

Passage performance of fishways:



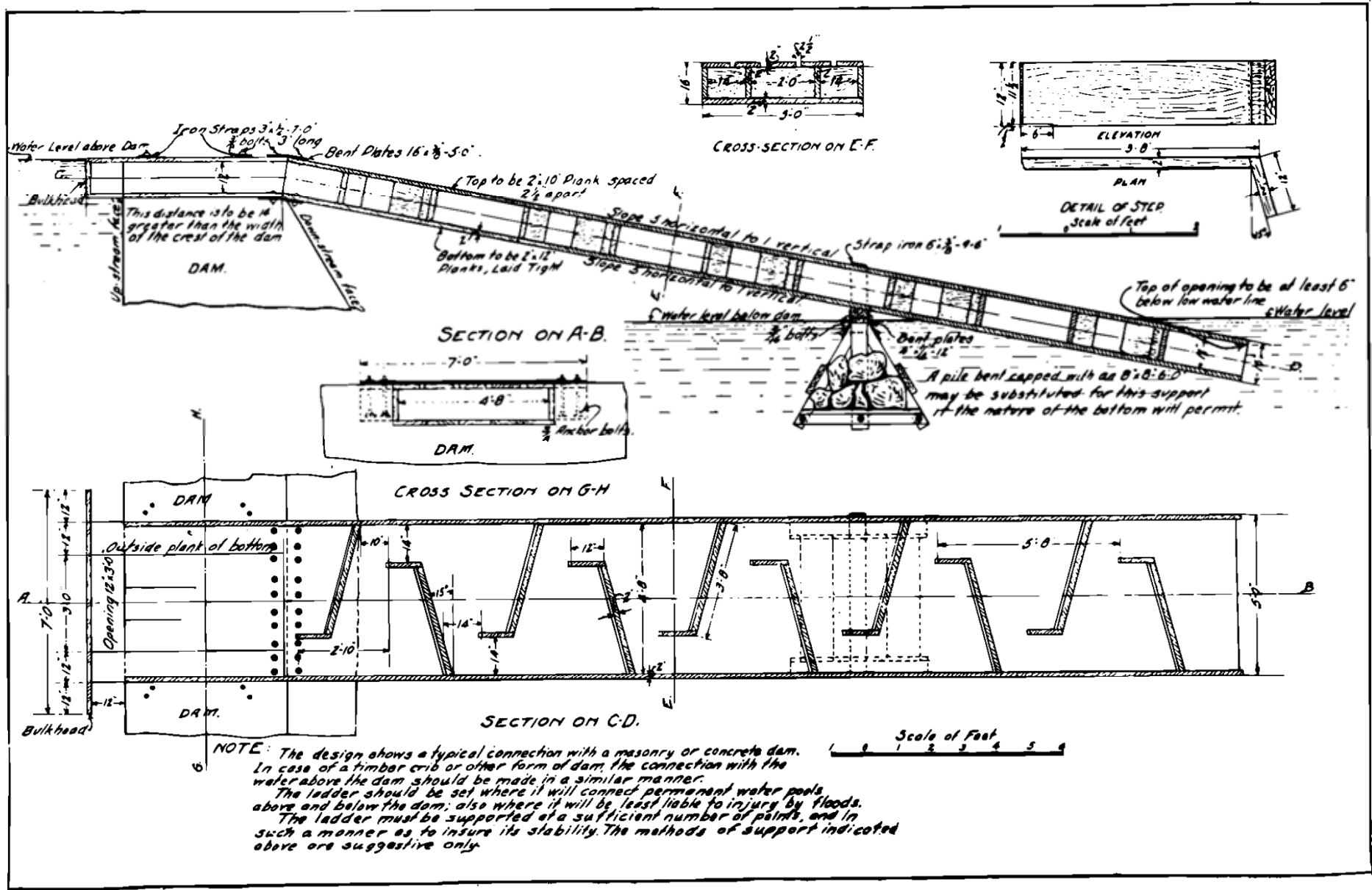
Toward a holistic understanding of effectiveness
and a framework for adaptive design.

T. Castro-Santos
S.O. Conte Anadromous Fish Research Center

A Little History

- Dusting off the archives
 - Worrall (1873)
 - Rogers (1892)
 - Cheney (1898)
 - Buck (1906; 1913)
 - Dyche (1912)
 - Prince (1913)

Source: Gary Whelan, History Section

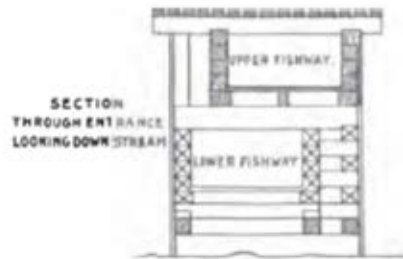


Estimated Cost of Materials for an 8' Dam: \$99

Dyche (1912)

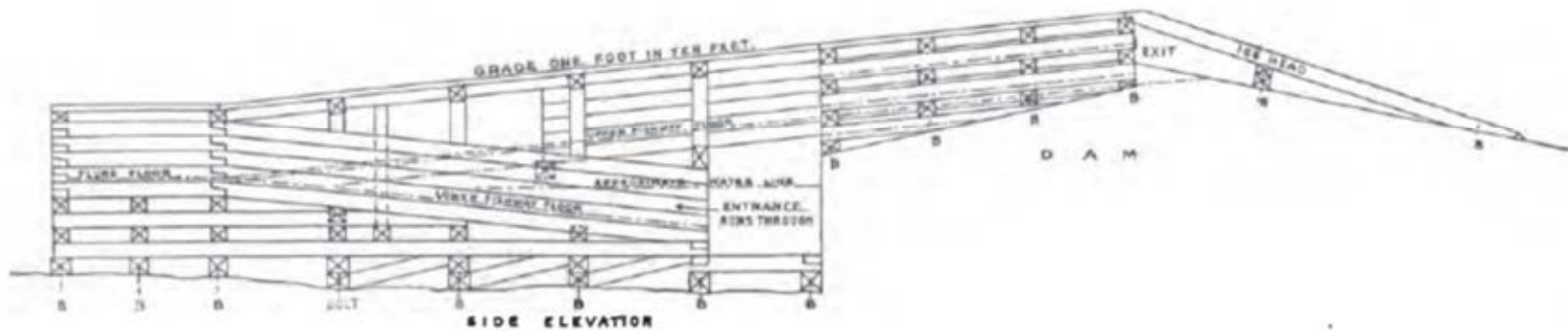
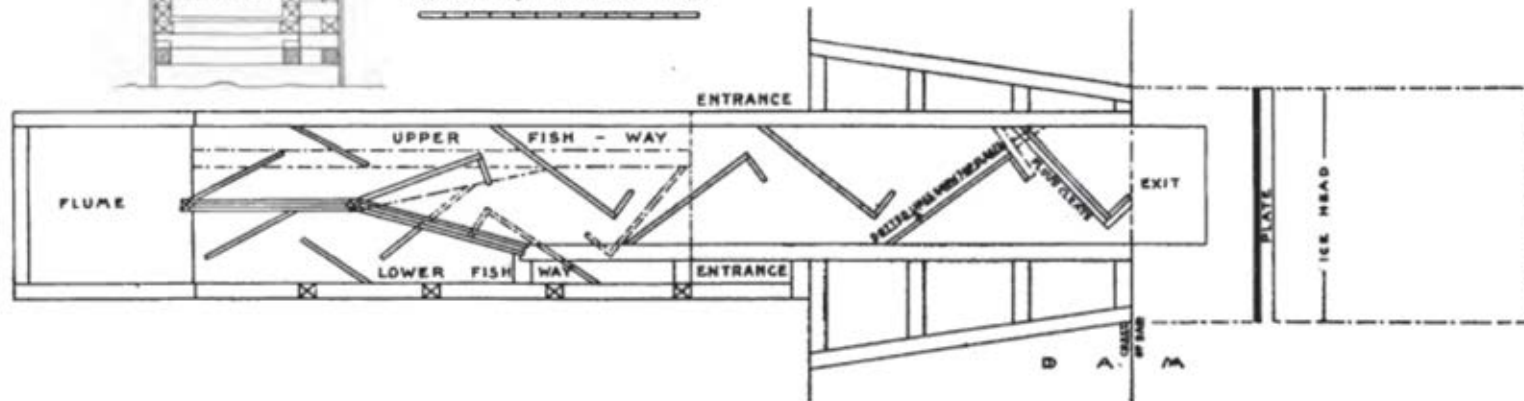


ORIGINAL McDONALD FISHWAY WITH WATER SHUT OFF, IN GREAT FALLS OF THE POTOMAC.

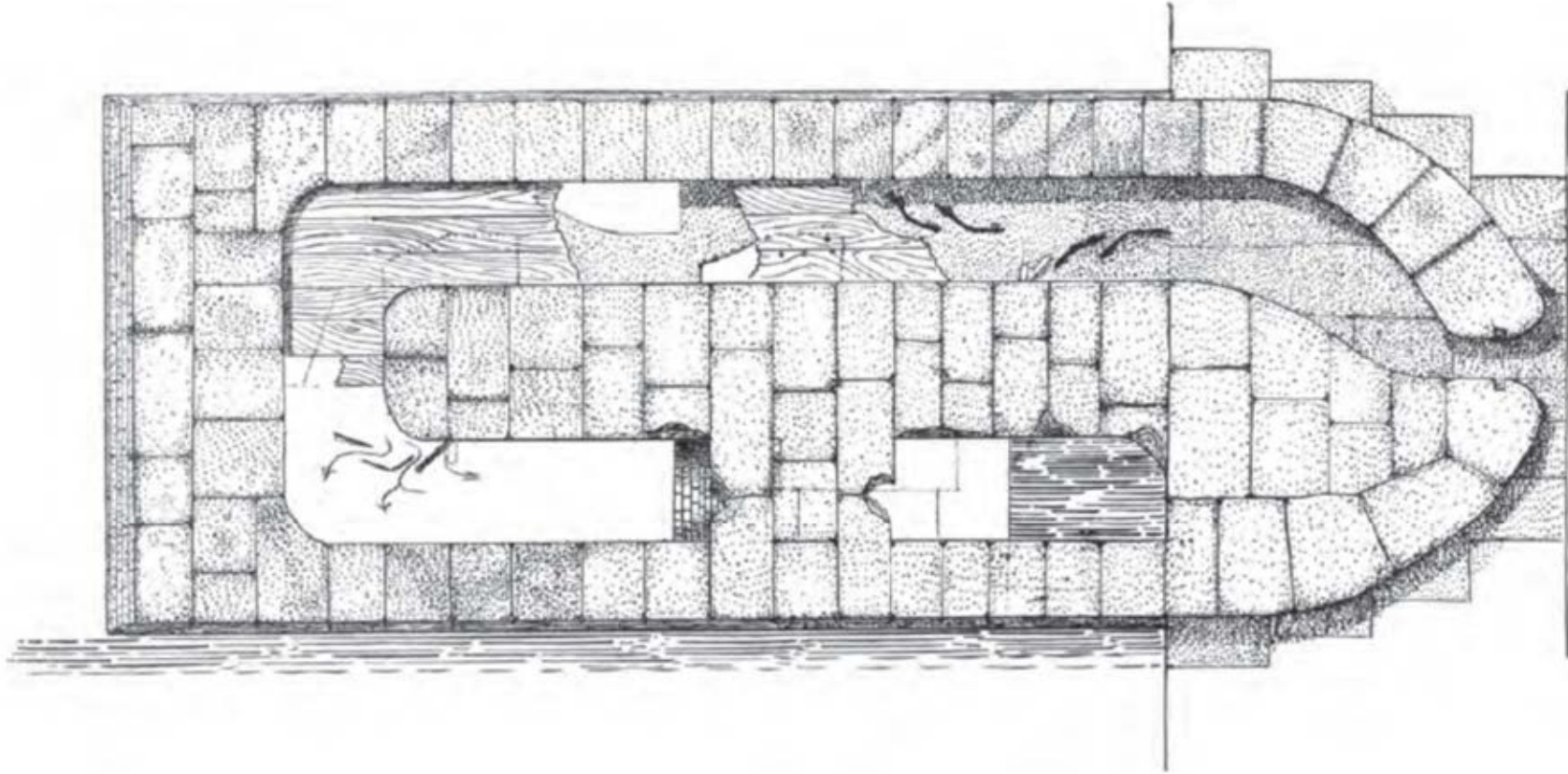
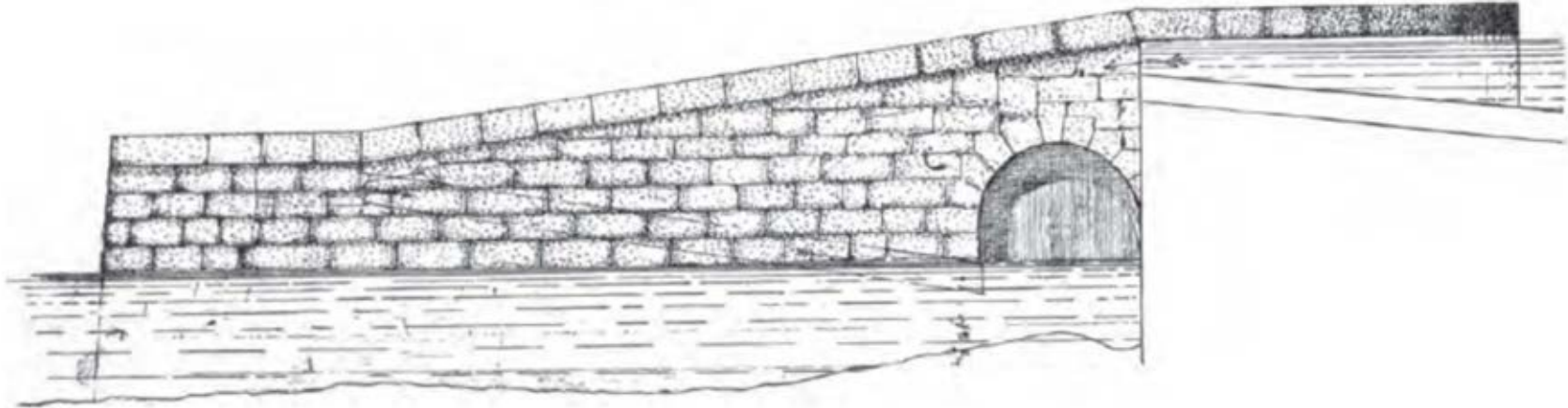


DETAIL DRAWING OF THE ROGERS FISHWAY
 FOR THE ROCK BOTTOM DAM
 AT BINGHAMTON N.Y.
 W.H. ROGERS BOSTON MASS.

