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Concurrent Sessions C: Prioritization - On The Cutting-Edge: Optimizing Fish Passage Mitigation Decisions in California Watersheds

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Presenter Information
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On the Cutting-Edge: Optimizing Fish Passage Mitigation Decisions in California Watersheds

Jesse O'Hanley
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Fish Passage 2013 Conference
Corvallis, Oregon

Overview

- Background
- A quick look at APASS
- Illustrative results from California

The California Fish Passage Forum

The Forum in a nutshell

- Mission:

  "*to protect and restore listed anadromous salmonid species, and other aquatic organisms, in California by promoting the collaboration among public and private sectors for fish passage improvement projects and programs*"
- Species of concern:
  - Coho salmon
  - Chinook salmon
  - Steelhead trout

The first-cut approach

- Create a "barrier ranking matrix", aka a Scoring & Ranking system for prioritizing mitigation actions
- Scores assigned based on:
  1. Barrier order
  2. Barrier extent (total vs partial/temporal ± assessment protocol)
  3. Habitat length (i.e., stream miles above barriers)

Scoring method

Order	Score
1	5
2	4
3	3
4	2
5	0

Barrier Score = Barrier Extent + Barrier Order

Total Score = Barrier Score + Habitat Score

Habitat Length (mi)	Score
≤ 10	length to the nearest 0.1
> 10	10

Barrier Extent	Score
Total + Protocol	5
Total	4
Partial/Temporal + Protocol	3
Partial/Temporal	2
Unknown	0

Protocol = DFG Restoration Manual or FishXing was used

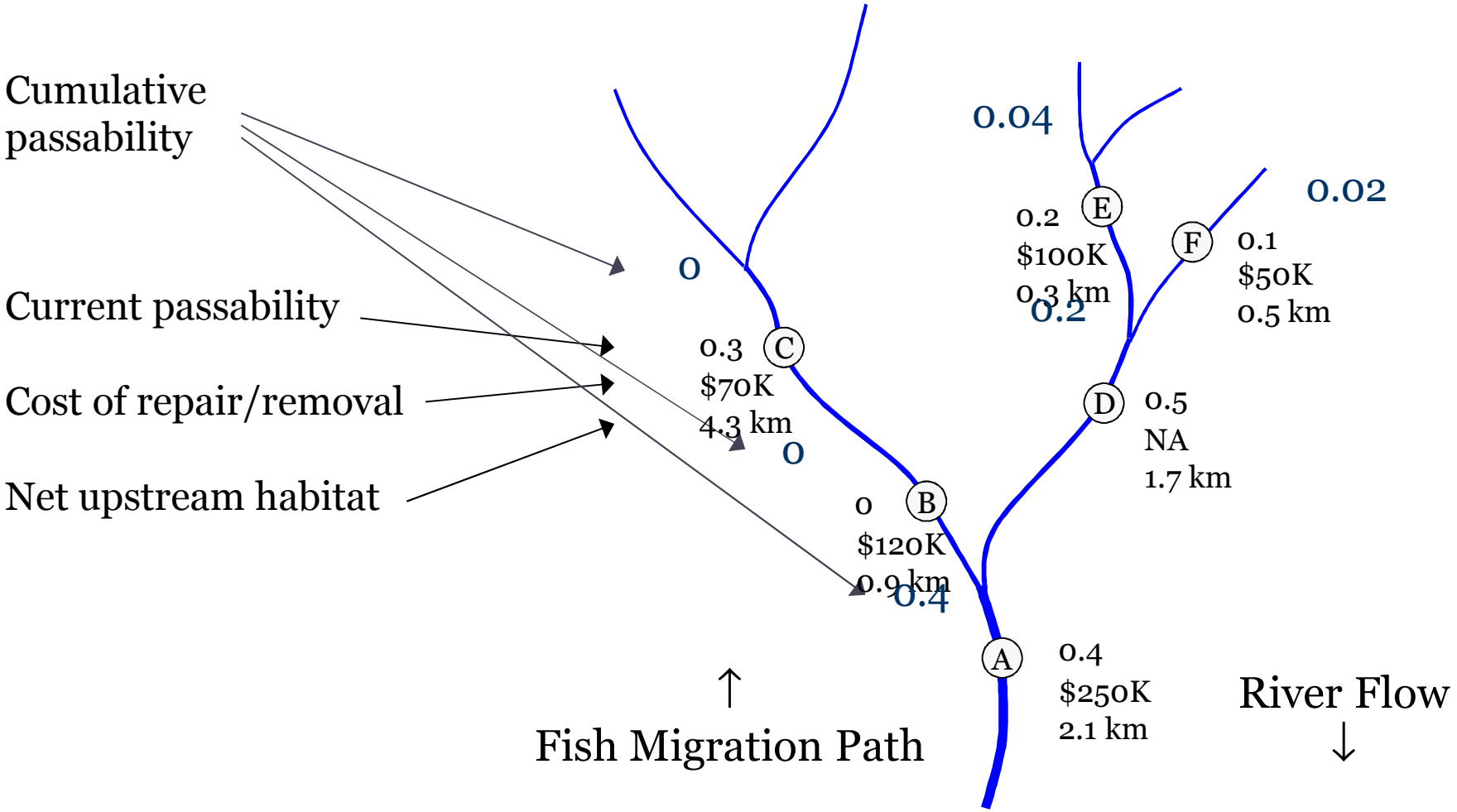
Don’t score & rank, optimize!

- Optimization based methods provide an ideal solution for dealing with the problem of barrier mitigation planning
- Offers an objective and systematic framework for thinking about the problem
- Makes the most efficient use of limited resources
- Can balance multiple, possibly competing, objectives and constraints
- Key uncertainties can even be incorporated in a coherent fashion

Framing the problem

- Goal: maximize the amount of accessible (possibly quality weighted) upstream habitat for one or more species
- Constraint: limited budget
- Problem statement: which barriers should be repaired/removed in order to maximize net habitat gain subject to a budget?

