Hydrologic Connectivity of Migratory Fauna in Puerto Rico

Kyle McKay and Jessica Chappell
601-415-7160
Kyle.McKay@usace.army.mil

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ERDC
Engineer Research and Development Center

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Presentation Overview

- Overview of hydrologic connectivity
- A case study in quantifying connectivity in Puerto Rico
  - Amazing migratory fauna
  - Establishing hydrologic conditions
  - Quantifying connectivity
  - Temporally varying connectivity
  - Trade-offs among species
  - Approaches for restoring connectivity
- Broader lessons in connectivity

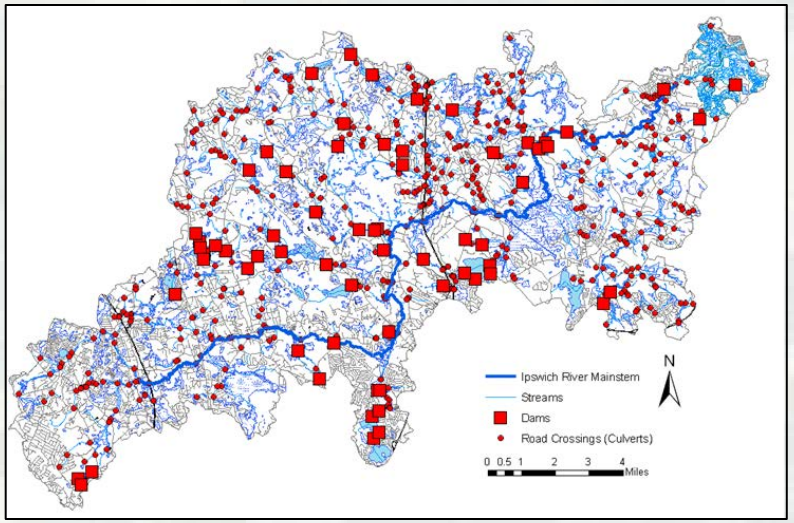
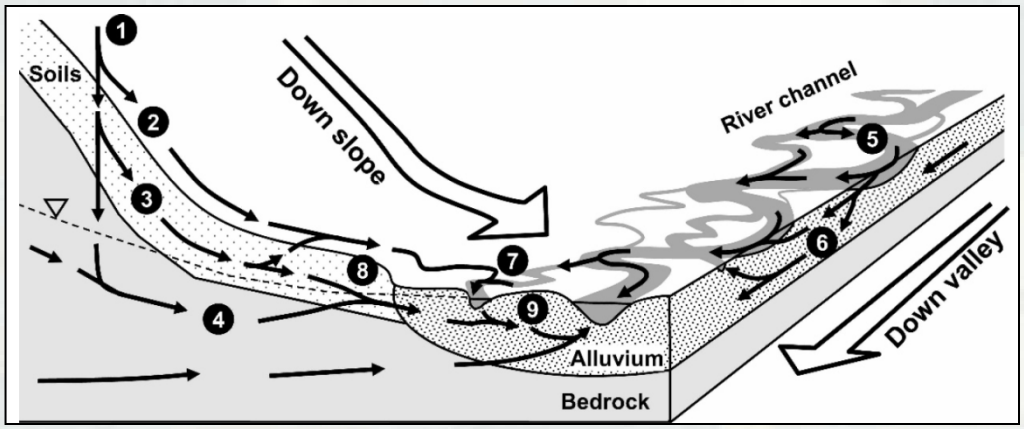
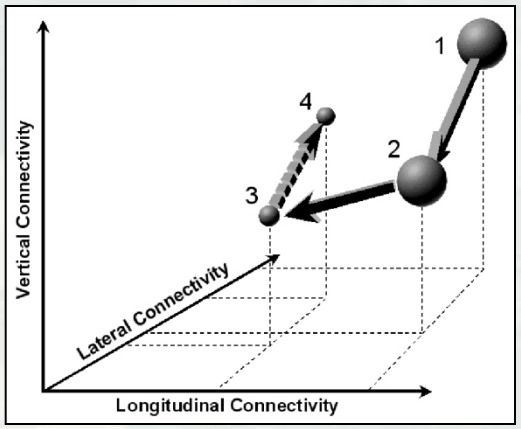


