Nitrate flux in the Mississippi River: a big government problem

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Speaker Introduction
by Professor Don Boesch
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Acknowledgements

June 17 – July 18 bottom DO contours, 2004

http://www.ncddc.noaa.gov/ecosystems/hypoxia/data2004
Nutrient-laden sediment plume entering the Gulf of Mexico.
Size of hypoxic zone in July depends on flux of nitrate/nitrate in May

\[ Y (\text{km}^2) = -1337953.4 + 672.1589 \times \text{Year} + 0.0998 \times (\text{May NO}_3^{+2} \text{ flux}) \]

Gulf Hypoxia

- Mississippi River/Gulf of Mexico Watershed Nutrient Task Force Hypoxia Assessment (Goolsby et al 1999, 2001)
- Other models: SPARROW model (Smith et al 1997, Alexander et al 2000); McIsaac et al 2001; Donner et al 2003, 2004

The biggest source of nitrogen is non-point runoff from agricultural sources, especially inorganic fertilizers
Linking gulf hypoxia to farm practices

It’s agreed that agricultural runoff is the biggest source of nitrogen to the Gulf of Mexico…

But what to do about it?
Fixing the Gulf: Mississippi River/Gulf of Mexico Watershed Nutrient Task Force Hypoxia Assessment and Action Plan

Increased monitoring
All voluntary compliance measures
Meanwhile...
Land use trends in the MRB

- Hectares fertilized
- Fertilizer N (kg)
- Hectares in conservation

Graphs showing trends from 1985 to 2005.
Current and proposed ethanol plant capacity in relation to corn acreage
No consistent change in extent of Dead Zone

Data source: Nancy N. Rabalais, Louisiana Universities Marine Consortium

http://www.gulfhypoxia.net/erf/Shelfwide%20Cruises.htm
What’s to be done?
Yearly agricultural payments in the MRB: Billions!

Commodity payments
Conservation subsidies

Objectives

Characterize the current extent and location of agricultural N runoff in the MRB;
Explore the relationship between agricultural subsidies and nitrate flux to the Gulf using actual and modeled data

Where can increases in conservation payments be most effective?
Locations of “small-drainage” sites
Approach

Regression model: time- and flow-weighted nitrate-N flux at USGS water quality monitoring sites as a function of:

- Runoff
- Fertilizer N inputs
- Population waste N inputs
- Animal waste N inputs
- Atmospheric nitrate deposition

within each site’s drainage for the years 1990-2002 (March – June)
Data sources

**Fertilizer inputs:** USDA “planted acres” data, USDA fertilizer application rates; commercial fertilizer sales database

**Animal waste inputs:** USDA Agricultural Census data, animal waste production estimates from various sources

**Human waste inputs:** Census data on population; Resources for the Future and EPA databases on municipal N discharges

**Atmospheric nitrate deposition:** National Atmospheric Deposition Program

**Runoff data:** USGS database
Approach

• Coefficients and exponents from the model applied to inputs data for each watershed in the MRB

• Modeled watershed-level flux estimates multiplied by denitrification efficiency value from SPARROW model (Alexander et al 2000: in-stream denitrification losses are highest in small streams with a high sediment: water contact ratio and long travel time)

• Modeled estimates summed to produce a whole-basin estimate for the MRB…

• Hotspots of agricultural N flux evaluated in terms of subsidies
Checking the fertilizer estimates

Illinois Fertilizer Sales (lb N as Fertilizer)
Estimated = 0.87*sales $R^2 = 0.92$

Indiana Fertilizer Sales (lb N as Fertilizer)
Estimated = 0.7*sales $R^2 = 0.85$
Model structure

\[
\text{flux\_ha} = \text{average\_runoff} \times ((\text{lbfert\_ha})^{2.13} + \text{animN\_ha} + \text{ndep\_ha}) + (\text{popn\_ha})
\]