Example barrier network



Drum roll please …

- APASS (**A**nadromous Fish **Pass**age Optimization Tool) is a decision support tool for optimizing barrier mitigation
  - Note the word “Anadromous”
- Identifies cost-efficient mitigation actions to maximize the amount of accessible, possibly quality-adjusted, habitat above barriers
  - Uses a mixed integer linear programming (MILP) formulation of the O’Hanley and Tomberlin (2005) model

How does it work?

- Integrates information on
  - Barrier passability
  - Potential habitat
  - Mitigation cost
- Crucially, accounts for:
  - Spatial structure of barrier networks
  - Interactive effects of mitigation decisions on longitudinal connectivity

A peak under the hood

$$\max z = \sum_{s \in S} \theta_s \sum_{j \in J} v_{sj} \alpha_{sj}$$

Maximize connectivity-weighted habitat

$$s.t. \quad \alpha_{sj} = \prod_{k \in D_j} \left(p_{sk}^0 + \sum_{i \in A_k} p_{ski} x_{ki} \right) \quad \forall j \in J, s \in S$$

Connectivity of habitat above barrier *j* for species *s*

$$\sum_{i \in A_j} x_{ji} \leq 1 \quad \forall j \in J^{Art}$$

Can only carry out one mitigation project at an artificial barrier *j*

$$\sum_{j \in J^{Art}} \sum_{i \in A_j} c_{ji} x_{ji} \leq b$$

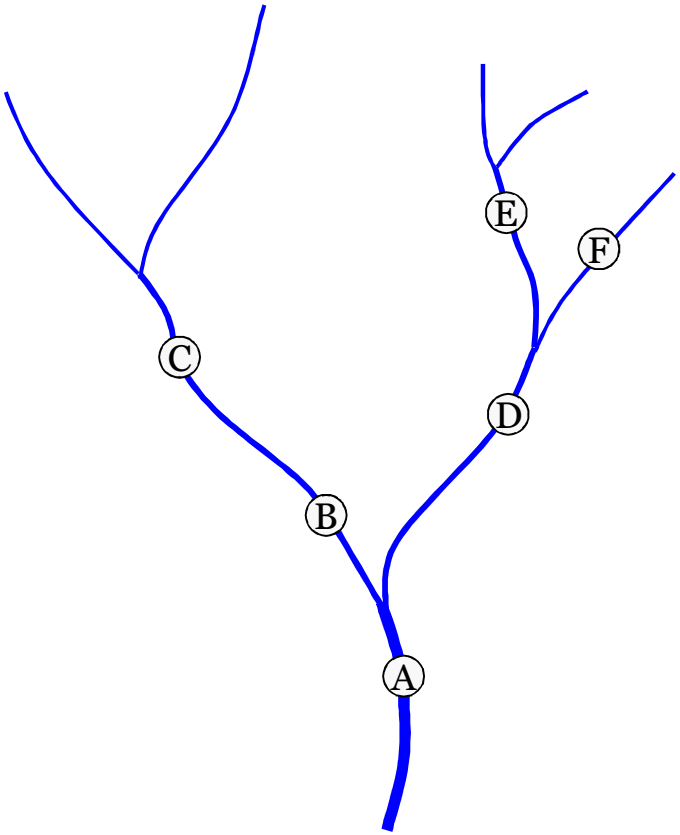
Limited budget for mitigation

$$x_{ji} \in \{0,1\} \quad \forall j \in J^{Art}, i \in A_j$$

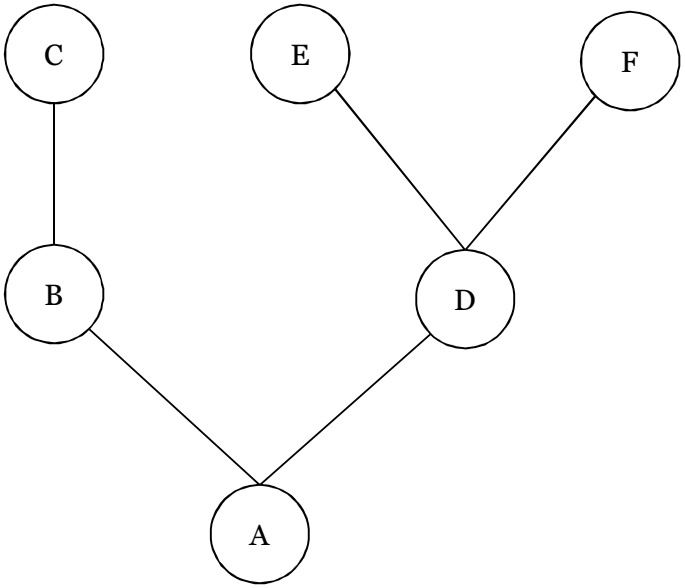
Either mitigate a barrier or not

For those who prefer a picture

River/Barrier Network



Graph Representation



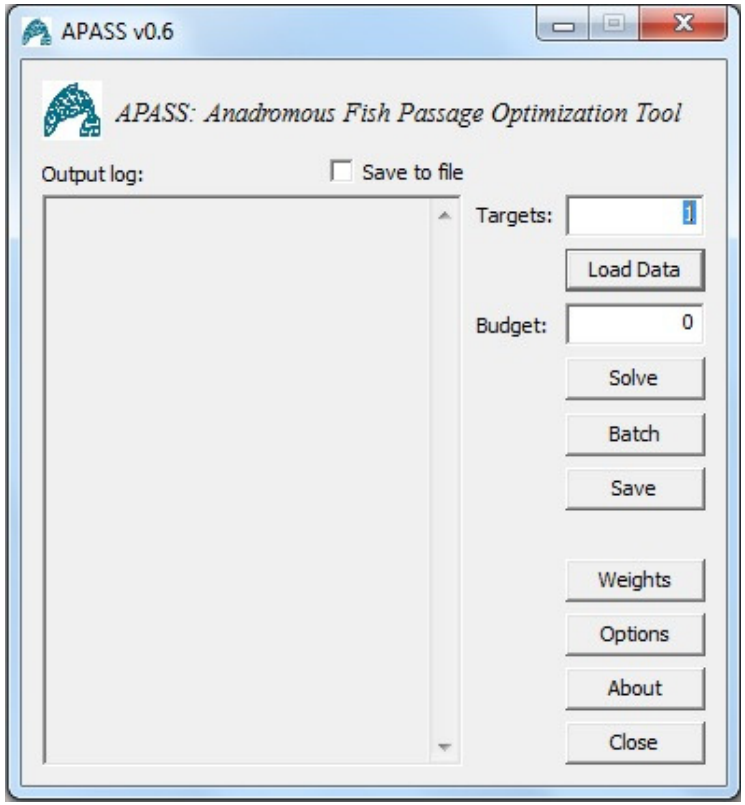
Node = Barrier

Data formatting requirements

APASS requires the following data fields:

- BARID: barrier ID
- BASIN: watershed, subwatershed, etc.
- DSID: immediate downstream barrier ID
- USHAB: net upstream habitat (up to the next set of barriers or the limits of anadromy)
- PREPASS: current barrier passability
- NPROJ: number of mitigation projects that can be carries out (normally 0 for natural barriers)
- COST: the cost to repair/remove/mitigate a barrier
- POSTPASS: barrier passability following mitigation

APASS demo


APASS v0.6
APASS: Anadromous Fish Passage Optimization Tool
Output log:
Save to file
Targets:
1
Load Data
Budget:
0
Solve
Batch
Save
Weights
Options
About
Close

Key APASS functionalities

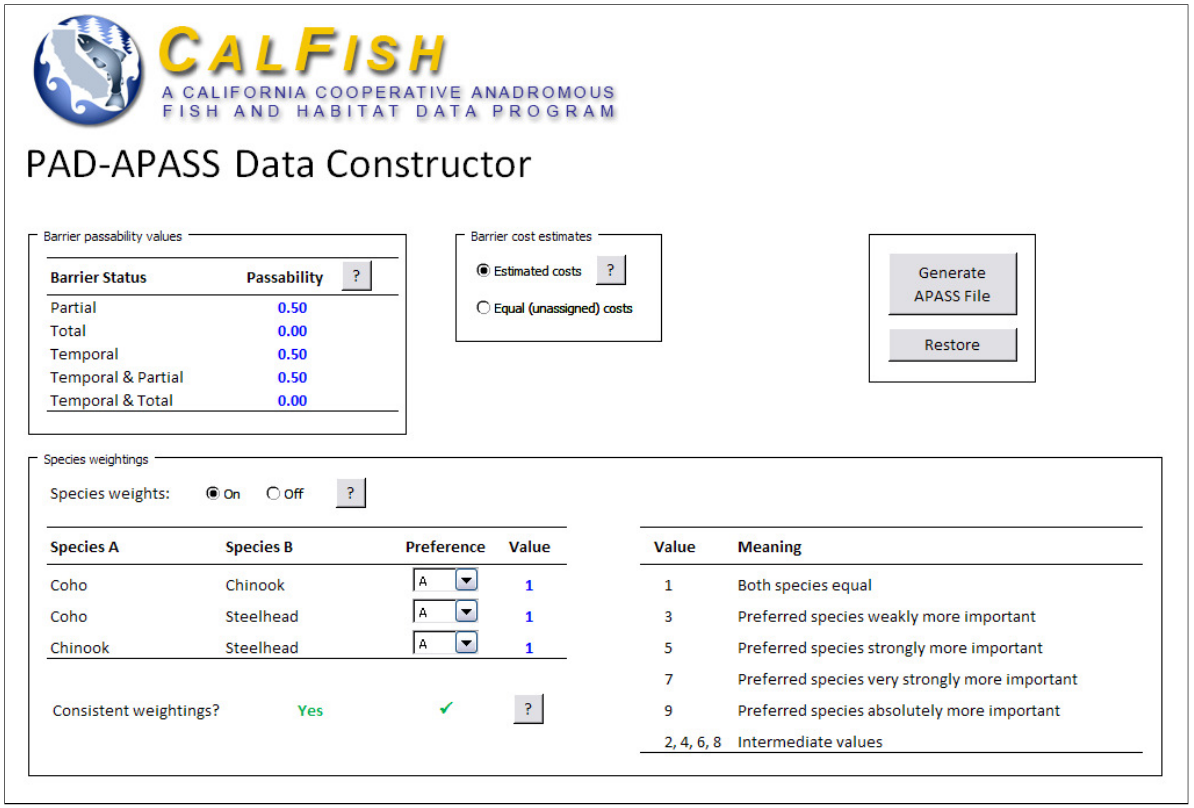
- Friendly graphical user interface (GUI)
- Easy upload of barrier datasets
- Performs optimization runs for any desired budget
- Performs batch runs (i.e., run the model across a range of budget values in set increments)
- Saves solutions as simple text files
- Carryout basic "what-if" analyses
  - Limit analyses to a subset of selected watersheds
  - Create user-defined solutions in which one or a handful of barriers are forced in or forced out of the final solution
- Handles
  - Multiple species, guilds, etc. (aka restoration targets)
  - Multiple alternative mitigation projects at any given barrier (e.g., fix the barrier a little or fix a lot)

Passage Assessment Database

- At the state level, the Passage Assessment Database (PAD) is *the* go-to resource for barrier data
- PAD contains geospatially referenced data on barriers throughout the state
  - More than 6000 barriers in total
  - Compiled from more than one hundred agencies, organizations and landowners throughout California
  - Includes key info like structure type, ownership and passability (i.e., impassable/partial/temporal)