SCALE TWO FEET TO ONE INCH



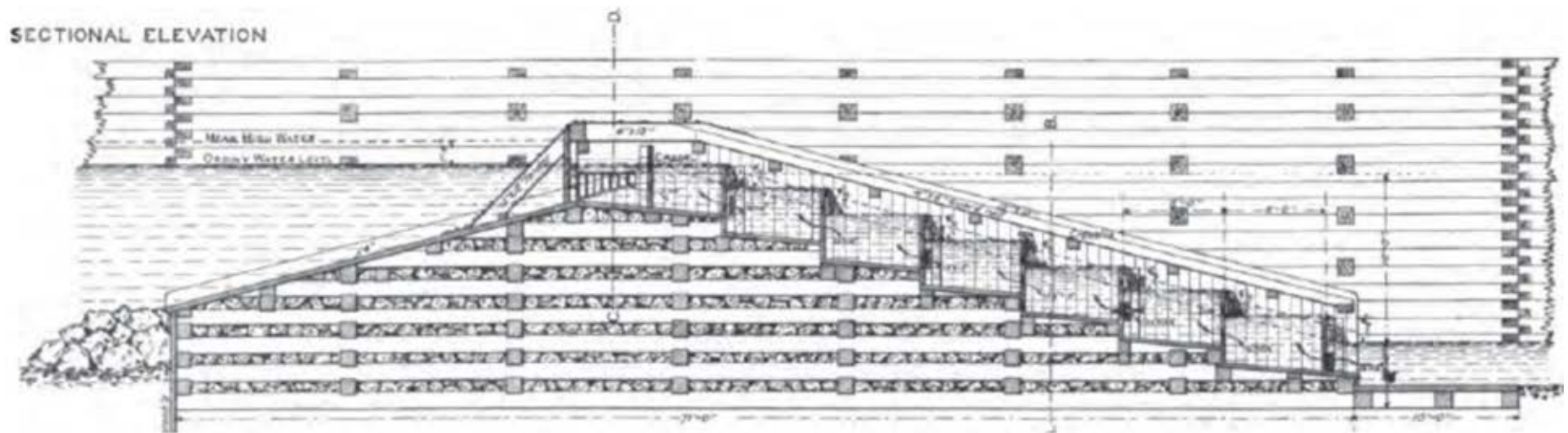
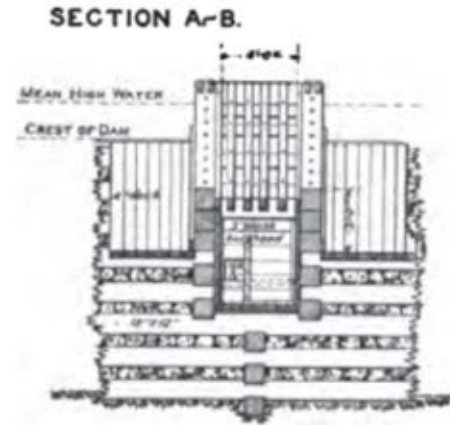
PLAN OF CONSTRUCTION ROGERS FISHWAY.
 TOP AND SIDE COVERING NOT SHOWN.



FROM ORIGINAL STUDY FOR FISHWAY ON RIVER VIENNE, FRANCE, BY MARSHALL McDONALD. PLAN AND SIDE ELEVATION.

Worrall (1873)

“...The timidity of the shad has baffled us a little at the outset, but we will yet accommodate him, and fishways will be made as attractive to him as to the salmon, The history of this fishery movement will become interesting one of these days, and I read this paper in the interest of the truth of that history. ...There is no doubt of ultimate success for we are moving in the right direction, even if we have not struck the actual pathway.”

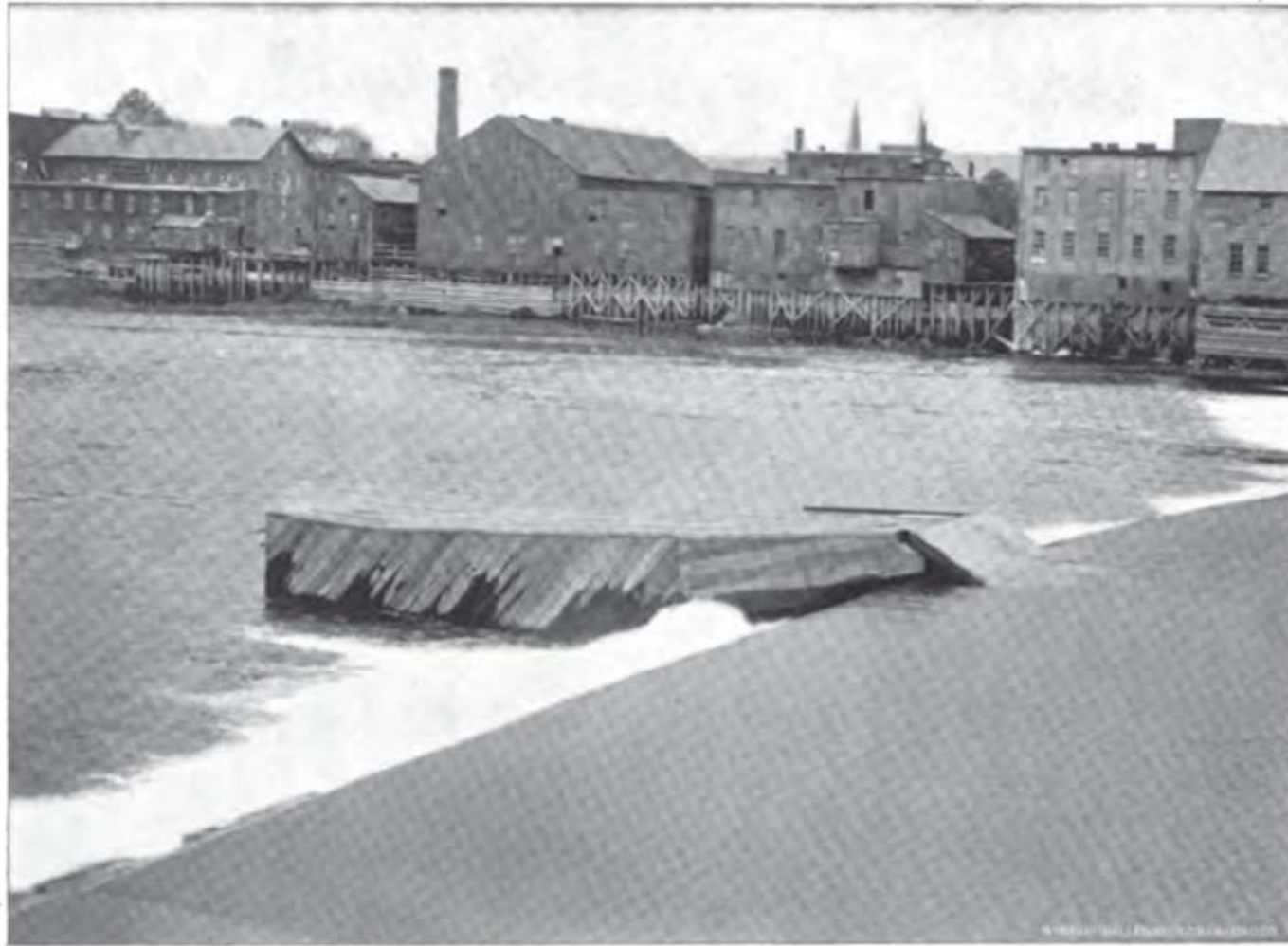


SECTIONAL ELEVATION AND CROSS SECTION IMPROVED CAIL SYSTEM FISHWAY.

APPROVED BY UNITED STATES FISH COMMISSION.

Rogers (1892)

The Rogers' Fishway, ... leaves nothing to be desired in a successful fishway ... therefore there is no need in longer spending money in fruitless experiments on theoretical and useless devices as in the past, but address ourselves to the more practical work of passing the fish up the stream as fast as possible.



DOWN-STREAM VIEW OF ROGERS FISHWAY IN SUSQUEHANNA RIVER, AT BINGHAMTON.
CONSTRUCTED UNDER THE DIRECTION OF THE FISHERIES, GAME AND FOREST COMMISSION.

State of Fish Passage Bioengineering: 1914

- Poor Fish Passage at obstacles is a primary factor limiting fisheries (both freshwater and coastal)
- Fishways aren't working
- Some claim to have the problem solved —
- Others greet these claims with derisive skepticism
- Upstream passage for Salmon and eels appears effective
- No-one knows what to do about shad
- Movement toward Nature-Like fishways and Spiral Designs

Williams et al. 2012

Research and experience suggest that with sufficient laboratory testing, it is possible to determine hydraulic conditions that fish will actively use as a conduit and develop a fishway that will effectively pass most upstream migrants of any species over a dam of just about any height. Nonetheless, economic considerations might limit the ability to construct an effective fishway for fish without good swimming abilities at dams of considerable height.

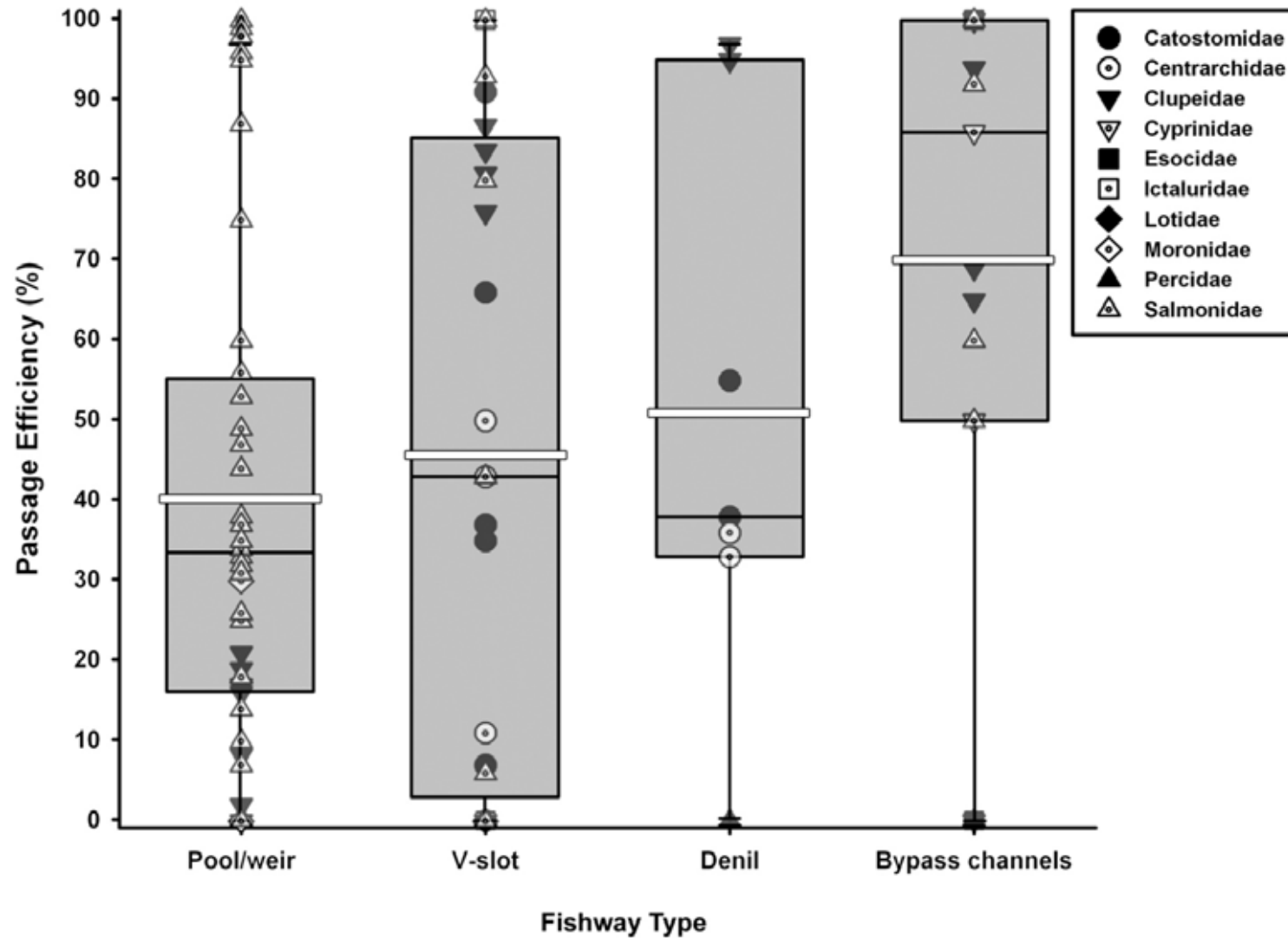


Thankfully, the Germans have solved the problem...