Figure from www.ipswich-river.org

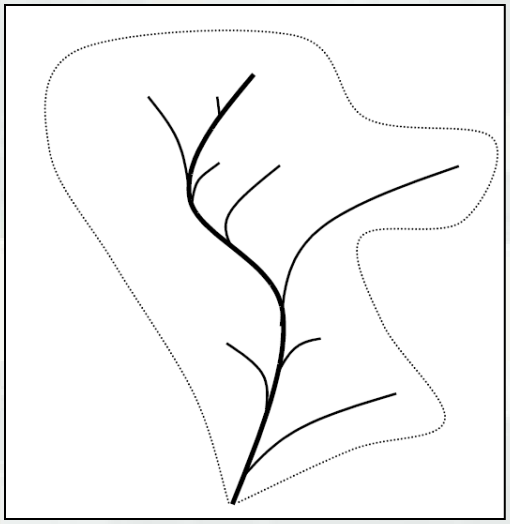
Hydrologic Connectivity





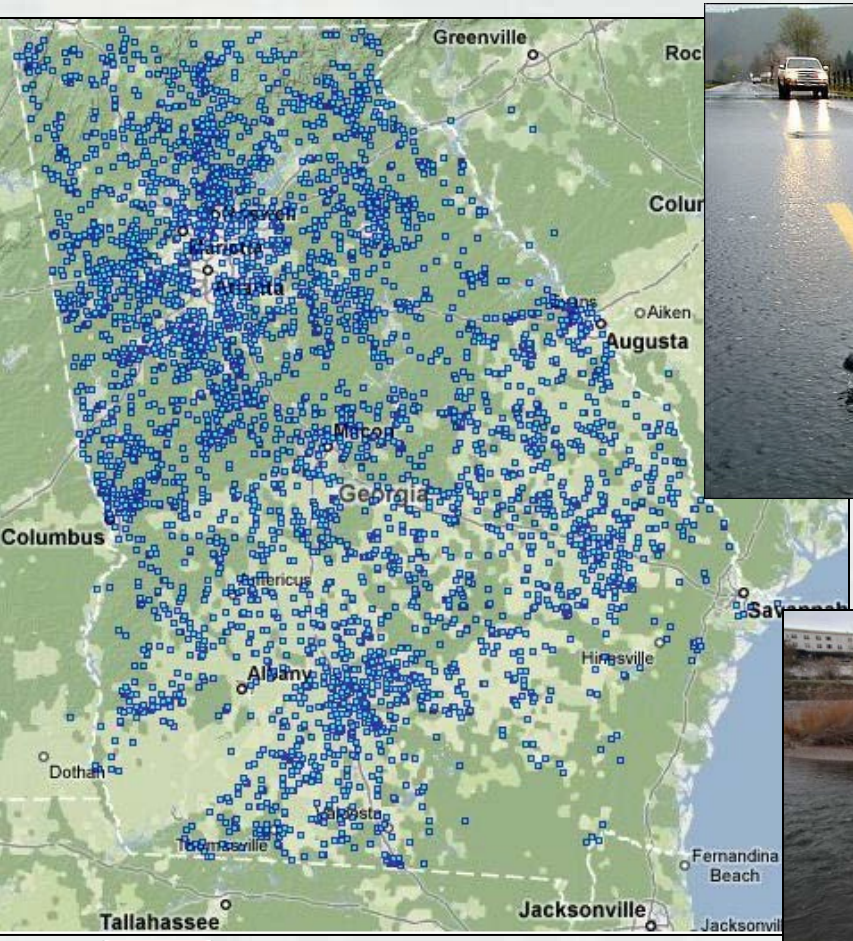
Hydrologic connectivity is the "water-mediated transfer of matter, energy, and/or organisms within or between elements of the hydrologic cycle."

– Pringle (2001, Ecological Applications)



Figures: Poole (2010), Kondolf et al. (2008), UGA-OVPR, Poole (2002)

We've systematically disconnected our watersheds!



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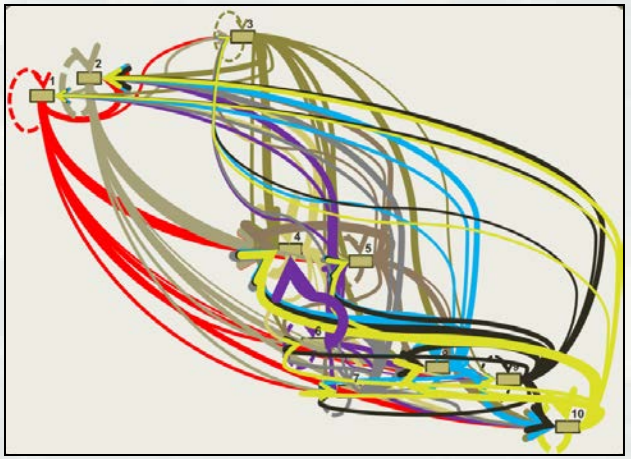
Figures: USACE National Inventory of Dams, Nancy Gleason, Sacramento River, Plant Vogtle (Glynn Environmental), McKay

ERDC Research Project

- Our fundamental premise: Connectivity must be assessed relative to the objectives and dimensionality of a given problem
- Focus of our research
  - **General principles** for conceptualizing and quantifying connectivity: dimensionality, biotic v. abiotic, structural v. functional,…
  - **Organism-centric case studies**: tropical stream migrants, oyster reefs (pros and cons)
  - **Transport-mediated case studies**: nutrient uptake on the MS River, channel dynamics and riparian vegetation in the arid southwest
  - **Restoration of connectivity**: dam operation, dam removal, sequencing matters