PAD Scenario Manager

An Excel based interface for working with PAD and APASS



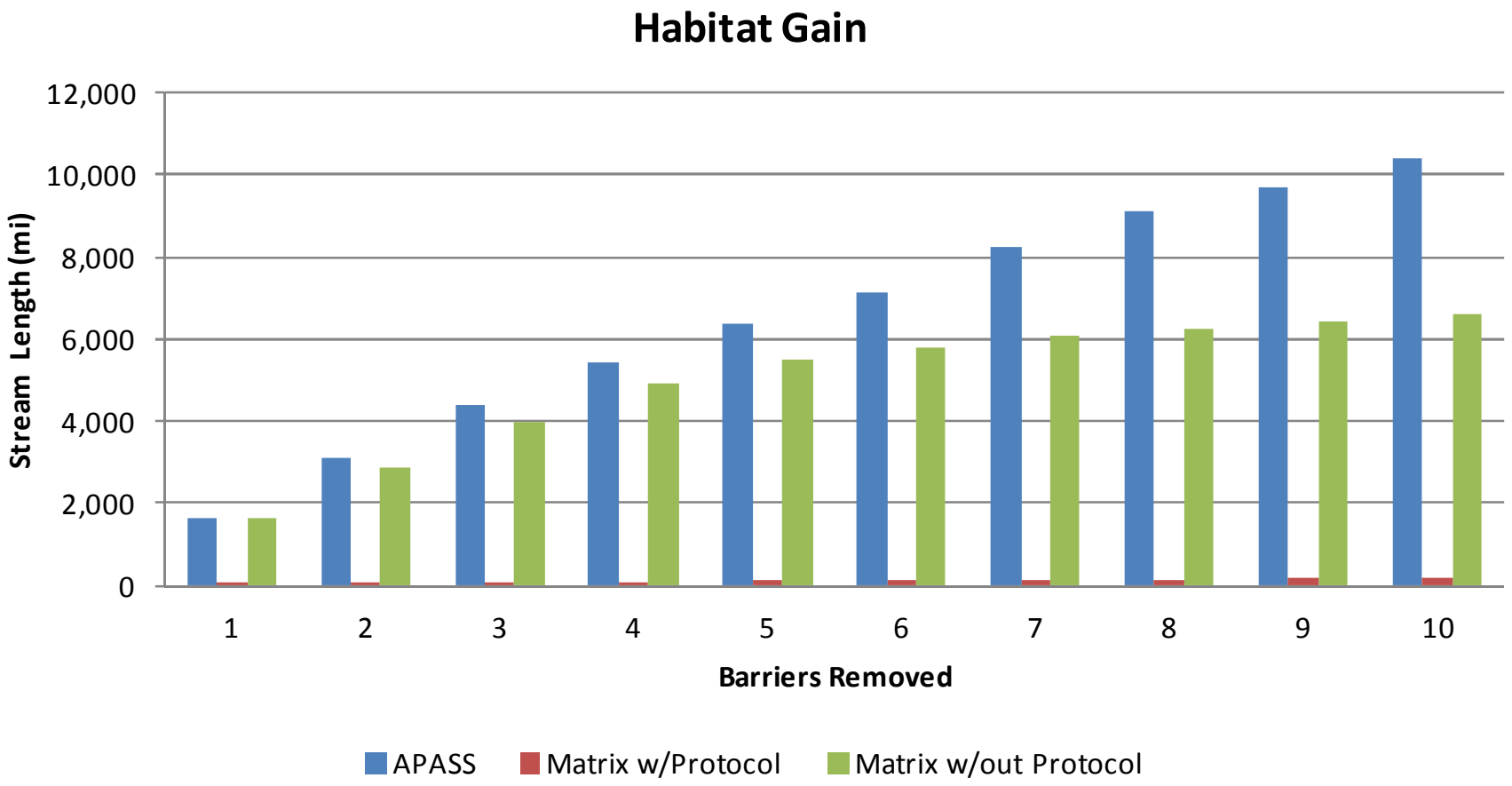
Scenario Manager functionalities

- Designed to generate APASS formatted files and subsequently summarize/analyze APASS results
- Helpful for carrying out more specialized what-if type analysis
- Allows users to optionally assign:
  - Barrier passability values
  - Mitigation costs
  - Species weights (i.e., relative importance of increasing habitat for Coho vs Chinook vs Steelhead vs “other”)
- Also provides a filter for
  - Focusing on specific regions of the state (Central Coast, Central Valley, North, South)
  - Specific ownership types (e.g., city, county, state, federal, private)

