Influencing mechanisms of eutrophication on sediment organic carbon sequestration within a typical tropical seagrass meadows

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Outline

- Research significance
- Current research progress
- Materials and methods
- Research results
- Ecological implications
Seagrass ecosystems have the important carbon sequestration function with referring as 'blue carbon';
Seagrass meadows contributed to 10% of the yearly OC storage in the oceans, despite only covering < 0.2% of global sea surface area (Fourqurean et al. 2012); SOC storage was influence by the source, composition, and transformation (Macreadie et al. 2014)
Seagrass decline 7%/year, nutrient enrichment (Waycott et al. 2009)
To explore the SOC storage mechanism of seagrass bed and its response to nutrient load -- provide scientific and technological support for promoting global carbon sink
Increased nutrient loads trigger the overgrowth of algae, in the form of epiphytes and macroalgae but decrease seagrass biomass (Burkholder et al., 2007), change the primary community (Schmidt et al., 2012), induced SOC sources variation.

The organic carbon burial rate of benthic microalgae (6%)、 phytoplankton(3.9%) and macroalgae (0.4%) lower than seagrass(15.9%) (Duarte and Cebrian, 1996), weaken the carbon sink capacity (Macreadie et al., 2012).
Current research progress

➢ SOC algal OC contribution increasing change microbial OC sources, and then induced sulfate reduction rate variation (Holmer et al., 2004);
➢ Nutrient loading——seagrass biomass decline (Hauxwell and Valiela, 2004); decrease the ability to capture OC (Gacia et al., 2002);
➢ Seagrass decline——the stored OC release and escape (Pendleton et al., 2012; Marbà et al., 2015)

Nutrients load increase bacterial and enzyme activities, lead to decrease 33% of sediment organic matter (Lopez et al. 1998)

Seagrass decline lead to the stored OC release and escape (Marba et al., 2015)
Materials and methods

Study area

The nutrient concentrations in the seawater and sediment were both higher in the area close to the fish farming area (Jiang et al., 2013; Zhang et al., 2014)

Fish farming

*Thalassia hemprichii*

*Enhalus acoroides*
Study area

Fish farming in Xincun Bay  Algae bloom within seagrass meadows

Thalassia hemprichii  Enhalus acoroides
Materials and methods

Three transects were selected according to the distance to the fish farming:

- **Surface sediment** (0-3 cm);
- **Core sediment** (0-30 cm);
- **Primary communities** (seagrass, macroalgae, phytoplankton and epiphyte)

**Analysis parameters**: SOC contents, labile organic carbon, \( \delta^{13}C \) of SOC and primary communities, PLFA composition, \( \delta^{13}C \) of PLFA, enzyme activities
Research results

1. Surface SOC sources

9 possible OC sources were separated into seagrass, macroalgae & epiphytes, and SPOM based on variations of $\delta^{13}$C.
Research results

<table>
<thead>
<tr>
<th>Sources</th>
<th>&lt;95%</th>
<th>&gt;95%</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saegrass</td>
<td>0.00</td>
<td>0.31</td>
<td>0.14</td>
</tr>
<tr>
<td>A Algae</td>
<td>0.00</td>
<td>0.60</td>
<td>0.33</td>
</tr>
<tr>
<td>SPOM</td>
<td>0.29</td>
<td>0.78</td>
<td>0.53</td>
</tr>
<tr>
<td>Saegrass</td>
<td>0.00</td>
<td>0.27</td>
<td>0.12</td>
</tr>
<tr>
<td>B Algae</td>
<td>0.00</td>
<td>0.57</td>
<td>0.29</td>
</tr>
<tr>
<td>SPOM</td>
<td>0.34</td>
<td>0.84</td>
<td>0.59</td>
</tr>
<tr>
<td>Saegrass</td>
<td>0.00</td>
<td>0.18</td>
<td>0.07</td>
</tr>
<tr>
<td>C Algae</td>
<td>0.00</td>
<td>0.43</td>
<td>0.17</td>
</tr>
<tr>
<td>SPOM</td>
<td>0.52</td>
<td>0.96</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Variations of the sediment $\delta^{13}C$ (‰) among the three transects

The relative contribution of seagrass, and macroalgae & epiphytes to SOC increased from transect 3 to 1, with the relative contribution of macroalgae & epiphytes increasing by 16%, while that of SPOM decreased.
Research results

2. Surface SOC compositions

➢ Differences of the SOC compositions under the two seagrass communities were not significant;

➢ SOC 、MBC showed significantly higher in transect 1 than other two transects;

Variations of the SOC content (I), the TN content (II), the SEC content (III), the MBC content (IV), the SEC/SOC (V), and the MBC/SOC (VI)
Research results

3. Surface sediment microbial communities

- Bacterial PLFAs and fungal PLFA accounted for about 40% and 7% of total PLFAs;
- PLFA compositions were not significant differences between *T. hemprichii* and *E. acoroides*;
- Total PLFA and bacterial PLFA in transect 1 > other transects;
- F/B in transect 1 < other transects.

Variations of total PLFAs (I), bacterial PLFAs (II), fungi PLFA (III) and F/B ratio (IV)
4. $\delta^{13}$C of SOC, i+a15:0 and 18:2ω6,9c

- Average $\delta^{13}$C bacteria = -11.73‰, higher than $\delta^{13}$C SOC (-14.82‰).
- $\delta^{13}$C bacteria showed significant difference between transects.
- $\delta^{13}$C fungi showed lower than the possible OC sources.

