Effects of riparian buffers on nitrate concentrations in watershed discharges: New models and management implications

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Briefest introduction

- Too much nitrogen is bad for the Bay
- We must cut nitrogen inputs
- Riparian buffers can help

- But, we haven’t measured the whole-watershed benefits of buffers
Strong evidence for nutrient removal in riparian buffers comes mainly from transect-scale studies.
Mid-Atlantic transect studies

Lowrance et al. 1997 Env. Mgt. 21:687-712
Transect results motivated restoration

![Graph showing the progress towards the revised goal of 10,000 miles by 2010. The graph indicates that 69% of the goal was achieved by 2010.]

Revised goal: 10,000 miles by 2010

Original goal

Year

Percent achieved

Bay Barometer: A Health and Restoration Assessment of the Chesapeake Bay and Watershed: http://www.chesapeakebay.net/status_forestbuffers.aspx
“Scaling-up” from transects to watersheds

• Assumes transect results
• Extrapolates to watersheds

• Fit to stream nutrient data
• Tests transects results at the watershed scale
• But, past results mixed
Common buffer metrics don’t work

Complete buffering vs. NO buffering

- Land use proportions identical
- Both have 50% forest in 100 ft buffer
- Both have 50% of stream length buffered
Need to retool

Buffers and water quality
Improved geographic analysis: *functionally based* buffer measures

- **Buffer prevalence along transport paths**
- **Metrics consider crop-stream pathways only**
- **Unites transect and watershed scales**

Application to the Chesapeake Bay watershed
**SERC watershed study**

**Sampling design**
- 321 watersheds
- 3 physiographic provinces
- 12 clusters
- Mostly rural watersheds

Liu et al. 2000 *JAWRA* 36:1349-1366
Water sampling

- Seasonal grab
- 1-2 yr
- Average baseflow nitrate concentration
- Strong indicator of total nitrogen discharge

Liu et al. 2000 JAWRA 36:1349-1366
Spatial data and GIS analysis

- National Land Cover Dataset 1990 (30 m pixels)
  - Cropland
  - Forest/wetland (buffers)
- 1:24K topography (DEM)
- 1:24K stream maps

Flow path metrics
- width metrics need finer resolution land cover
- buffer gaps below cropland distinguish buffered and unbuffered cropland

Baker et al. 2006 Land. Ecol. 21:1327-1345
Cropland and buffers


<table>
<thead>
<tr>
<th>Physiographic province</th>
<th>Unbuffered</th>
<th>Buffered</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>53%</td>
<td></td>
</tr>
<tr>
<td>PD</td>
<td>32%</td>
<td></td>
</tr>
<tr>
<td>AM</td>
<td>13%</td>
<td></td>
</tr>
</tbody>
</table>
Improved statistical analysis

- Land cover proportions only
  \[ \text{NO}_3 = \beta_0 + \beta_c C \]
- Land cover \textit{and} buffer
  \[ \text{NO}_3 = \beta_0 + \beta_c C + \beta_u C_u \]
- Separate \( \beta \)'s for 3 physiographic provinces
- Both explain \( \sim 75\% \) of the variability in nitrate
- Compared with information theory (\( \text{AIC}_c \))
- \textbf{Buffer model is 10,000 times more likely!}
Model parameters estimate province average source strength and buffer removal potential
Removal potentials

Model predictions estimate nitrate sources, current nitrate removal in buffers, and maximum nitrate removal
Buffer scenario predictions

Stream nitrate concentration (mg N/l) vs. Physiographic province

- CP: Current buffers
- PD: No buffers
- AM: Restored buffers

Components of stream nitrate

Overall reductions

Overall reductions in nitrate concentration (mg N/l) across different physiographic provinces and removal types. The diagram shows:

- Current buffer removal: 16%
- Restored buffer removal: 32%
- Buffer leakage: 68%

Cautions

- Results apply to wide buffers detectable with 30 m data (but method can and should be applied to higher resolution data)
- “Restoration” refers to buffer gaps below cropland
- Restoration sites not the same as current buffers
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Other management applications
Prioritizing management efforts

Buffer Width

- >375 m
- 250 m
- 120 m
- 20 m
- <20 m
Software ToolBox for ArcGIS

http://ches.communitymodeling.org/models.php#buffer
Summary—geographic analysis

- Developed new flow-path measures of buffer prevalence
- Accounted for source-buffer-stream connections
- Correctly scaled from transects to whole watersheds
Summary—statistical analysis

- Demonstrated that buffer effects *ARE* significant at the watershed scale
- Quantified loading rates from unbuffered and buffered cropland
- Estimated nitrate removal in current buffers
- Estimated upper limit for additional restoration removal
- Documented differences in buffer removal among physiographic provinces
Acknowledgements

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EPA Watershed Classification Program

The Cooperative Institute for Coastal and Estuarine Environmental Technology
For more information . . .

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Ecological applications preprints
http://www.esajournals.org/toc/ecap/0/0

Riparian analysis toolbox
http://ches.communitymodeling.org/models.php#buffer