Biogeochemical Connectivity in Semi-Arid River Systems

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Outline

- Hydrology of arid and semi-arid systems
- Dissolved and particulate linkages of arid uplands to perennial rivers
- Influence on riparian biogeochemistry
- Riparian dynamics
- Two key points
  - Connections are infrequent but important
  - Runoff may be small but it is important
Precipitation Seasonality

San Pedro
Statement of the problem:

- Mountain Front Recharge
- Basin-Floor Recharge
- Mountain Block Recharge
- Ephemeral Channel Recharge
- WET
- MOIST
- DRY

Diagram showing groundwater recharge in different conditions: WET, MOIST, DRY. The diagram illustrates the movement of groundwater and the recharge processes in various environments.
DISCHARGE AT USGS 09471000
SAN PEDRO RIVER AT CHARLESTON, AZ

Flood of 5/30/05
~6.3 M.P.F.
~8.4 M.P.F.
~2.2 M.P.F.
~7.3 M.P.F.

Flood of 5/30/06

M.P.F=months post flood
=Sampling Campaign

Personal Communication – Carlos Soto
Problem statement: Legacies of past extreme flood events may be shaping current vegetation trajectories and response to climate change.

Climate extremes + land use extremes $\rightarrow$ Historic entrenchment of San Pedro River

“It was probably during the 1896 flood that a channel almost 244 m wide and 6 m deep developed...” (Hereford and Betancourt 2009).

Results: As a legacy of past extreme disturbance, pioneer woody vegetation has been expanding over past ½ century.

<table>
<thead>
<tr>
<th></th>
<th>Populus Salix</th>
<th>Shrub. / wood.</th>
<th>Grassland</th>
<th>Bare ground</th>
<th>Farm + urban</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status in 1955</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Populus/Salix</td>
<td>15%</td>
<td>3%</td>
<td>7%</td>
<td>9%</td>
<td>0%</td>
</tr>
<tr>
<td>Shrub. /wood.</td>
<td>10%</td>
<td>46%</td>
<td>4%</td>
<td>23%</td>
<td>0%</td>
</tr>
<tr>
<td>Grassland</td>
<td>19%</td>
<td>22%</td>
<td>41%</td>
<td>18%</td>
<td>0%</td>
</tr>
<tr>
<td>Bare ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm + urban</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Most *Populus/Salix* points mapped in 2003 arose from bare ground (as mapped in 1955).
Conceptual Model For Arid and Semi-arid Catchment Biogeochemistry

Nutrients - Move - React and Repeat

Arrive at riparian Area

Consistent Wet Conditions Allow for More reactions

Continuous pumping by stream and ET allow for continuous mixing

Dry conditions may allow disconnection within Riparian
Ephemeral Streamflow

Event of Aug. 27, 1982

Contour Interval = 5 mm

Flume 1
Volume: 155,400 cubic meters
Peak Discharge: 55 cms

Flume 2
Volume: 197,300 cubic meters
Peak Discharge: 73 cms

Flume 6
Volume: 246,200 cubic meters
Peak Discharge: 107 cms

Rainfall Intensity (mm/hr)

Elapsed Time (min)

0 10 20 30 40

0 20 40 60 80 100 120

Discharge (m³)
Water Balance of Uplands

Renard et al. 2008
DISCHARGE AT USGS 09471000
SAN PEDRO RIVER AT CHARLESTON, AZ

Mean Daily Discharge (cfs)

Flood of 5/30/05

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~8.4 M.P.F.

Flood of 5/30/06

~7.3 M.P.F.

~2.2 M.P.F.

M.P.F.=months post flood

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Personal Communication – Carlos Soto
• Isotopes of water – natural tracer of source
• Riparian wells span range between end members
• Baseflow skewed toward monsoon runoff
• Quantify % using simple mixing model
• Uncertainty associated with runoff end member
Riparian Water Sources

- Baseflow >50% monsoon runoff regardless of season
- Riparian groundwater variability related to gaining / losing status

Baillie et al., 2007 JGR-B
Thursday talks by Soto and Simpson provide follow up research
Percent Summer Floodwater in Riparian Groundwater

Mixing Model Results (Baillie et al., 2007)
Can Flood Mechanism be Modeled Simply?
Uplands Erode – Biggest Events

Nearing et al WRR 2007
Sediment Yield Decreases with Scale

Figure 6. The relationship between sediment yield and watershed area including 4 WGEW stock tank watersheds (Branson et al. 1981, Figure 6-24).
Suspended Sediment Carries Organic Matter

- According to Nichols et al 2006
  - Average Suspended Sediment yield from small catchments is 195 kg ha\(^{-1}\) year\(^{-1}\)
  - Calculated as spilled = suspended

- Using Data from Rhoton et al 2006
  - Carbon export from uplands is 4.7 kg-C ha\(^{-1}\) year\(^{-1}\)
  - With C/N ratio of 14.7 this means 0.318 kg-N ha\(^{-1}\) year\(^{-1}\)

- Observed Flux at Boquillas was
  - \(\sim\)300,000 kg POC
  - \(\sim\) 20,000 kg PON
  - Both 500 times smaller than scaled upland flux

- Obvious sediment redistribution within system
  Brooks, Haas and Huth 2007 - JGRB
Floods Remobilize Nutrients
Nutrients at All Scales From Terrestrial Source

- Pre-Monsoon River disconnected
- Change increases inorg. N
- Organic matter (FI) indicates change - influx of terrestrial organic matter

Figure 1. Diagram of the stream-corridor ecosystem in cross section, showing the surface stream, hyporheic zone, parafluvial zone, and riparian zone subsystems. The water table is shown by dashed line, and double-headed arrows denote hydrologic interactions among subsystems (cross-links).
Wetter Places Process More

Harms and Grimm 2008
Monsoon’s Sustained Impact on Water Quality

[Graph showing data points and trend lines for different months, with annotations for mean values and data for Mar-06, May-06, Nov-06, and Apr-07.]
Figure 10. Extent of interception of laterally flowing runoff by riparian zones in arid, semiarid, and humid watersheds. In arid regions, riparian vegetation is restricted to larger channels whereas, in semiarid regions, gallery forest may occupy only the lower reaches of tributary streams. In humid areas, riparian vegetation is found along the lengths of all tributaries in a forested catchment. Runoff from the shaded area of catchments must move through the riparian zone before entering the stream channel. Runoff from the unshaded areas enters the stream channels directly.

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Future Research Directions

- How is suspended sediment redistributed within the system?
  - How is it reprocessed?
  - What effect does it have on hydraulic properties?

- How does flood magnitude influence annual scale groundwater fluctuations?
  - Impact on biogeochemical processing
  - Impact on nutrient conditions
  - Impact on Water Quantity
  - Mechanism of storage and release

- What is influence of sediment quality on water quality within system?
Acknowledgements

- Bureau of Land Management
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