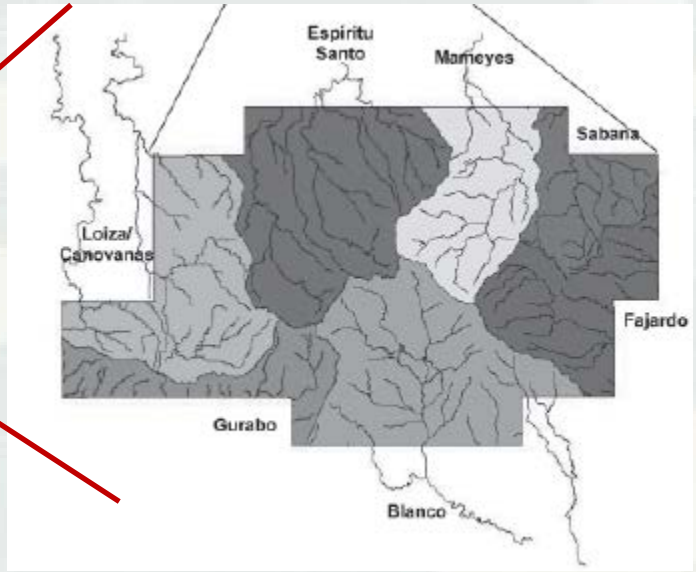


Figures: Swannack, Theiling

Puerto Rico's Amazing Animal Migrations

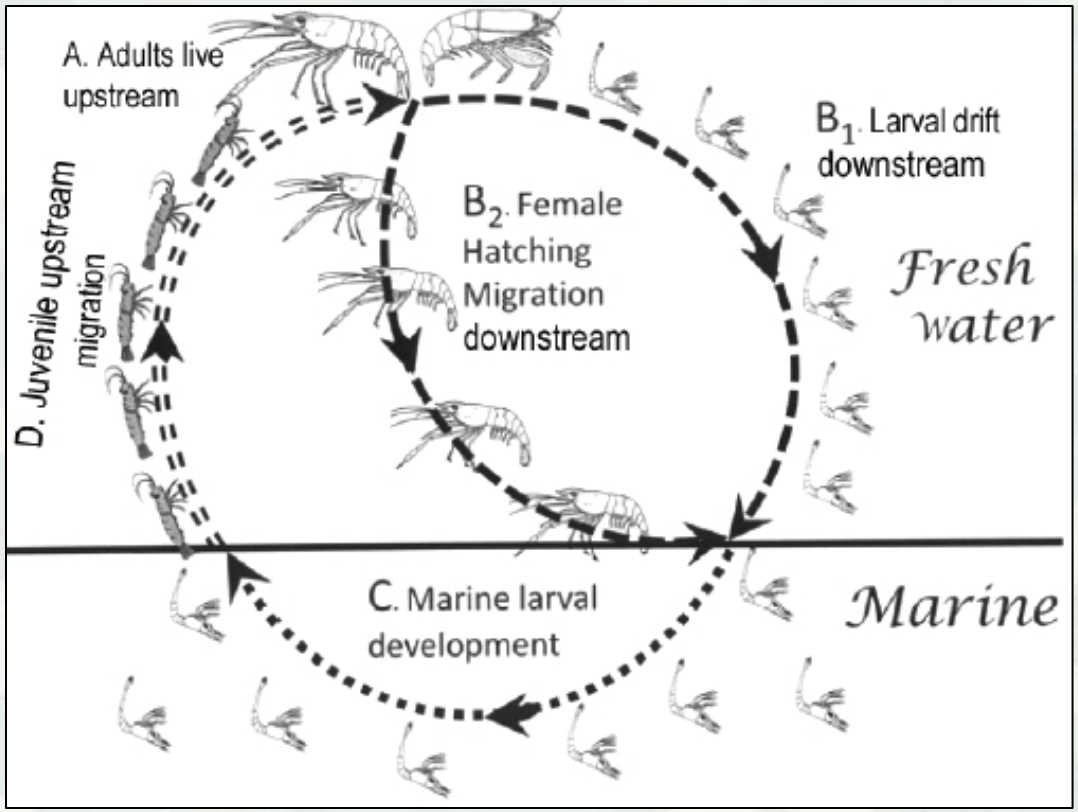
El Yunque National Forest, Puerto Rico

- Long history of scientific studies: USFS-IITF, NSF (long-term ecological research, critical zone observatory), USGS,…
- Forest supplies water for 20% of Puerto Rico's population
- Only tropical forest managed by the US Forest Service



Figures: Crook et al. (2007)

Tropical Migratory Fauna

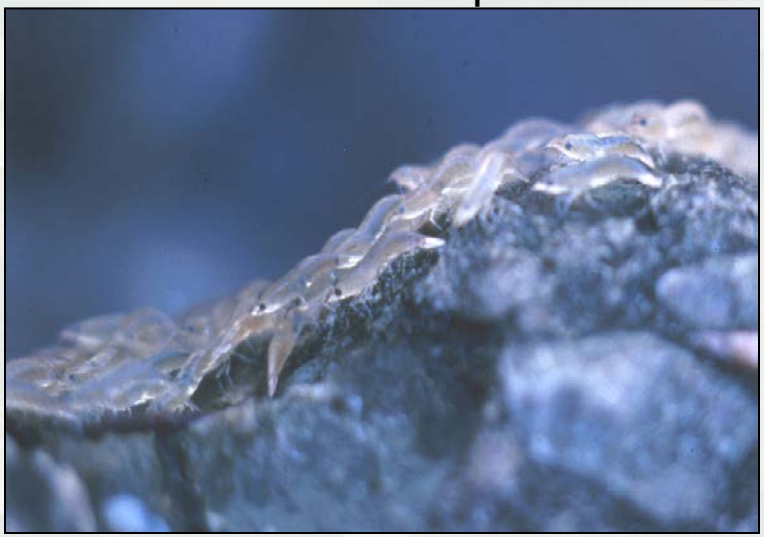


- Abundance of migratory life histories!
  - Freshwater shrimp
  - Snails
  - Gobi
  - Mullet
  - American eel
- Longitudinal pathways are crucial to survival

Figures: Bauer (2013)

Adaptation to Migration

Juvenile shrimp climb



Mountain mullet jump

Sirajo goby use suctioning pelvic fins

Snails use low velocity channel margins

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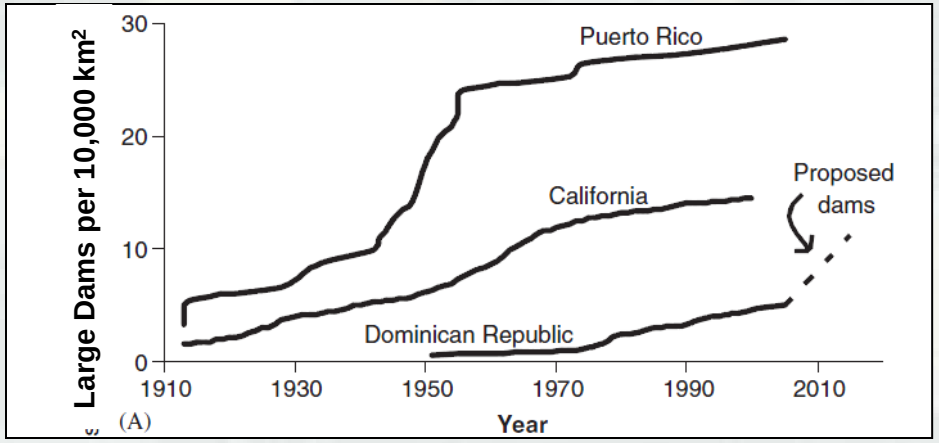
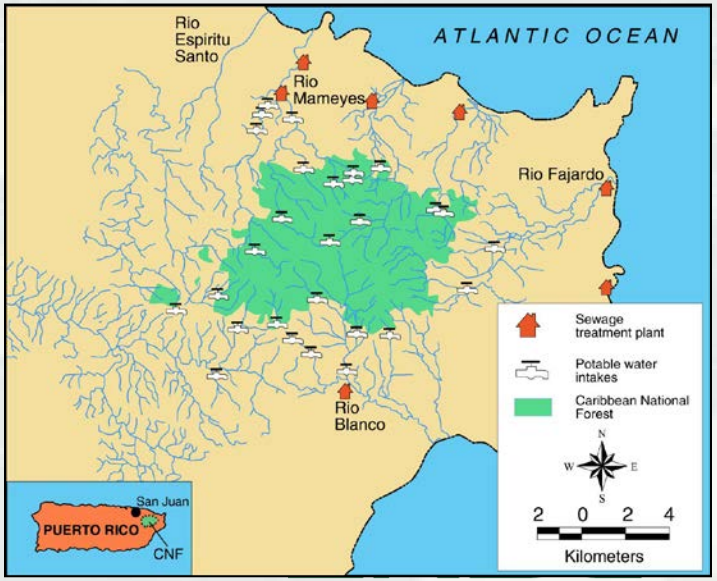
Figures: Jon Benstead, Patrick Cooney, David Herasimtschuk