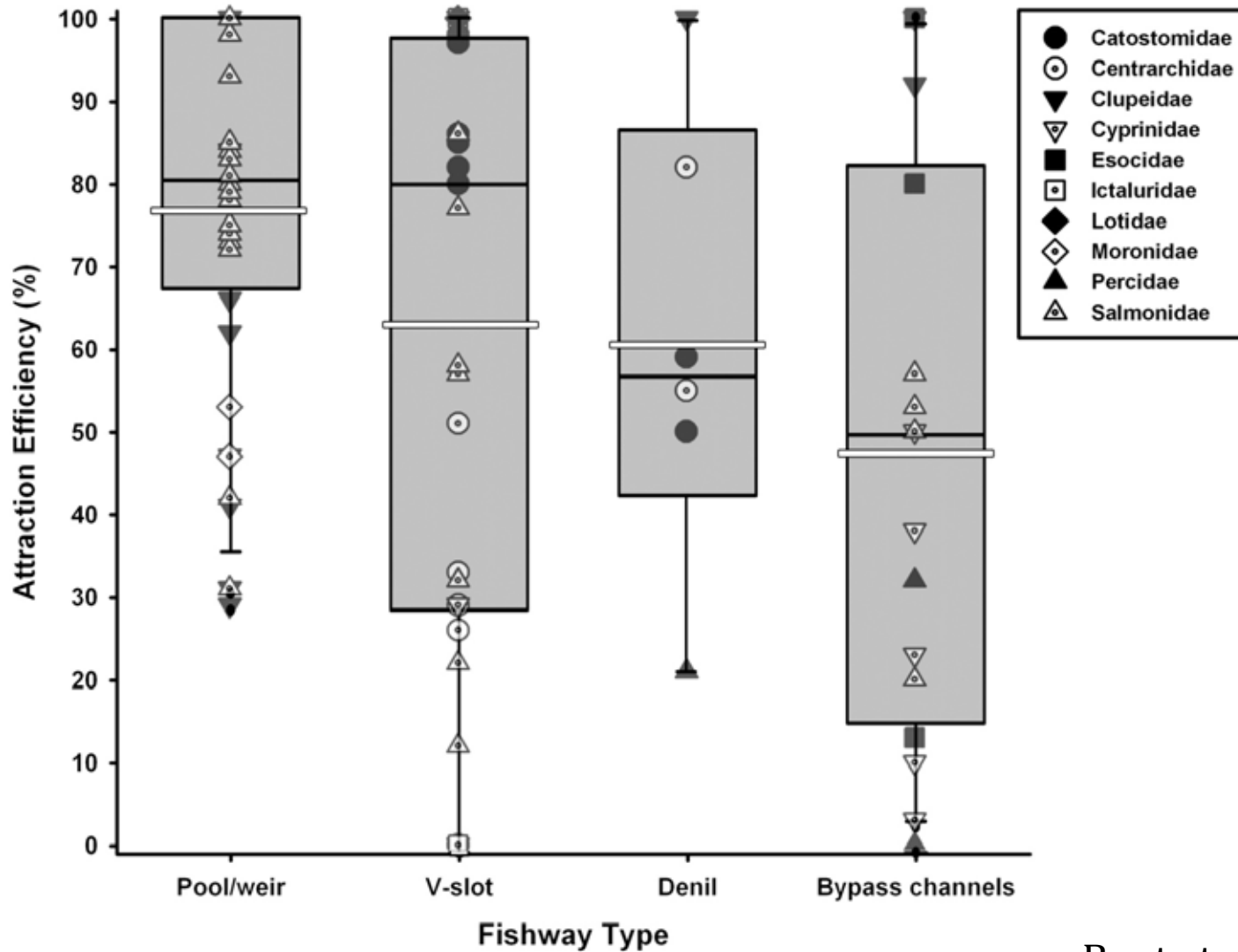


‘Quality Assurance’ in lieu of biological monitoring

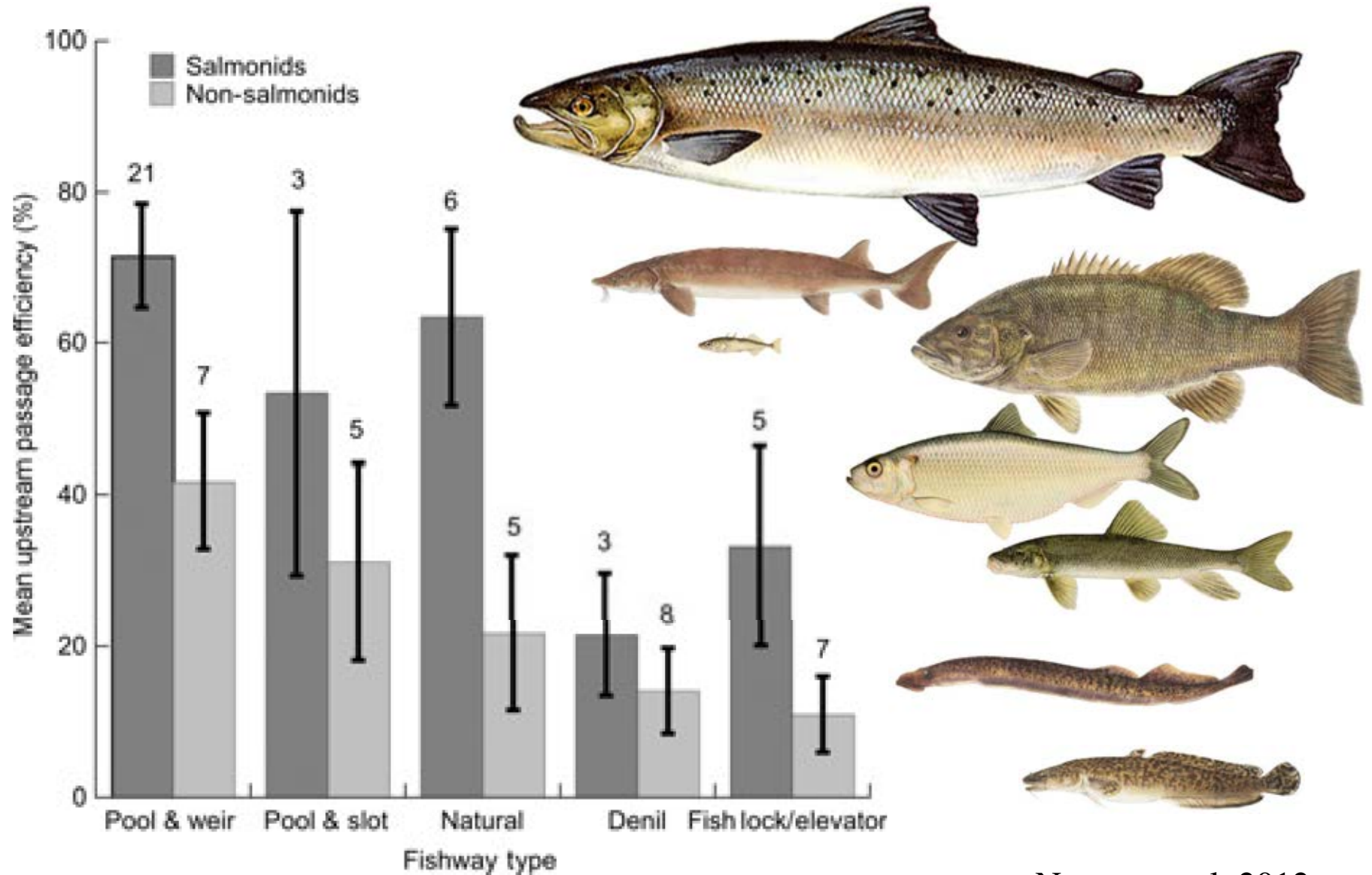
Percent Passing



Percent Entering



Confirmation is as good as affirmation

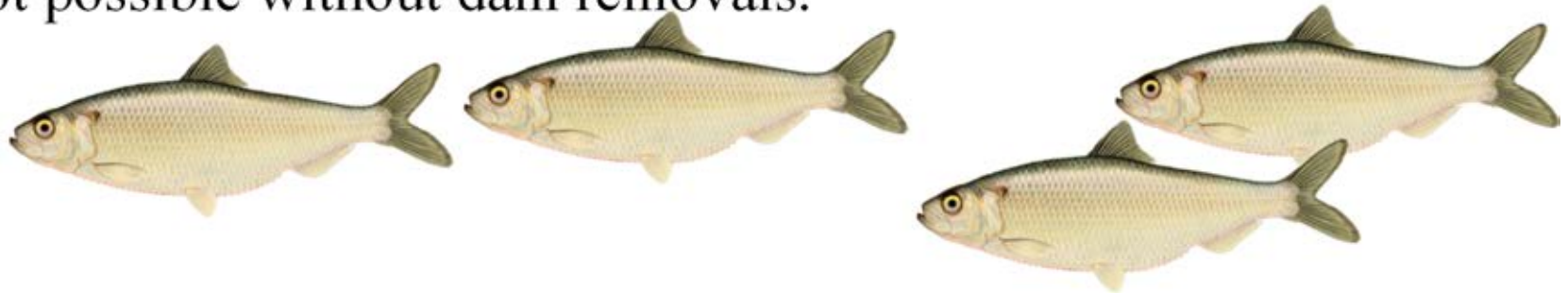


State of Fish Passage Bioengineering: 2014

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What is keeping fishways from working?

- Bunt et al. (2012): “...This meta-analysis revealed that the species of fish monitored and structural design of the fishways have strong implications for both attraction and passage performance, and in most cases, **existing data are not sufficient to support design recommendations.**”
- Brown et al. (2013): “...It may be time to admit failure of fish passage and hatchery-based restoration programs and acknowledge that significant diadromous species restoration is not possible without dam removals.”

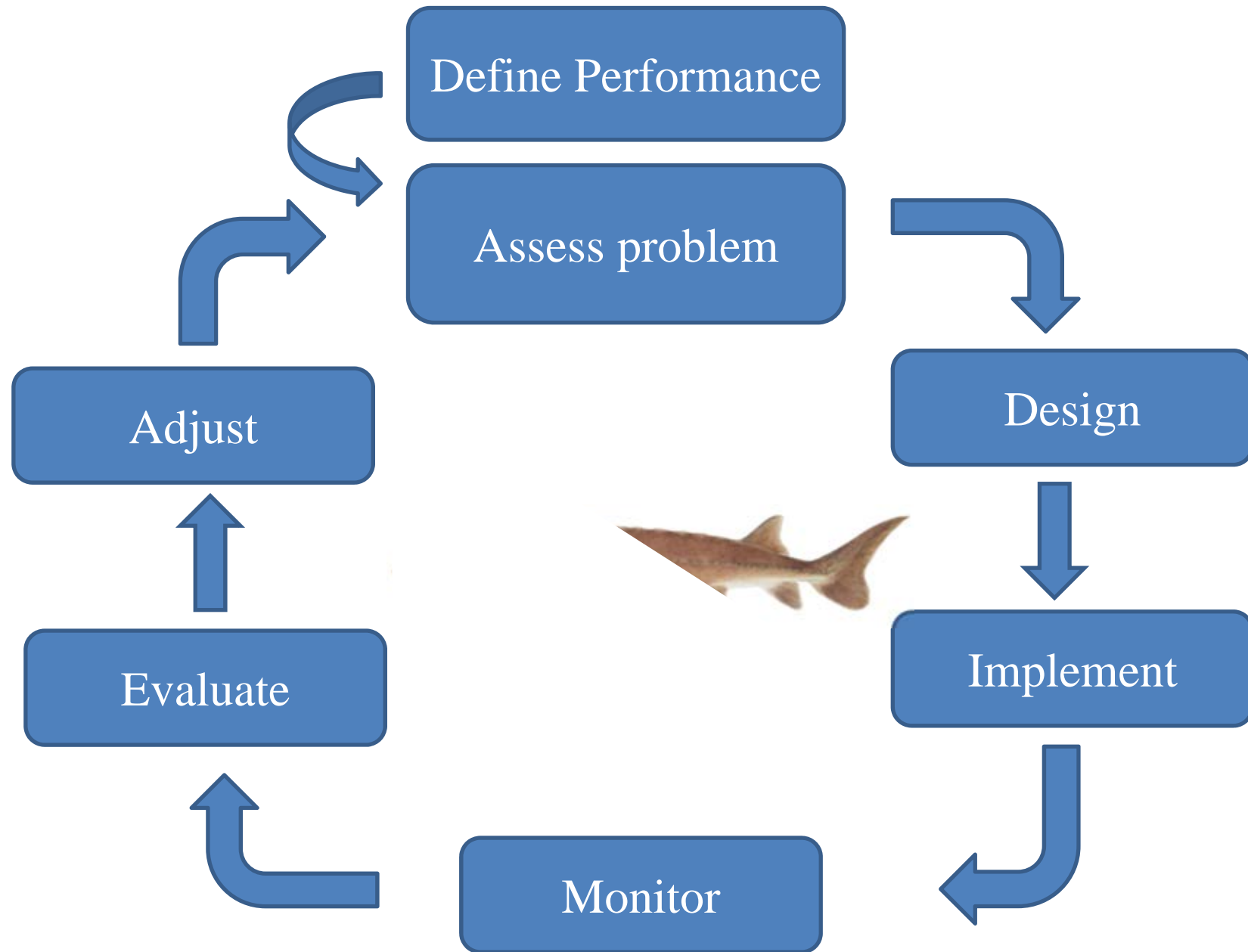


The credibility crisis and the need for adaptive management

- Consensus: claims of victory are premature
- Adaptive management –a tool for tricky problems
- Standardized protocols:
 - Take advantage of existing infrastructure
 - Incremental progress toward design optimization
 - Empirically observable patterns can be used to frame hypotheses and design experiments
 - Necessary components to Adaptive Management



Adaptive Management—what is it?

