National Conference on Ecosystem Restoration 2011

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

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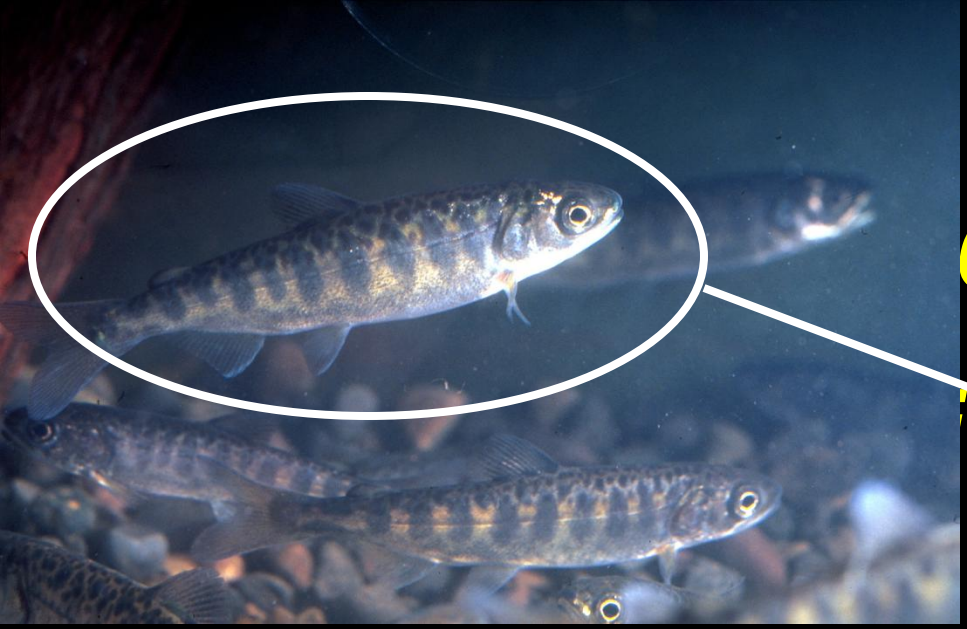
Background Status and Issues:

- 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?



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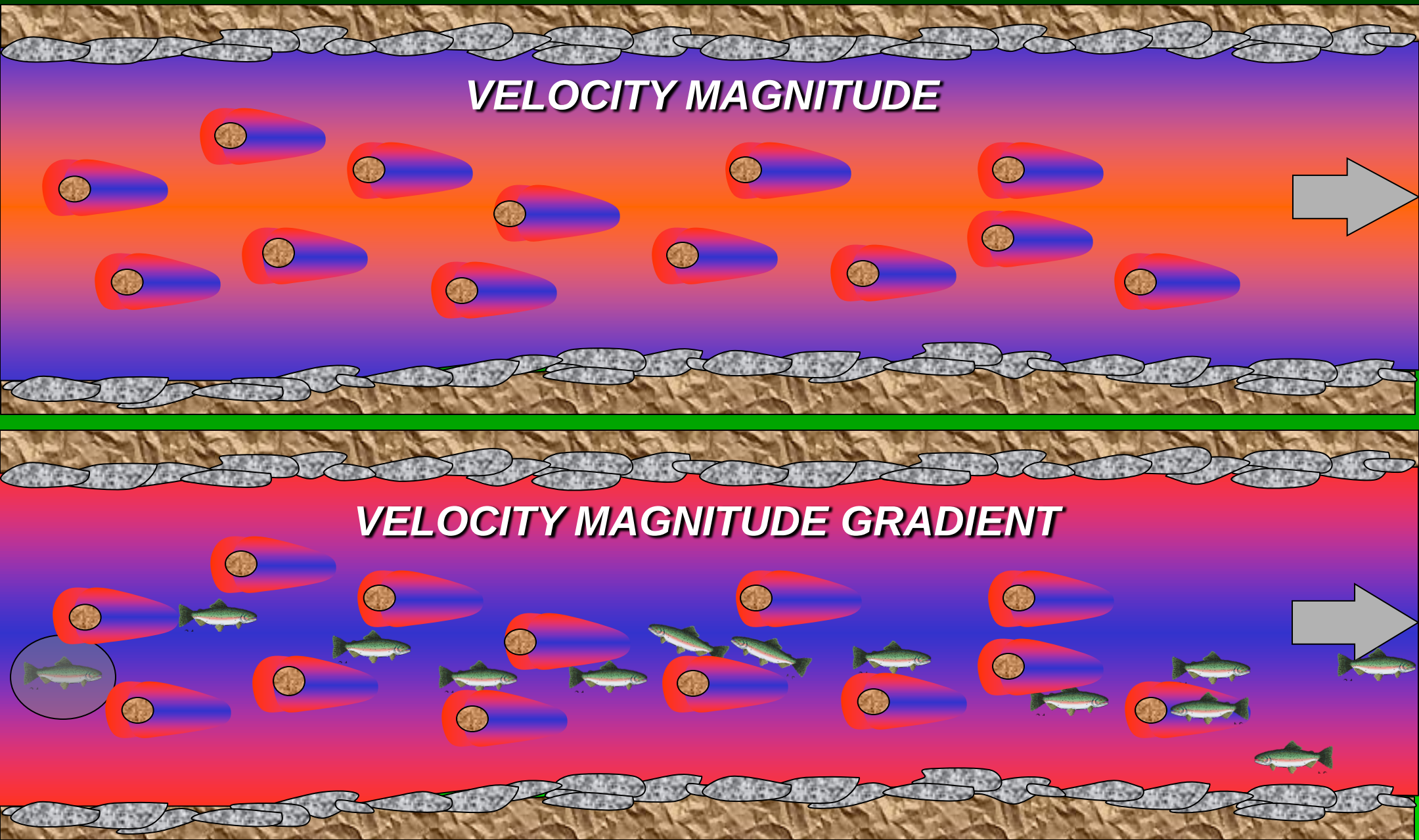
- **What Causes Flow Pattern in Streams?**
  - **Flow Resistance - without it there is nothing to change a unit volume of water once it is set into motion by gravity.**