Disconnecting a Resilient Migration

- Large dams can be built at high densities in the tropics
- Water withdrawals and associated small dams are the primary influence in El Yunque
- Massive water withdrawal (over 50% of freshwater not reaching the ocean, Crook et al. 2007)

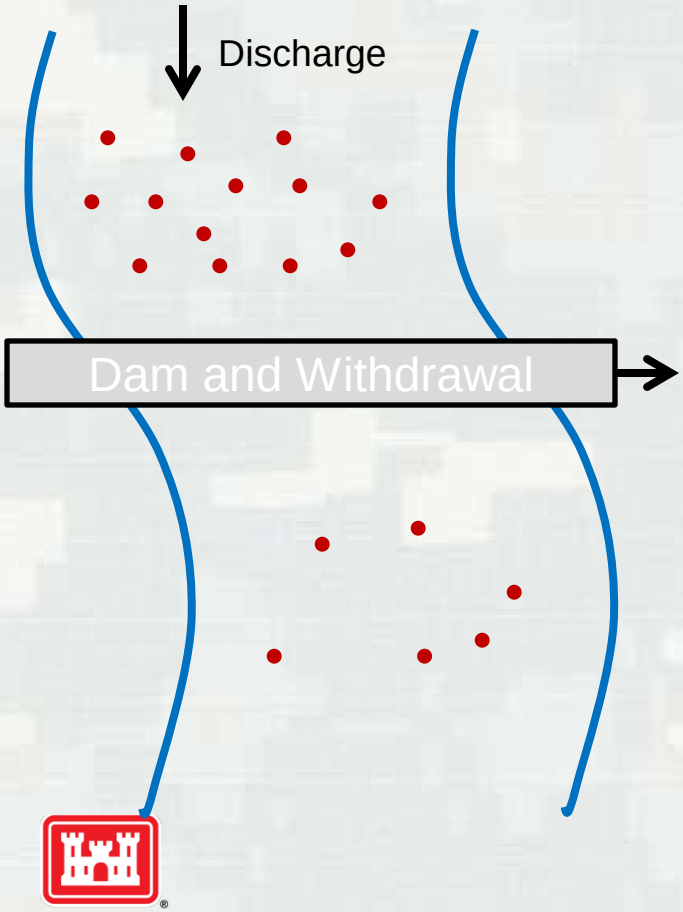




Figures: Greathouse et al. (2006), Kelly Crook, Jessica Chappell

Withdrawal and Shrimp Connectivity

Downstream Larval Drift



High drift density

Larval uptake into withdrawal

Decreased drift density

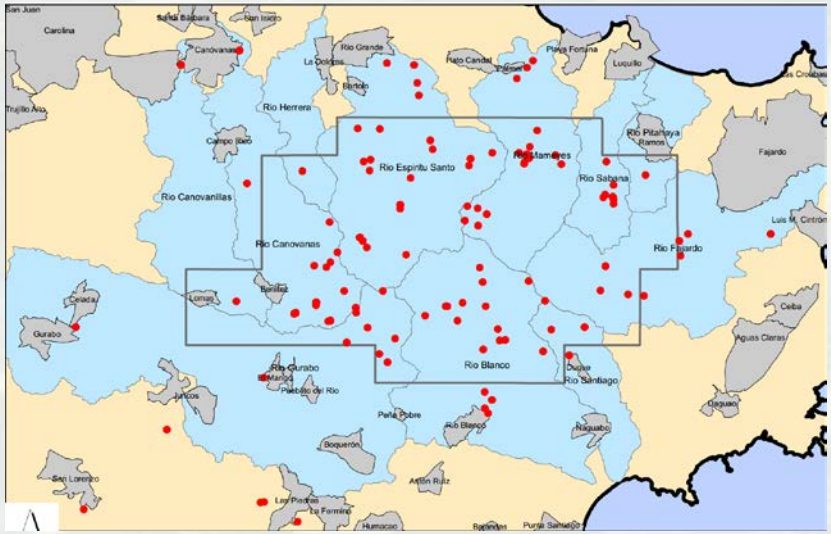
Upstream Juvenile Migration

Spillage creates an analog to waterfalls!

