - \( R^2 = 0.0763 \)

The graph includes linear equations and correlation coefficients for each environmental category.
Photosynthesis rate
II(SG) > III(SG+Coral) > IV(Coral)

Calcification rate
IV(coral) > III(SG+Coral) > II(SG)

There are no “Synergistic Effect“ between coral and SG.
If there is synergistic effect, III might have the highest rate.

We found that “Dissolution of CaCO$_3$“
in SG and SG+Coral community.

CaCO$_3$ is dissolved in SG community!?
Dissolution must not be a benefit for coral community.

(by carbonate approach)

No chemical benefit !?
In sand and AC worm community, carbon production was relatively low at day time and night time.

In SG community, calcification rate was low. Photosynthesis rate was the highest.

In coral community, high calcification rate was found. Photosynthesis rate by coral symbiotic algae was lower than that by SG.

In SG + CR community, photosynthesis and calcification rates were rates between in SG and in coral only community.

In day time, inorganic and organic production were relative to photon flux.

In night time, dissolution of CaCO$_3$ was found in SG and SG+CR community. Dissolution must not be a benefit for coral community.

We could not find chemical benefit between CR and SG.