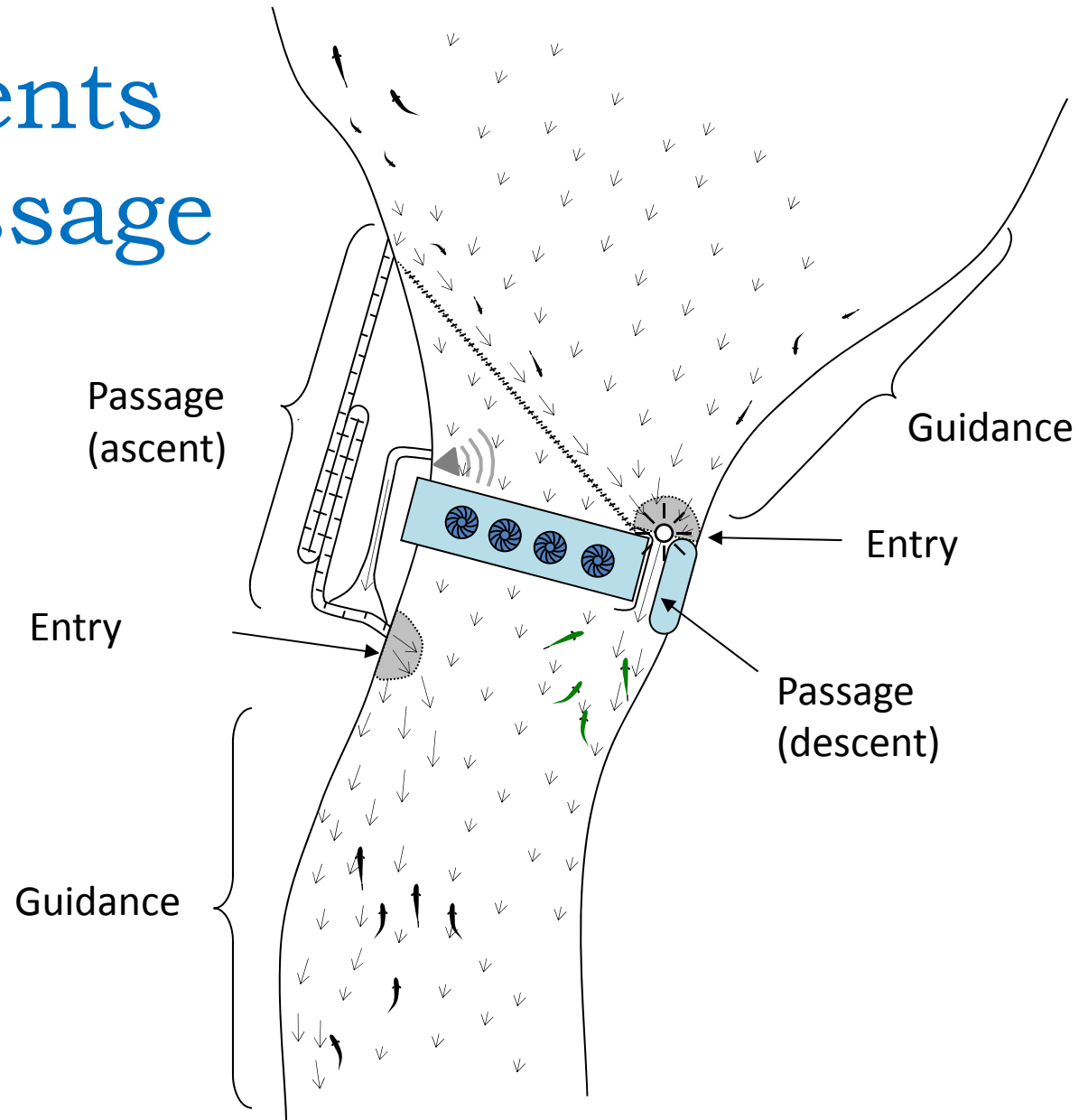


Adaptive Management: Application

- To be robust and universal, evaluations need to be founded on Movement Theory
- Proper identification of performance metrics
- Recognize drivers:
 - ‘One way to pass, six ways to fail’



Elements of Passage



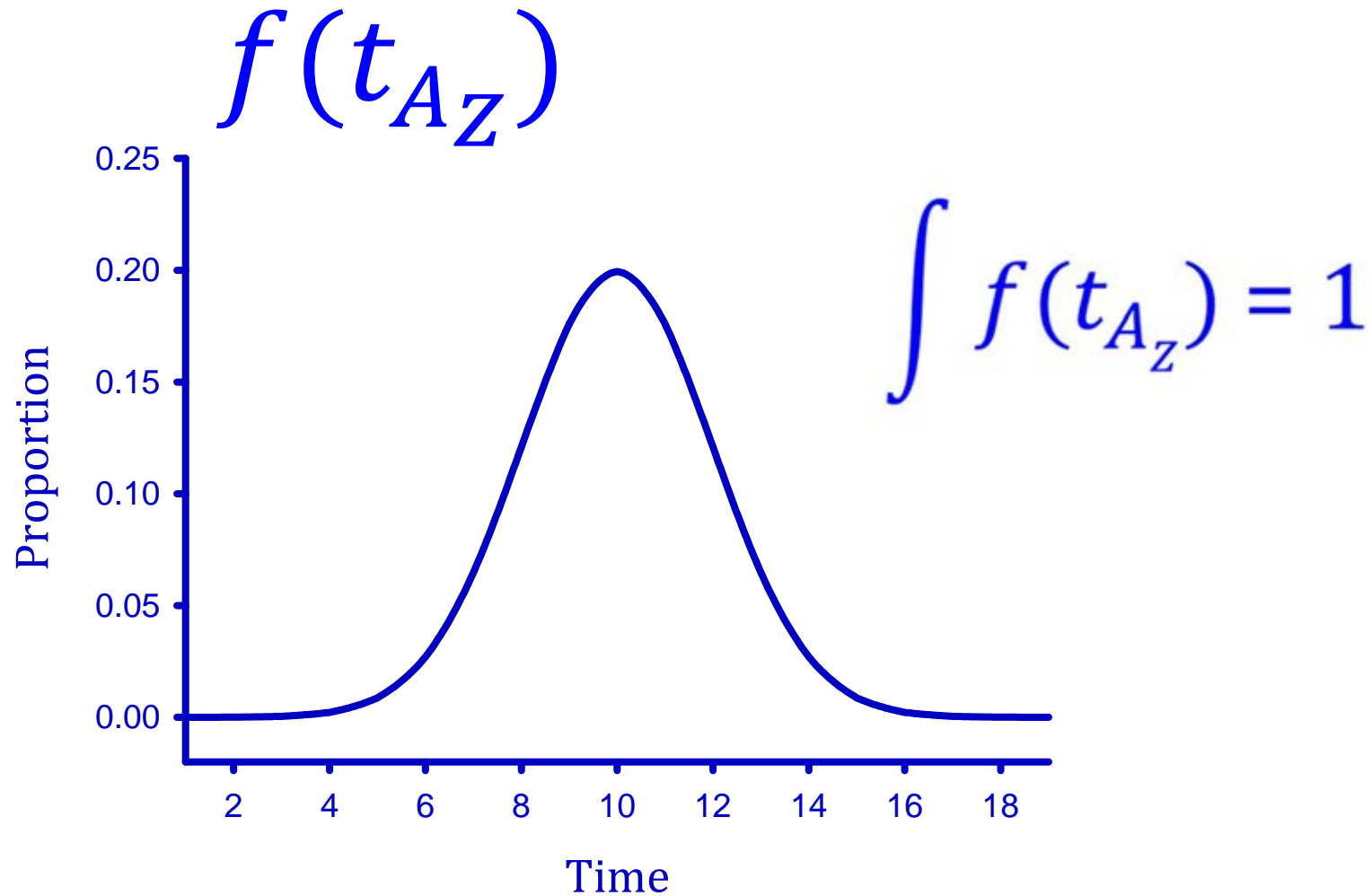
A unifying formula for fish passage?

$$P(P) = \prod_{z=G}^A \int_t f(t_{A_z}) \times S(t_{R_z}) dt$$

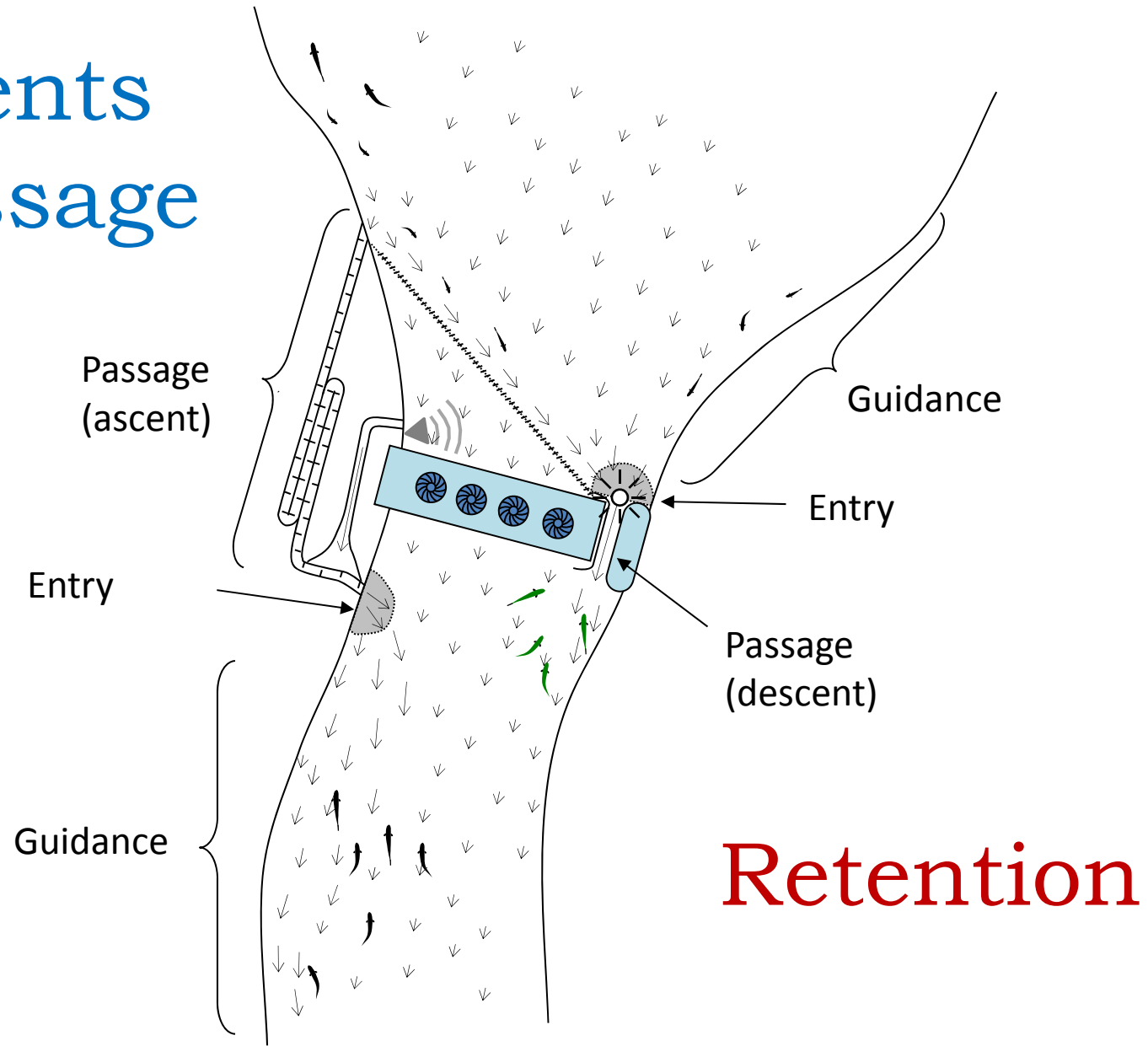
$f(t_{A_z})$ = pdf of arrival time to next zone
(i.e. guidance, attraction, or passage)

$S(t_{R_z})$ = Survivorship function of Retention Time
within a zone

Rate of progress (Advance)

