Prioritizing Fish Passage Improvement

Engineer Research and Development Center

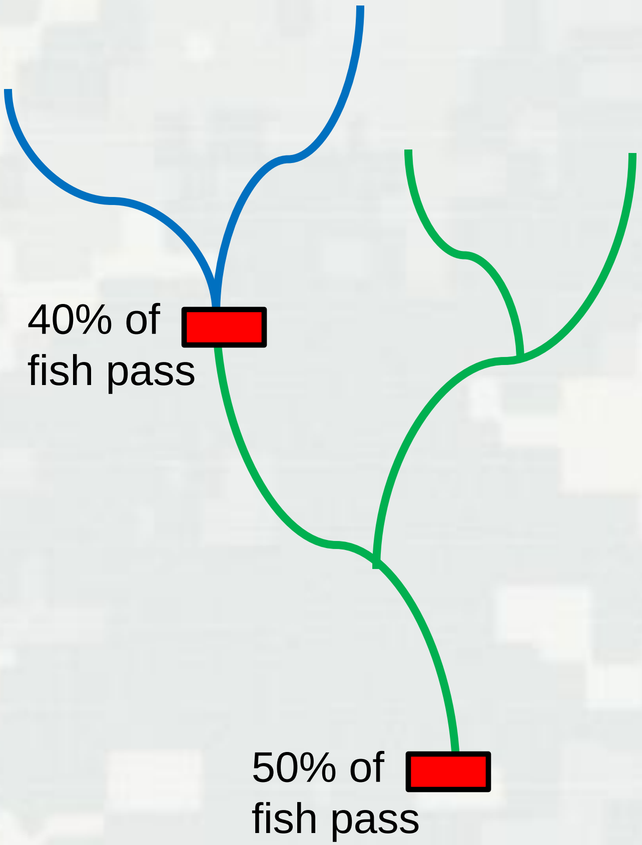
Kyle McKay, Jock Conyngham, and Craig Fischenich
601-415-7160
Kyle.McKay@usace.army.mil

USACE Webinar
September 17, 2013

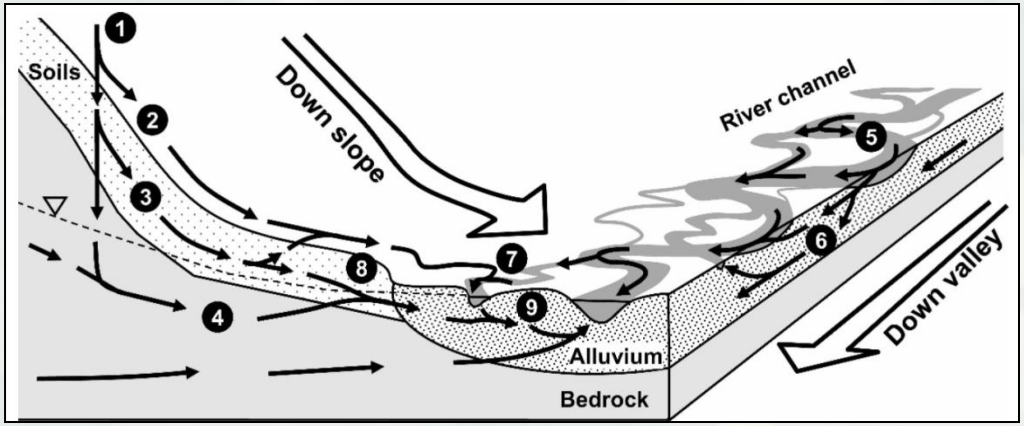
US Army Corps of Engineers®

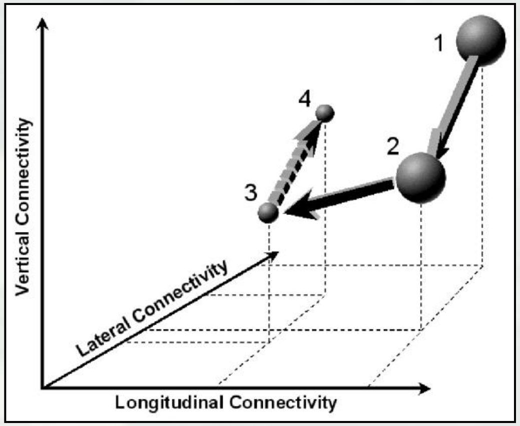
Project Overview

- Overview of hydrologic connectivity
- What alternatives exist to improve fish passage?
- How do we compare alternatives at a single barrier?
- How do we evaluate cumulative effects of multiple barriers?



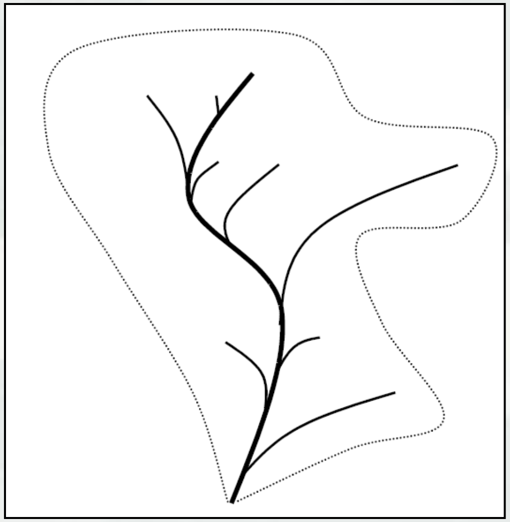
Hydrologic Connectivity





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)



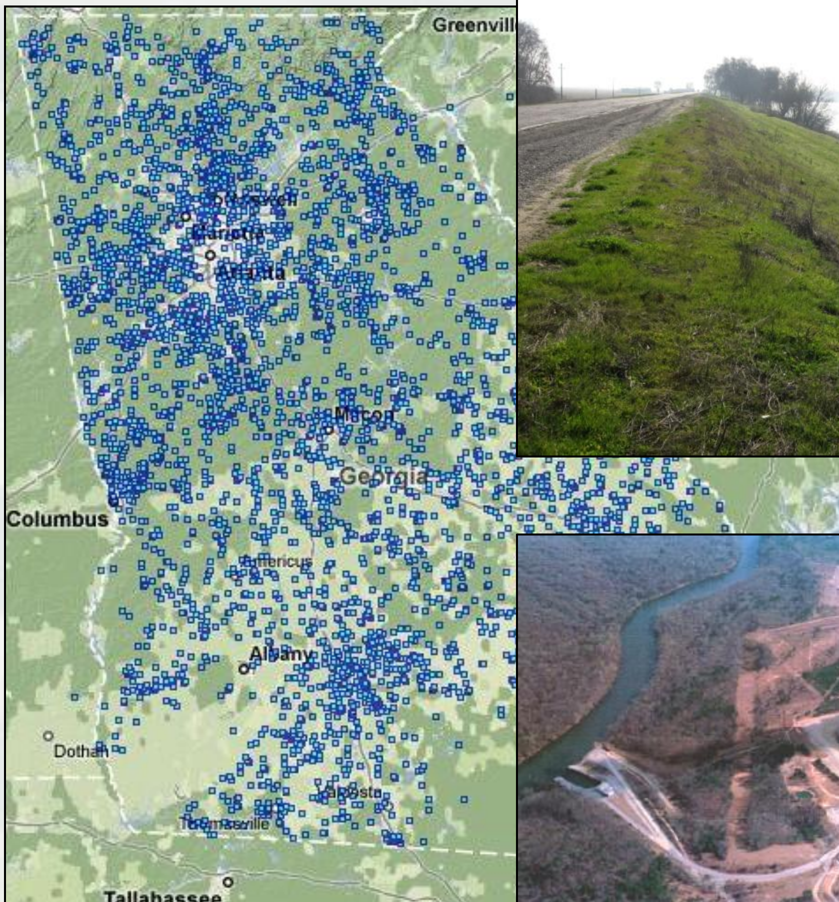
ERDC

BUILDING STRONG®

Innovative solutions for a safer, better world

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

We’ve systematically disconnected our watersheds!