$\delta^{13}$C of SOC, bacterial biomarker i + a 15:0 PLFA and fungal biomarker 18:2ω6, 9c among the stations.
### Research results

#### Isotopic mixing models results based on $\delta^{13}$C (%) values

<table>
<thead>
<tr>
<th>Species</th>
<th>Transect</th>
<th>Seagrass</th>
<th>Macroalgae and epiphyte</th>
<th>SPOM</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>T. hemprichii</em></td>
<td>1</td>
<td>32%-88% (60%)</td>
<td>0%-59% (30%)</td>
<td>0%-23% (10%)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>13%-62% (39%)</td>
<td>0%-68% (35%)</td>
<td>4%-46% (26%)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>13%-62% (38%)</td>
<td>0%-67% (35%)</td>
<td>5%-47% (27%)</td>
</tr>
<tr>
<td><em>E. acoroides</em></td>
<td>1</td>
<td>11%-59% (36%)</td>
<td>0%-67% (35%)</td>
<td>6.6%-50% (29%)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>12%-61% (38%)</td>
<td>0%-68% (35%)</td>
<td>4.5%-47% (27%)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0%-27% (12%)</td>
<td>0%-57% (30%)</td>
<td>34%-84% (58%)</td>
</tr>
</tbody>
</table>

- Relative contribution of seagrass-derived carbon to bacteria ($\delta^{13}$C$_{bacteria}$) increased with nutrient loading;
- The relative contribution of seagrass plant material to sediment BOC in *E. acoroides* meadows were half that of *T. hemprichii* meadows living side-by-side.
Research results

5. Sediment enzyme activities

➢ Polyphenol oxidase, invertase, and cellulases showed significantly higher in transect 1 than other transects.

➢ Polyphenol oxidase and cellulases in *T. hemprichii* observed higher than *E. acoroides*.

Variations of polyphenol oxidase (I), peroxidase (II), invertase (III) and cellulases (IV) activities
Research results

6. SOC compositions in core sediment

Vertical distributions of organic carbon concentration and density in the sediment cores

- No significant difference of SOC between *T. hemprichii* and *E. acoroides*;
- Higher values of SOC and SOC density in T3;
- SOC and SOC density increased with depth in T3 but not in other transects.
The MBC showed significantly higher in T1 and T2 than T3;
MBC was shown the highest in the layer of 6–9 cm and 9–12 cm in T2 and T3 due to OC releasing from root;
SEC in T1 (260 mg/kg) > other transects (200 mg/kg)
MBC and SEC were shown higher in *T. hemprichii* than *E. acoroides*
Research results

MBC/SOC and SEC/SOC in T3 showed much lower than T1, the MBC/SOC 和 SEC/SOC in *T. hemprichii* generally higher than *E. acoroides*;

MBC/SOC and SEC/SOC decrease with depth in T3, while other transects were similar or increase with depth.
7. $\delta^{13}$C in sediment cores

- $\delta^{13}$C in *E. acoroides* generally showed higher than *T. hemprichii*, and the $\delta^{13}$C in T3 showed higher than other transects;
- $\delta^{13}$C in T3 increase with depth but not other transects;
- Higher seagrass contribution in T3 than other transects

*Vertical distributions of $\delta^{13}$C of SOC in the sediment cores*
8. SOC storage

➢ The estimated SOC stock of the top 30 cm of sediment in the seagrass bed in Xincun Bay was 6.80 Mg C/ha;

➢ The SOC storage in T3 showed higher 28% than other transects, SOC storage of *E. acoroides* showed higher 1.54 Mg C/ha than *T. hemprichii*.
Nutrient loading changes the relative contribution of seagrass and algal sources to SOC pools, boosting sediment microbial biomass and extracellular enzyme activity, thereby enhancing SOC transformation.
Research results

Nutrient load increase the labile organic carbon and transformation in the whole sediment core, thus would weaken the SOC sequestration. In addition, the carbon storage potential in *E. acoroides* showed higher than *T. hemprichii*. 

Carbon storage
Ecological implications

1. To control the nutrient discharge to seagrass meadows

Nutrient enrichment decrease the carbon storage potential, but previous study reported that long-term changes in the nutrient supply to oligotrophic coastal ecosystems could increase C storage (Armitage and Fourquarean 2016). Non-linear and hysteretic nature response of SOC to eutrophication occurred, and a nutrient threshold may also exist with distinct effects on seagrass SOC.

Determine the nutrient threshold that nutrients do not lead to the loss of seagrasses at each seagrass meadows. eg. Rough estimation, the DIN and DIP in the seagrass meadows of Xincun Bay were 5~7 μmol/L and 0.5~0.7 μmol/L, respectively.
2. How to evaluate the SOC storage potential?

Most of the previous studies merely used the SOC contents to estimate the carbon sequestration potential (Fourquerean et al., 2012; Marbà et al., 2015; Trevathan-Tackett et al., 2018b). However, nutrient enrichment can enhance SOC contents in the surface sediment, which can not indicate that the SOC storage potential increasing.

The labile organic carbon (eg. MBC and DOC) and enzyme activities (eg. Polyphenol oxidase and cellulases) should be taken as the important indicators to evaluate the carbon sequestration.
3. How to amplified the ‘Blue carbon’ of seagrass meadows?

To recovery the seagrass meadows is the good way to amplify the blue carbon, which has been attempted as shown in previous studies (Marba et al., 2015).

According to this study, we can select that higher carbon sequestration capacity seagrass species to amplify the ‘Blue carbon’ on condition that this seagrass sepcies is favorable for the local environment.
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