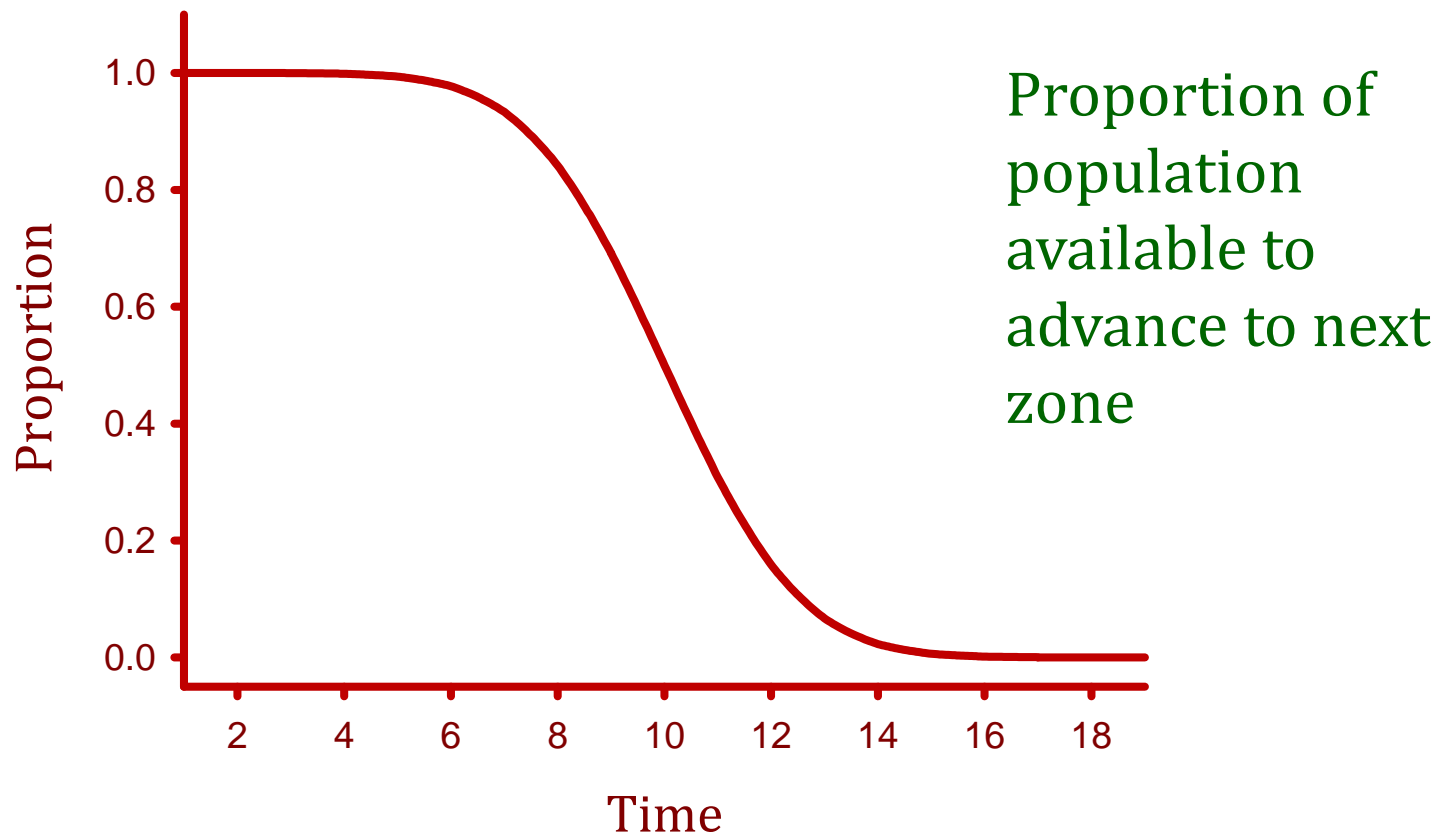


Elements of Passage



Retention time

$S(t_{R_7})$ Complement of the cdf



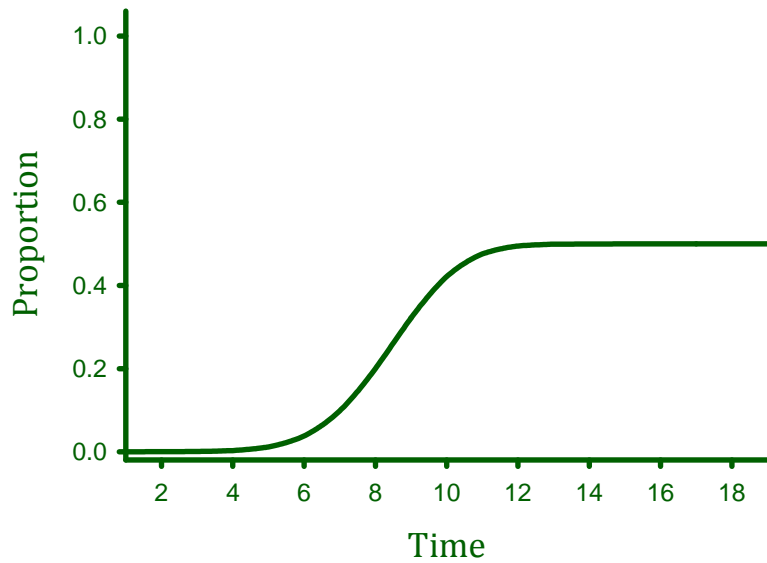
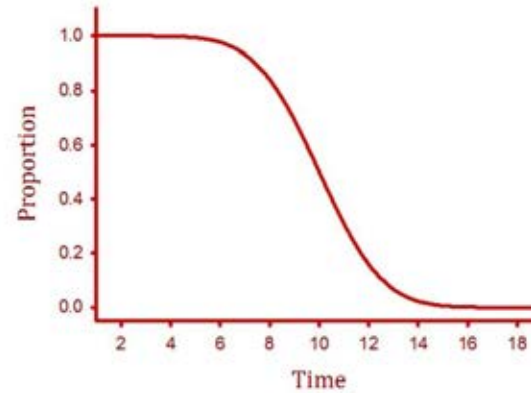
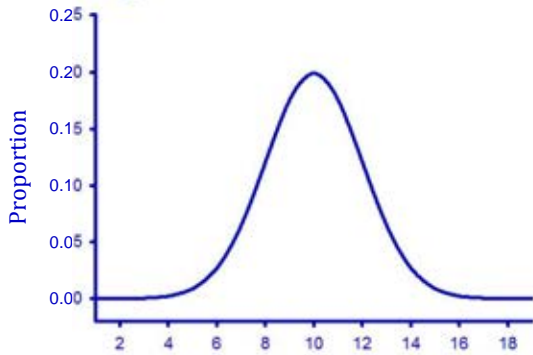
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$$\int f(t_{A_Z}) \times S(t_{R_Z})$$



Proportion
advancing
to the next
zone

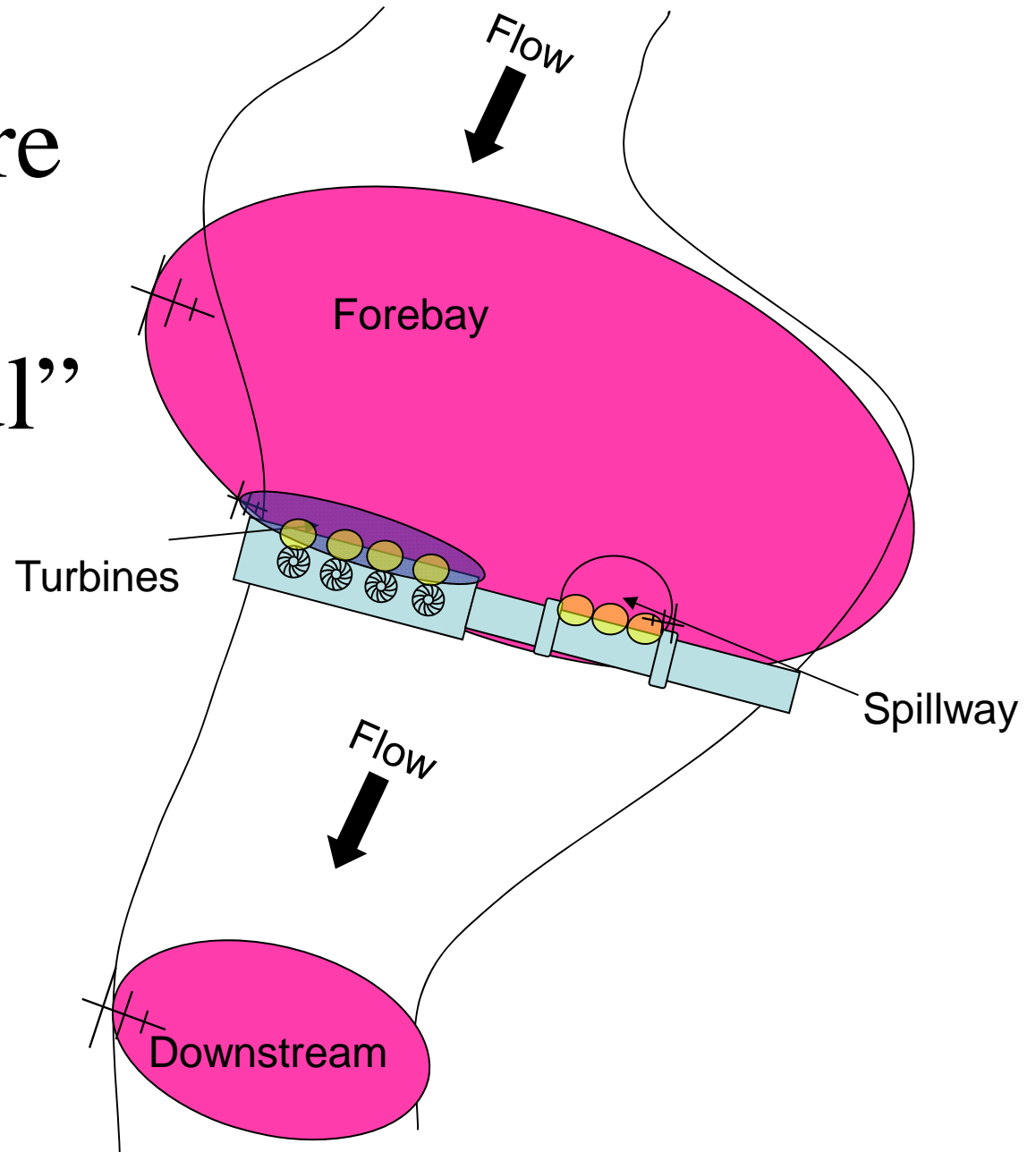
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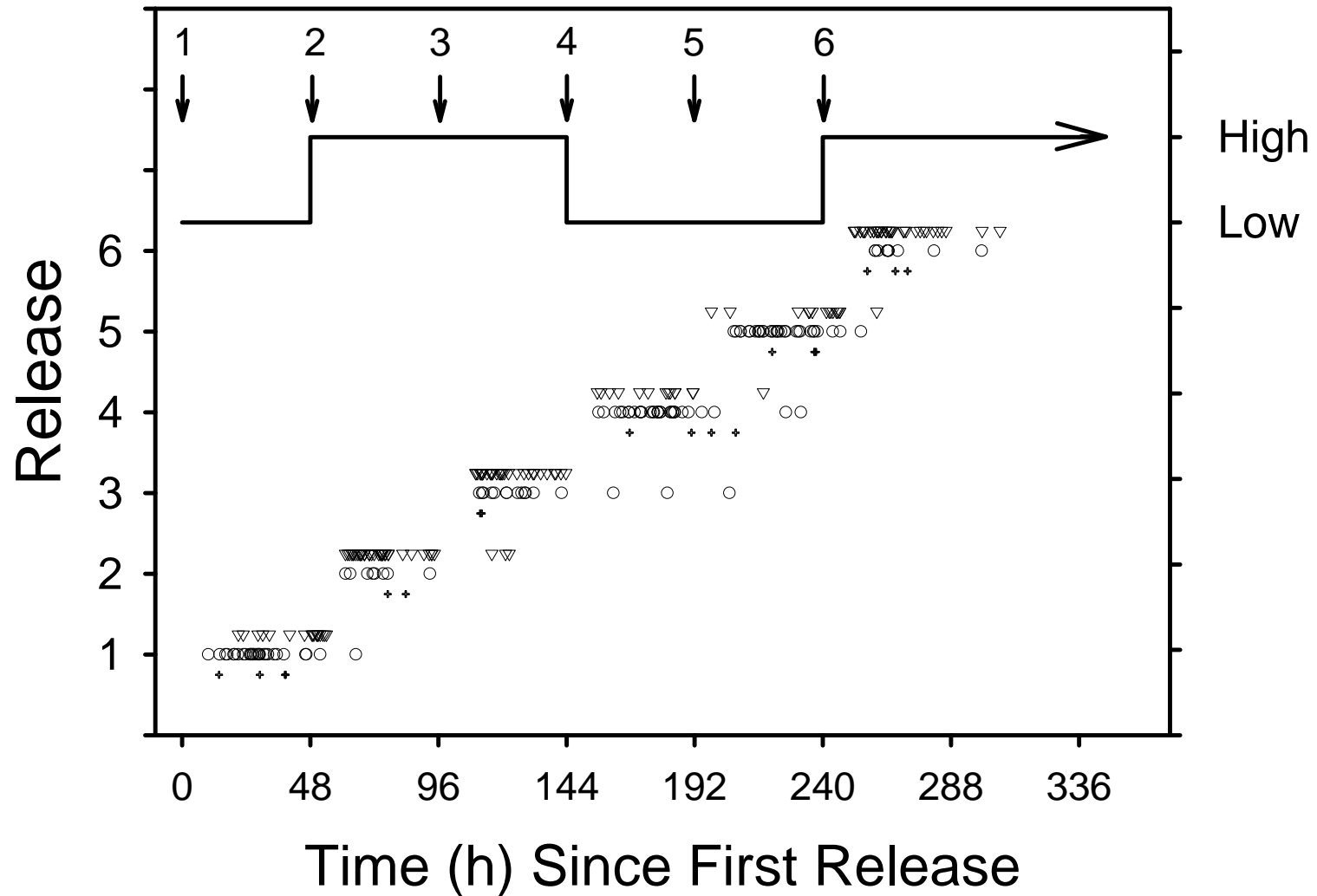
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“All models are wrong...
some are useful”

