Nutrient ‘outwelling’: A 50 year old tale

At the same time the tides remove 45% of the production before the marsh consumers have a chance to use it and in so doing permit the estuaries to support an abundance of animals.
A Research Challenge: Evaluating the Productivity of Coastal and Estuarine Water

Eugene P. Odum

1968.
Proceedings of the 2nd Sea Grant Conference,
University of Rhode Island, Kingston, pp. 63-64.

Most fertile zones in coastal areas capable of supporting expanded fisheries result either from the “upwelling” of nutrients from deep water or from “outwelling” of nutrients and organic detritus from shallow-water nutrient traps such as reefs, banks, seaweed or sea grass beds, algal mats and salt marshes. The importance of the latter as “primary production pumps” that “feed” large areas of adjacent waters has only been recently recognized, and

Concepts and Controversies in Tidal Marsh Ecology

Edited by
Michael P. Weinstein and Daniel A. Kreuger

TIDAL MARSHES AS OUTWELLING/PULSING SYSTEMS

Odum, 2002

Kluwer Academic Publishers
DOM

POM

Google Earth, off the coast of Georgia

Outwelling Systems?

Sequestrating Systems?

Google Earth, off the coast of NC
INTRIGUING DATA FUELING THE DEBATE

Restored marsh studied

Estuary

Created Marsh

Agricultural Production
One of the Project Goals

- Ability of a restored coastal marsh to provide ecosystem services, including
  - water quality: dissipate excess nutrients from upstream agricultural drainage

Methods: mass balance
Water Movement in the Marsh

Flow dynamics
Flow Monitoring

- Doppler Velocity and water depth recorded every 15 minutes in flume

- Use manual stream gauging to relate Doppler velocity to actual flow in the flume

Nutrient Monitoring

<table>
<thead>
<tr>
<th>Parameter</th>
<th>R²</th>
<th>RMSEP (mg L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₃-N</td>
<td>0.998</td>
<td>0.1</td>
</tr>
<tr>
<td>TKN</td>
<td>0.91</td>
<td>0.3</td>
</tr>
<tr>
<td>DOC</td>
<td>0.94</td>
<td>1</td>
</tr>
<tr>
<td>TSS</td>
<td>0.92</td>
<td>7</td>
</tr>
<tr>
<td>PO₄-P</td>
<td>0.66</td>
<td>0.01</td>
</tr>
<tr>
<td>TP</td>
<td>0.73</td>
<td>0.02</td>
</tr>
<tr>
<td>Salinity</td>
<td>0.97</td>
<td>2</td>
</tr>
</tbody>
</table>
Load calculations

\[ M = k \sum_{i=1}^{i=t} q_i c_i \Delta t \]

- M = total mass of N either exported or imported (kg)
- t = time (min)
- k = constant for converting units
- q_i = water flow at time i (m³ s⁻¹)
- c_i = concentration at time i (mg L⁻¹)
Positive Mass Balance = Retention
Negative Mass Balance = Release

Mass Balance

Upstream

+ [Brackish Marsh] +

- [Marsh]

Downstream

- [Brackish Marsh] -

Positive Mass Balance = Retention
Negative Mass Balance = Release
Downstream Station

Long-term results

[Map with labels: Monitoring Station, Marsh Boundary]

TSS dynamics

Flow and TSS dynamics at the downstream station during hurricane Sandy

Dates in 2012, Flow (grey), TSS (red)
Spring/Summer: \[ \text{ET} \quad \succ \quad \text{R} \]
Fall: \( R > ET \)
Water balance intrigue...

Expected: ET + Rain

Observed: 1100 mm

2-way water pump!

Water Balance at the Flow Stations

- Export
- Import

Volume of Water (m$^3$)

- Expected: ET + Rain
- Observed


NC STATE UNIVERSITY
What mechanism?

Spring-Summer
Spring-Summer
Spring-Summer

[Diagram showing spring-summer season with grass, water, and an arrow indicating direction]

Spring-Summer

[Diagram showing spring-summer season with grass, water, and an arrow indicating direction]
TKN balance: net export

DOC balance: net export

1-way nutrient pump!
## Nitrate Mass Balance

![Nitrate Mass Balance Graph](image)

## Mass Balance Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Input Mass (kg)</th>
<th>Output Mass (kg)</th>
<th>Mass Balance (kg)</th>
<th>Percent Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_3$-N</td>
<td>470</td>
<td>430</td>
<td>40</td>
<td>9%</td>
</tr>
<tr>
<td>TKN</td>
<td>1,290</td>
<td>1,410</td>
<td>-120</td>
<td>-29%</td>
</tr>
<tr>
<td>TN</td>
<td>1,760</td>
<td>1,840</td>
<td>-80</td>
<td>-5%</td>
</tr>
<tr>
<td>DOC</td>
<td>18,000</td>
<td>19,400</td>
<td>-1,400</td>
<td>-8%</td>
</tr>
<tr>
<td>PO$_4$-P</td>
<td>57</td>
<td>59</td>
<td>-2</td>
<td>-4%</td>
</tr>
<tr>
<td>TP</td>
<td>117</td>
<td>125</td>
<td>-8</td>
<td>-7%</td>
</tr>
<tr>
<td>TSS</td>
<td>48,000</td>
<td>51,000</td>
<td>-3,000</td>
<td>-6%</td>
</tr>
</tbody>
</table>
Conclusion

- Long-term 15-min data: essential to make meaningful conclusions
- Nitrate retention values mid-way between stream and non-tidal wetlands
- Marsh: 2-way water pump, 1-way nutrient pump
- Nutrient outwelling confirmed?

Questions?