Nitrogen Movement in Cranberry Water

Carolyn DeMoranville, UMass Cranberry Station
Rachel Jakuba, Buzzards Bay Coalition
Chris Neill, Marine Biological Laboratory
Casey Kennedy, USDA-ARS
Nick Alverson, UMass Environmental Conservation

study partnership
Outline of today’s panel

- Carolyn: Setting the stage – the issues and the partnership.
- Rachel: Study design for our first work.
- Chris: First study results.
- Casey: The evolution to continuous data collection.
- Nick: A case study of floods and ‘big rain events’.
- Carolyn: The next steps.
- Questions and discussion.
Environmental considerations

- Biggest concern is movement of N in surface water
- Leaching potential is limited
  - layered soil and barrier layers (why the bog can hold a flood)
  - ammonium N forms
- Groundwater pathway – total extent unknown
Flooding practices

Potential export pathway

N study partnership
Why environmental nitrogen matters

- N that moves into surface waterways becomes a pollutant in the estuaries

- All land uses potentially contribute to N in the water – Mass Estuaries Project models this

- Septic/sewer are biggest contributors in most watersheds

- Some SE Mass watersheds are cranberry dominated
Distribution of N sources

- Examples of models from the Mass Estuaries Project reports

Agawam River subwatershed

Wankinko River subwatershed

Data from Mass Estuaries Project (Howes et al. 2013)
How are the cranberry numbers generated?

- One detailed study of a flow-through bog (Howes and Teal, 1995)
  - Net output (outgoing water load minus incoming water load) = 20.6 lb/acre N

- Values were different in a less rigorous study that focused primarily on floods
  - 4 to 14 lb/acre N
## CES/SMAST Field Study
### Cranberry Bog NET Nitrogen Loss

<table>
<thead>
<tr>
<th>Bog ID --&gt;</th>
<th>EH</th>
<th>PV</th>
<th>BEN</th>
<th>WS</th>
<th>M-K</th>
<th>ASH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nitrogen Inflow to Bog</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>0.4</td>
<td>1.5</td>
<td>0.6</td>
<td>0.2</td>
<td>1.7</td>
<td>2.4</td>
</tr>
<tr>
<td>Groundwater</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
<td>0.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Frost Protection</td>
<td>0.8</td>
<td>1.8</td>
<td>1.4</td>
<td>0.5</td>
<td>1.6</td>
<td>2.0</td>
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<tr>
<td>Pest Management</td>
<td>0.0</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
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<tr>
<td>Harvest</td>
<td>1.3</td>
<td>3.4</td>
<td>4.5</td>
<td>1.2</td>
<td>4.2</td>
<td>2.9</td>
</tr>
<tr>
<td>Winter Protection</td>
<td>3.0</td>
<td>3.7</td>
<td>5.2</td>
<td>1.4</td>
<td>4.8</td>
<td>4.0</td>
</tr>
<tr>
<td><strong>Total IN</strong></td>
<td>5.5</td>
<td>10.5</td>
<td>12.8</td>
<td>3.6</td>
<td>12.4</td>
<td>11.3</td>
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<tr>
<td><strong>Nitrogen Outflow from Bog</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage/Infiltration</td>
<td>5.7</td>
<td>6.7</td>
<td>10.5</td>
<td>4.6</td>
<td>7.7</td>
<td>7.2</td>
</tr>
<tr>
<td>Harvest</td>
<td>2.1</td>
<td>5.3</td>
<td>9.4</td>
<td>2.5</td>
<td>4.5</td>
<td>2.8</td>
</tr>
<tr>
<td>Winter</td>
<td>4.0</td>
<td>4.6</td>
<td>6.4</td>
<td>1.7</td>
<td>4.0</td>
<td>5.2</td>
</tr>
<tr>
<td><strong>Total OUT</strong></td>
<td>11.9</td>
<td>16.5</td>
<td>26.3</td>
<td>8.8</td>
<td>16.2</td>
<td>15.2</td>
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<tr>
<td><strong>Net Nitrogen Loss (lb/a/yr)=</strong></td>
<td>6.2</td>
<td>6.0</td>
<td>13.5</td>
<td>5.2</td>
<td>3.7</td>
<td>3.8</td>
</tr>
</tbody>
</table>