- **flux\_ha**: kg NO\textsubscript{3}^-\text{-N} leaving the watershed, per ha/day
- **average\_runoff**: daily runoff per hectare, in mm
- **lbfert\_ha**: kg fertilizer nitrogen applied, per ha/year
- **animN\_ha**: kg nitrogen as animal waste, per ha/year
- **ndep\_ha**: kg NO\textsubscript{3}^-\text{-N} deposited per ha/year
- **popn\_ha**: population* 0.0144 lb N per day/person
Results
Modeled flux compared to USGS flux: kg nitrate-N d\(^{-1}\) entering the Gulf

\[ y = 0.83x + 300343 \]

\[ R^2 = 0.85 \]
Spring nitrate loading model results compared to SPARROW model

<table>
<thead>
<tr>
<th>Source</th>
<th>Spring nitrate model</th>
<th>SPARROW model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer</td>
<td>70%</td>
<td>49%</td>
</tr>
<tr>
<td>Municipal waste</td>
<td>11%</td>
<td>6%</td>
</tr>
<tr>
<td>Atm nitrate dep</td>
<td>6%</td>
<td>18%</td>
</tr>
<tr>
<td>Animal waste</td>
<td>12%</td>
<td>14%</td>
</tr>
<tr>
<td>Other non-ag</td>
<td>NA</td>
<td>13%</td>
</tr>
<tr>
<td>Total daily flux (as nitrate, in spring)</td>
<td>3,546,970 kg/d</td>
<td>6,078,137 kg/d (as total N, year-round)</td>
</tr>
</tbody>
</table>
SPARROW model and Spring Nitrate model comparison

SPARROW

Spring nitrate model
Nitrate flux vs. fertilizer inputs: big sites
Nitrate flux vs. fertilizer inputs: small sites
Proportion of land area accounting for spring flux

- 5% of area: 40% flux
- 10% of area: 65% flux
- 15% of area: 80% flux

And 45% of crop subsidies
Commodity support dollars per hectare
(County sum, 1995-2002)
Relationship between nitrate flux and corn subsidies
Value of fertilizer N lost in spring

- $270 million a year (average, 1990-2002)
- At current fertilizer prices, $391 million
Critiquing the model:

Is the nonlinear response of nitrate flux real, or an artifact of land drainage?
Percent of county drained, ~1978

0 – 10% drained
10 – 25% drained
25 – 45% drained
>45% drained

Drainage map courtesy of Bill Battaglin, USGS
Percent of county fertilized

- 0 – 10% fertilized
- 10 – 25% fertilized
- 25 – 45% fertilized
- >45% fertilized
Percent of county drained, ~1978

Drainage map courtesy of Bill Battaglin, USGS
Nonlinearity of nitrate flux and inputs

Recommendations
Solutions to aquatic N loading depend on the nature of the problem

Where fertilizer runoff is increased by artificial drainage, need wetland and riparian zone restoration

Where runoff is a function of high N inputs, need reductions in inputs and diversification of land use
Whatever the nature of the problem…
Conservation money needs to be increased in the Farm Bill.

For Illinois, Indiana and Iowa:
2004 crop subsidies
$2.7 billion

2004 Unfunded Applications for Environmental Quality Incentive Program (EQIP):
$235 million in conservation and water quality grants
11,000 farmers

2004 Unfunded Applications for Wetlands Reserve Program (WRP):
$411 million, 321,000 acres, 2,450 farmers
Commodity support dollars per hectare
(County sum, 1995-2002)
Conservation payments per hectare (whole county basis, 1995-2002)

- < $25
- $25 - $75
- $75 - $150
- $150 - $330

Map showing the distribution of conservation payments across the United States.
## Estimates for restoration efforts

<table>
<thead>
<tr>
<th></th>
<th>N removal efficiency</th>
<th>Area for significant reduction in N loading</th>
<th>Multiple of current conservation effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riparian forests</td>
<td>4 g m$^2$ yr$^{-1}$</td>
<td>78,000-200,000 km$^2$</td>
<td>At least 3x</td>
</tr>
<tr>
<td>Wetlands</td>
<td>10-20 g m$^2$ yr$^{-1}$</td>
<td>21,000-52,000 km$^2$</td>
<td>10 - 25x</td>
</tr>
</tbody>
</table>

Conservation effort is inversely related to agricultural effort.
Current relationship of conservation area to fertilized area for watersheds of the MRB
Proposed relationship between conservation area and fertilized area
A legislative goal: Conservation compliance!

Farmers should not expect to receive federal commodity support dollars unless they demonstrate responsible use of inputs and compliance with conservation goals.
Question Time

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Question Time
(cont’d)

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