Science Overview of Nutrients in Illinois

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What I will cover

• focus on where nutrients come from and go
• nutrient sources and transport in Illinois
  - mass balances
  - point versus non point
  - fate of nutrients
  - seasonality
• Gulf Hypoxia
  - contribution of Illinois
Sources of Nutrients in Illinois

• agriculture
  - surface runoff
  - tile drainage
  - many watersheds > 90% row crop
  - animal agriculture less important

• sewage effluent
  - Illinois has ~ 12.9 million people
  - dominates upper Illinois River
  - generally, no N or P removal technology used
Mass Balances of N and P
Components of Nitrogen Mass Balances

• net nitrogen inputs (NNI)
  = inputs - outputs
  inputs (deposition, fertilizer, fixation)
  outputs (grain harvest - human and animal consumption)

• NNI is N available for leaching, denitrification, adding to N pools

• data from agricultural statistics, fertilizer industry, assumptions about N in various components
Components of Phosphorus Mass Balances

- **net P inputs**
  
  \[ \text{inputs} - \text{outputs} \]
  
  inputs (fertilizer)
  
  outputs (grain harvest - human and animal consumption)

- net P is N available for adding to soil P pools

- little P (relative to N) is lost to streams, but it biologically important

- surface runoff and tile leaching
Fertilizer N
$N_2$ Fixation (Soybean)
Grain Harvested
Nutrient Mass Balances

inputs

- outputs
Illinois N Budget

- Fertilizer
- Legume N
- Deposition
- Grain harvest
- Manure
- Net Nitrogen Inputs

Nitrogen (kg N ha⁻¹)

Year:
- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010
Illinois P Budget

Phosphorus (kg P ha⁻¹)

- Fertilizer
- Grain harvest
- Manure
- Human consumption
- Balance

Years:
- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010
Drainage by tiles and ditches
Illinois Drainage Tile Installed

Year
1870 1880 1890 1900 1910 1920
Cumulative Drain Tile Produced (million feet)
Tile drainage in the upper Embarras River watershed, Illinois

From Richard Cooke
Nitrification

\[ \text{NH}_3 \rightarrow \text{NO}_3^- \]

Transport in tile water
Embarras River - Camargo
Embarras River

NITRATE (mg N L⁻¹)

0  5  10  15  20
Nitrate Export (kg N ha$^{-1}$ yr$^{-1}$)

Water Year

Embarras River
Soil erosion and phosphorus in surface water
Distribution of tile-drained soils and phosphorus in surface water
Distribution of tile-drained soils and nitrate in surface water
Phosphorus - top 200 point sources in Illinois = 90% of all 1800 sources
Nitrogen - top 200 point sources in Illinois = 81% of all 1800 sources
Sewage Effluent -12.9 million people

16% of total N load statewide
21% for Illinois River, 14% for others

47% of total P load statewide
70% for Illinois River, 33% for others
Timing of export
Nutrient Export Patterns
Importance of a Few Storm Events

The graph shows the nutrient export (cumulative %) and discharge (m$^3$ s$^{-1}$) over time, with precipitation (cm d$^{-1}$) on the right axis. The nutrient export is represented by lines for NO$_3^-$-N, DRP, and Total P. The discharge is depicted with a series of spikes, indicating storm events. The water year spans from 2002 to 2003.
Major Mississippi Subbasins
Major Mississippi Subbasins
Nutrient loads for 2001 to 2005
Nutrient yields for 2001 to 2005

**Total P**

**Nitrate-N**
USPEA SAB Hypoxia Advisory Panel Recommendations

• panel consensus was a 45% reduction in both N and P loads to the Gulf
  - five year average compared to 1980 to 1996
• spring most important
• reduce both point and agricultural sources
## Nutrient Concentrations – seldom limiting

Table 1. Distribution of water chemistry values from the 2004 state-wide surveys.