### Nitrogen Output to Downgradient Systems (lb N/acre/yr)
- Pine-Oak Forest | 0.4
- Cranberry Bog Nitrogen Output | 6.4 (Flow Through Bog = 20.6)
- Residential (density 1 per 2.5 acres) | 5.7
- Direct Precipitation on Bay | 9.8
So the N numbers are uncertain – so what?

- Uncertainty can lead to finger pointing and bad decisions
- If the models are wrong and are used to decide on actions, the outcomes will not be as expected
- Informed choices are always better than uninformed ones
- Bad or inadequate data can divert attention from important problems facing the estuaries
How to reconcile the differences from the studies

- More studies!
- Partnership to find funding and conduct research – the Wareham Nitrogen Consensus group
- The groups represented on this panel
  - Cranberry Station
  - Buzzard Bay Coalition
  - Marine Biological Laboratory
  - USDA-ARS (since Casey Kennedy arrived at the Station)
- Not here on stage
  - CCCGA
  - Town of Carver
Rachel Jakuba - Study Design
First study

- Look at 6 non-flow-through bogs
- Collect data for ~14 months (two harvests, two winter floods)
- Collect samples every ~2 months and more frequently during water movement
- Funded by DEP and BBNEP
Basic study design

- Look at 3 examples of two bog configurations
  - Closed loop – where water enters and exits to same water body
  - Long tail – where water exits through a vegetated channel
Basic Study Design

- Measure N & P in water before and after it is on the bog
  - Groundwater up and down gradient
  - Surface water in and out
- Measure surface water levels to estimate flow
- Combine N & P concentration data with water flow estimates to calculate mass of N & P leaving the bogs
Measuring inputs and outputs

**Inputs**
- Flood water pumped in (conc. by grab sample, vol. by logger)
- Precipitation (conc. by NADP, vol. by Cran. Station)
- Groundwater?

**Outputs**
- Surface water released (conc. by grab sample, vol. by logger)
- Seepage to groundwater (vol. estimated from previous work)
Example Site: State Bog
Chris Neill – Preliminary Study Results
Groundwater

Ammonium

mg N/L

0.0
0.2
0.4
0.6
0.8
1.0

WS
RO
PV
ST
LI
BE

Upgradient

Downgradient

Bog

N study partnership
Groundwater

Nitrate

mg N/L

Upgradient
Downgradient

Bog

WS  RO  PV  ST  LI  BE
Groundwater

Total Dissolved Nitrogen

mg N/L

Bog

WS, RO, PV, ST, LI, BE

Upgradient
Downgradient

N study partnership
Findings—groundwater

• No consistent pattern indicating major source or sink
• Connectivity of bogs with groundwater variable and complicated
• High ammonium in one bog but unlikely to travel in groundwater
• High nitrate in one bog, source not clear
• Concentrations of nitrate low compared with groundwater in locations with denser housing
Surface Water

Ammonium

mg N/L

Inflowing
Outflowing

Bog

WS  RO  PV  ST  LI  BE
Surface Water

Total Nitrogen

mg N/L

<table>
<thead>
<tr>
<th>Bog</th>
<th>Inflowing</th>
<th>Outflowing</th>
</tr>
</thead>
<tbody>
<tr>
<td>WS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RO</td>
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<td>PV</td>
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<tr>
<td>ST</td>
<td></td>
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</tr>
<tr>
<td>LI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE</td>
<td></td>
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</tr>
</tbody>
</table>
Findings—surface water

• Inflow concentrations relatively similar to outflow concentrations
• No consistent pattern indicating major source or sink
• Dissolved and particulate N are collectively greater than ammonium and nitrate
• Do not account for dynamics and large amounts of water moving during floods
Preliminary Findings—flood N inputs vs outputs

- Individual floods can be sources or sinks of nitrogen to surface water
- Depends primarily on relative concentrations of dissolved (and to a lesser extent particulate) nitrogen in inflowing and outflowing water
- Annual budget for a bog depends on the sum of nitrogen balances in all floods
- Some bogs likely net sources, some net sinks
- Not an easy matter to scale to watershed based on total bog area
- This approach has limitations because nitrogen concentrations vary during flooding and release
Questions remaining after this study

- Is our methodology capturing all the data needed for a good budget model for cranberry?