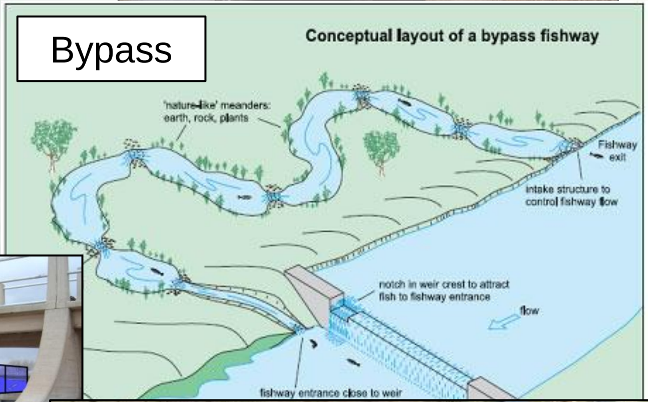


Figures: USACE National Inventory of Dams, Nancy Gleason, Sacramento River, Plant Vogtle (Glynn Environmental)

Fish Passage Alternatives

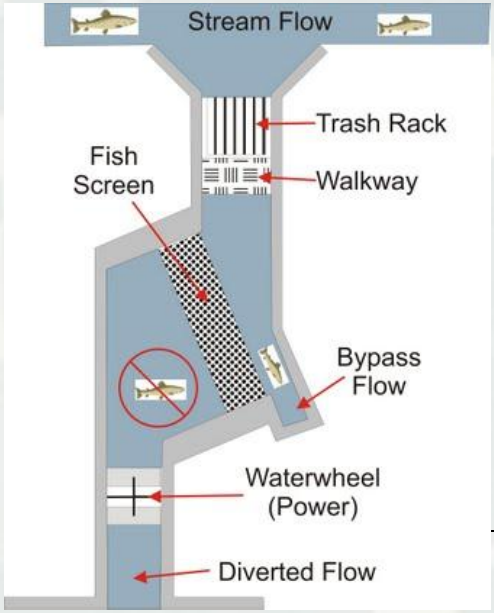
Upstream Passage Technologies

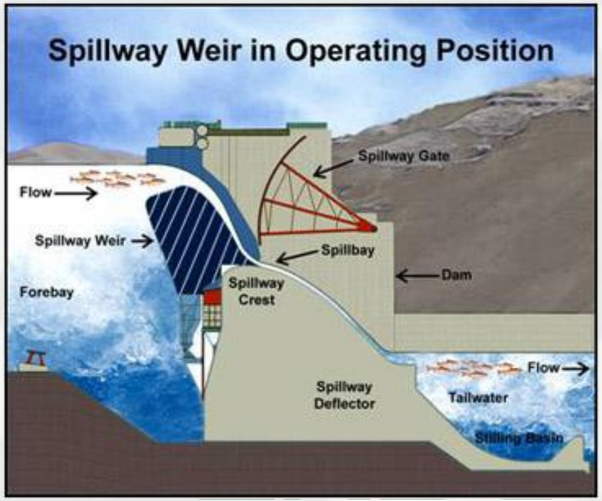
- Technical structures (e.g., slot ladders, Denial fishways)
  - High head
  - Low head
- Natural template structures (e.g., natural bypasses, rock ramps)
- Operational or hybrid passage techniques (e.g., special passage flows or trap-and-truck)
- Special cases (e.g., eel ladders)



Downstream Passage Technologies

- Physical barriers (e.g., screens, infiltration galleries)
- Diversion or structural guidance systems (e.g., trash racks)
- Behavioral guidance devices (e.g., sound, light, turbulence)
- Collection systems (e.g., trap-and-truck)
- Non-structural techniques (e.g., spilling, sluicing)



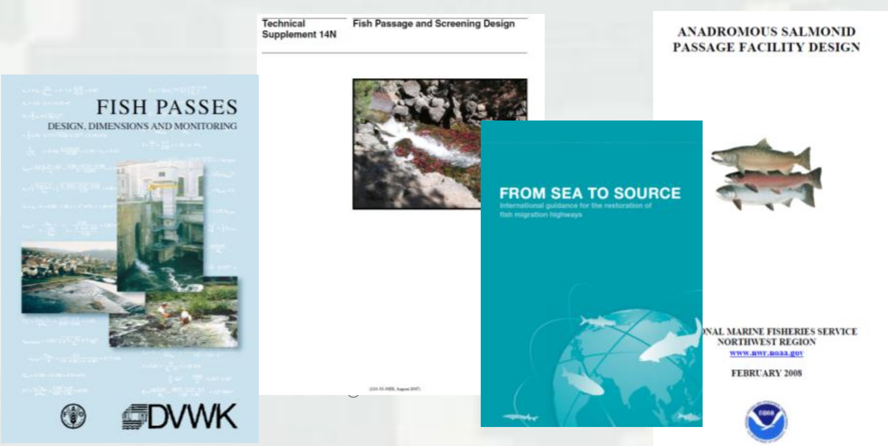


Selection Criteria

- Ecological design requirements
  - Identification of relevant ages, species, guilds, or communities
  - Life history needs, swimming capabilities, behavioral characteristics, and vulnerability to injury
- Site or design elements
  - Local hydraulics: discharge, operation, head differential,…
  - Lateral and longitudinal footprint constraint
  - Site dynamism
  - Site access for construction, operations, monitoring, and maintenance
- Other relevant processes and issues
  - Transport of sediment, debris, ice,…
  - Vandalism
  - Operational dependability
  - Local and regional expertise for design, construction, and maintenance

Coming soon!

- Volumes of fish passage guidance
- "Reader's digest"
  - ► Boiling down into a usable matrix of alternatives
  - ► Qualitative comparison of strengths and weaknesses
  - ► Key metrics for comparing fish passage alternatives



emrrp Ecosystem Management and Restoration Research Program

ERDC TN-12-x
xxx_xxxx

Restoration of Fish Passage: Alternatives, Applications, and Selection Principles

By Jock Conyngham[1] and Craig Fischenich[2]

OVERVIEW: Fragmentation of streams and rivers represents a major impact to aquatic populations and ecosystems. Complete physical blockages preventing movement of fish to spawning, rearing, refuge, or feeding habitats are the most extreme form, causing major impacts to populations and communities (Lucas and Baras 2001). These major impacts are, in large measure, well-recognized; laws mandating the temporary removal of weirs from German rivers during salmon migrations, for example, date to the 13th century (FAO/DVWK 2002). Fragmentation, however, can stem from an array of physical, hydraulic, thermal, or water quality alterations and vary from complete blockages affecting population viability, distribution and resilience to partial blockages that truncate population size, alter age and gender structure in individual populations, or change community structure through the elimination of weaker swimming species. Minor obstructions may cause movement delays that are individually minor but cumulatively significant. Furthermore, impacts are not expressed solely on anadromous species, though fish passage efforts have historically focused on them. Increasing attention is now accruing to potamodromous (particularly adfluvial obligates), catamodrous, and amphidromous species as well as resident populations that respond to stress, condition, or seasonal life history needs by movement.