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>25th Percentile</th>
<th>Median</th>
<th>75th Percentile</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High-Q† survey (May–July, n = 138)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DRP‡ (mg L⁻¹)</td>
<td>&lt;0.005</td>
<td>0.038</td>
<td>0.069</td>
<td>0.156</td>
<td>1.9</td>
</tr>
<tr>
<td>Total P (mg L⁻¹)</td>
<td>0.013</td>
<td>0.123</td>
<td>0.185</td>
<td>0.326</td>
<td>2.0</td>
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<tr>
<td>NH₄⁻N (mg L⁻¹)</td>
<td>0.008</td>
<td>0.040</td>
<td>0.058</td>
<td>0.089</td>
<td>0.387</td>
</tr>
<tr>
<td>NO₃⁻N (mg L⁻¹)</td>
<td>0.10</td>
<td>1.0</td>
<td>4.3</td>
<td>10.2</td>
<td>20.2</td>
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<tr>
<td>Total N (mg L⁻¹)</td>
<td>0.37</td>
<td>2.2</td>
<td>5.6</td>
<td>11.0</td>
<td>20.9</td>
</tr>
<tr>
<td>Silica (mg L⁻¹)</td>
<td>1.5</td>
<td>6.7</td>
<td>9.6</td>
<td>11.8</td>
<td>16.6</td>
</tr>
<tr>
<td>pH</td>
<td>7.0</td>
<td>7.7</td>
<td>7.9</td>
<td>8.1</td>
<td>8.7</td>
</tr>
<tr>
<td>Specific conductivity (μS cm⁻¹ @ 25°C)</td>
<td>106</td>
<td>586</td>
<td>658</td>
<td>751</td>
<td>2240</td>
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<tr>
<td>Turbidity (NTU§)</td>
<td>&lt;1</td>
<td>21</td>
<td>36</td>
<td>61</td>
<td>614</td>
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<tr>
<td><strong>Low-Q survey (Sept., n = 109)</strong></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>DRP (mg L⁻¹)</td>
<td>0.001</td>
<td>0.029</td>
<td>0.081</td>
<td>0.345</td>
<td>2.8</td>
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<tr>
<td>Total P (mg L⁻¹)</td>
<td>0.007</td>
<td>0.112</td>
<td>0.168</td>
<td>0.456</td>
<td>2.8</td>
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<tr>
<td>NH₄⁻N (mg L⁻¹)</td>
<td>0.002</td>
<td>0.011</td>
<td>0.022</td>
<td>0.042</td>
<td>0.696</td>
</tr>
<tr>
<td>NO₃⁻N (mg L⁻¹)</td>
<td>&lt;0.05</td>
<td>0.18</td>
<td>1.5</td>
<td>3.9</td>
<td>18.0</td>
</tr>
<tr>
<td>Total N (mg L⁻¹)</td>
<td>0.21</td>
<td>1.0</td>
<td>2.5</td>
<td>5.0</td>
<td>18.7</td>
</tr>
<tr>
<td>Silica (mg L⁻¹)</td>
<td>1.3</td>
<td>6.4</td>
<td>8.6</td>
<td>11.2</td>
<td>29.2</td>
</tr>
<tr>
<td>pH</td>
<td>6.8</td>
<td>7.6</td>
<td>7.9</td>
<td>8.2</td>
<td>8.9</td>
</tr>
<tr>
<td>Specific conductivity (μS cm⁻¹ @ 25°C)</td>
<td>132</td>
<td>556</td>
<td>664</td>
<td>814</td>
<td>3246</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>&lt;1</td>
<td>10</td>
<td>18</td>
<td>29</td>
<td>159</td>
</tr>
</tbody>
</table>
Conclusions

- Illinois major source of N and P to Gulf of Mexico
- high concentrations of nitrate and total P in most streams of the state
- for nitrate, source is mainly tile drained agricultural fields
- for P, agricultural sources and sewage effluent
- most of the export from the state occurs during a relatively few high flow days in winter/spring