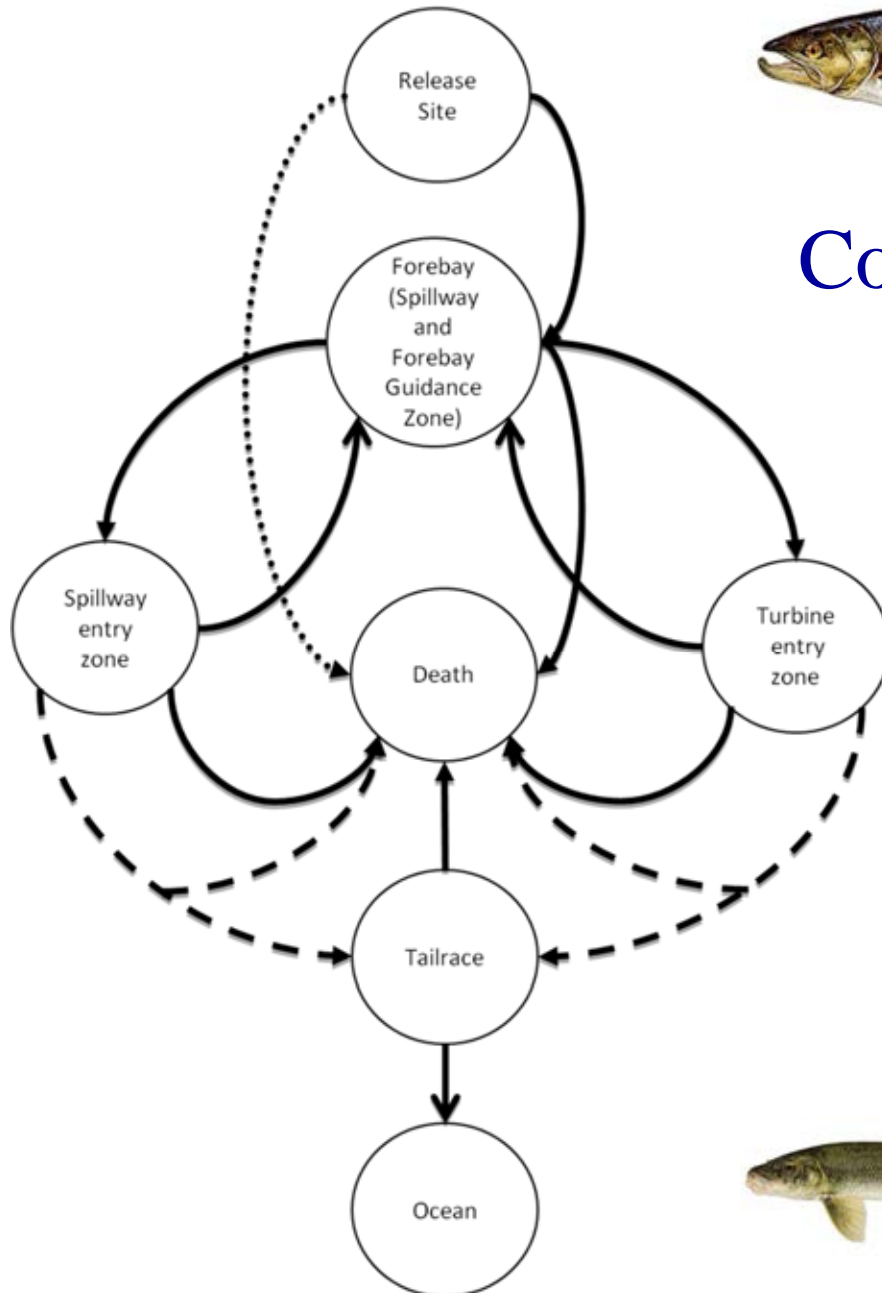


Simulated study design





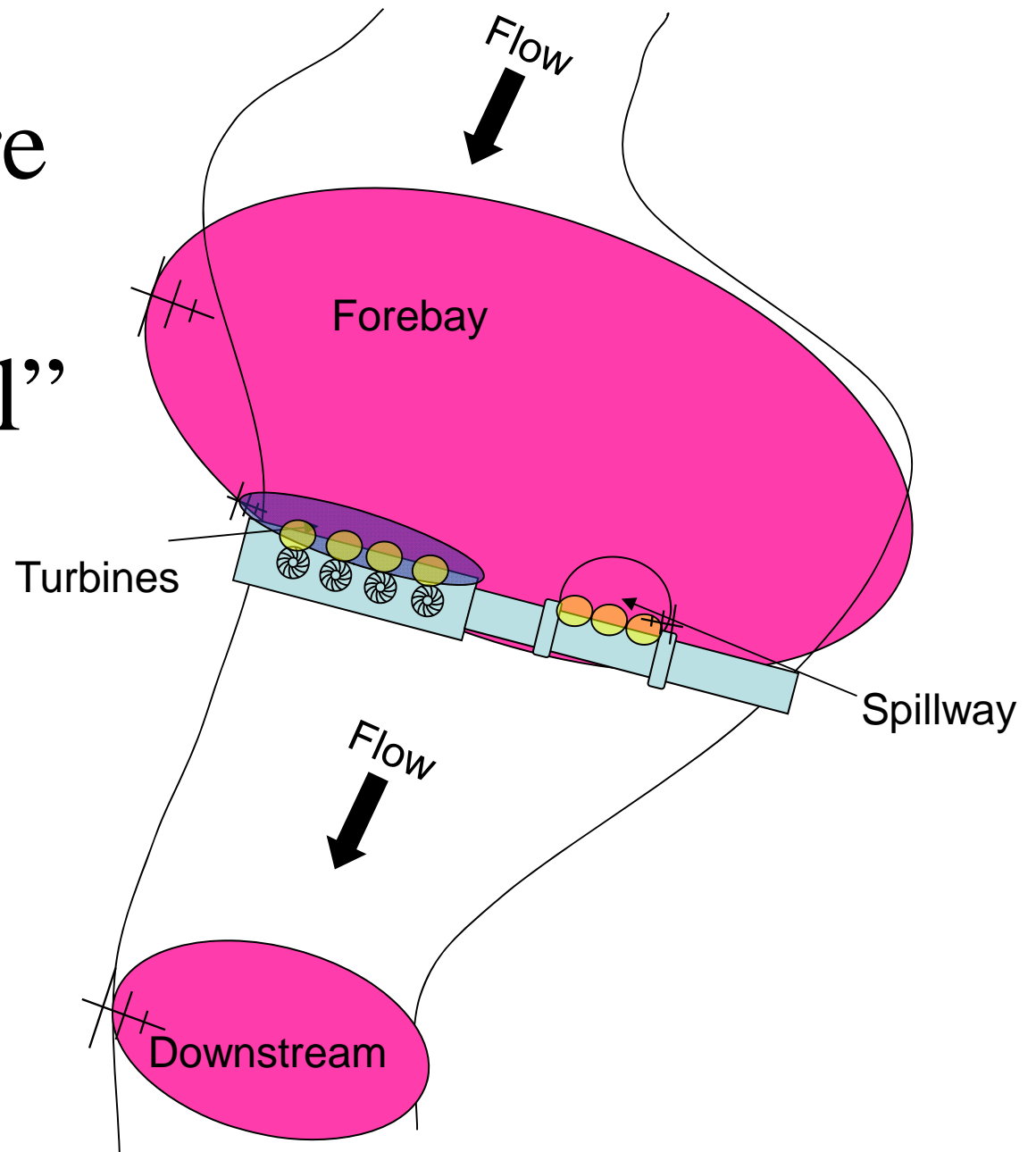
Consider what is changing:



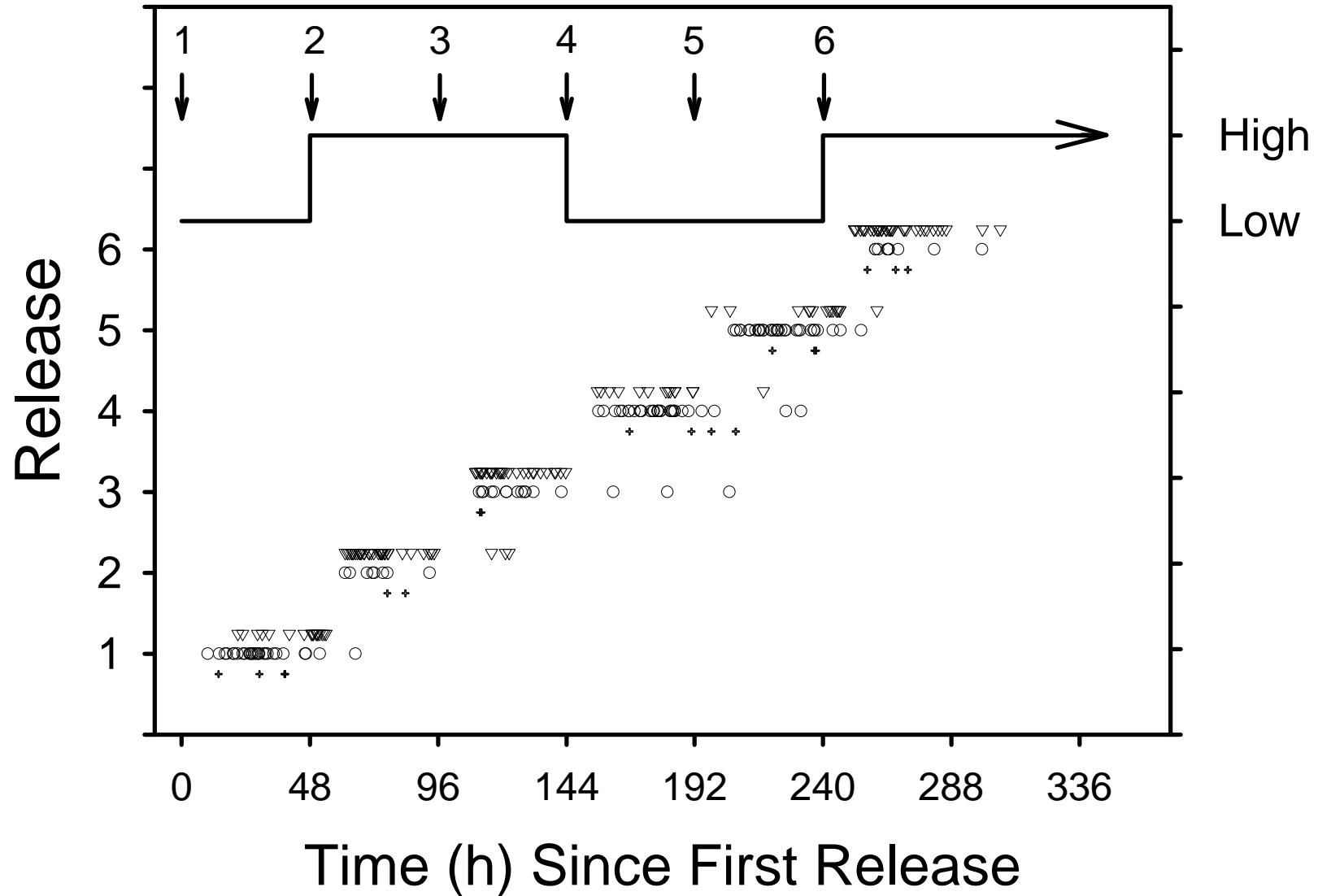
- Time
- Discharge
- Temperature
- Light
- Generation/Operations
- Energetics



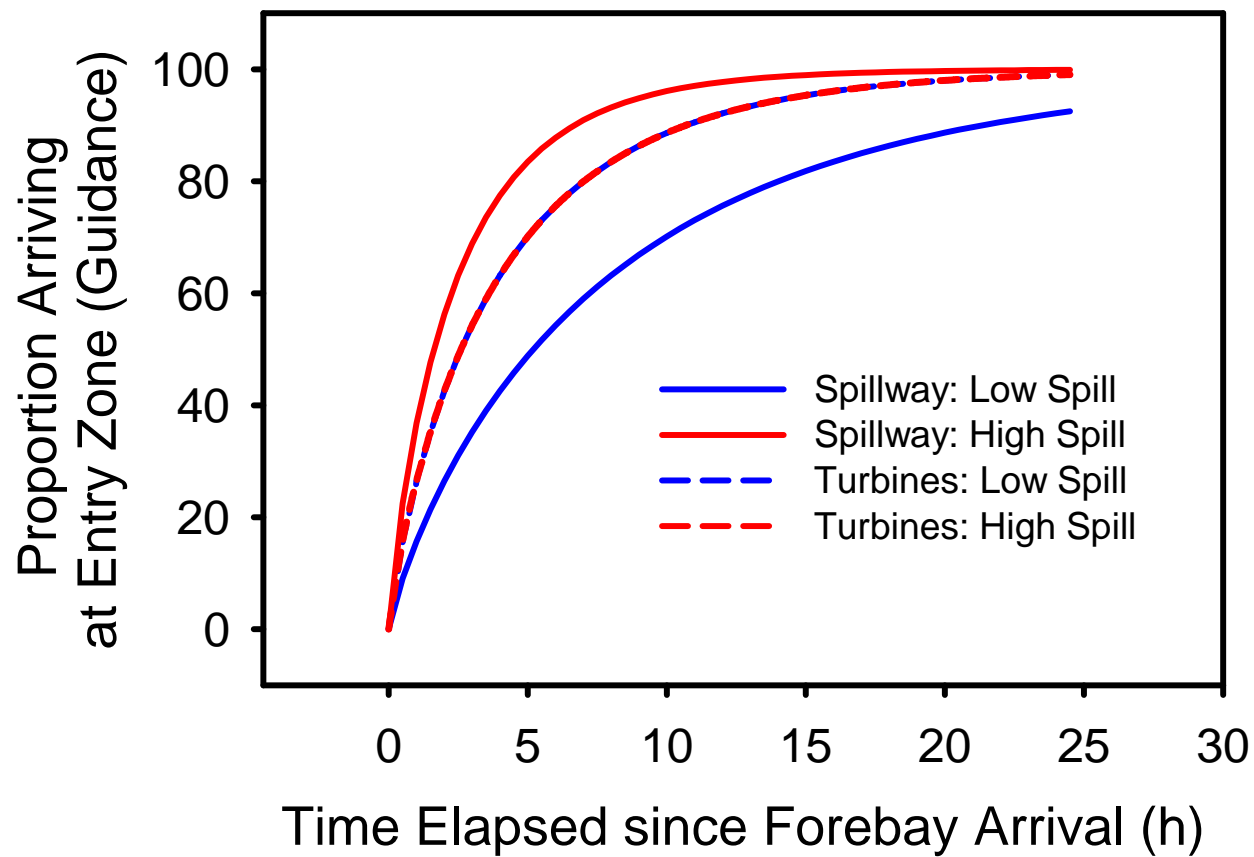
“All models are wrong...
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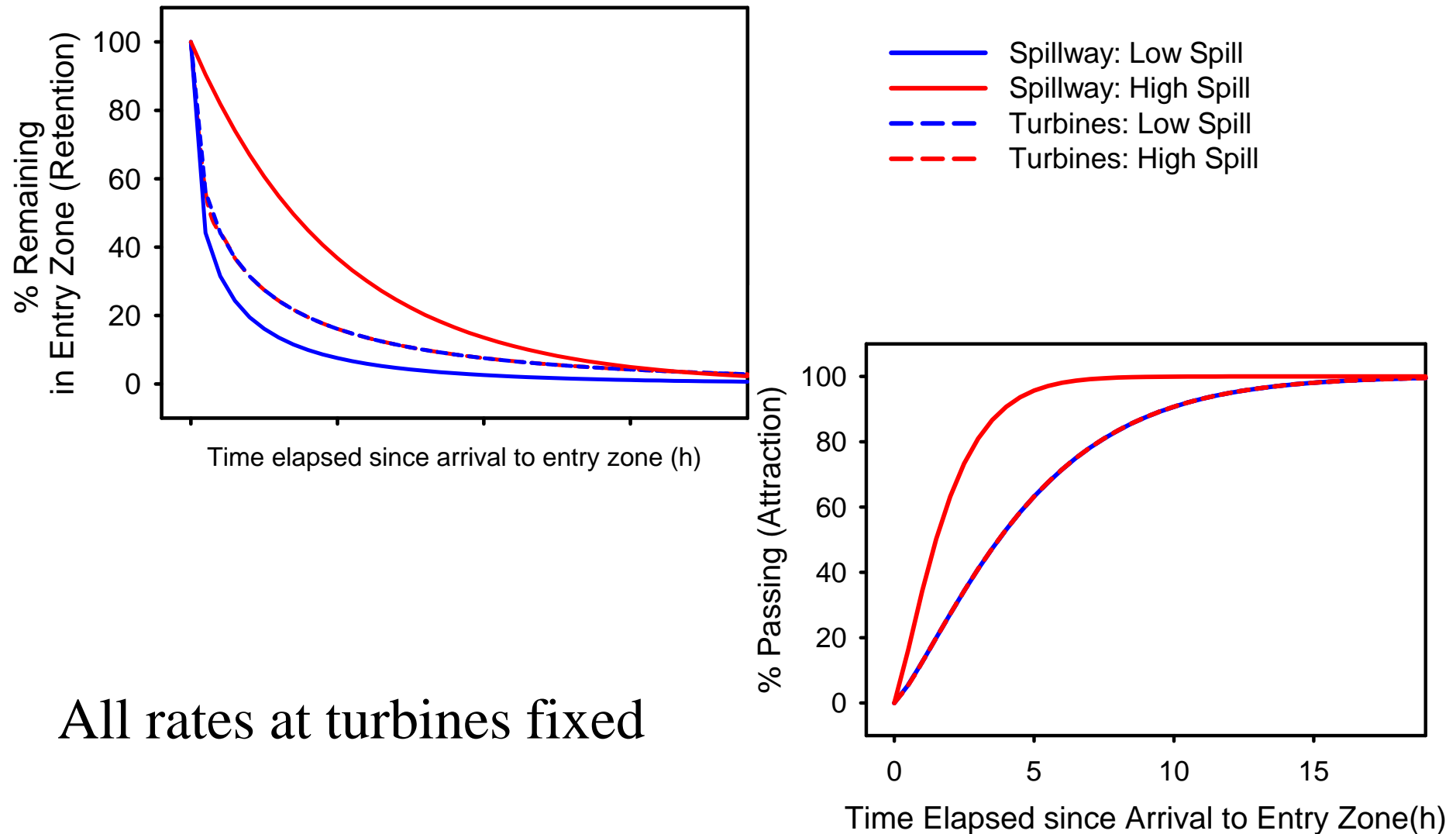
Simulated study design