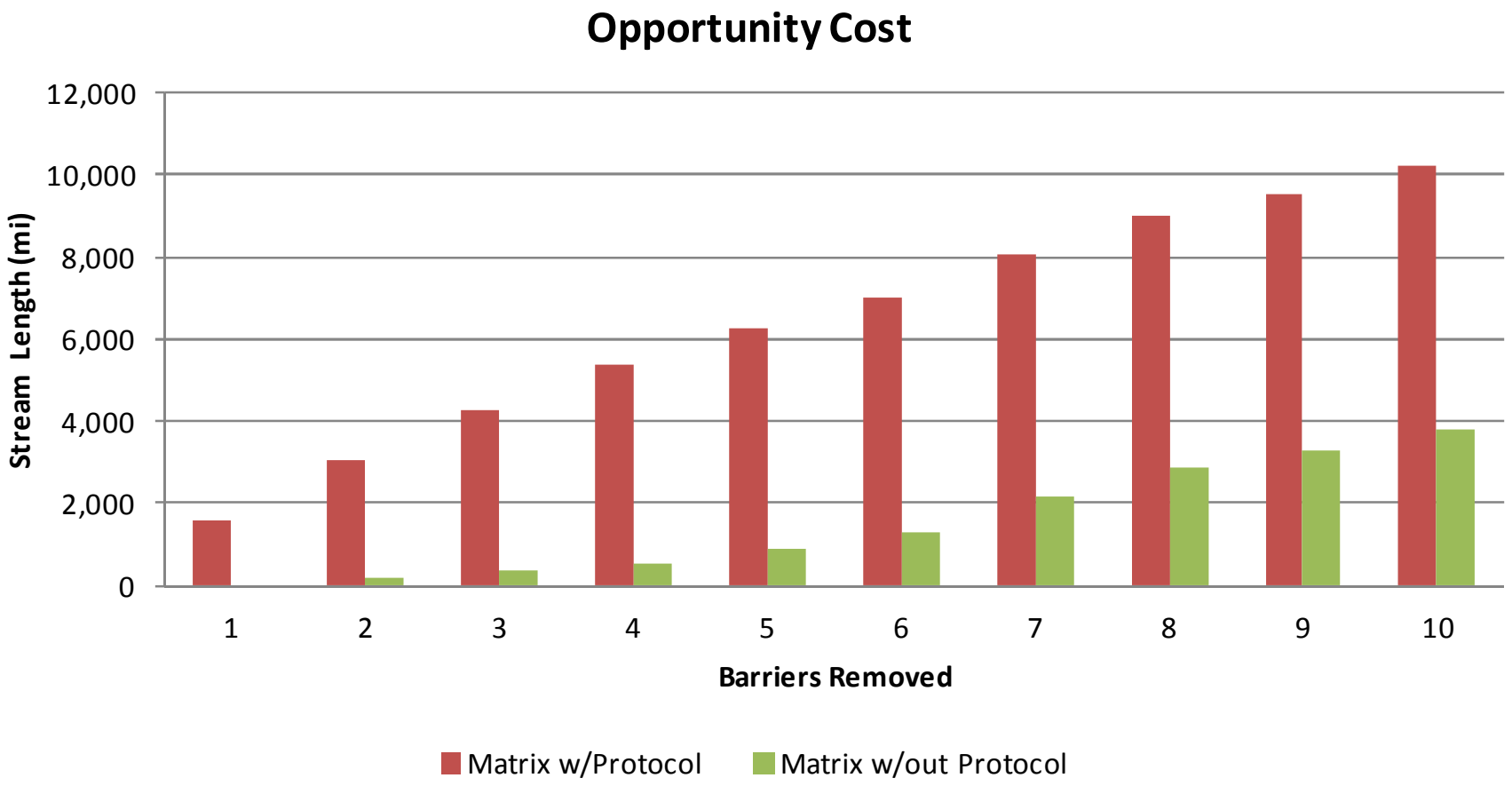
APASS – turbo injected with all the extras!

	APASS		Ranking Matrix		Ranking Matrix (without Protocol)	
Barriers Removed	Accessible Habitat (mi)	Habitat Gain (mi)	Accessible Habitat (mi)	Habitat Gain (mi)	Accessible Habitat (mi)	Habitat Gain (mi)
0	9,030	–	9,030	–	9,030	–
1	10,650	1,620	9,056	26	10650	1620
2	12122	3092	9097	67	11923	2893
3	13395	4365	9115	85	13014	3984
4	14487	5457	9124	94	13920	4890
5	15393	6363	9138	108	14510	5480
6	16159	7129	9161	131	14846	5817
7	17250	8220	9167	137	15106	6076
8	18156	9126	9170	140	15279	6249
9	18746	9716	9192	162	15467	6437
10	19447	10417	9213	183	15632	6602

Put another way …



Or on the flip side …



What's wrong with Scoring & Ranking?

- Usually ignores spatial structure
  - Connectivity invariably affected by passability at barriers downstream!
  - In this regard, the ranking matrix is way better than most in that it considers barrier order as a criterion
- Repair decisions made independently
  - Assumes passability at other barriers remains fixed
  - Doesn't allow for coordinated planning
- Put another way, S&R ignores the interactive effects that multiple barrier mitigation actions have on cumulative passability
- Optimization overcomes all this in spades

Is there an economist in the room?

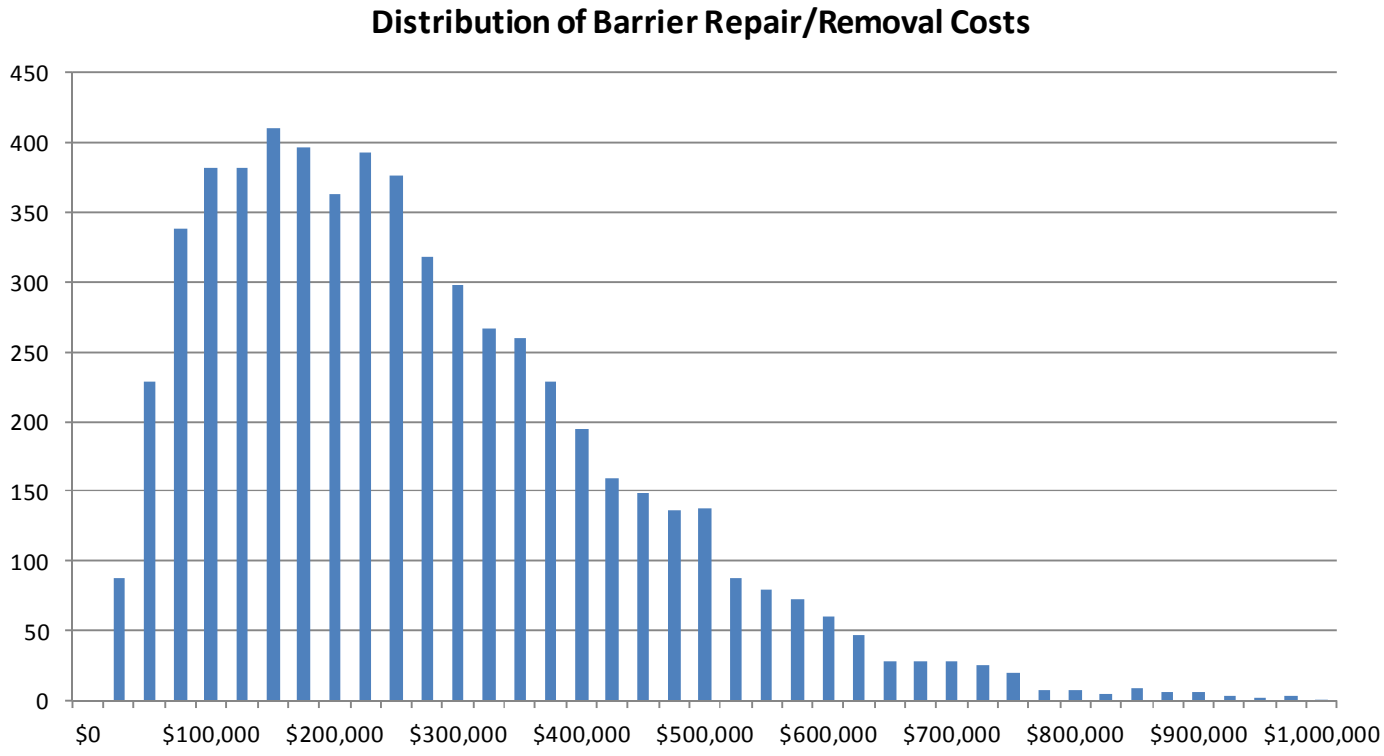
- In the previous analysis we were completely ignoring the cost of repairing/removing barriers
- Factoring in costs, however, can make a big difference as to which barriers you choose to fix
- Question: Would you rather remove the barrier that gets you the single biggest habitat gain of 50 miles at a cost of $200K or remove 3 different barriers for the same cost but that combined get you 80 miles of habitat?
- Answer: … I know what I'd choose

