Watershed-Scale Wetland Functions Affect Downstream Systems

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Presentation Overview

• Wetland Extent
• State of the Science: Habitat/Biogeochemical Functions
• Study: Hydrological and Biogeochemical Functions
• Implications
Wetlands Across the CONUS

- Current estimates of 45 million ha.
- 95% are freshwater systems
- 16% are non-floodplain wetlands
Historical Wetlands Losses: ~ 50%

Source: fws.gov
Wetland Destruction and Modifications

- Ditching and Draining
- Filling and Destruction
- Climate Change
- Invasive Species

Source: FredWasmer.com; Congaree NP
Ditching and Draining
Annual Loss Rate

<table>
<thead>
<tr>
<th>Decade</th>
<th>Loss (Acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950s–1970s</td>
<td>-458,000</td>
</tr>
<tr>
<td>1970s–1980s</td>
<td>-290,000</td>
</tr>
<tr>
<td>1980s–1990s</td>
<td>-58,550</td>
</tr>
<tr>
<td>1998–2004</td>
<td>32,000</td>
</tr>
<tr>
<td>2004–2009</td>
<td>-13,800</td>
</tr>
</tbody>
</table>

Wetland Losses

• Not all wetlands are “lost the same”
• Existing: circular, ~same size
• Perimeter:Area ratio

• Serran et al. (2017) Wetlands
• No Net Loss Policy (Alberta, Canada)
• Losses (in red) since ~1900
• Creed et al. Nature Geoscience (2017)
Watershed-Scale Effects of Wetland Losses

• Biodiversity/Habitat Functions
• Biogeochemical Functions
• Hydrological Functions
Biodiversity and Habitat Functions

• Prairie Pothole Region
• 715,000 km\(^2\)
• US states and Canadian provinces

[Image of a prairie pothole region map]
Importance of Wetlands: Biodiversity

- North American waterfowl
- 5 million breeding pairs
Wetlands: Habitat

- Landscape element diversity promotes biodiversity
- Deep & shallow (refugia & breeding)
- Streams (drought)
- Panmictic population

Uden et al. (2014) Ecological Applications 24(7):1569-1582
• Historical: 482 m
• Current: 1083 m
Wetland Inundation: Waterfowl

7-10 million waterfowl
Wetlands: Habitat is “Easy”
Wetland Biogeochemical Sink & Transformation

- Denitrification, sedimentation, sorption, etc.
- “Biogeochemical reactors” (Marton et al. 2015, Bioscience 65(4):408-415)
  - Sediment: 230-3600 g/m²/yr
  - Carbon: 21-317 g/m²/yr
  - Phosphorus: 0.01 – 5.0 g/m²/yr
  - Nitrogen: 0.8 – 2.0 g/m²/yr
- Cheng and Basu (2017, WRR 53:5038-56)
  - Literature review and metanalysis of 600 studies
  - 50% of N load removed by wetlands <300 m² (0.03 ha)
Wetland Biogeochemical/Hydrological Functions

Carbon Storage (Lane and Autrey 2017 Mar. Fresh. Res.)
- Emergent Marsh: 66.1 g Org.C m\(^{-2}\) yr\(^{-1}\)
- Forested: 33.8 g Org.C m\(^{-2}\) yr\(^{-1}\)

Phosphorus Storage (Lane and Autrey 2015 Wetl. Ecol. & Mgmt. 24:45-60)
- Emergent Marsh: 418 mg P kg\(^{-1}\)
- Forested: 1275 mg P kg\(^{-1}\)

Denitrification (Lane et al. 2015 Wetlands 35:459-471)
- Emergent Marsh: 8.99 µg N kg DW\(^{-1}\) hr\(^{-1}\)
- Forested: 3.11 µg N kg DW\(^{-1}\) hr\(^{-1}\)

Water Storage (Lane and D’Amico 2010 Wetlands 30:967-977)
Watershed-Scale Effects
Non-floodplain wetlands...
• ...are critical habitat
• ...affect watershed storage and inundation
• ...affect surface runoff dynamics
• ...affect nutrient dynamics

JAWRA 2018 54(2) Featured Collection (Lane et al.; Schofield et al.)
Wetlands and Watershed Functions

- How do wetlands affect watershed functions?
  - Watershed-scale storage
  - Stream-contributing area
  - Streamflow

- Scenario Exploration - Losses
  - Complete loss of non-floodplain wetlands
  - Preferential loss based on area
  - Proximity-based losses or maintenance

(Wu and Lane 2017 Hydrol. Earth Syst. Sci. 21, 3579-3595)
Watershed-Scale Effects: Approaches

- DEM from LIDAR-based topography
- NWI input data layer
  - Volumes calculated (ArcGIS v10.x)
  - Min. volume 100 m$^3$
  - ~13,000 wetlands
- Fill-and-Spill network
- Soil and Water Assessment Tool (SWAT)
- Modified SWAT to focus on non-floodplain wetlands (Evenson et al. 2016 Hydrol. Proc. 30:4168-4184)

(Schematics courtesy Qiusheng Wu, SUNY-Binghamton, wetlands.io)
Watershed-Scale Effects: Approaches

Scenarios Examined
- Complete loss of non-floodplain wetlands
- Preferential loss based on area
- Proximity-based losses or maintenance
- All contrasted versus a ‘baseline’ model

