CH$_4$ flux from an aquaculture zone in a subtropical lake

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2020/07/24
Outline

- Introduction
- Methods
- Results and discussion
- Conclusions
Aquaculture systems are major anthropogenic sources of $\text{CH}_4$ emission: $6.04 \pm 1.17 \text{Tg CH}_4 \text{yr}^{-1}$, and China contributes 68% of global budgets (Yuan et al., 2019).

- Rice-fish systems
- Extensive systems
- Semi-intensive systems
- Intensive systems

◆ aquaculture site  ◆ stocking density  ◆ management practices (aeration)

CH$_4$ emission from intensive systems is negligible  

Yuan et al., 2019
• The presence of aquatic plants in aquaculture systems will increase CH$_4$ emission by 14% ~ 128% (Ma et al., 2018; Hu et al., 2016; Liu et al., 2016).

• Dredging will greatly reduce the sediment C substrate for CH$_4$ production, and drainage will destroy the anaerobic environment in sediments (Hu et al., 2016).

Objective 1: To investigate CH$_4$ emission from aquaculture zones of lakes
Whether the disturbance of intensive aquatic animal activities will affect the pathway of CH$_4$ emission?

Objective 2: To determine the ratio of CH$_4$ ebullition from aquaculture zones of lakes

For lakes, ebullition ratio: 40%~60% (Bastviken et al., 2004)

CH$_4$ transfer efficiency largely depends on ebullition

Bastviken et al., 2004
Objective 3: To examine the driving factors that control CH$_4$ dynamics

The water DO concentration in aquaculture systems: $>5 \text{ mg L}^{-1}$

In small closed aquaculture ponds, DO dynamics caused by artificial aeration is the key factor affecting CH$_4$ emission.

In aquaculture zones of lakes, there is no need to aerate because of sufficient DO.
Objective 4: To quantify the ratio of CH$_4$ emission to total carbon inputs from aquaculture zones of lakes.
2.1 Site description

DTH site
31°03’40"N 120°28’14"E

Observation time: 2018.04~2018.12
2.2 Aquaculture management practices

<table>
<thead>
<tr>
<th>Management practices</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quicklime sterilization</td>
<td>Mid January</td>
</tr>
<tr>
<td>Young crabs stocking</td>
<td>Mid January</td>
</tr>
<tr>
<td>Freshwater prawn fry stocking</td>
<td>Late January</td>
</tr>
<tr>
<td>Plant <em>Elodea nuttallii</em></td>
<td>May</td>
</tr>
<tr>
<td>Harvest freshwater shrimps</td>
<td>June</td>
</tr>
<tr>
<td>Giant river prawn fry stocking</td>
<td>July</td>
</tr>
<tr>
<td>Harvest crabs and shrimps</td>
<td>Mid September-late December</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feeds</th>
<th>Application rate (t ha⁻¹)</th>
<th>Contents of C and N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C (%)</td>
</tr>
<tr>
<td>Pellet feed</td>
<td>3</td>
<td>21.4</td>
</tr>
<tr>
<td>Trash fish</td>
<td>54</td>
<td>8.41</td>
</tr>
<tr>
<td>Corn seeds</td>
<td>9</td>
<td>46.4</td>
</tr>
</tbody>
</table>

The crabs were fed once daily at 4:00~6:00 a.m.
2.3 Eddy covariance data processing

1) Data correction for CO$_2$

- 2-D coordinate rotation
- Sonic temperature correction
- WPL correction
- Spectroscopic correction

2) Data correction for CH$_4$

- 2-D coordinate rotation
- Sonic temperature correction
- Frequency correction
- WPL correction
2.4 CH$_4$ ebullition partitioning

**Principle**

- **Local scalar similarity** between the CH$_4$ concentration and other reference scalars, e.g., Ta or q.