Understanding the impact of costs

- Carried out experiments looking at prioritization based on:
  - Habitat alone (all barriers have the same cost of removal) versus
  - Combination of habitat and estimated mitigation cost
- Cost estimates generated at random from a distribution fitted to a sample of 40 culvert mitigation projects obtained from the California Habitat Restoration Project Database (CHRPD)

Distribution of costs

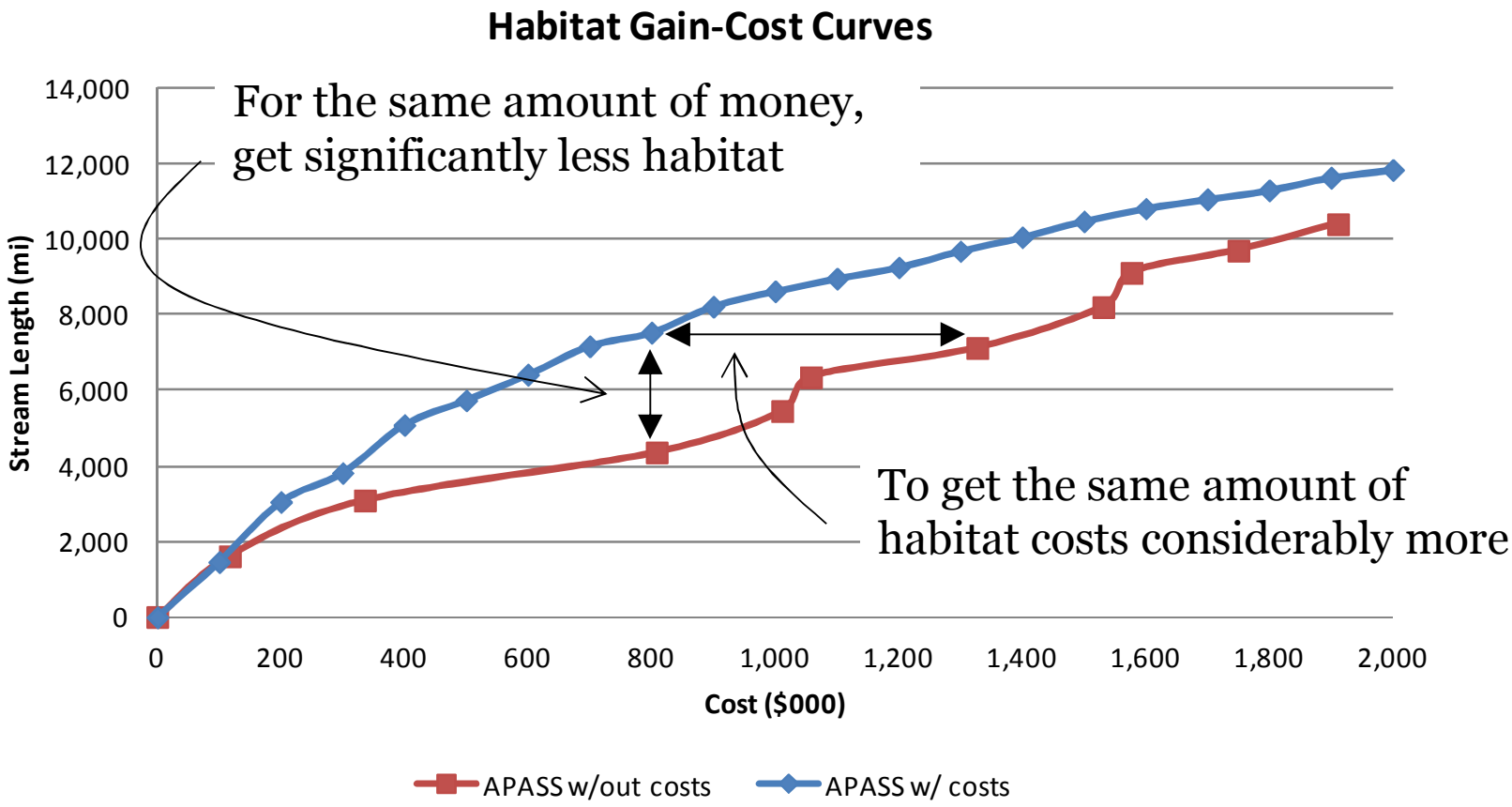
Generated cost estimates ranged from $8,600 to $1.26M with an average of $258k and were right skewed



Surprise, surprise

Excluding Costs			Including Costs	
Barriers Removed	Cost ($000s)	Habitat Gain (mi)	Cost ($000s)	Habitat Gain (mi)
1	117	1620	117	1620
2	336	3092	336	4433
3	808	4365	808	7558
4	1,012	5457	1,012	8649
5	1,058	6363	1,058	8851
6	1,327	7129	1,327	9900
7	1,531	8220	1,531	10569
8	1,577	9126	1,577	10664
9	1,750	9716	1,750	11145
10	1,911	10417	1,911	11656

