Sequestration and storage ability and process of blue carbon in shallow coastal ecosystems

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CO2 absorption, Sequestration?
CO2 absorption, Sequestration

Seagrass bed
Ishigakijima Island, Okinawa, Japan
CO2 absorption, Sequestration

Mangrove forest

Salt marsh

Sargassum forest

Kelp forest
Global carbon cycle

Land area
147 × 10^6 km^2

Forest area
40 × 10^6 km^2

Sea area
593 × 10^6 km^2

Kuwae and Hori (2018), LeQuere et al. (2018) for atmospheric data (mean ± SD for 2007–2016), and IPCC (2013) for terrestrial input
What is Blue Carbon?

“Blue carbon” is defined as marine green carbon

Green carbon is defined as carbon that plants have assimilated via photosynthesis and incorporated into organic matter

“Blue carbon ecosystems”
Seagrass beds, Salt marsh, Mangrove forest

Importance of blue carbon stocks in sediments of shallow coastal ecosystems

Nellemann et al. (2009) “Blue Carbon “
CO₂ sequestration

(1) Atmosphere – sea water CO₂ exchange

Dissolved CO₂ ↔ Bicarbonate and carbonate ion

Absorption by marine plants

Dissolved CO₂ emission by calcified organisms

(2) Organic Carbon in living creatures

(3) Refractory Organic Carbon

(4) Carbon buried in sediment

(5) Other carbonates (shell, bone, etc)

Revised from Hori et al. (2018)
Blue carbon in shallow coastal ecosystems

**CO₂ sequestration as annual net primary production**

![Graph showing CO₂ sequestration in various ecosystems.](image)

- **Seagrass bed**: 3.2 ± 2.4 ton C/ha/year
- **Sargassum forest**: 4.0 ± 0.7 ton C/ha/year
- **Kelp forest**: 6.1 ± 1.2 ton C/ha/year
- **Temperate kelp forest**: 3.4 ton C/ha/year

Modified from Yoshida et al. (2018)

Storage processes

(1) Sedimentation

(2) Refractory Particle Organic Carbon (RPOC)

(3) Transportation to the deep sea
Practice: Seto Inland Sea, Japan
Practice: Seto Inland Sea, Japan

Rs: respiration, Ph: photosynthesis, Of: outflowing, Fo: falling off, St: settling, Fr: fragmentation, Ss: suspension, Dc: decomposition, Ac: accumulation, Fl: floating, Rss: resuspension

Abo et al. (2018)
Practice: Seto Inland Sea, Japan

Abo et al. (2018)
Practice: Seto Inland Sea, Japan

Inside eelgrass beds:
- Accumulation: 27,432 ton C (37.6%)
- Outflow: 25,715 ton C (35.2%)
- Decomposition: 19,812 ton C (27.2%)

Outside eelgrass beds:
- Accumulation: 6,017 ton C (8.3%)
- Outflow: 72,959 ton C (35.2%)
- Decomposition: 37,041 ton C (67.0%)

Seto Inland Sea, Total:
- Accumulation: 37,041 ton C (67.0%)
- Outflow: 72,959 ton C (35.2%)
- Decomposition: 29,823 ton C (40.9%)

Transportation to the deep sea

Abo et al. (2018)
Blue carbon in shallow coastal ecosystems

Contribution of macroalgal forests

More than 10% of annual net production of sargassum species can be considered as blue carbon storage
Estimation of BC sequestration in a national scale

<table>
<thead>
<tr>
<th>Sequestration rate (t-CO₂/ ha / year)</th>
<th>2013</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>average</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seagrass</td>
<td>5.8</td>
<td>33.4</td>
</tr>
<tr>
<td>Sargassum</td>
<td>2.7</td>
<td>5.1</td>
</tr>
<tr>
<td>Saccharina</td>
<td>10.3</td>
<td>36.0</td>
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<tr>
<td>Ecklonia</td>
<td>4.2</td>
<td>7.9</td>
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<tr>
<td>Mangrove</td>
<td>68.5</td>
<td>68.5</td>
</tr>
<tr>
<td>Tidal flat</td>
<td>2.6</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Area total: 28.3 ×10⁴ ha

Japan Blue Carbon Research Group (2019), *Nikkei construction*
Newly unraveled storage processes

1. Sedimentation

2. Refractory Particle Organic Carbon (RPOC)

3. Transportation to the deep sea

4. Refractory Dissolved Organic Carbon (RDOC)
Newly unraveled storage processes

RDOC measurement

This process have never been included in any estimation of Blue Carbon storage!

Watanabe et al. (in prep)
Aquaculture can work as a climate change mitigation and adaptation measures: macroalgal (kelp, wakame, sargassum, nori laver, etc.) cultivation.

RDOC released from growing algae contributes to blue carbon storage.
Take-home message:

- The blue carbon contribution to atmospheric CO$_2$ sequestration is larger than terrestrial green carbon.
- Approximately 50% of blue carbon sequestration is conducted in shallow coastal areas where is only 0.8% of the total ocean area.
- Coastal marine vegetation can work not only as fishery grounds and fish nurseries but also as an effective CO$_2$ sink.
- Macroalgal forests also function as CO$_2$ sink due to various organic carbon storage process.
- Macroalgal aquaculture can also work as CO$_2$ sink by considering refractory dissolved organic carbon.

Need conservation and restoration of coastal marine vegetation!