‘some are useful’ ...known rates

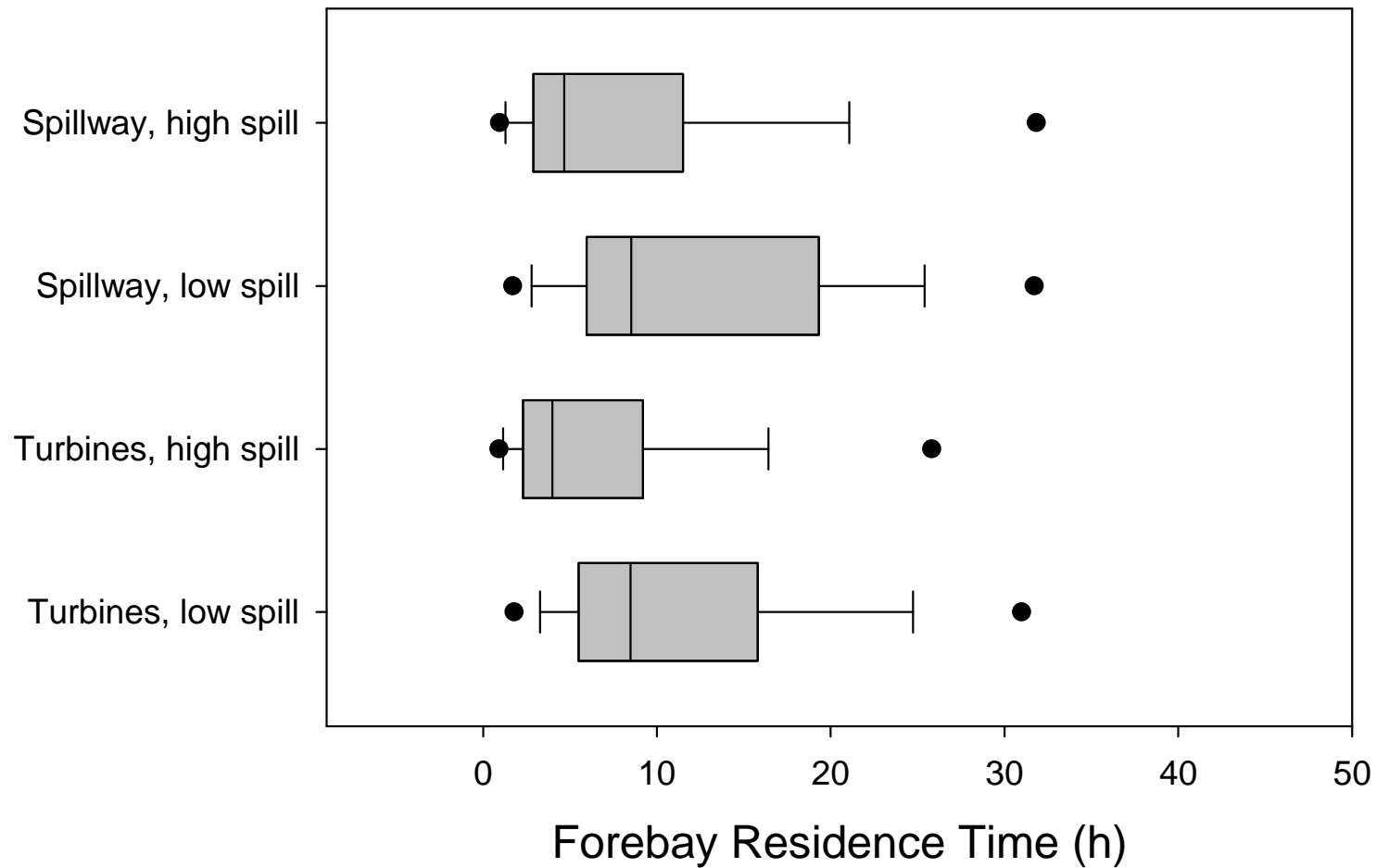


'some are useful' ...known rates

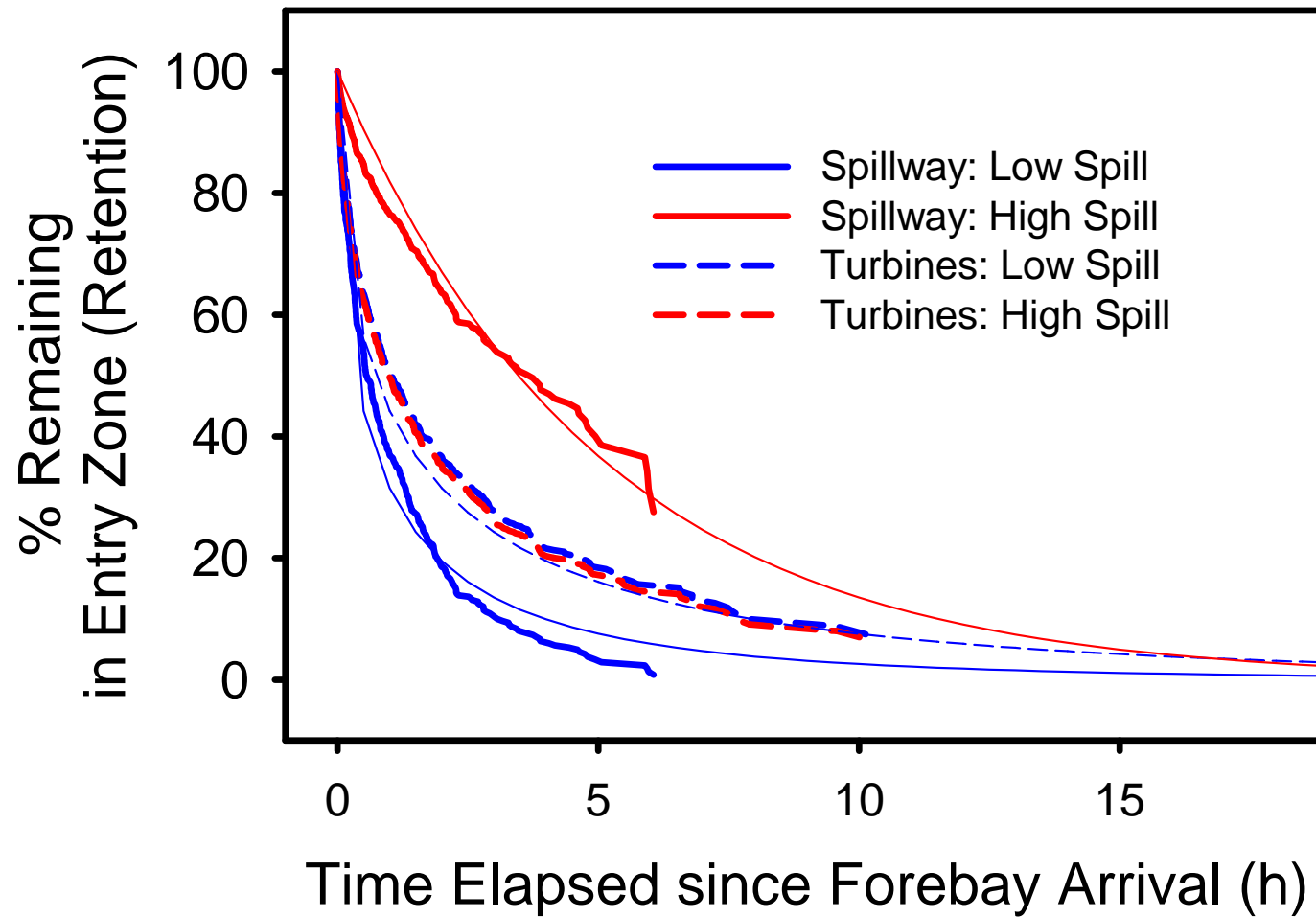


All rates at turbines fixed

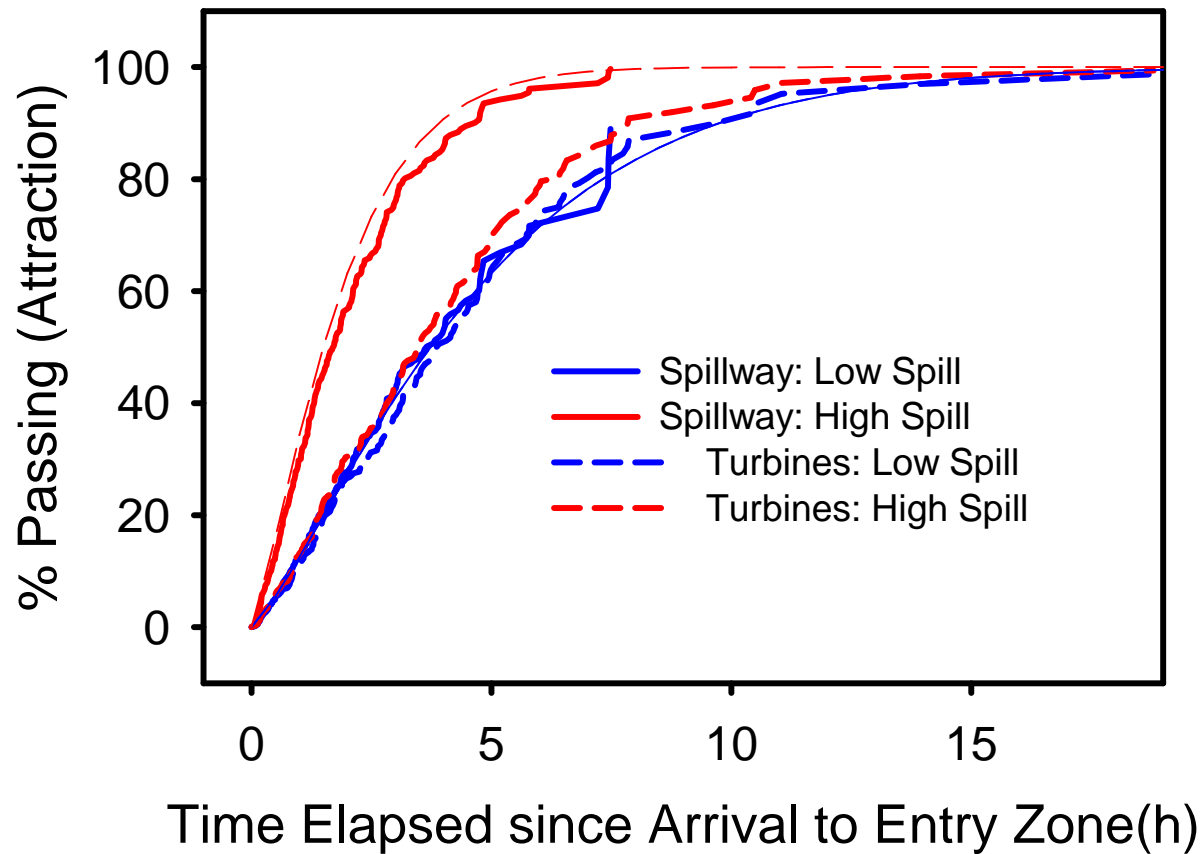
The danger of inappropriate methods