The presence of more than 86,000 large dams in US waterways and millions of smaller culverts, utility crossings, diversion structures, and others sources of impeded passage means that longitudinal fragmentation is a central issue in the restoration of this nation's waterways and the biological integrity of its lotic ecosystems. Furthermore, the benefits of restored connectivity are clear and can be achieved rapidly. One empirical review of aquatic habitat restoration techniques linked removal or mitigation of barrier effects to many of the largest increases in fish production (Roni et al., 2002).

Fish passage restoration has begun to move away from single-site, highly engineered approaches that focus solely on spawning movements of adult members of recreationally or commercially important species to more system-based thinking that addresses basin-scale planning needs, varying life histories, adults and juveniles, a broader range of the aquatic community, implications for invasive species, and both upstream and downstream passage. The fish passage

[1] Research Ecologist, U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL), Missoula, Montana
[2] Research Civil Engineer, ERDC-EL, Vicksburg, Mississippi

Measuring Passage Rates

What is a "fish passage rate"?

- Multiple definitions dependent upon scale of interest
  - Organism: the proportion of successful attempts **by an individual** at passing a barrier (Kemp and O'Hanley 2010)
  - Population: the proportion of fish **of a given species** that are able to pass through a barrier while migrating upstream (O'Hanley and Tomberlin 2005)
  - Community: the **proportion of species** successfully passing (Roscoe and Hinch 2010)

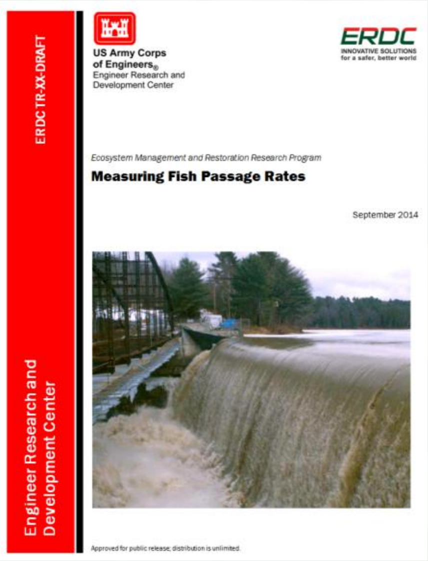
- Passage rates (aka., efficiency, passability) are defined here as the proportion of fish passing a structure scaled from 0 to 1.

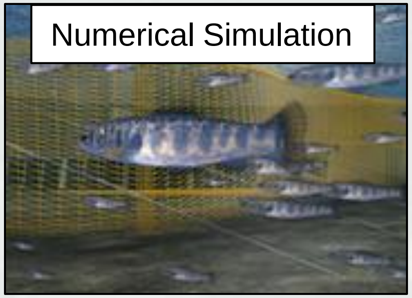
What we want to give you…

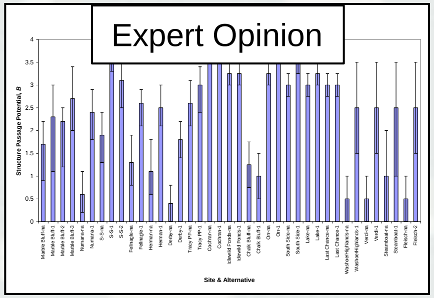
- A comprehensive table of passage rates by species and structure type would be great!
- However,….
  - Data are scattered and/or unavailable
  - Passage rates are variable at a single structure (and possibly for a single species)
  - Passage rates are not collected comprehensively for numerous structure types
  - Data rarely (if ever) exist for non-game and non-migratory species

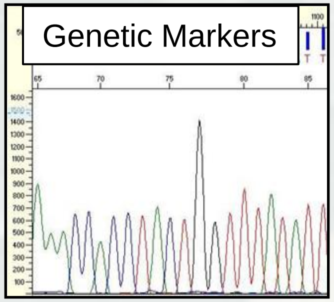
What we can give you…

- What methods exist (Kemp and O'Hanley 2010)?
  - ▸ Empirical / data-driven / monitoring
  - ▸ Analytical / forecasting / predicting
- What are the steps to selecting a passage assessment method?







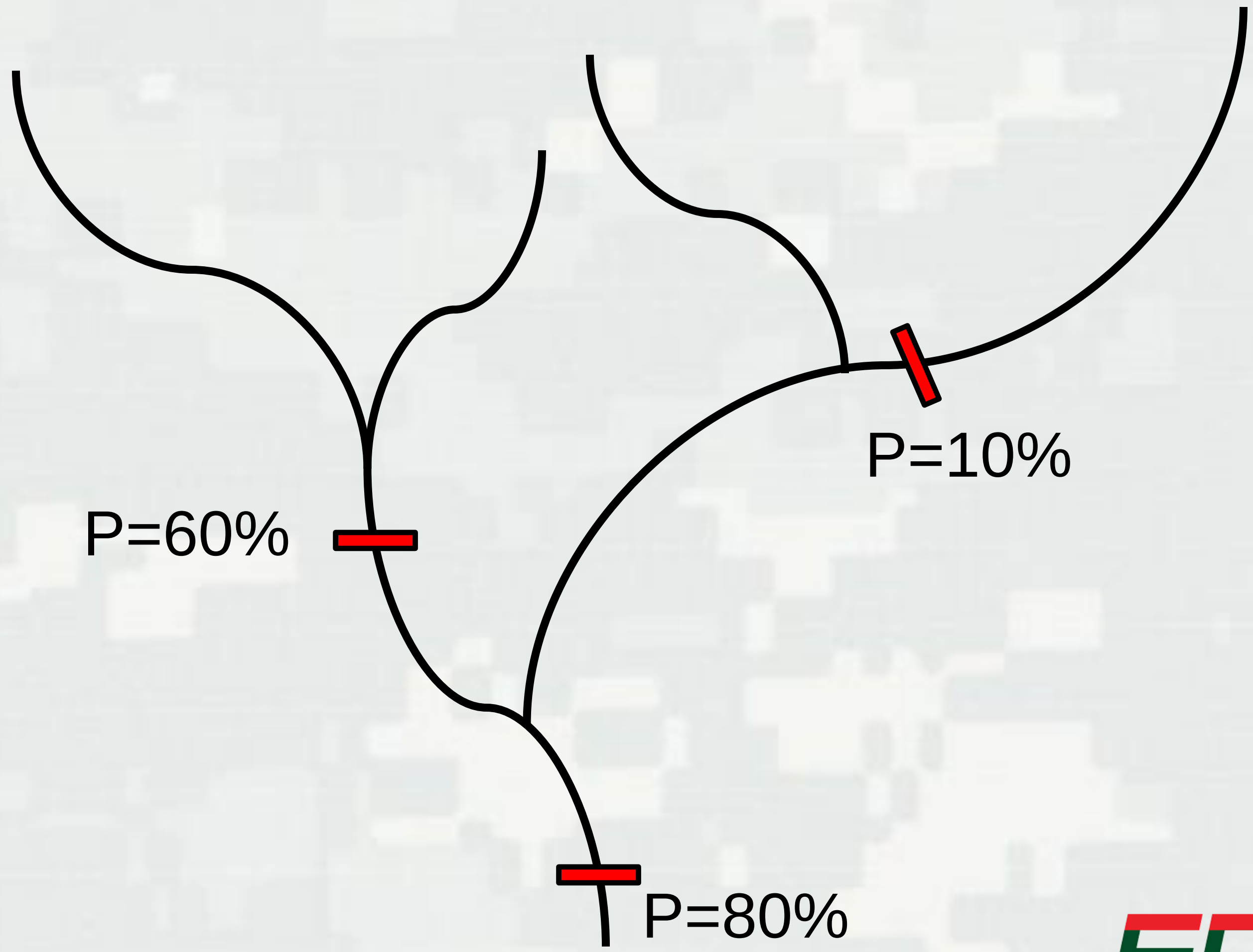


Ongoing Studies of Passage Rates

- Delta stream weir passage (MS)
- New Madrid floodgates (MO)
- Recreational wave (Missoula, MT)
- Lock and Dam #1, Cape Fear River (NC)

Barrier Prioritization

What is the cumulative effect of multiple barriers?