- **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

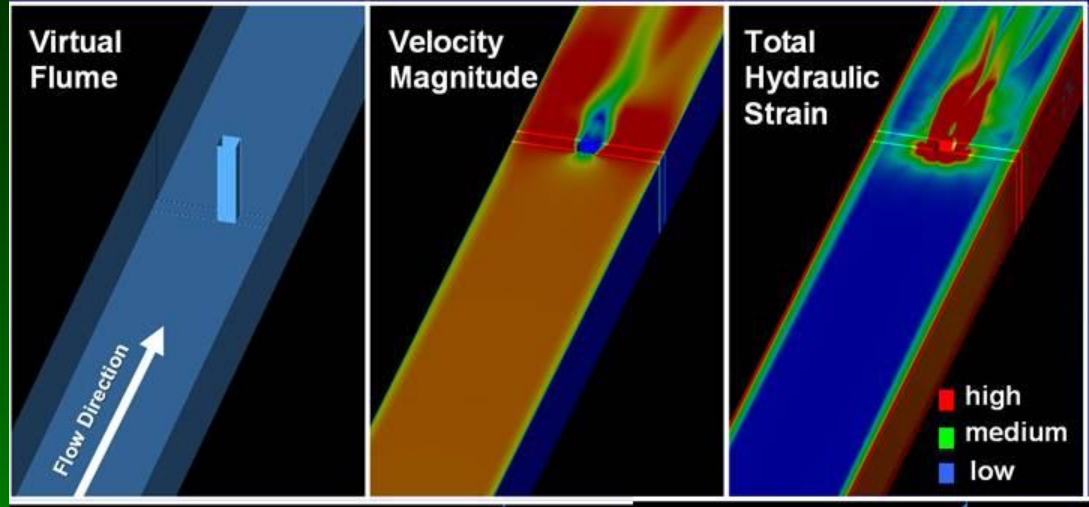
Out-migrating juvenile salmon – excellent model system

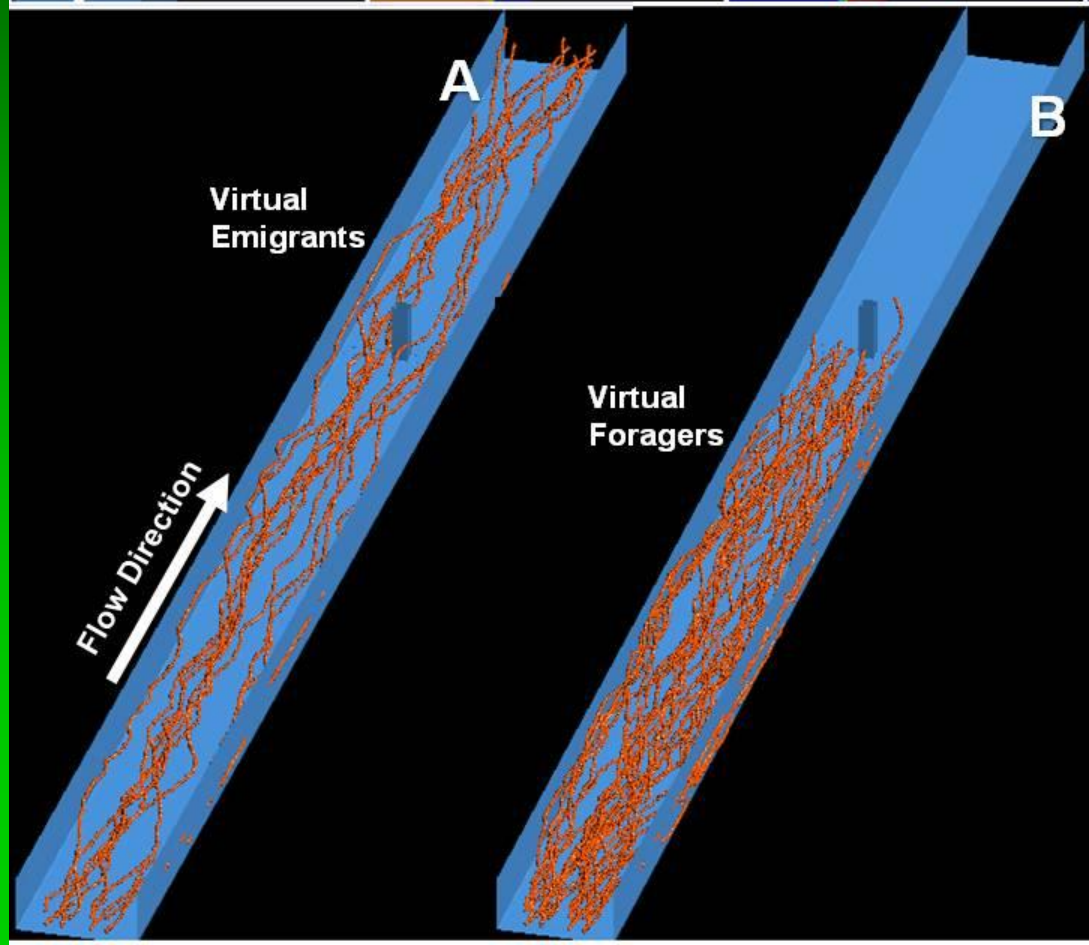


Exploring the Conceptual Model Using A Virtual Flume with Virtual Fish:

Migration vs Habitat Selection

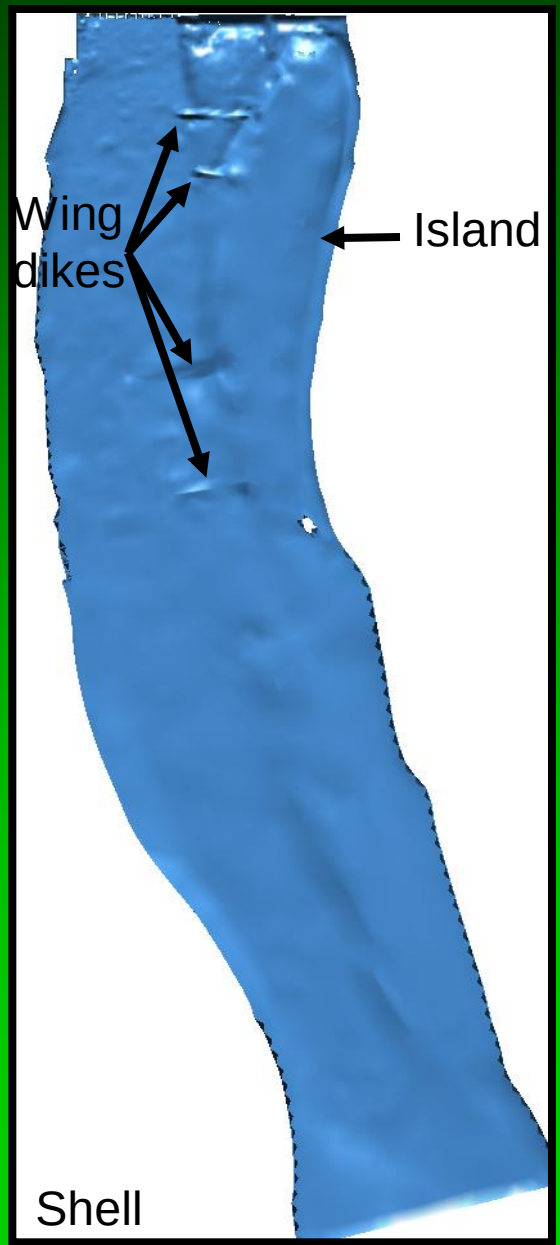
(Documented in peer papers Citations at end)