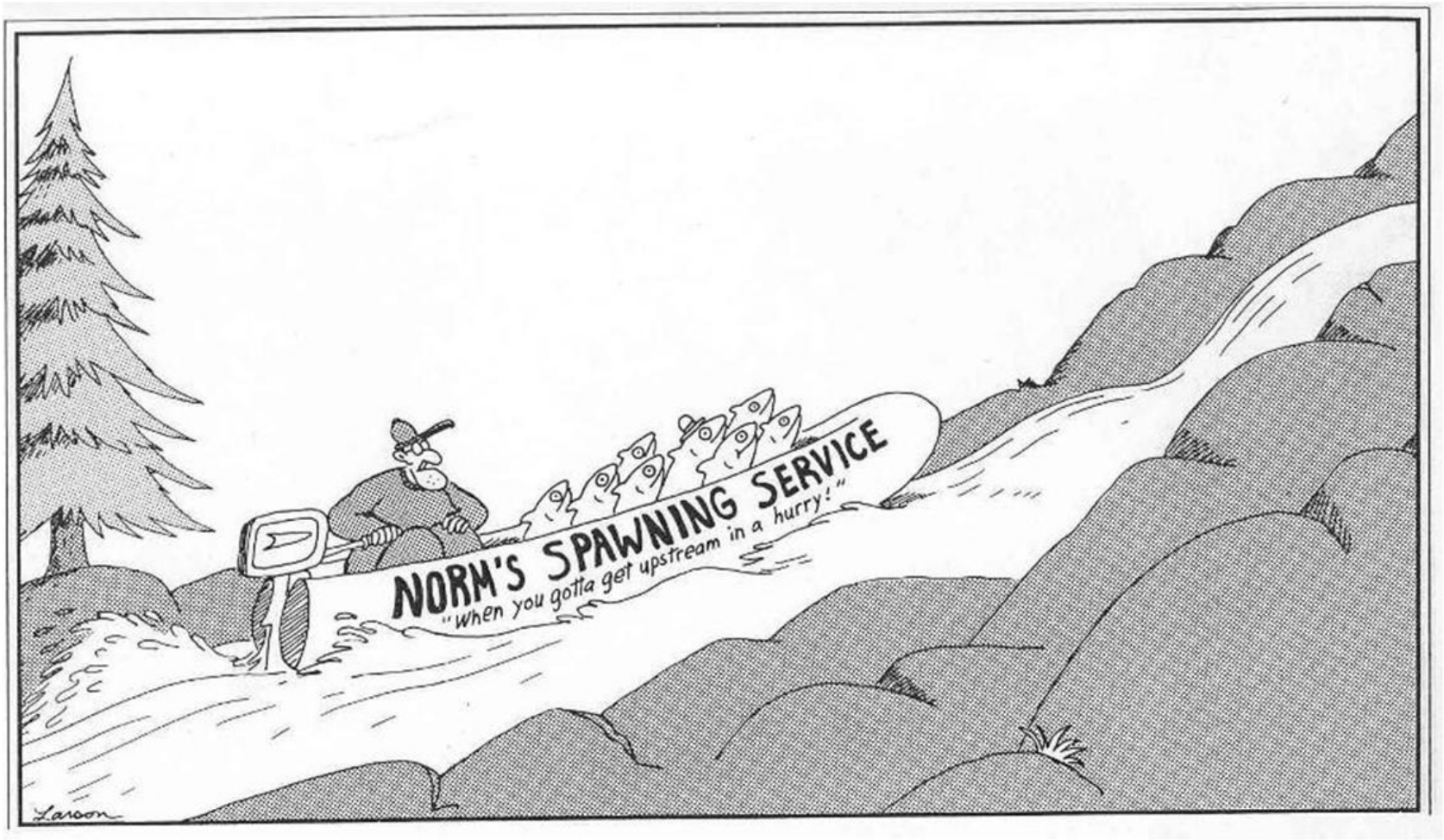
Any way you slice it, ignoring costs leaves a lot on the table