Original Pruned Topped Cut

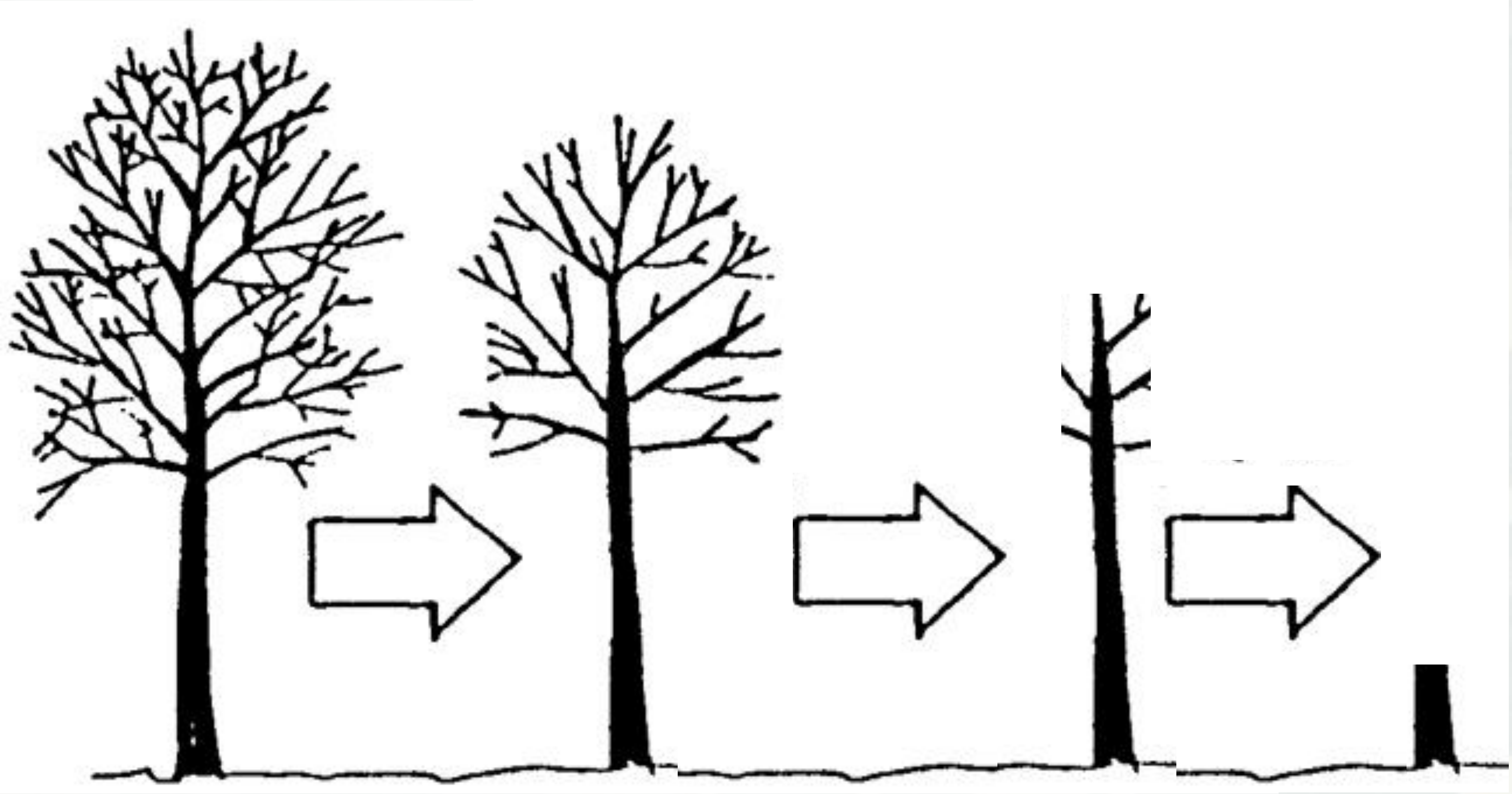
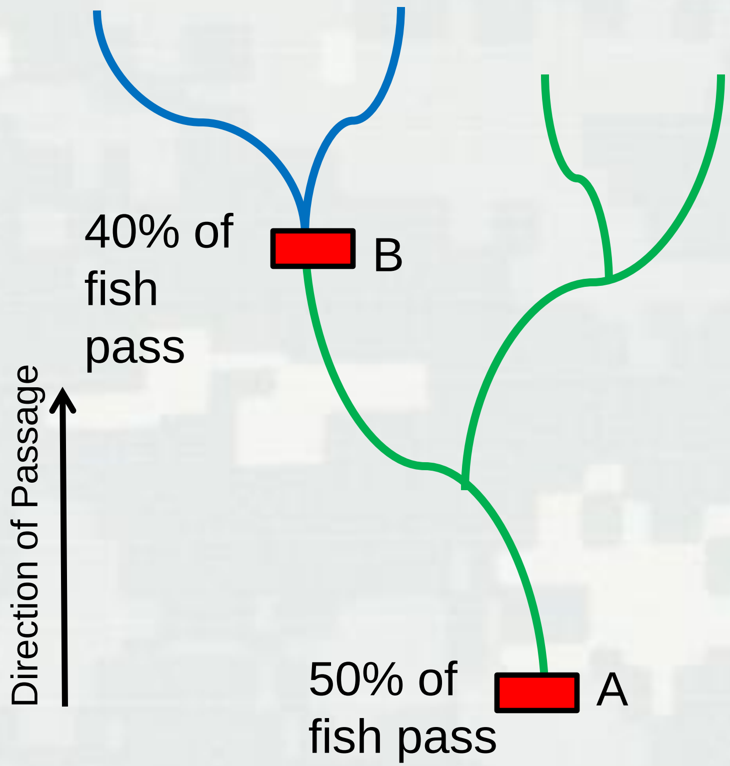
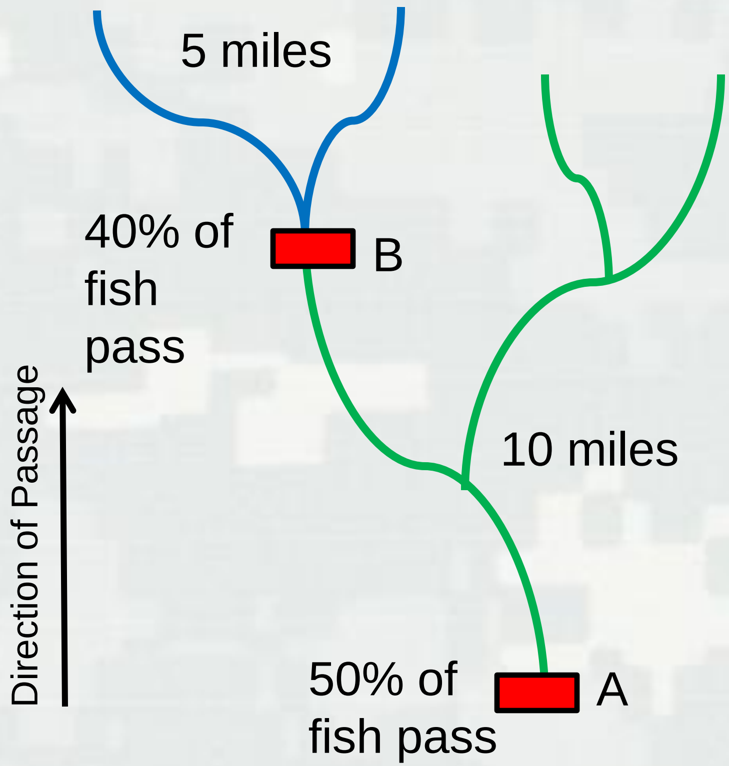