A Hydrologic Basis for Connectivity

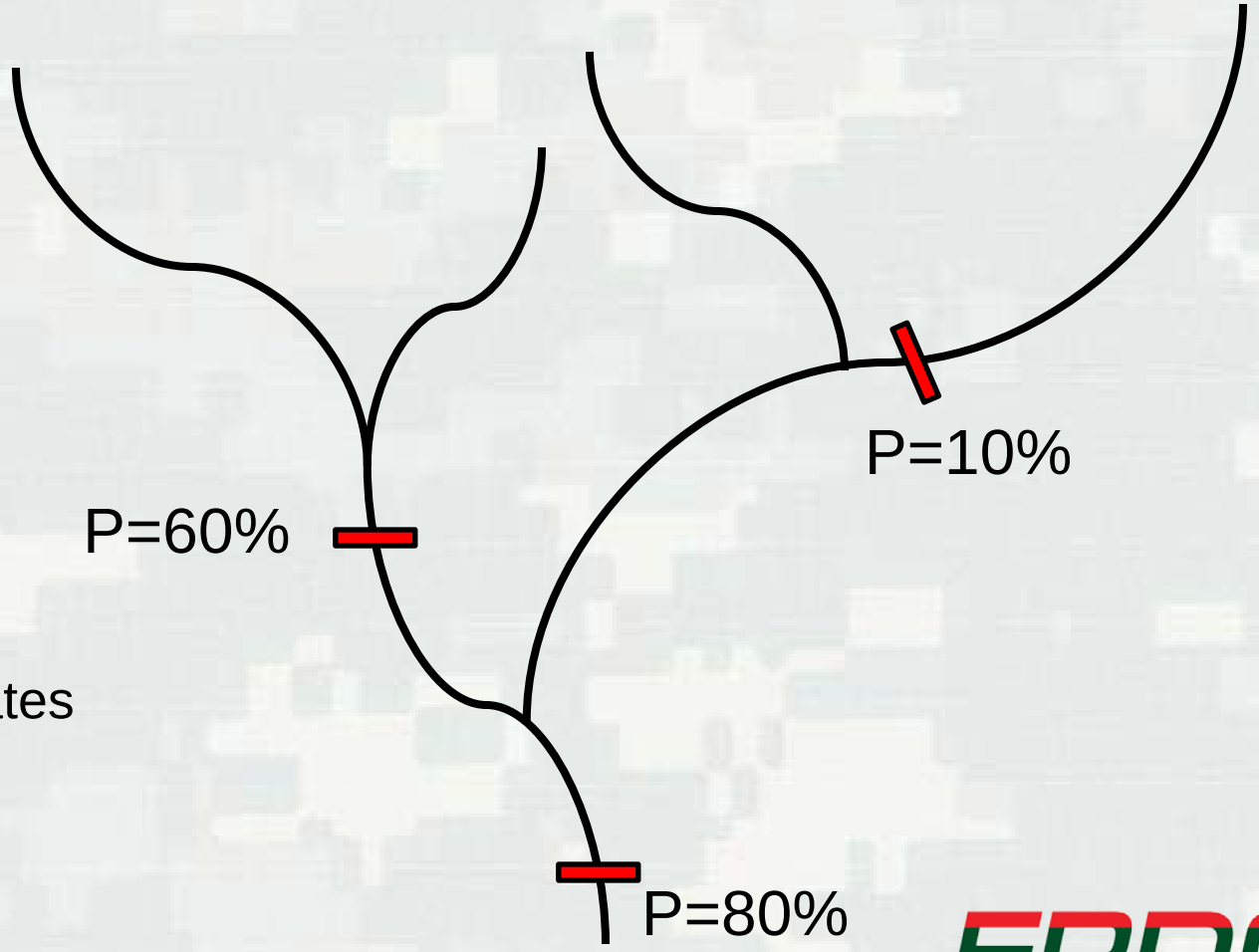
(Dr. Jason Christian and Joel Martin)

- Developing runoff and intake estimates at each structure
- Mass balance water budgets in 1994, 2004, and 2014
- Estimating withdrawal rates using intake records, structure capacity, permitted rates, and municipal service areas
- Developing predictive unit hydrograph approach



Figures: Jason Christian

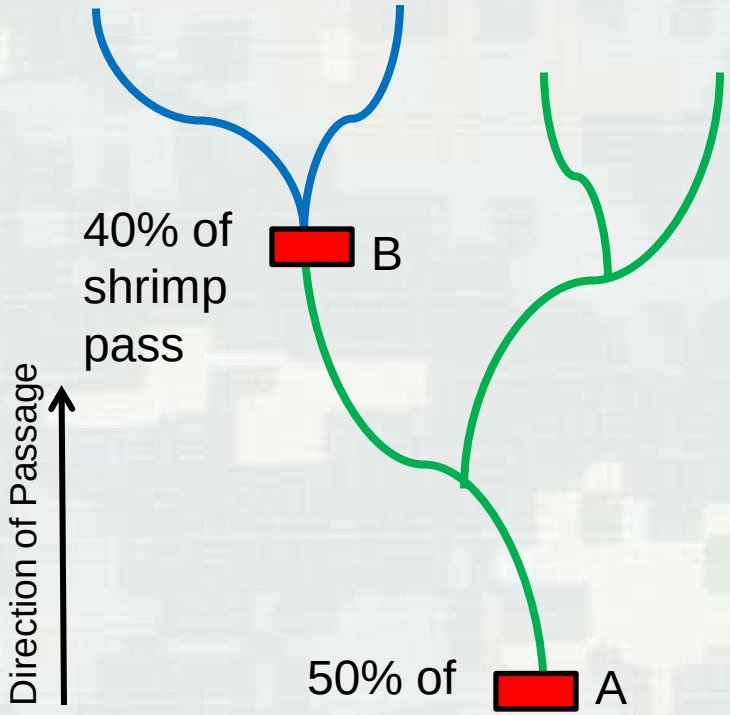
Quantifying the cumulative effect of multiple barriers on connectivity



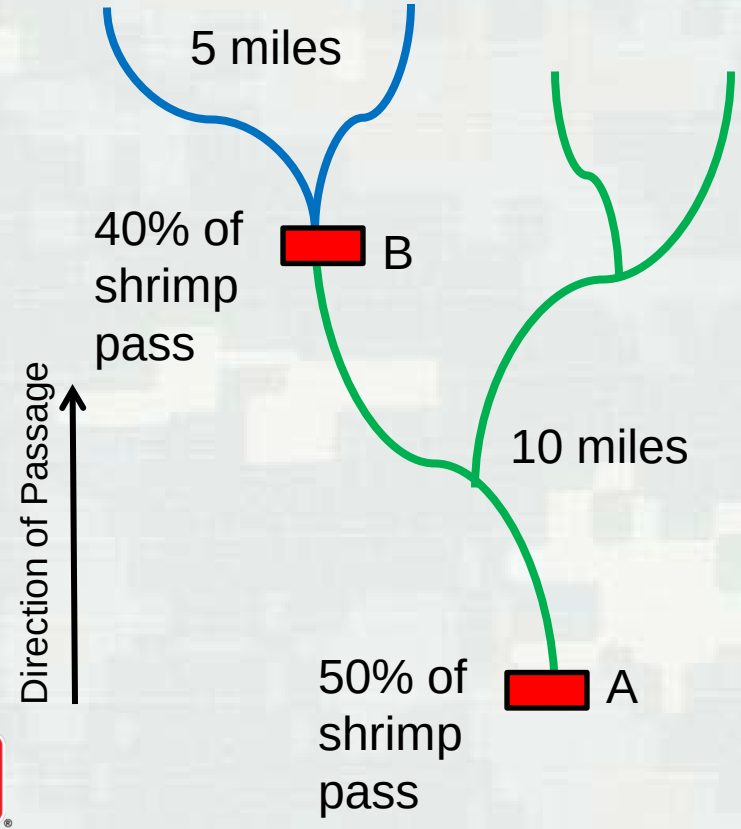
Key Variables

- Partial passage rates
- Habitat size
- Habitat quality

Barrier	Passage Rate	Cumulative Passage Rate
A	0.5	0.5
B	0.4	0.2



Barrier	Passage Rate	Cumulative Passage Rate	Upstream Habitat	Accessible Habitat
A	0.5	0.5	10	5
B	0.4	0.2	5	1
Total			15	6