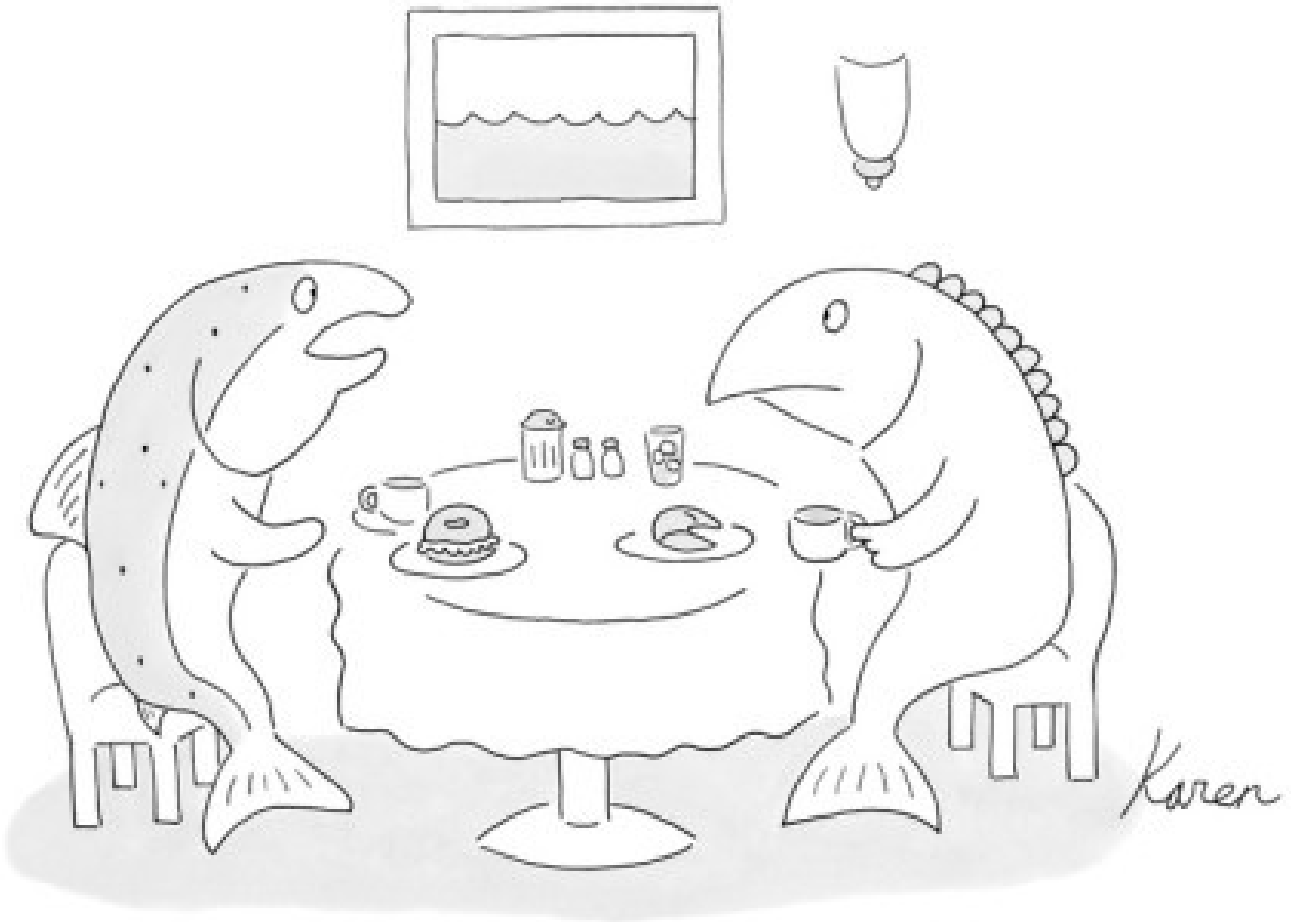


Thank you …

I’m here all week!

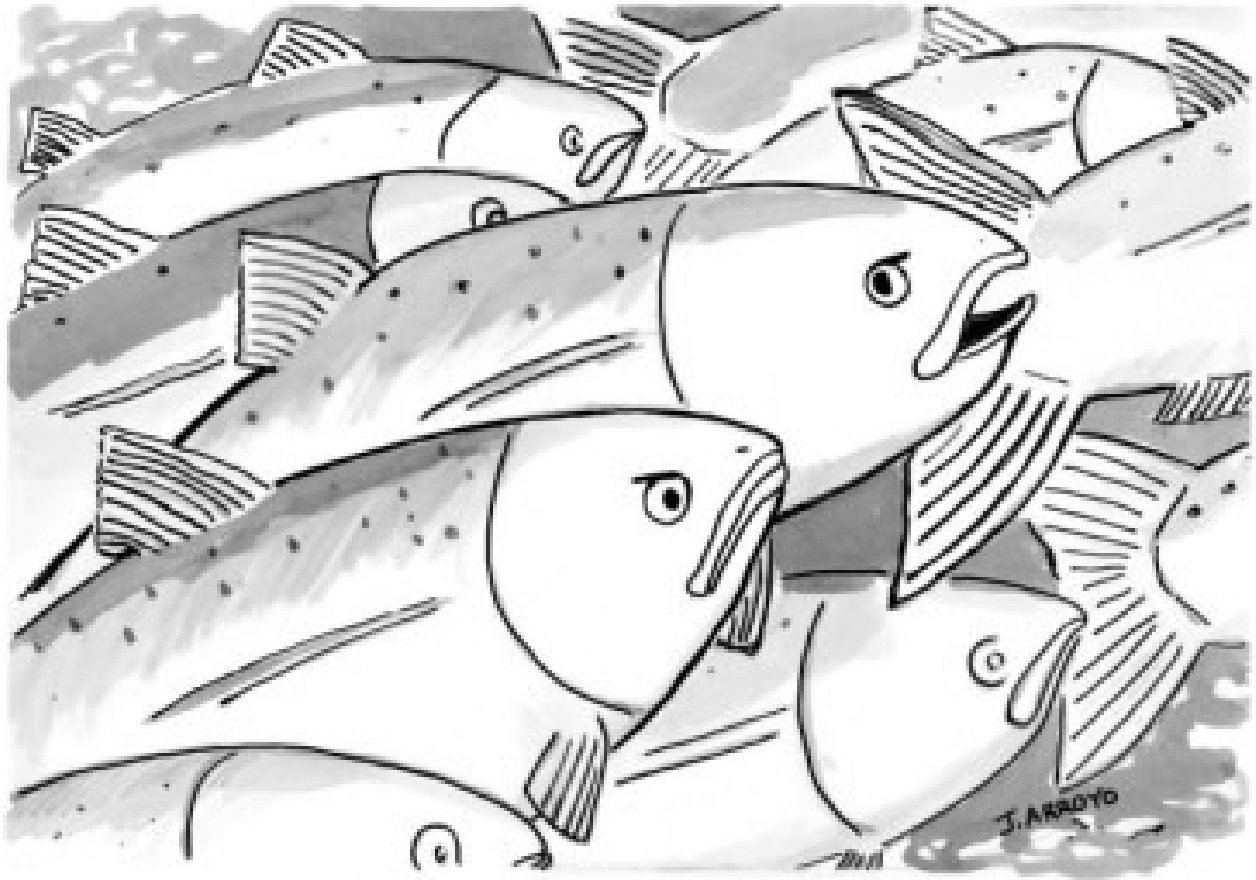
Encore?


NORM'S SPAWNING SERVICE
"When you gotta get upstream in a hurry!"
Larson



"We spawned once, but I only pretended to die."

"Next year, I'm pleasuring myself."



"Well, you have three hundred miles and two more waterfalls to get in the mood!"