Figure modified from www.aces.nmsu.edu

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



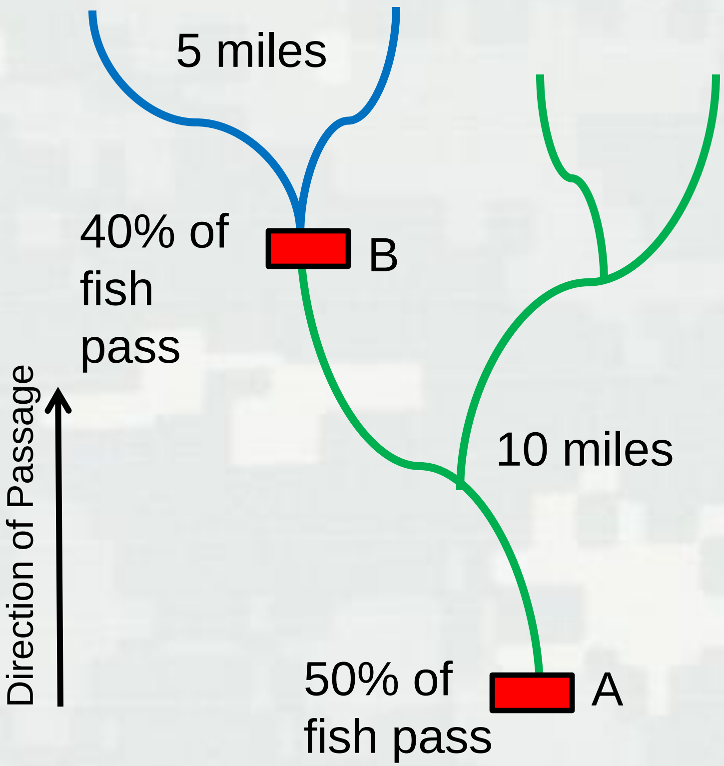
Barrier	Passage Rate	Cumulative Passage Rate	Upstream Habitat	Accessible Habitat
A	0.5	0.5	10	5
B	0.4	0.2	5	1
Total			15	6



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

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

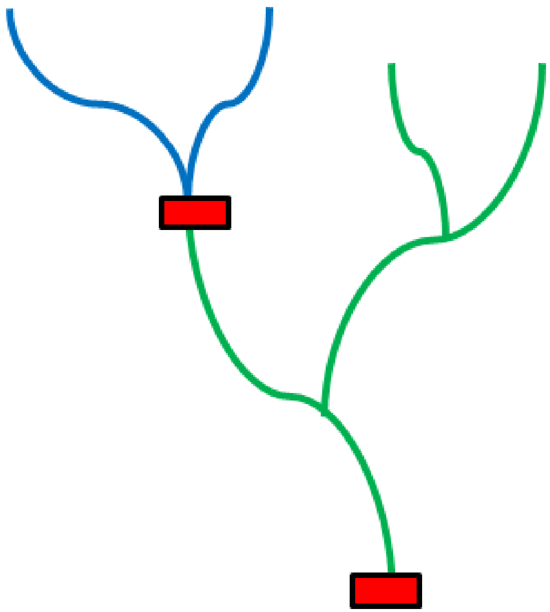
Barrier	Passage Rate	Cumulative Passage Rate	Upstream Habitat	Accessible Habitat
A	0.5	0.5	10	5
B	0.4	0.2	5	1
Total			15	6



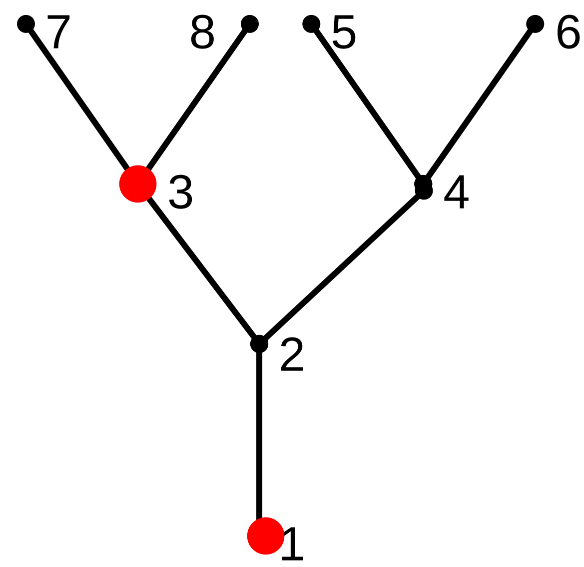
Which barrier should we remove?

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

Watershed



Network Diagram



Adjacency Matrix

$$\begin{pmatrix} 0&0&0&0&0&0&0&0 \\ 1&0&0&0&0&0&0&0 \\ 0&1&0&0&0&0&0&0 \\ 0&1&0&0&0&0&0&0 \\ 0&0&0&1&0&0&0&0 \\ 0&0&0&1&0&0&0&0 \\ 0&0&1&0&0&0&0&0 \\ 0&0&1&0&0&0&0&0 \end{pmatrix}$$

Node-1 is connected upstream to node-2.

Node-3 is connected upstream to node-7 and node-8.

Passage Rates

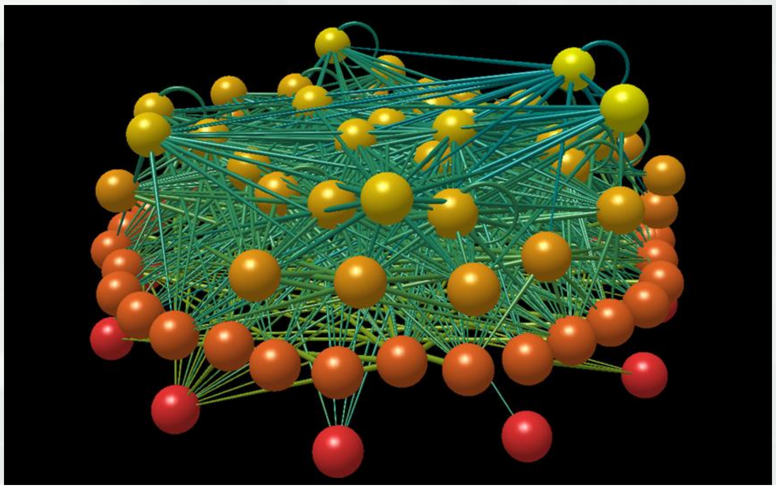
$$\begin{pmatrix} 0.5 \\ 1.0 \\ 0.4 \\ 1.0 \\ 1.0 \\ 1.0 \\ 1.0 \\ 1.0 \end{pmatrix}$$

Upstream Habitat

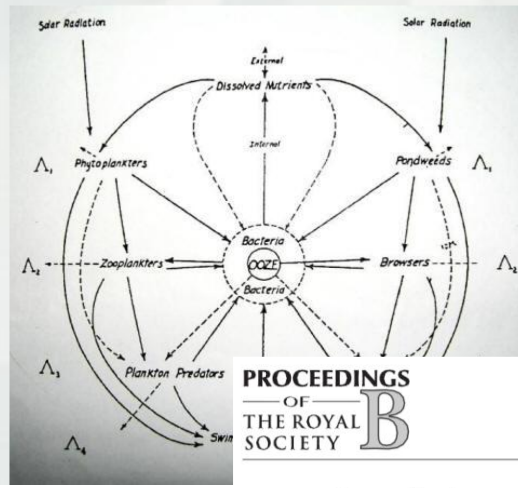
$$\begin{pmatrix} 1 \\ 2 \\ 2 \\ 2 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Are we the first folks to use networks in ecology? NO WAY!

