Elements of carbon cycling: aquatic primary producers under global change

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Aquatic carbon cycling in a (very simplified) nutshell
Overview

Environmental changes
- Elevated pCO2
- Eutrophication
- Warming

Organisms of choice
- Phytoplankton
- Submerged macrophytes
Talk outline

Warming effects
Aquatic carbon cycling in macrophyte dominated systems

Macrophyte decomposition
The role of stoichiometry and phenolics
Warming effects on aquatic carbon cycling
Carbon cycling under climate warming

Based on:
Barko et al., 1981 Ecological monographs
Liboriussen et al., 2010 Freshwater biology
McKee et al., 2002 Aquatic botany
Moss et al., 2011 Inland waters
Experimental system – the limnotrons

1000 l indoor mesocosm facility

Macrophyte dominated system:

– *Myriophyllum spicatum* (submerged rooted plant)
Experimental set-up

Inoculum of plants

+ 

Nutrients
92 µM N (1.3 mg/l)
2.6 µM P (76 µg/l)

Natural sediment
Experimental set-up

warmed

control

Heatwave

Date

Temperature (°C)

9-3  8-5  7-7  6-9  5-9  4-11  3-1  3-3

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Picture by Ralf Aben
Experimental team – the limnonauts

Picture by Sarian Kosten
Results *M. spicatum*

Higher plant biomass
Elongated growth season
Sedimentation methods

Sedimentation sampler in middle of limnotron
Collect over a period of 3 days
Determine dryweight & carbon content
Calculate carbon-based sedimentation rate
Results sedimentation

![Graph showing sedimentation data with error bars, comparing control and warm treatments over time from May 15 to Feb 16. The graph includes labels for the x-axis months and y-axis sedimented C (g/m²).]

LME:
- treatment*
- time***
- treatment x time***

Mean ± SE
Decomposition methods

Litterbag method – 500 micrometer mesh
Dried *M. spicatum* leaves
Hung in water column just above the sediment
Carbon based mass loss after ½, 1, 2, 4, 6 and 8 months
Fit decomposition model

\[ m \times e^{-k \times \text{day}} + s \]

\( m = \) fraction start material ( = 100%)
\( k = \) decomposition rate
\( s = \) fraction remaining carbon
Results decomposition

- Similar decomposition rate \((k)\) for temperature treatments
- Less remaining carbon \((s)\) in warm treatment

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Warm</th>
<th>T-test</th>
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<tbody>
<tr>
<td>Decomposition rate</td>
<td>0.023 ± 0.0032</td>
<td>0.018 ± 0.0021</td>
<td>n.s.</td>
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<tr>
<td>fraction remaining material</td>
<td>0.26 ± 0.05</td>
<td>0.11 ± 0.02</td>
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Overview results

Increased plant biomass
Enhanced sedimentation
More complete decomposition

Zero net effect?
Carbon budget model

Labile organic carbon at the sediment (what breaks down)

\[ LOC_t = LOC_{t-1} + (1 - s) \times SR \times \Delta t - LOC_{t-1} \times e^{-k\Delta t} \]

Organic carbon burial (what remains)

\[ OCB_t = OCB_{t-1} + s \times SR \times \Delta t \]
Results carbon budget model
Summary warming effects on carbon cycling

- Warming increased sedimentation and decomposition, with zero net effect on carbon burial
- But what about macrophyte quality?
Macrophyte decomposition: stoichiometry and polyphenols
Expressions of macrophyte quality

Carbon:nutrient stoichiometry

$\uparrow$ C:nut $\rightarrow$ poor quality
$\downarrow$ C:nut $\rightarrow$ good quality

Polyphenols
Carbon-rich compounds
Difficult to degrade
Quality dependent on environment

Nutrient treatment


Gross (2003) OIKOS

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Mesocosm experiment

_Elodea nuttallii_
June – August 2018
Decomposition under field conditions
Take home message

Macrophyte decomposition
Macrophyte quality influenced by environment
Subsequent effects on decomposition seem small

Warming effects on aquatic carbon cycling
Quantity over quality
Temperature doubles individual carbon fluxes
Important to take whole cycle into account (zero net effect)
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