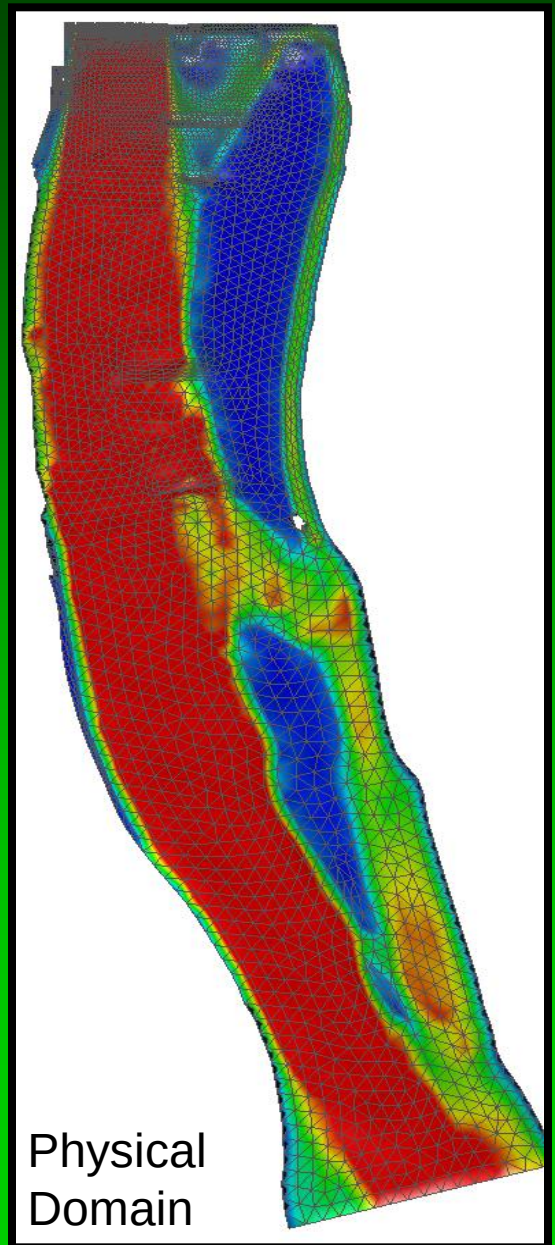


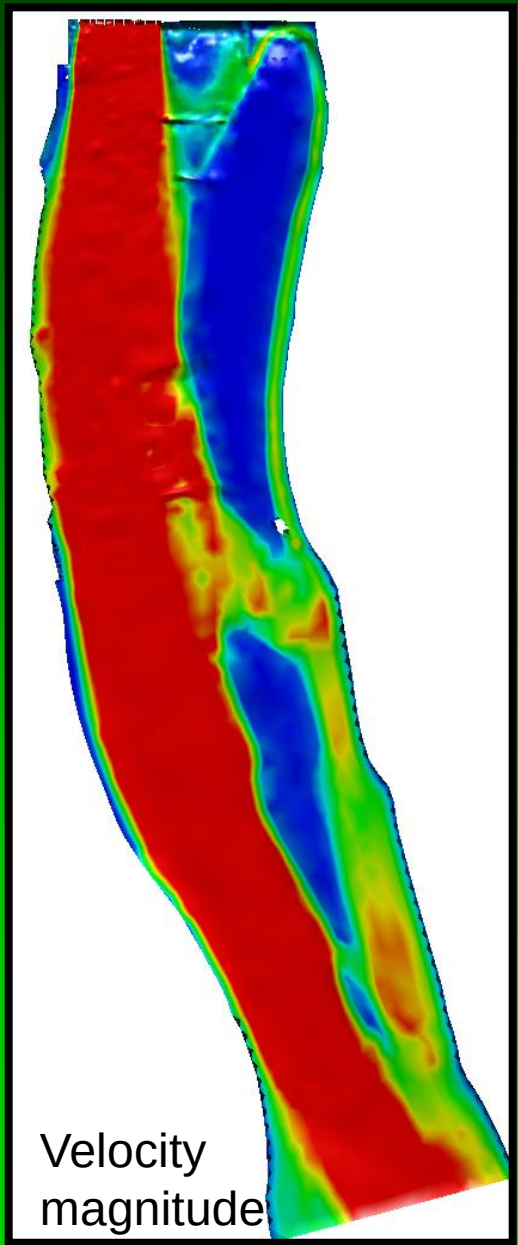


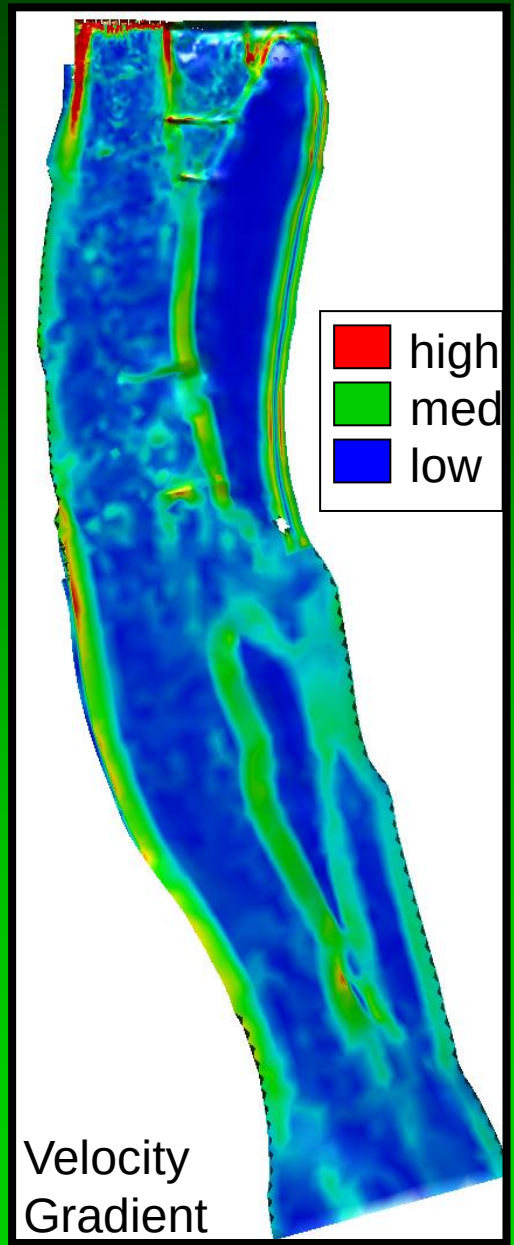
More Exploring: Lock & Dam 22

Lock & Dam 22 Physical Domain & Patterns