$$C = \frac{\sum H_{accessible}}{\sum H_{total}}$$

$$C = \frac{6}{15} = 0.4$$

Barrier	Passage Rate	Cumulative Passage Rate	Upstream Habitat	Accessible Habitat
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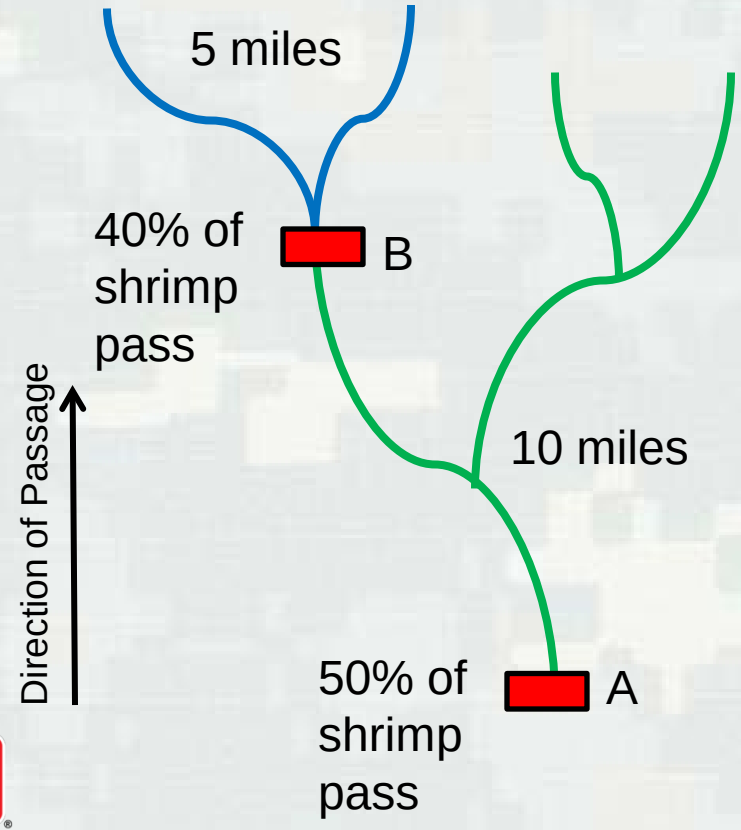
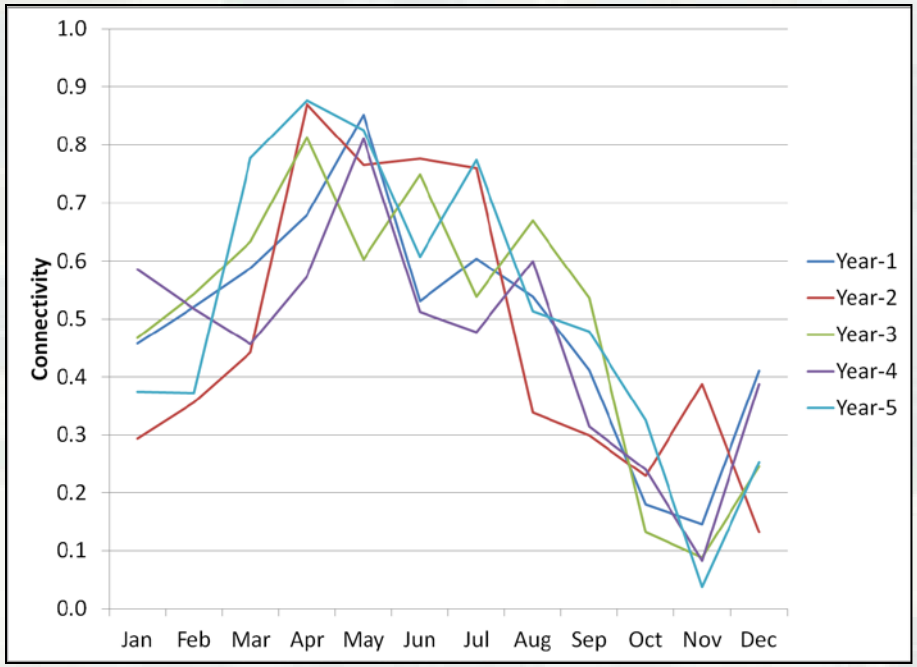


Restoration Alternatives

Action	Metric
Do Nothing	0.40
Remove A	0.80
Remove B	0.50
Remove Both	1.00

Analysis #1:
Temporally Varying Connectivity

Natural Fluctuation
Seasonal: wet v. dry season
Annual: wet v. dry year



Tracking Lost Connectivity
Declines over time with increased intake
Comparison across 9 watersheds

