River Machine: Conceptual Model for Large Rivers
Integrating Fish Movement & Habitat, Fluvial Geomorphology, Fluid Dynamics, & Biogeochemical Cycling

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Background Status and Issues:

- Progress in large river (LR) restoration sporadic
- Recovery of LR fishes is sporadic
- Fundamental questions about LR fishes unanswered:
  • Why do they have complex life histories?
  • Basis of sophisticated movement strategies?
  • Why do they use “space” at a system-level?
What Causes Flow Pattern in Streams?
- Flow Resistance - without it there is nothing to change a unit volume of water once it is set into motion by gravity.

Are There Different Types of Flow Resistance?
- Four total, but two for steady-state
- Friction resistance (skin friction)
- Form resistance (distortion resistance)

Minimum Hydraulic Information Separating Q Resistance?
- Should point to conceptual model
Movement Conceptual Model: Friction Vs Form Resistance
Out-migrating juvenile salmon – excellent model system
Exploring the Conceptual Model Using A Virtual Flume with Virtual Fish:
Migration vs Habitat Selection

(Documented in peer papers Citations at end)
Lock & Dam 22 Physical Domain & Patterns

Wing dikes

Shell

Physical Domain

Velocity magnitude

Velocity Gradient

Island

High

Med

Low
UMRS L&D 22 Virtual Sturgeon
River Machine & Hydrologic (Flood Pulse) Engine:
What the Machine Does: 1) Erosion/Deposition driven by shear (strain – VGM)
2) Transport/residence time driven by velocity magnitude

Same as Fish Movement / Habitat Variables!

Flood Pulse
Low Flow
River Machine & Hydrologic (Flood Pulse) Engine:
What the Machine Supports: Immense abundance & diversity of life

- Illinois River – One of worlds most productive fisheries
  – provided portion of protein needs of Chicago
- Mekong River – catch of ~2M metric tons
  - provides protein needs of ~200,000 people
- Parana River – yield of 1,000 kg/hectare of sabolo
  - artisanal fishery and base of food chain
Important Functions of Flood Pulses
(Many Mediated by VM & VG)

Connectivity
- Carbon export
- Import of nutrients
- Movement of biota

Biotic Diversity from
- Physical Complexity
- Patch Disturbance

Primary Production
- Spawning
- Migration
- Recruitment

Life History
- Spawning
- Migration
- Recruitment

Biotic Dispersal

Nutrients

Channel-forming flows

Nutrient-rich, clear

Spring Rise

Bankfull

Drawdown

Carbon

Flood pulse

Are Migratory Fishes Really That Affected? Example: São Francisco River, BR
Monthly Hydrograph
São Francisco River, BR

Velhas River – Unregulated

Middle São Francisco River – regulated but with significant downstream tributary inflow

Lower São Francisco River - highly regulated and no significant tributary inflows
# Hydrology & Fishery Characteristics of Three Floodplain Reaches São Francisco Basin, Brazil

Summarized from Sato & Godinho 2003; Pompeu & Godinho, 2006; Santos, 2009; Santos et al, 2009

<table>
<thead>
<tr>
<th>São Francisco River Floodplain regions</th>
<th>Lower Velhas River</th>
<th>Middle São Francisco River</th>
<th>Lower São Francisco river</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>490-510 m</td>
<td>430-500 m</td>
<td>10-90 m</td>
</tr>
<tr>
<td>Number large reservoirs upstream</td>
<td>zero</td>
<td>one</td>
<td>eight</td>
</tr>
<tr>
<td>Flow regulation</td>
<td>insignificant</td>
<td>moderate</td>
<td>severe</td>
</tr>
<tr>
<td>Floodplain fish biodiversity</td>
<td>61 species</td>
<td>48 species</td>
<td>48 species</td>
</tr>
<tr>
<td>Large migratory fish extinction?</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Status of fisheries</td>
<td>*No information</td>
<td>decreased catches</td>
<td>decreased catches</td>
</tr>
</tbody>
</table>

*No information available for the status of fisheries in Lower Velhas River.
The River Machine, Function, Process, Large River Fishes, and Disturbance

“Natural”

Reduce system into fields

Flow Fields

Geophysical Fields

Biochemical Fields

Outcome: fish use river machine at system level

Velocity Magnitude Vel Mag Gradient Scale Filter

Outcome: fish cannot use river machine at system level

Flow Fields

Geophysical Fields

Biochemical Fields

"Disturbed"
Conclusions

- Biology of fluvial dependent fishes linked to EECs that define large rivers:
  - Strain – erosion & deposition
  - Velocity – transport

- Biodiversity conservation requires understanding / managing these inter-relationships (i.e., multi-variate vs uni-variate; holism vs reductionism).

- Environmental flow methods (and channel restoration methods) must control for both form resistance and grain resistance – by so doing link EECs of large rivers at relevant scales.

- Something like the NFS / ELAM needed to supplement existing microhabitat approaches.
Thank you