- Should we look at changes to monitoring methods?

- Should we monitor more than floods?
Casey Kennedy - Other approaches to data gathering
Continuous Monitoring
Nitrogen Concentration – Seasonal Variation

Month (2014)

- Total N
- Ammonium
- Nitrate

N study partnership
Nitrogen Concentration – Event Variation
Six Core Study Sites – 2 illustrated here

These 2 sites, State Bog and Rocky are common to the partnership study.
Site F – “Wisconsin Style” Bog

- Cranberry Bed
- Drainage Ditch
- Sampling site
- Discharge Flume
- Input Flume
- Flow Direction of ditch
- Drainage tile

TD4

TD3

TD2

TD1

FLUME
Case study – the work of graduate student Nick Alverson
Surface Water Discharge

In Progress

Cubic feet per day

0 20000 40000 60000 80000 100000 120000 140000 160000 180000 200000


N study partnership
Hydrologic Inputs

- Irrigation: 1.17
- Precip: 4.10
- Flood input: 6.50
- Input from adjacent bed: 1.48
Surface Water Discharge: Storms Vs. Harvest Flood
August Storm Event - Flow

1.6 inches of Rain

cubic feet per second

7/31/2013 0:00  8/1/2013 0:00  8/2/2013 0:00  8/3/2013 0:00  8/4/2013 0:00  8/5/2013 0:00  8/6/2013 0:00  8/7/2013 0:00
August Storm Event – Nitrogen Concentrations

TDN (mg N/L)

NH4 (mg N/L)

DON (mg N/L)

NO3+NO2 (mg N/L)
August Storm Event - Dissolved Nitrogen Export

<table>
<thead>
<tr>
<th>Date</th>
<th>TDN</th>
<th>NH4</th>
<th>NO3+NO2</th>
<th>DON</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/1/2013</td>
<td>.454</td>
<td>.433</td>
<td>-0.065</td>
<td>0.086</td>
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</tbody>
</table>

Net Export (kg)
2013 Harvest Flood Discharge

- Y-axis: cubic feet per second
- X-axis: dates from 10/23/2013 to 10/26/2013 with times ranging from 0:00 to 12:00
2013 Harvest Flood Nitrogen Export

Net Export (kg)

- TDN: 2.93
- NH$_4$: 0.02
- NO$_3$+NO$_2$: 0.16
- DON: 2.75
Net Export of Storms and Flood

<table>
<thead>
<tr>
<th></th>
<th>Total Storms</th>
<th>Harvest Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TDN (kg)</strong></td>
<td>2.932</td>
<td>2.414</td>
</tr>
<tr>
<td><strong>DON (kg)</strong></td>
<td>2.750</td>
<td>0.985</td>
</tr>
<tr>
<td><strong>NH4 (kg)</strong></td>
<td>1.945</td>
<td>-0.524</td>
</tr>
<tr>
<td><strong>NO3+NO2 (kg)</strong></td>
<td>0.160</td>
<td>-0.524</td>
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</tbody>
</table>
Next steps

- Partner group
  - Will continue study of 6 sites, funding from the EPA via Coastal Zone Management
  - Methods modified to more continuous approach
  - Focus on floods AND big rain events
  - Develop better numbers for the Mass Estuaries model

- ARS
  - Annual nutrient budgets

- Cranberry Station
  - Refine BMP recommendations based on research outcomes
Questions and discussion