<table>
<thead>
<tr>
<th><strong>X = loss</strong></th>
<th><strong>Count</strong></th>
<th><strong>Max. Volume (m³ x 10⁴)</strong></th>
<th><strong>Surface Area (ha)</strong></th>
<th><strong>Distance to Stream (m)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Median (Std. Dev.)</strong></td>
<td><strong>Median (Std. Dev.)</strong></td>
<td><strong>Median (Std. Dev.)</strong></td>
</tr>
<tr>
<td>Baseline</td>
<td>12921</td>
<td>0.04 (2.4)</td>
<td>0.3 (2.6)</td>
<td>1633 (2760)</td>
</tr>
<tr>
<td>ALLWETX</td>
<td>0</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>WET&lt;3haX</td>
<td>616</td>
<td>2.5 (9.5)</td>
<td>5.0 (9.1)</td>
<td>2430 (2973)</td>
</tr>
<tr>
<td>WET&gt;3haX</td>
<td>12305</td>
<td>0.04 (0.3)</td>
<td>0.3 (0.5)</td>
<td>1599 (2742)</td>
</tr>
<tr>
<td>WET&gt;30mX</td>
<td>120</td>
<td>0.03 (3.0)</td>
<td>0.2 (6.6)</td>
<td>18.4 (10.0)</td>
</tr>
<tr>
<td>WET&gt;457mX</td>
<td>2668</td>
<td>0.04 (1.2)</td>
<td>0.2 (1.8)</td>
<td>219.3 (124)</td>
</tr>
</tbody>
</table>
Watershed-Scale Effects: Results

Depressional wetlands affect watershed hydrological, biogeochemical, and ecological functions

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2 US Environmental Protection Agency, Office of Research and Development, National Exposure Research Laboratory, Cincinnati, Ohio 45220 USA
3 CSS Corporation, Cincinnati 45220 Ohio USA

http://www.stateofthebirds.org
<table>
<thead>
<tr>
<th></th>
<th>Inundated Area (ha)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean*</td>
<td>Std. Dev.*</td>
</tr>
<tr>
<td>Baseline</td>
<td>0.26</td>
<td>0.09</td>
</tr>
<tr>
<td>WET&lt;3haX</td>
<td>2.98</td>
<td>0.73</td>
</tr>
<tr>
<td>WET&gt;3haX</td>
<td>0.14</td>
<td>0.06</td>
</tr>
<tr>
<td>WET&gt;30mX</td>
<td>0.43</td>
<td>0.15</td>
</tr>
<tr>
<td>WET&gt;457mX</td>
<td>0.19</td>
<td>0.06</td>
</tr>
</tbody>
</table>

**A. Baseline**

**B. WET<3haX**

**C. WET>3haX**

**D. WET>30mX**

**E. WET>457mX**

Inundated Area (% of Grid Cell)

Min: 0  Max: 100

Inundated Area (%) of Grid Cell
### Residence Time (Days x 10^4)

<table>
<thead>
<tr>
<th></th>
<th>Mean*</th>
<th>Std. Dev.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.73</td>
<td>2.59</td>
</tr>
<tr>
<td>WET&lt;3haX</td>
<td>1.20</td>
<td>4.56</td>
</tr>
<tr>
<td>WET&gt;3haX</td>
<td>0.69</td>
<td>2.51</td>
</tr>
<tr>
<td>WET&gt;30mX</td>
<td>0.37</td>
<td>1.64</td>
</tr>
<tr>
<td>WET&gt;457mX</td>
<td>0.74</td>
<td>2.95</td>
</tr>
</tbody>
</table>

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**A. Baseline**

**B. WET<3haX**

**C. WET>3haX**

**D. WET>30mX**

**E. WET>457mX**

**Residence Time (Years)**

Min: 0.0 - Max: 4.0
<table>
<thead>
<tr>
<th>Runoff Contributing Area (% of Watershed Area)</th>
<th>Sum†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>11.1</td>
</tr>
<tr>
<td>WET&lt;3haX</td>
<td>14.0</td>
</tr>
<tr>
<td>WET&gt;3haX</td>
<td>17.1</td>
</tr>
<tr>
<td>WET&gt;30mX</td>
<td>30.5</td>
</tr>
<tr>
<td>WET&gt;457mX</td>
<td>25.9</td>
</tr>
</tbody>
</table>

**A. Baseline**

**B. WET<3haX**

**C. WET>3haX**

**D. WET>30mX**

**E. WET>457mX**

Probability of Runoff/Spillage Reaching Stream (%)

Min: 0  Max: 100
Watershed-Scale Effects: Main Findings

Non-floodplain wetlands...
• ...are critical habitat
• ...affect watershed storage and inundation
• ...affect surface runoff dynamics
• ...affect nutrient dynamics

JAWRA 2018 54(2) Featured Collection (Lane et al.; Schofield et al.)
Additional Watershed Modeling Studies:
- Storage and inundation dynamics
- Surface runoff dynamics
- Nutrient dynamics

Regional “well behaved” models required to tease signal:noise
Restoration Potential?

Estimating restorable wetland water storage at landscape scales

Charles Nathan Jones1,2 | Grey R. Evenson2 | Daniel L. McLaughlin2 | Melanie K. Vanderhoof3 | Megan W. Lang4 | Greg W. McCarty5 | Heather E. Golden6 | Charles R. Lane6 | Laurie C. Alexander7

Jones et al. 2018, Hydrological Processes; 32:305-313
Non-floodplain wetlands...

• ...are critical habitat
• ...affect watershed storage and inundation
• ...affect surface runoff dynamics
• ...affect nutrient dynamics

Additional regional studies needed