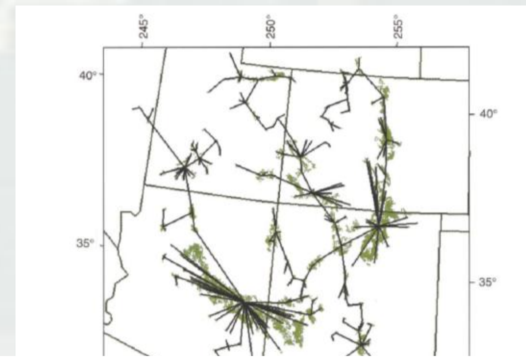
Little Rock Lake food web



Systems Diagrams



Nature Reserve Design



PROCEEDINGS OF THE ROYAL SOCIETY B
Proc. R. Soc. B (2006) 273, 1429–
doi:10.1098/rspb.2005.
Published online 21 February

Spatial network structure and amphibian persistence in stochastic environments

Miguel A. Fortuna[1,*], Carola Gómez-Rodríguez[2] and Jordi Bascompte[1]
[1]Integrative Ecology Group, and [2]Department of Wetlands Ecology, Estación Biológica de Doñana, CSIC, Apdo. 1056, 41080 Sevilla, Spain

A high-resolution human contact networ infectious disease transmission

Marcel Salathé[a,1,2], Maria Kazandjieva[b], Jung Woo Lee[b], Philip Levis[b], Marcus W. Fe

Freshwater Biology (2009) 54, 450–465 doi:10.1111/j.1365-2427.2008.02121.x

Predator–prey interactions in river networks: comparing shrimp spatial refugia in two drainage basins

ALAN P. COVICH*, TODD A. CROWL[†], CATHERINE L. HEIN[†], MATT J. TOWNSEND[†] AND WILLIAM H. MCDOWELL[‡]
*Institute of Ecology, Odum School of Ecology, University of Georgia, Athens, GE, U.S.A.
[†]Ecology Center and Department of Watershed Sciences, Utah State University, Logan, UT, U.S.A.
[‡]Department of Natural Resources and the Environment, University of New Hampshire, Durham, NH, U.S.A.

PROCEEDINGS OF THE ROYAL SOCIETY B
Proc. R. Soc. B (2008) 275, 2515–2520
doi:10.1098/rspb.2008.0744
Published online 22 July 2008

Behavioural phenotype affects social interactions in an animal network

Thomas W. Pike[1,*], Madhumita Samanta[1], Jan Lindström[1] and Nick J. Royle[2]
[1]Division of Environmental and Evolutionary Biology, University of Glasgow, Glasgow G12 8QQ, UK
[2]Centre for Ecology and Conservation, School of Biosciences, University of Exeter, Cornwall Campus, Penryn, Cornwall TR10 9EZ, UK

Figures: Berlow et al. (2010), Lindeman (1942), Urban and Keitt (2001)

We're not even the first to do it in fish passage prioritization!

- O'Hanley et al. (2005, 2010, 2011, 2013,…)
- Cote et al. (2008)
- Bourne et al. (2011)
- Diebel et al. (2010)
- Neeson et al. (2011, 2012)
- Schick and Lindley (2007)
- Padgham & Webb (2010)
- Eros et al. (2011, 2012)
- …

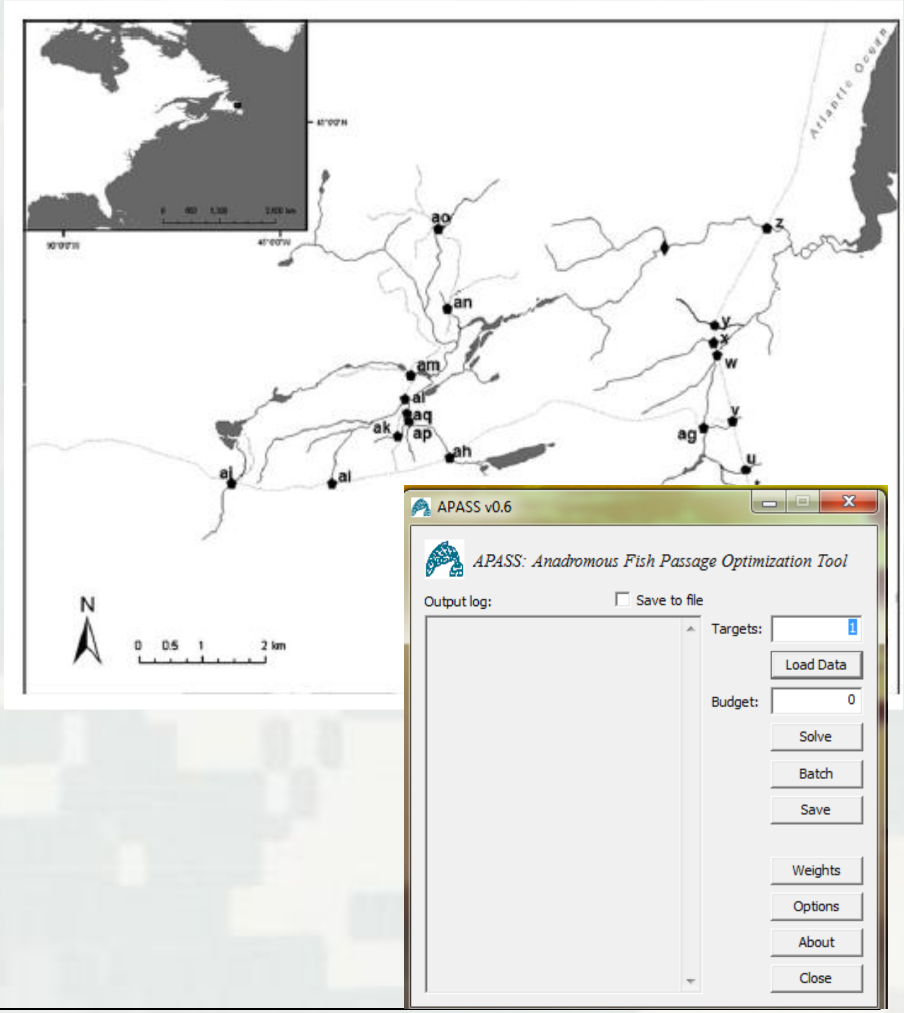
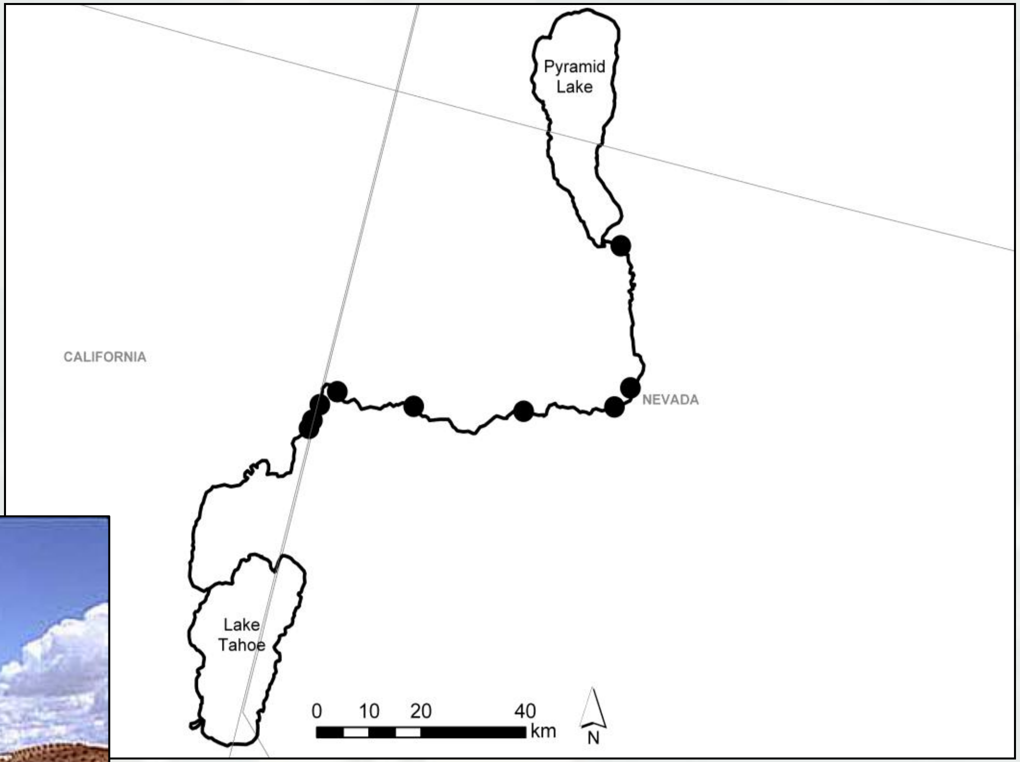