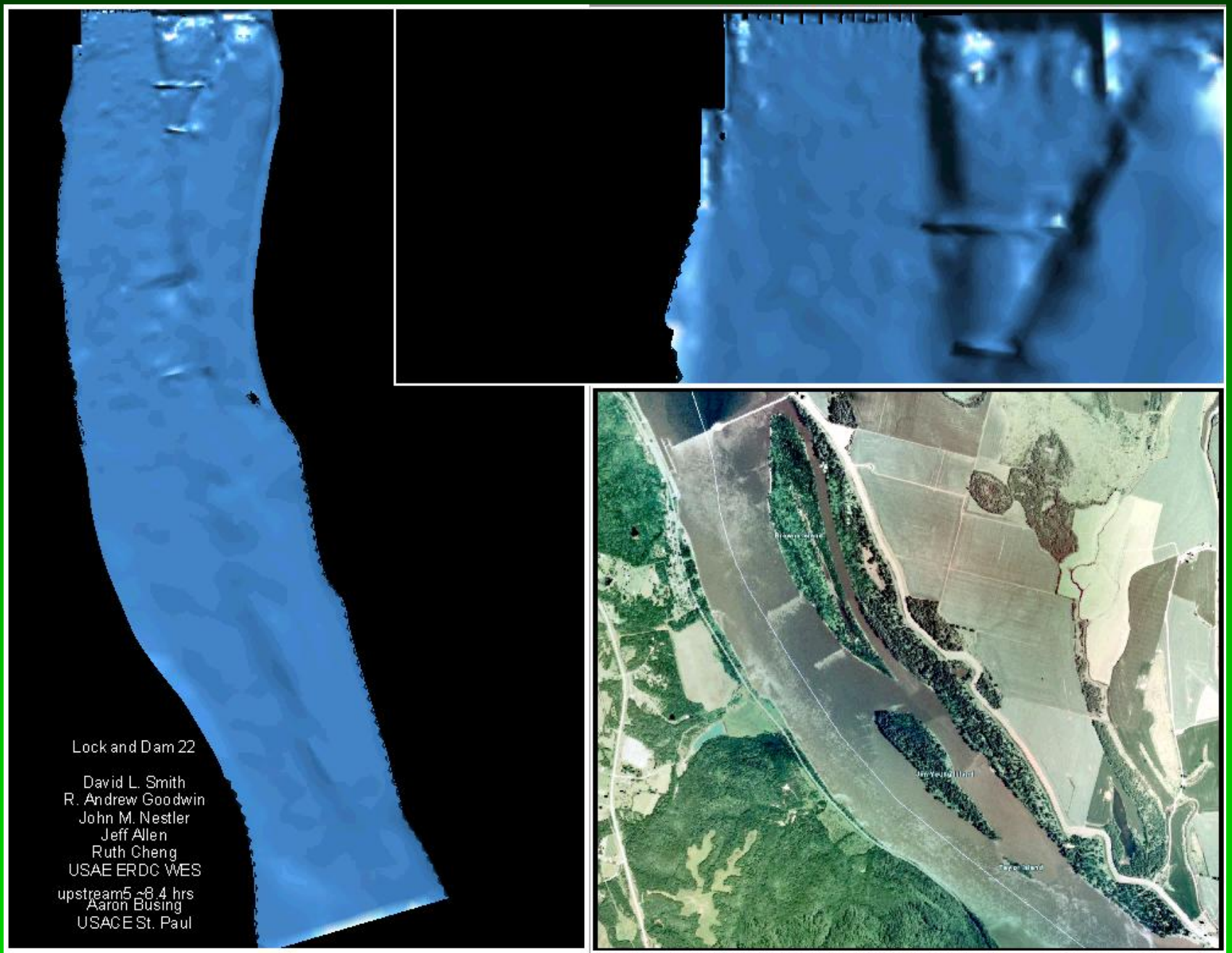








UMRS L&D 22 Virtual Sturgeon



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!

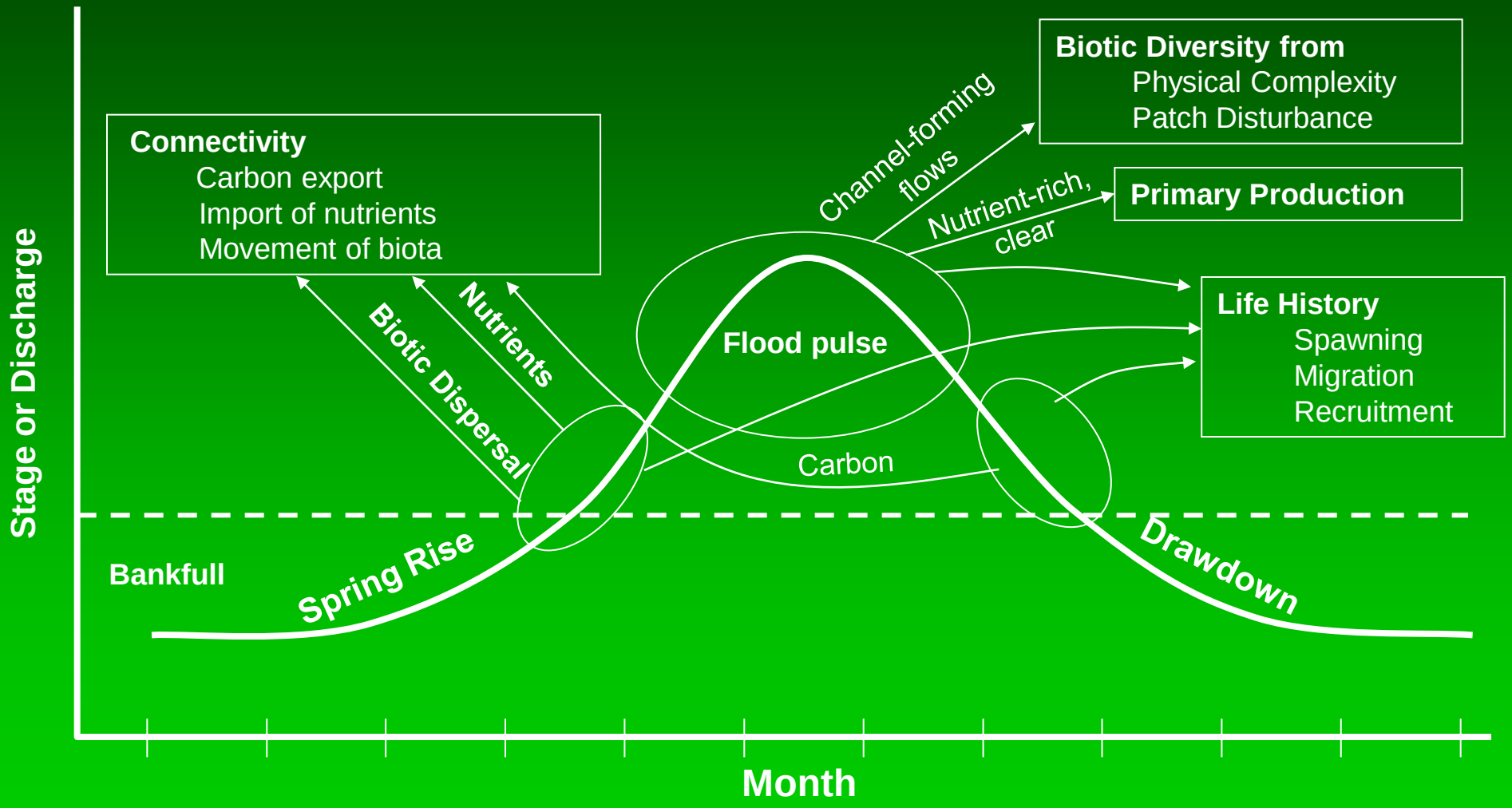
River Machine & Hydrologic (Flood Pulse) Engine:

What the Machine Supports: Immense abundance & diversity of life

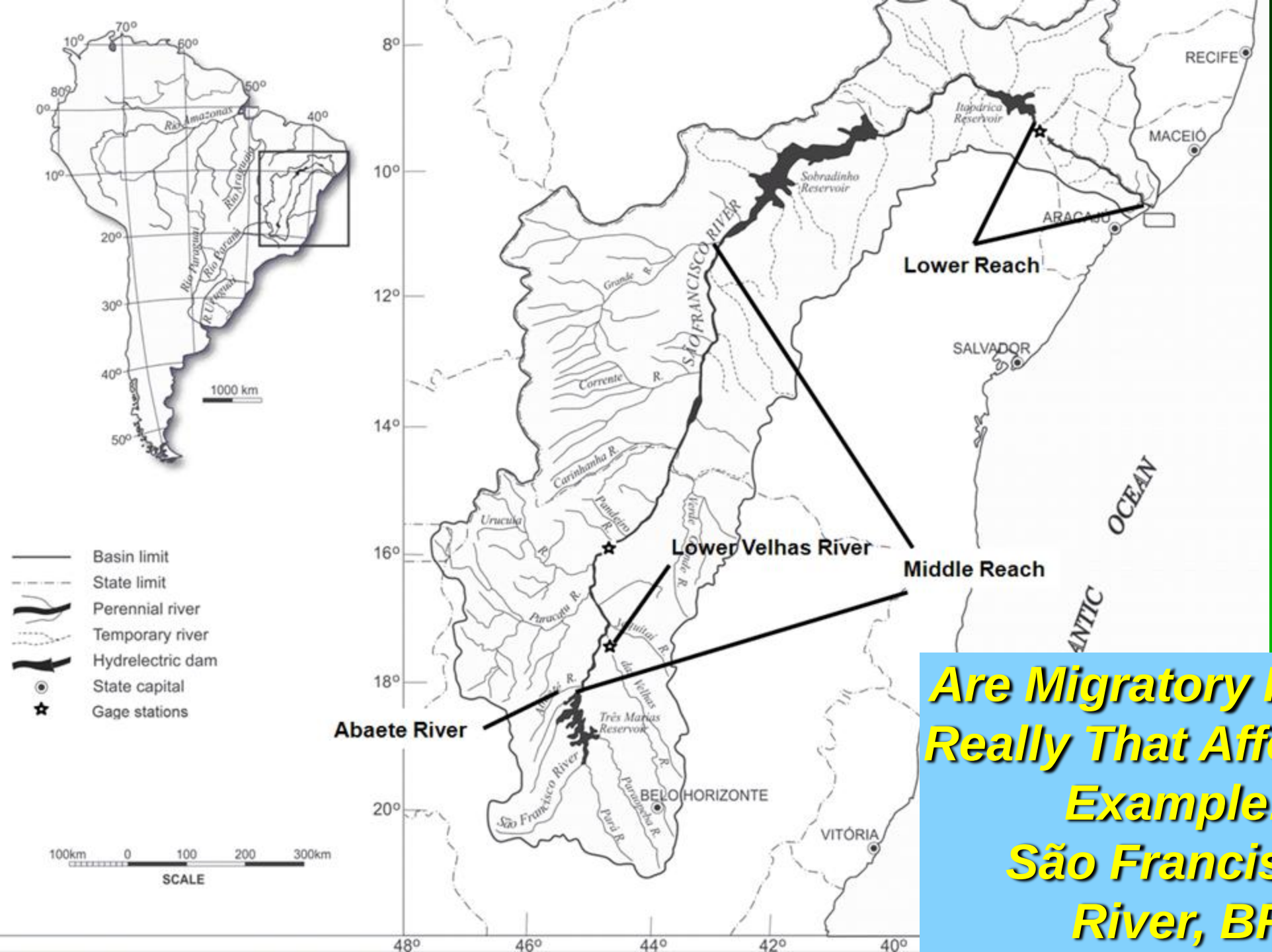
- Illinois River – One of worlds most productive fisheries
  - provided portion of protein needs of Chicago
- Mekong River – catch of ~2M metric tons
  - provides protein needs of ~200,000 people
- Parana River – yield of 1,000 kg/hectare of sabolo
  - artisanal fishery and base of food chain