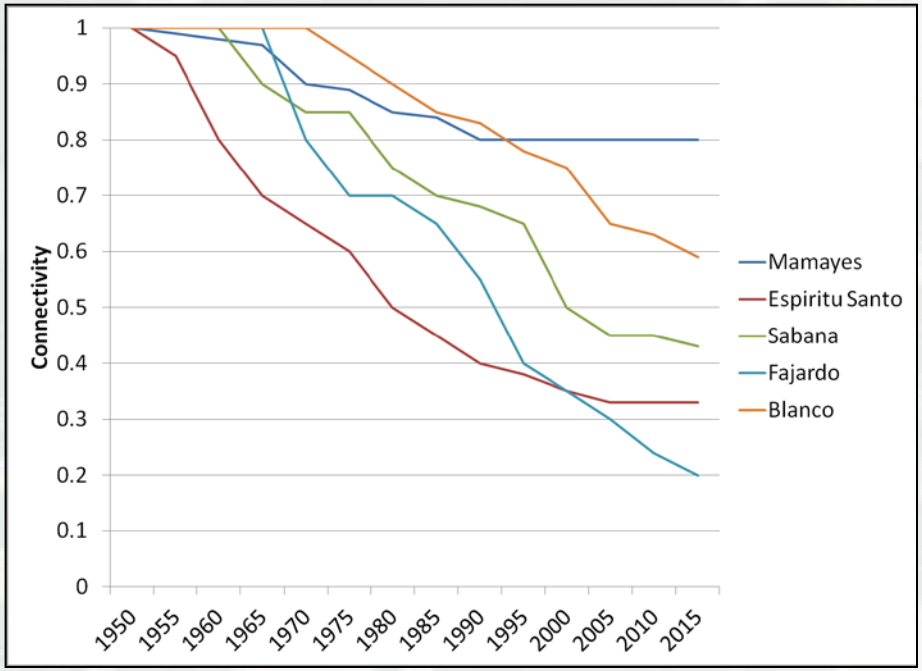
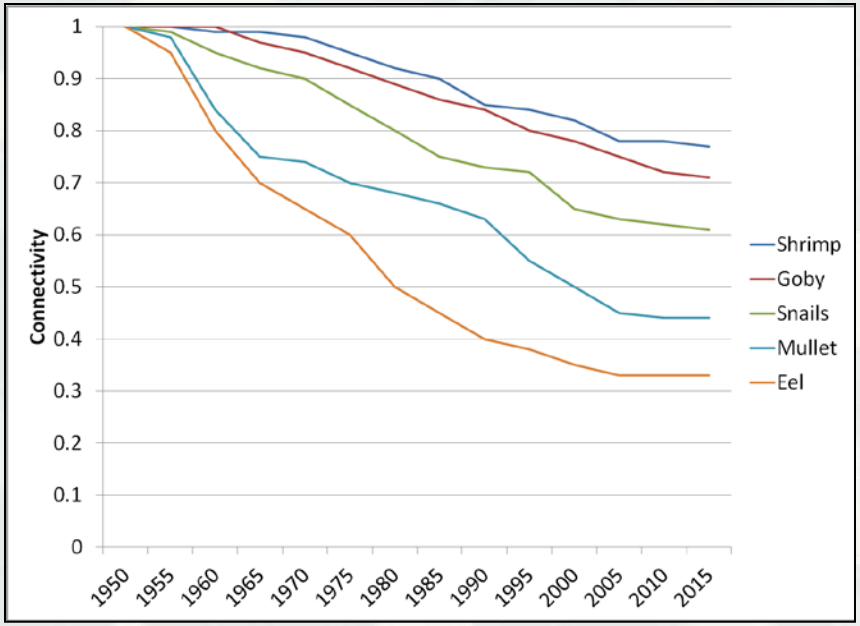


Figure: Expected patterns in Puerto Rico

Analysis #2: Community view of connectivity

- Parameterizing for unique physiological capability and life history needs
  - Shrimp (Benstead, March, Pringle, Covich, Crook, et al.)
  - Blanco and Scatena (2005/6)
  - Cooney and Kwak (2013)
- Some species may be more resilient to disconnection or increased withdrawal
- Community-wide view of connectivity (rather than a single species perspective)



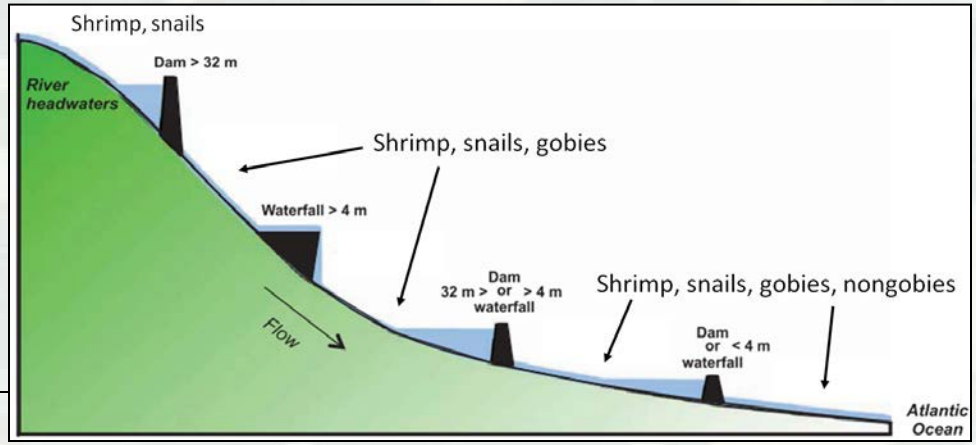
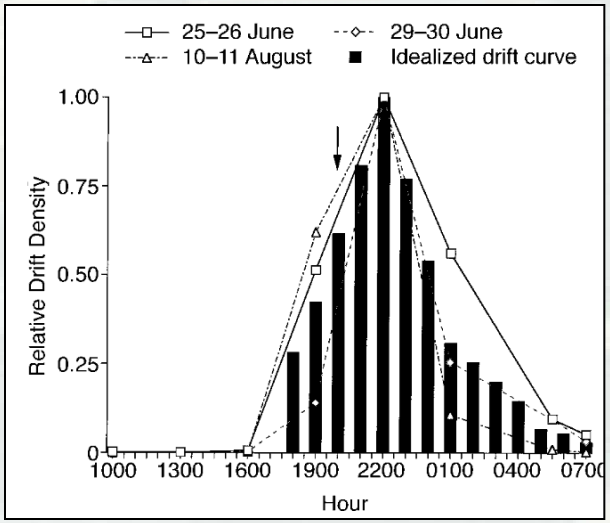
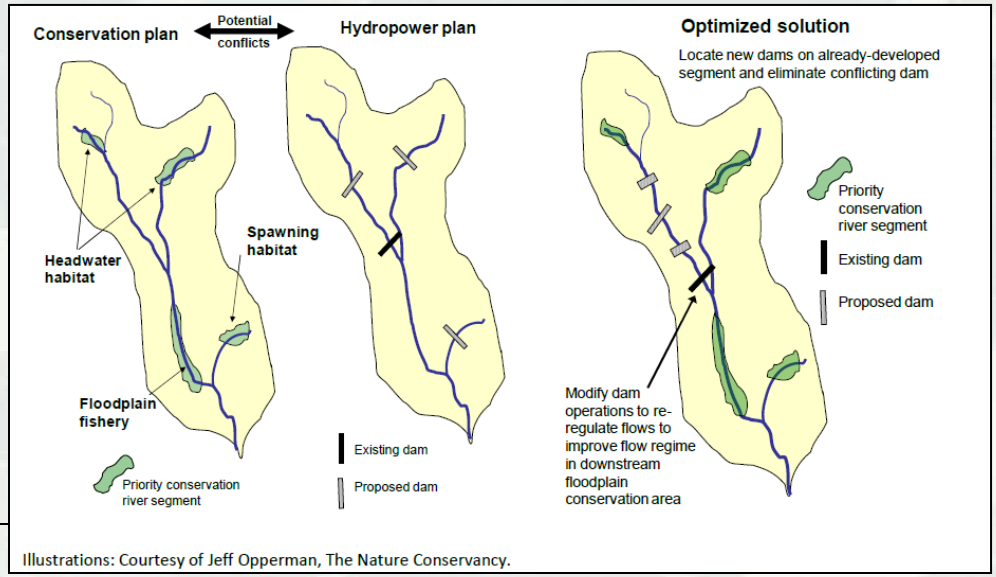