Figure: Bourne et al. (2011)

Example Application: Truckee River Fish Passage Improvement Project

- 9 barriers
- 2-4 alternatives per barrier
- Passage rates were estimated by an expert panel
- What actions should be taken to get the most bang for our buck?



Threatened Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*)

Conyngham J., McKay S.K., Fischenich C., and Artho D. 2011. *ERDC TN-EMRRP-EBA-06*.

ERDC

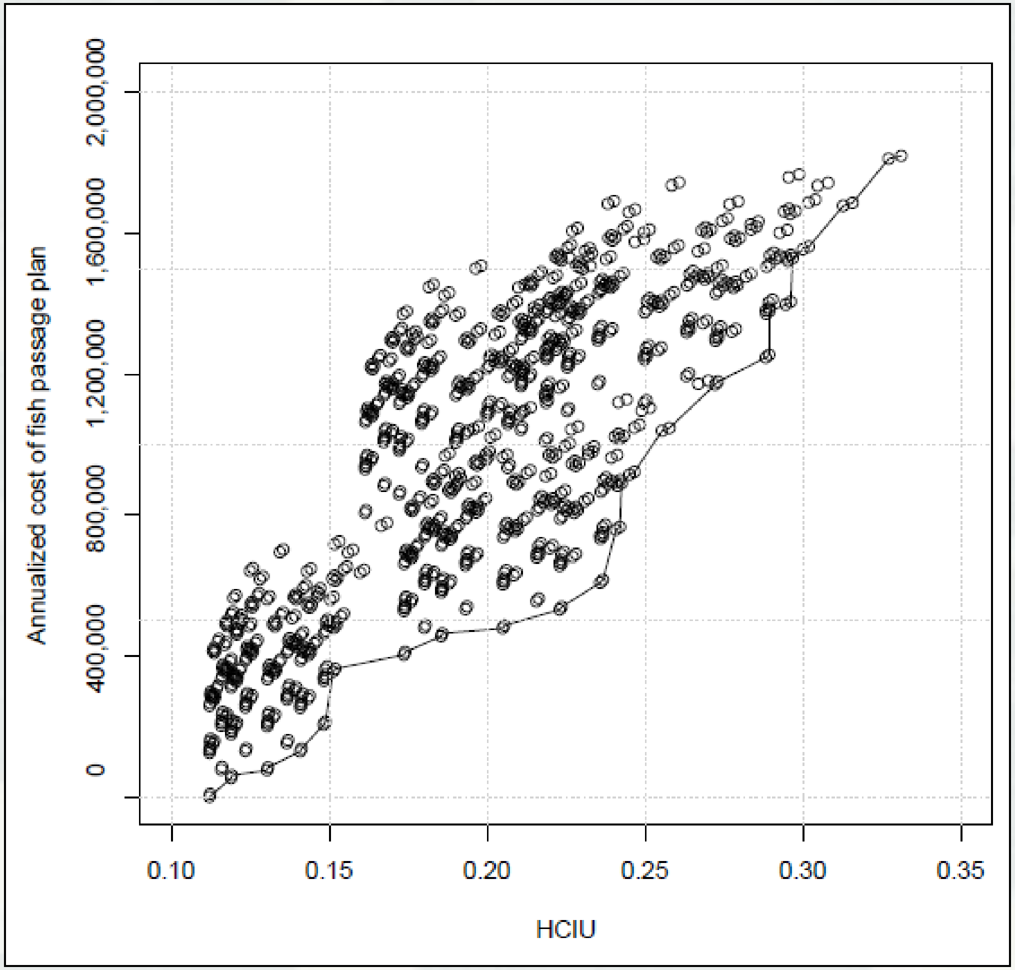
Figure: www.desertfishes.org

Structure	River mile (mi)	Diversion Discharge (% of river)	Structure Height (ft)
Pyramid Lake	0		
Marble Bluff	4	0.0	35
Fellnagle	27	0.6	4
Herman	31.5	1.9	2.4
Tracy PP	44	3.9	na
Chalk Bluff	69.8	10.7	3
Washoe-Highlands	76	34.9	8 - 10
Verdi	80.5	40.6	13
Steamboat	83.5	7.0	10
Fleisch	86	44.0	14
Lake Tahoe	121.1		