Important Functions of Flood Pulses

(Many Mediated by VM & VG)

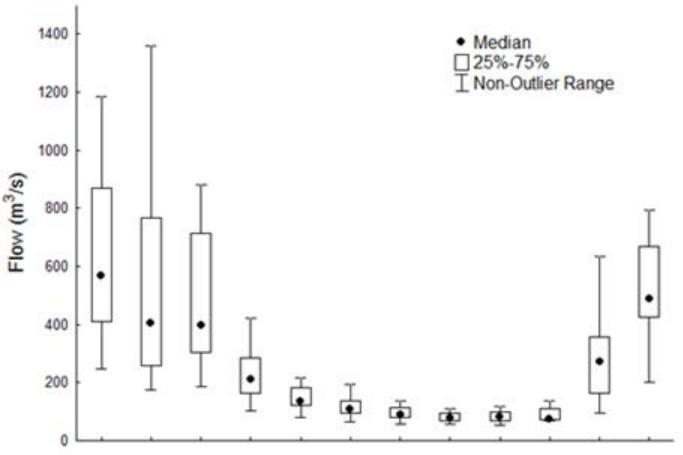


Modified from Bunn & Arthington. 2002. Environmental Management 30(4): 492-507
Nestler et al. 2008. Journal of River Basin Management *5(4): 305-319*

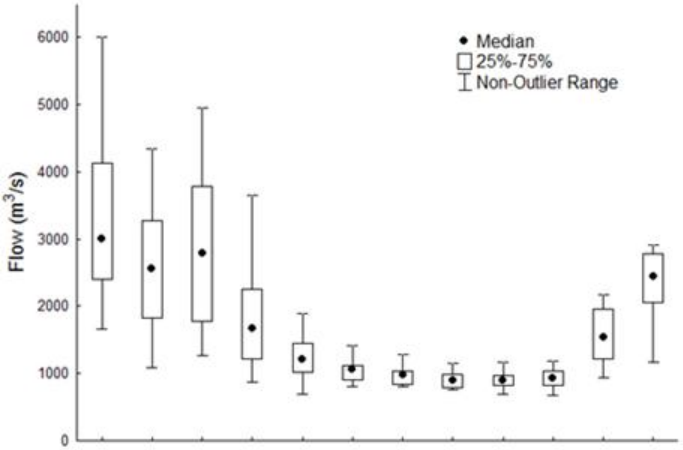


Are Migratory Fishes Really That Affected? Example: São Francisco River, BR

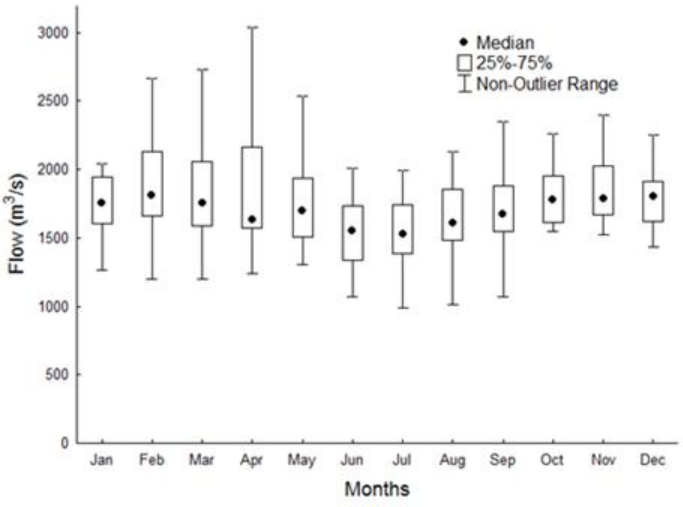
Monthly Hydrograph São Francisco River, BR



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

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

The River Machine, Function, Process, Large River Fishes, and Disturbance

Reduce system into fields

Flow Fields

Geophysical Fields

Biochemical Fields

Velocity Magnitude Vel Mag Gradient

Scale Filter

Velocity Magnitude VM Gradient

Flow Fields

Geophysical Fields

?