- Similar and dissimilar fluctuation components are related to diffusive and ebullitive CH$_4$ fluxes, respectively.

\[
W_x^{j,i} = \int_{-\infty}^{\infty} x(t) \psi_{j,i}(t) \, dt,
\]

Iwata *et al.*, 2018
Choice of the reference scalar

\[ y = 3.4 x^{-1/3} \]

\[ y = 3.3 (1 + 1.4 x)^{-1/3} \]
# Results and discussion

## (1) Environmental condition

- **Area**: Dongtaihu Bay
- **DOC**: 7.09 (mg L\(^{-1}\))
- **TN**: 1.12 (mg L\(^{-1}\))
- **TP**: 0.06 (mg L\(^{-1}\))
- **DO**: 9.95 (mg L\(^{-1}\))

### (a) Temperature 

- \(T_a\): 18.0 °C

### (b) Wind Speed 

- \(WS\): 3.2 m/s

### (c) Depth 

- Depth: 1.3 m
(2) \( \text{CH}_4 \) emission

\[ \text{CH}_4 \text{ flux: } 2.07 \, \mu\text{g/(m}^2\text{s)} \]
feeding

4~5
Initial stage

6~9
Middle stage

10~12
Final stage

\[ F_{\text{in}} \] [\mu g/(m^2 \cdot s)]

Time

0:00 4:00 8:00 12:00 16:00 20:00 24:00

\[ F_{\text{in}} \] [\mu g/(m^2 \cdot s)]

Time

0:00 4:00 8:00 12:00 16:00 20:00 24:00

\[ F_{\text{in}} \] [\mu g/(m^2 \cdot s)]

Time

0:00 4:00 8:00 12:00 16:00 20:00 24:00

NDVI

Month

J  F  M  A  M  J  J  A  S  O  N  D
-0.1 0.1 0.2 0.3 0.4 0.5
(3) CH₄ ebullition ratio

Overall: 57.3%

BFG: 49% (Xiao et al., 2017)
Factors influencing CH$_4$ flux

Production

$Q_{10}=5.47$

$Q_{10}=2.46$

$Q_{10}=13.46$
Thermal disturbance (water-side convection)

\[ B = \frac{g a Q_{\text{eff}}}{c_{\text{pw}} \rho_{\text{w}}} \]
Mechanical disturbance (wind forcing)
Water depth

\[ y = -0.98x + 5.6 \quad R^2 = 0.01 \quad p = 0.39 \]

\[ y = 0.64x + 0.3 \quad R^2 = 0.03 \quad p = 0.24 \]

\[ y = -2.62x + 6.47 \quad R^2 = 0.10 \quad p < 0.05 \]
Photosynthesis
C budgets

![Graph showing seasonal fluctuations of CH₄ emissions.]

<table>
<thead>
<tr>
<th>System</th>
<th>CH₄</th>
<th>NEP</th>
<th>Feeds input</th>
<th>Harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dongtaihu Bay</td>
<td>34.21</td>
<td>233.80</td>
<td>935.94</td>
<td>26.85</td>
</tr>
</tbody>
</table>

CH₄/C inputs: 2.99%
(6) Comparison with other published literatures

\[ F_{m} \text{ [mg/(m}^2\text{-h})] \]

- Extensive systems
  - n=13
  - Box plot with mean and median
- Semi-intensive systems
  - n=12
  - Box plot with mean and median
- Our study
  - Star

0.34 Tg CH\textsubscript{4} yr\textsuperscript{-1}
The CH$_4$ flux from the aquaculture zone of East Lake Taihu was 1.45 μg/(m$^2$·s), which is between the values of semi-intensive systems and extensive systems.

The ratio of CH$_4$ ebullition from the aquaculture zone of East Lake Taihu was about 57%, which means the disturbance of intensive aquatic animal activities will not affect the pathway of CH$_4$ emission.

Different CH$_4$ emission process is influenced by different environmental variables. The superposition effect made sediment temperature and thermal disturbance become the driving factors of CH$_4$ dynamics. Besides, O$_2$ produced by photosynthesis of aquatic plants may have a greater impact on CH$_4$ emission compared to productivity.

In spite of large amount of organic C input, the ratio of CH$_4$ to total carbon inputs from the aquaculture zone of East Lake Taihu was still close to that of natural wetlands.
Thanks for your attention!