Figure: Expected outcomes, Adapted from Cooney and Kwak (2013)

Connectivity Restoration Strategies

- Operating structures to reduce connectivity impacts
  - Timing matters for migration: Seasonal? Moon phase? Hourly?
  - Environmental flow analog
- Spatial arrangement of dams
  - Construction / permitting
  - Restoration / removal
- Effect of connectivity index on decision-making
  - Upstream v. Up-Down
  - Cote v. O'Hanley v. McKay





Figures: Benstead et al. (1999), Richter et al. (2010)

Lessons Learned from our Case Study

Key Outcomes of the PR Case Study

- Direct application of results
  - Permitting and restoration in Puerto Rico, Hawaii, & Guam
  - American eel assessments
- Developing and demonstrating a suite of connectivity assessment methods
  - Moving beyond a fish-only view of connectivity
  - Time-varying properties of connectivity
  - Coupling connectivity and hydrology
  - Trade-offs between species (community-level perspective)
  - Operational effects on connectivity

Figures: Parham et al. (2009)

Does connectivity matter?

- Connectivity is one of seven budget criteria used for project ranking
  - Need a suite of methods for objectively quantifying and informing rankings
- USACE projects could be operated or adaptively managed for connectivity benefits (e.g., river-floodplain connection)
- Techniques may also transfer to regulatory decision making associated with multiple, interacting mitigation projects

	PROGRAM NAME	CONNECTIVITY	CONNECTIVITY DOCUMENTATION	SPECIAL STATUS SPECIES	SPECIAL STATUS SPECIES DOCUMENTATION	HYDRO LOGIC CHARA CTER	HYDROLOGIC CHARACTER DOCUMENTATION
48	COASTAL MISSISSIPPI HURRICANE AND STORM DAMAGE PROTECTION STUDY, MS	18	Restores vital link of habitat to establish large areas for animal migration use including Ms Flyway corridor, which provides valuable essential resting/ feeding habitat/federally protected species	10	Emergent tidal marsh is EFH for red drum, Span mackerel, white/brown shrimp. Fed listed Gulf Sturgeon feed upon numerous species that depend upon tidal marsh as nursery & cover.	20	Restores historic hydrology in coastal MS by re-establishing conditions condusive to more productive wetlands that filter pollutants from runoff/flood waters and storage capacity and re-establishing historic hydrologic connections.These areas provide less fragmentation for the overall coast.
49	COASTAL MISSISSIPPI HURRICANE AND STORM DAMAGE PROTECTION STUDY, MS	18	Restores vital link of habitat to establish large areas for animal migration use including Ms Flyway corridor, which provides valuable essential resting/ feeding habitat/federally protected species	10	Restored areas will provide critical habitat for MS Sandhill Craneand Gulf Sturgeon.Emergent tidal marsh is EFH for numerous fish & shellfish	20	Restores historic hydrology in coastal MS by re-establishing conditions condusive to more productive wetlands that filter pollutants from runoff/flood waters and storage capacity and re-establishing historic hydrologic connections.These areas provide less fragmentation for the overall coast.
	COASTAL MISSISSIPPI HURRICANE AND STORM DAMAGE PROTECTION STUDY, MS	18	Restores vital link of habitat to establish large areas for animal migration use including Ms Flyway corridor, which provides valuable essential resting/ feeding habitat/federally protected species	10	Restored areas will provide critical habitat for the federally protected species, MS Sandhill Crane. Emergent tidal marsh is EFH for numerous fish & shellfish.	20	Restores historic hydrology in coastal MS by re-establishing conditions condusive to more productive wetlands that filter pollutants from runoff/flood waters and storage capacity and re-establishing historic hydrologic connections.These areas provide less fragmentation for the overall coast.

Questions and Feedback

Take-away Points:

- Hydrologic connectivity is much larger than fish passage
- This project focuses on tools, techniques, and demonstrations
- Connectivity often fluctuates naturally through time
- Declines in connectivity can be measured using multiple indices
- Migratory communities are a next step in extending USACE analysis of connectivity

Acknowledgements

- A big thank you Jessica Chappell for photos and slides!
- UGA team: Cathy Pringle, Jason Christian, & Joel Martin
- USACE Ecosystem Management and Restoration Research Program
  http://el.erdc.usace.army.mil/emrrp/
- US Forest Service

Contact Information

Kyle McKay

601-415-7160

Kyle.McKay@usace.army.mil