Biochemical Fields

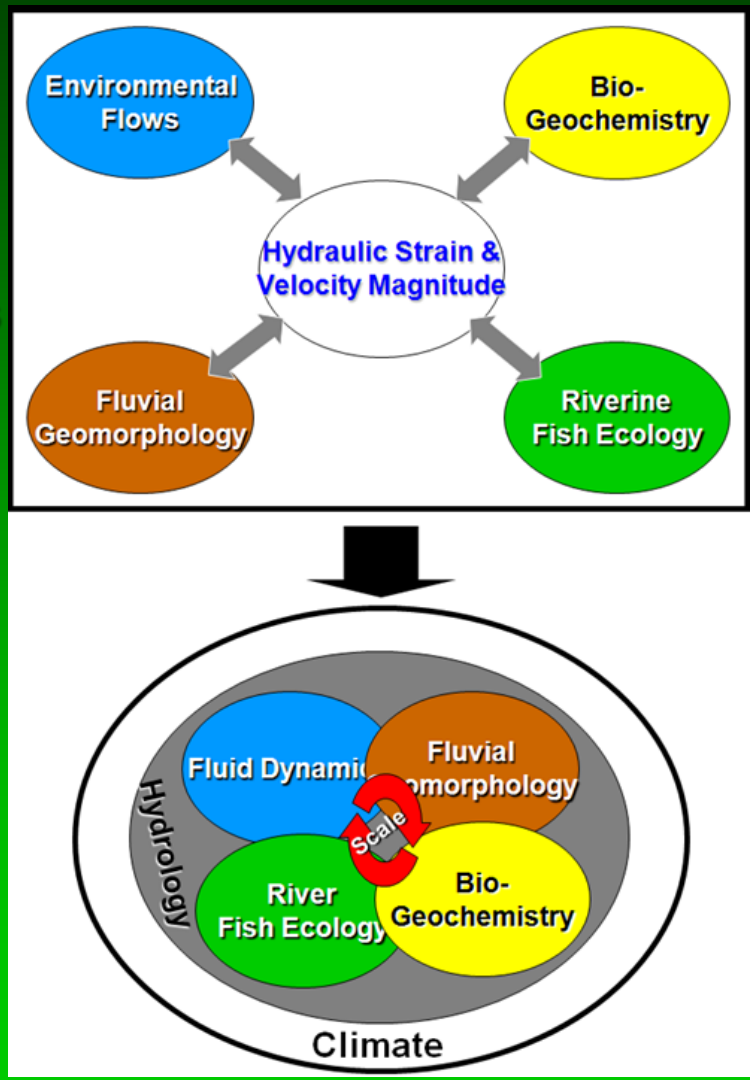
Outcome: fish use river machine at system level

Outcome: fish cannot use river machine at system level

Conclusions

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

  } Material Transformations
- 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



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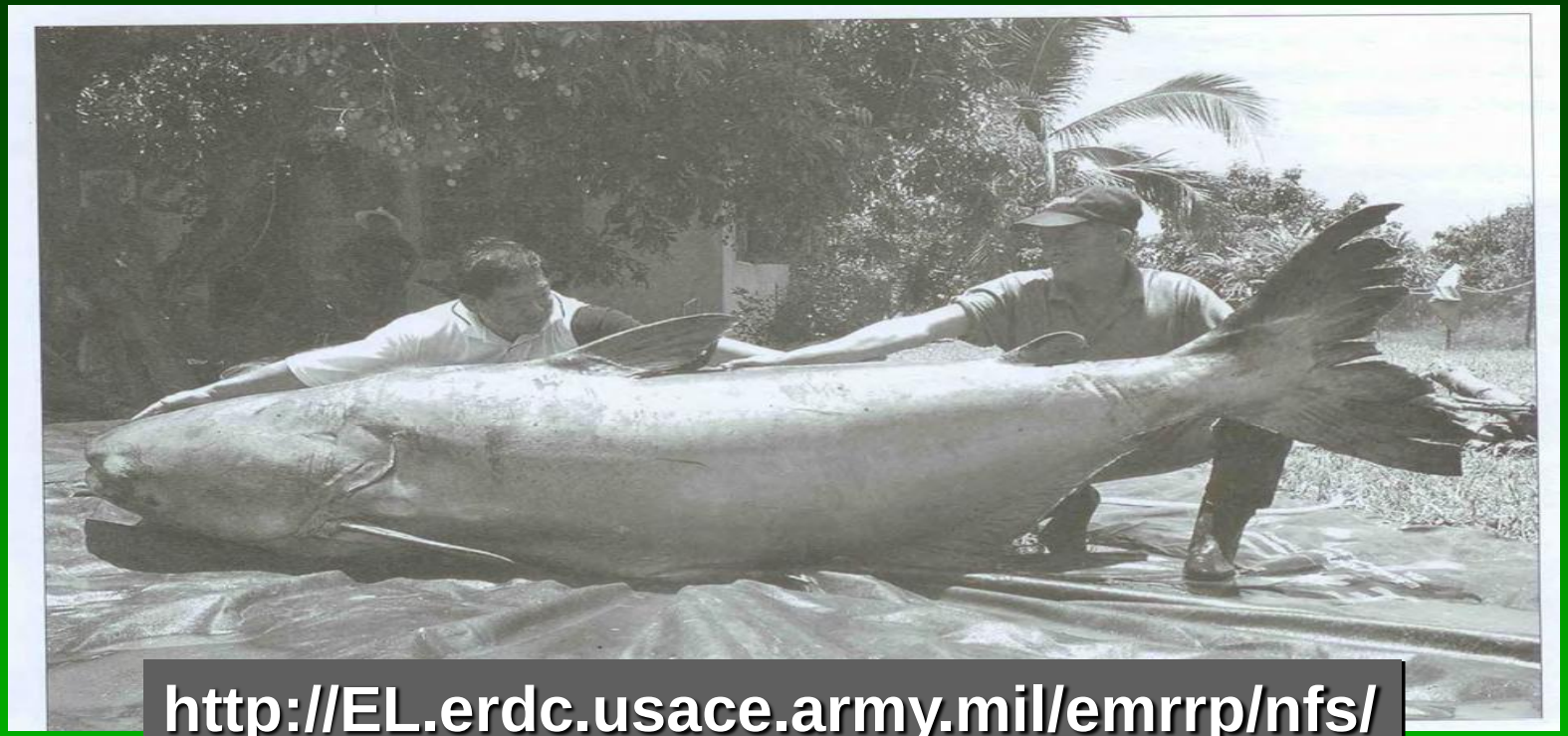

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