Figures: Jock Conyngham, Craig Fischenich, Mike Channell

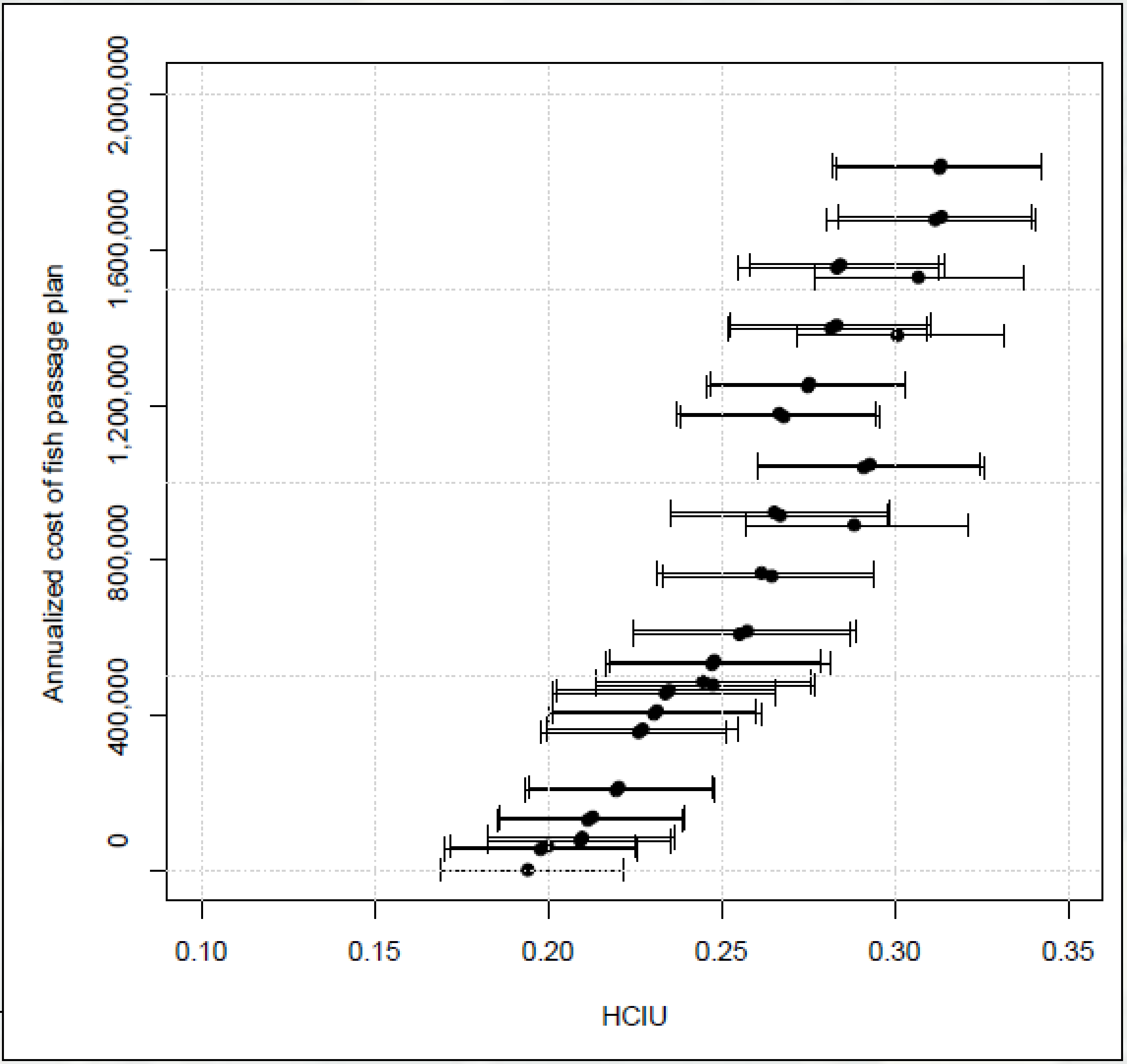
Cost-effective restoration actions

- 1,024 potential combinations of restoration actions
- Cost-effective alternatives identified.
- Multiple methods may be used for choosing a restoration plan.



Accounting for Uncertainty…

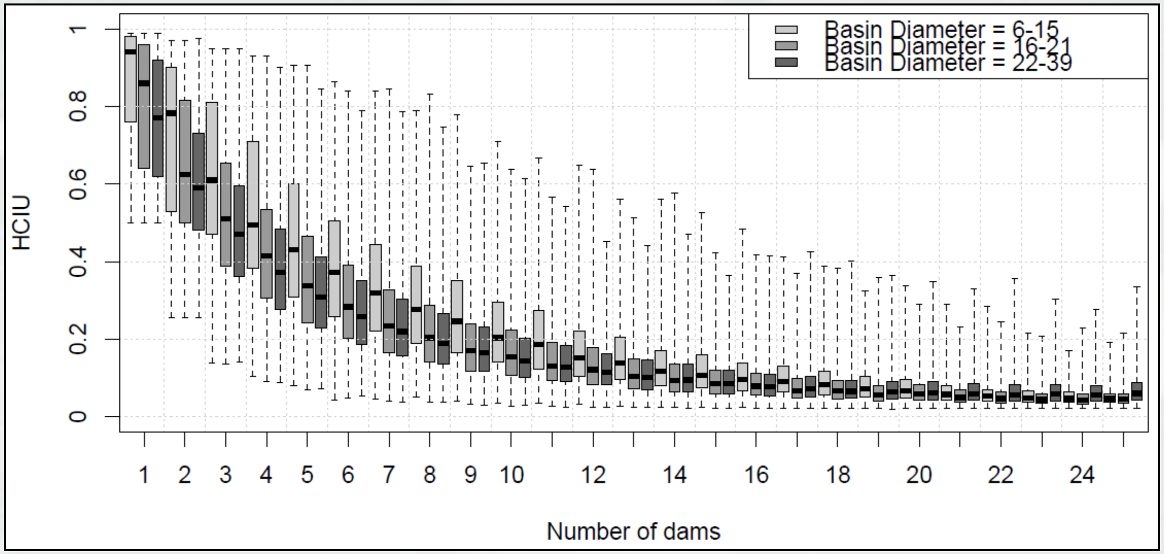
- Experts provided minimum, expected, and maximum estimates of passage
- Random combinations for cost-effective plans



BUILDING STRONG®

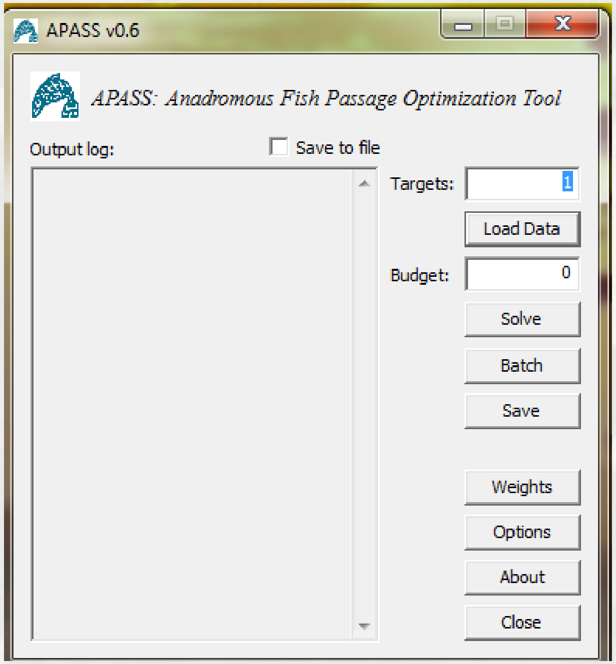
Another Application of Connectivity Metrics

- Looking for general trends in connectivity
- Generate hypothetical watersheds
- Distribute random dam configurations
- Examine the effect of partial passage rates



Ongoing Work on Barrier Prioritization

- Currently developing algorithms for assessing downstream passage and cyclic movement of resident fishes
- Developing a model for importing watershed shape, dam locations, and passage rates
- Novel applications addressing seasonality, multiple species, episodic fragmentation, uncertainty, etc.
- Comparing connectivity metrics



Products Related to this Project

- Conyngham, McKay, Fischenich, and Artho. 2011. Truckee case study. *ERDC TN-EMRRP-EBA-06*.
- Conyngham and Fischenich. Fish passage alternatives. In print.
- McKay, Schramski, Conyngham, and Fischenich. 2013. In print at Ecological Applications.

Ecological Applications, 00(0), 0000, pp. 000–000
© 0000 by the Ecological Society of America

Assessing upstream fish passage connectivity with network analysis

S. Kyle McKay,[1,5] John R. Schramski,[2] Jock N. Conyngham,[3] and J. Craig Fischenich[4]

Questions and Feedback

Take-away Points:

- Hydrologic connectivity is much larger than fish passage
- Reader's digest of passage alternatives
- Estimating passage rates is tricky
- Barrier prioritization tool is in the works

Additional Information

- A big thank you to Jock Conyngham & Craig Fischenich!
- USACE Ecosystem Management and Restoration Research Program
  http://el.erdc.usace.army.mil/emrrp/

Contact Information
Kyle McKay
601-415-7160
Kyle.McKay@usace.army.mil