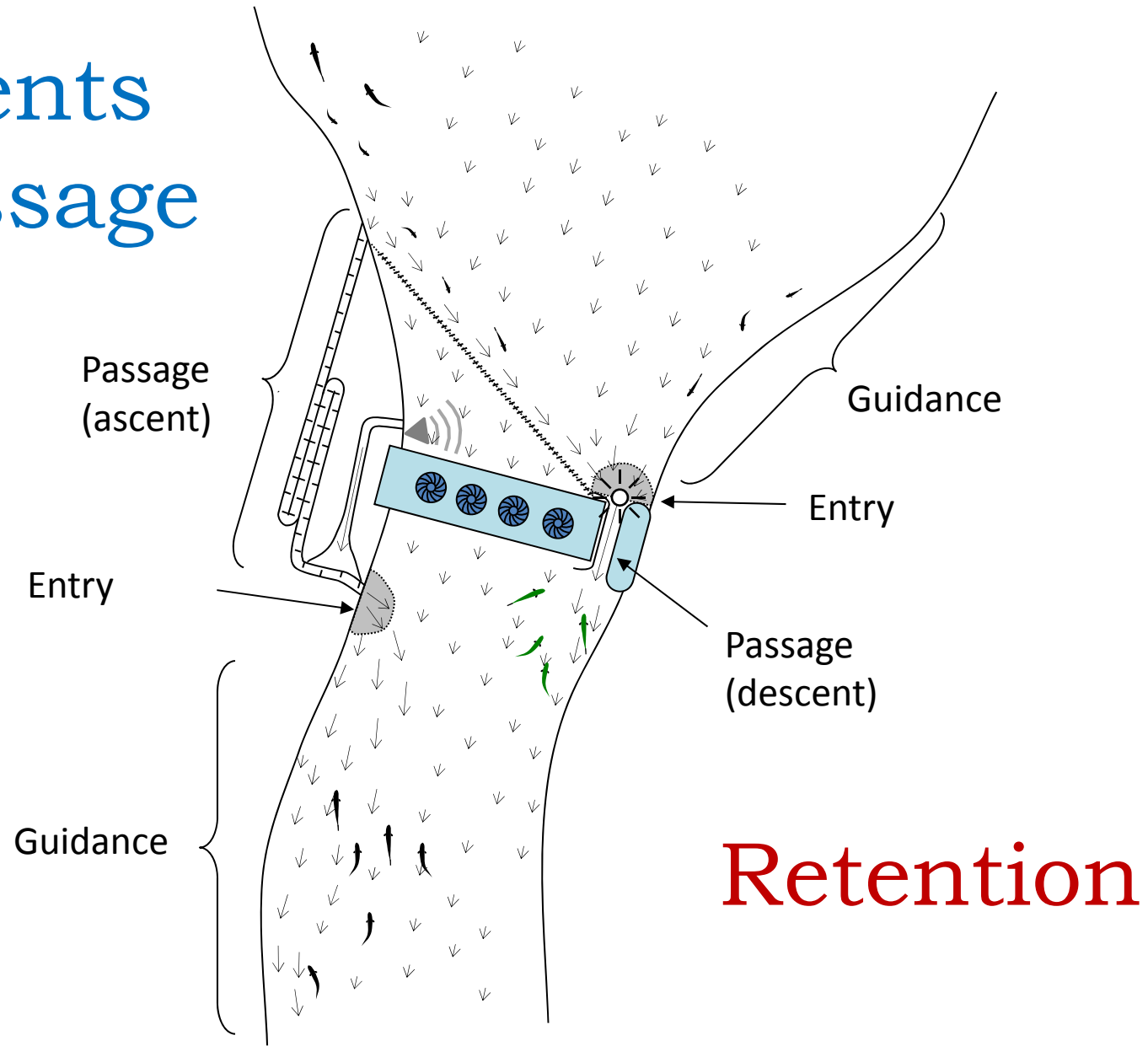
‘...some are useful’: Getting it right

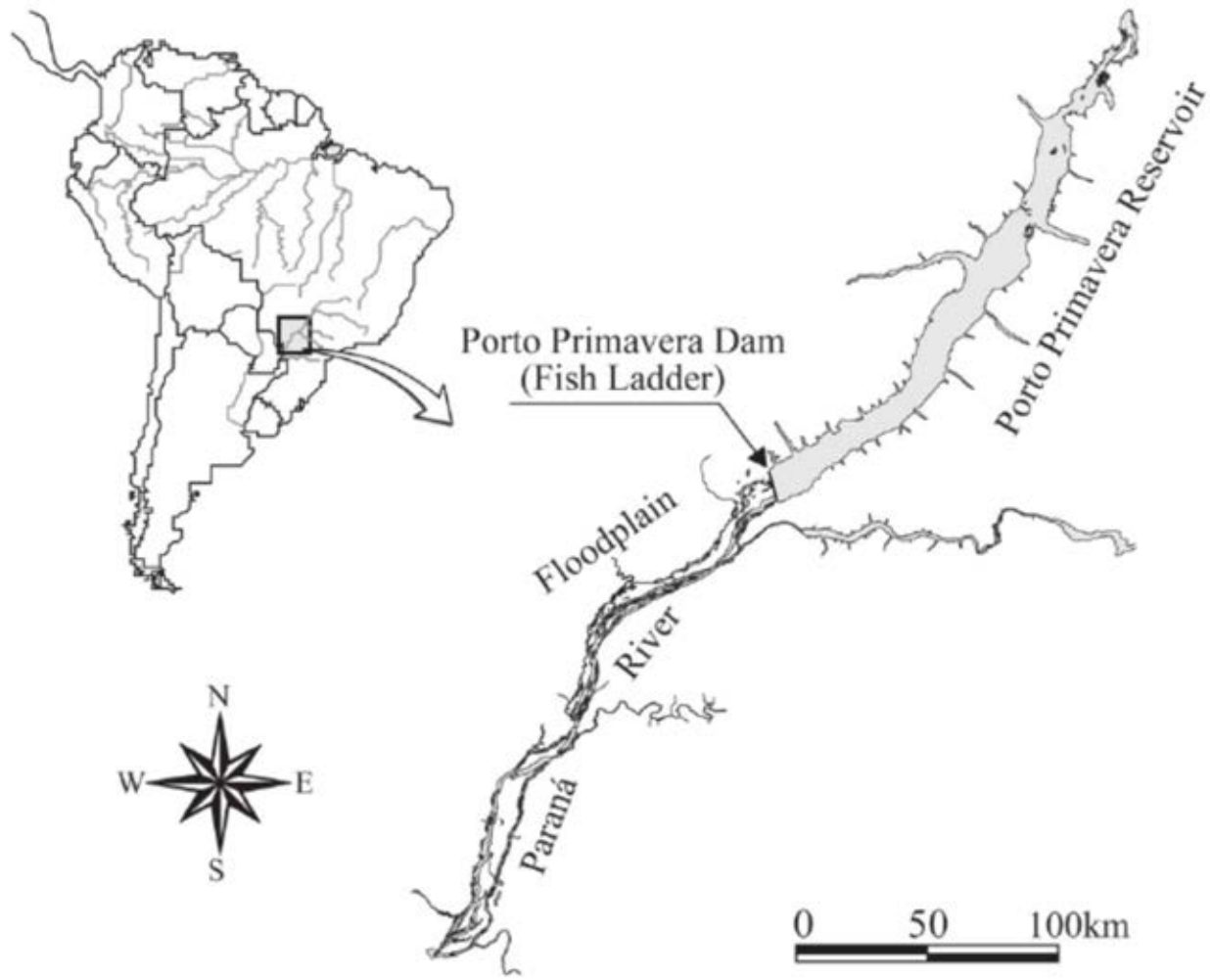


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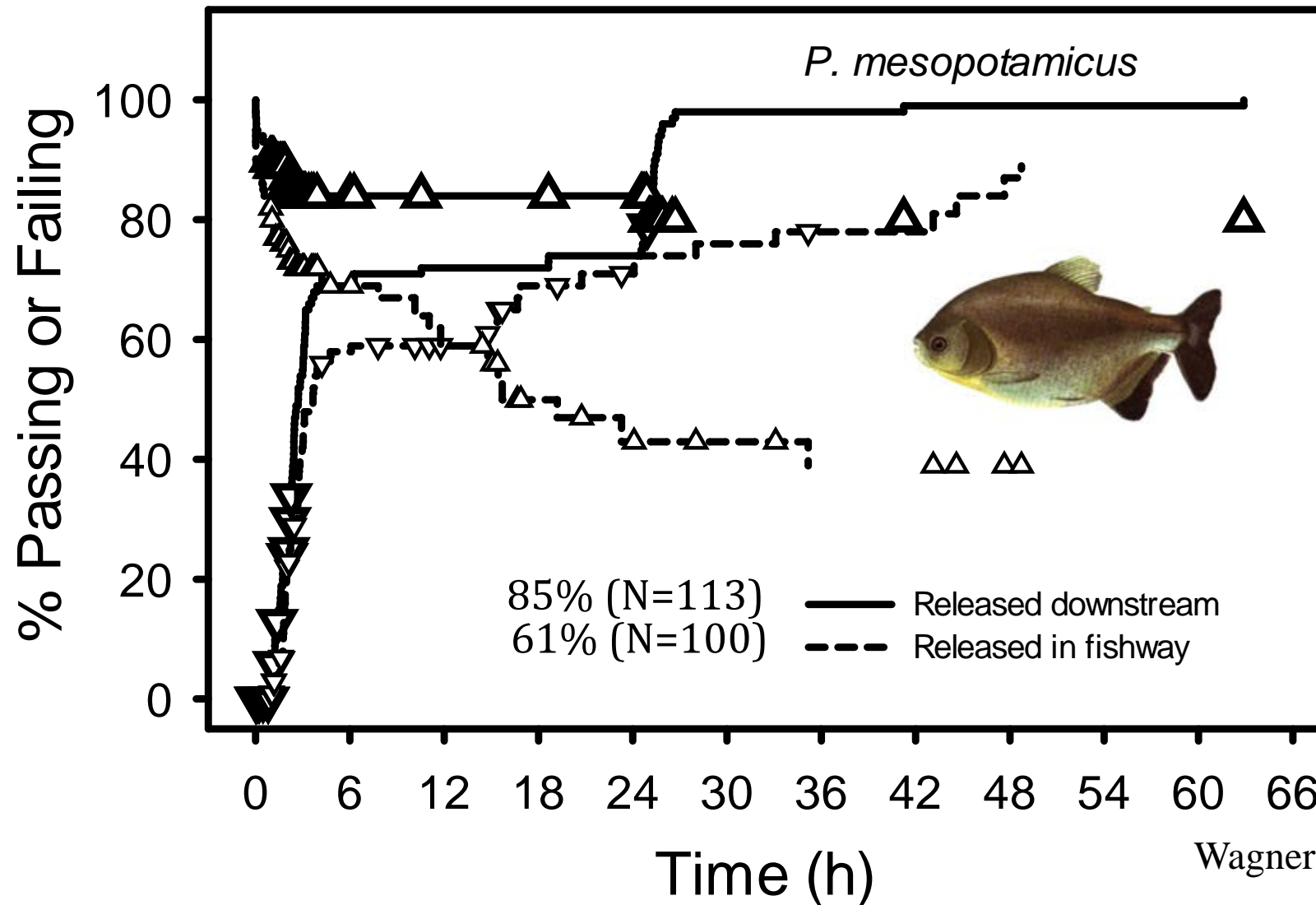
Elements of Passage



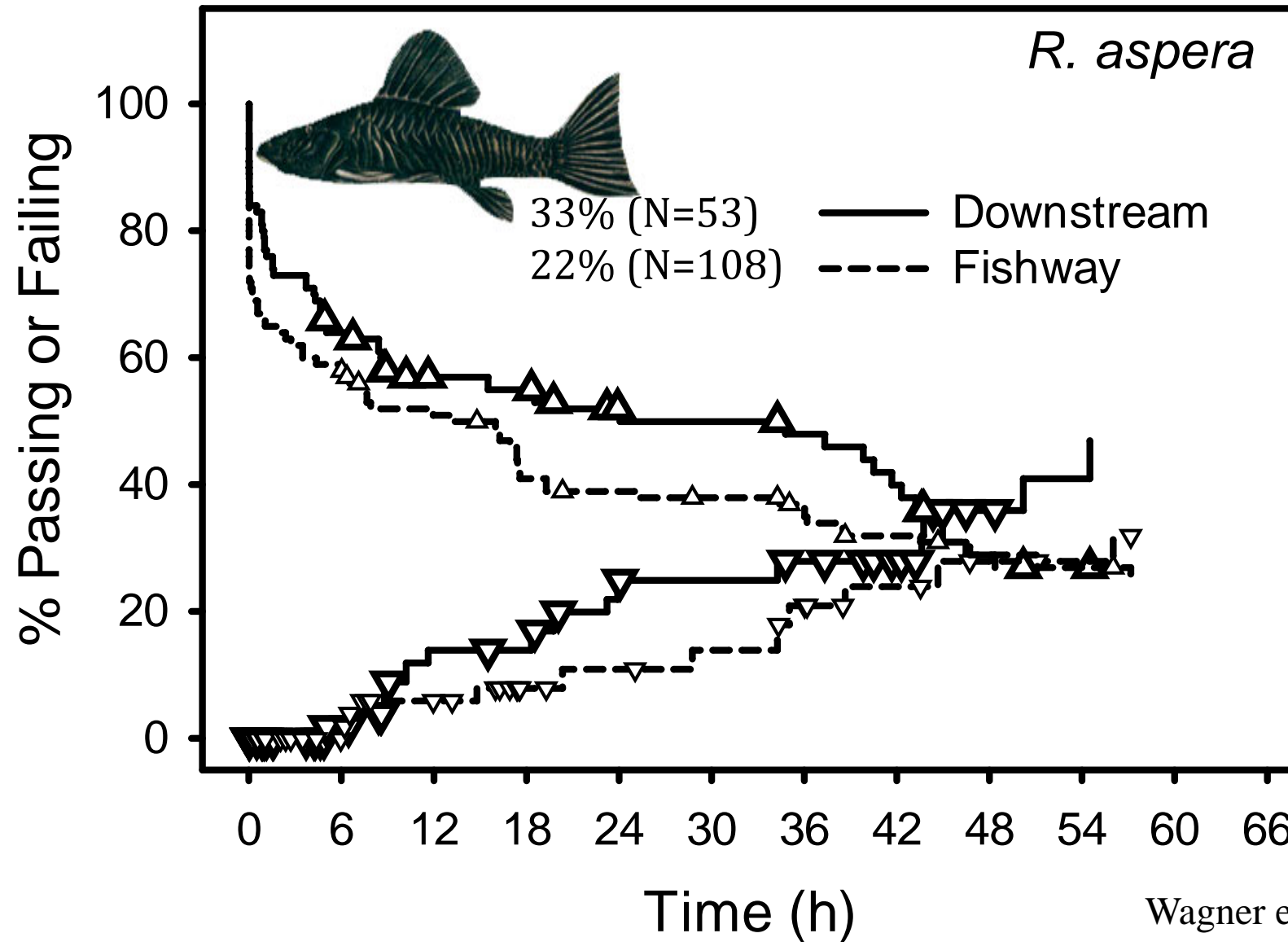


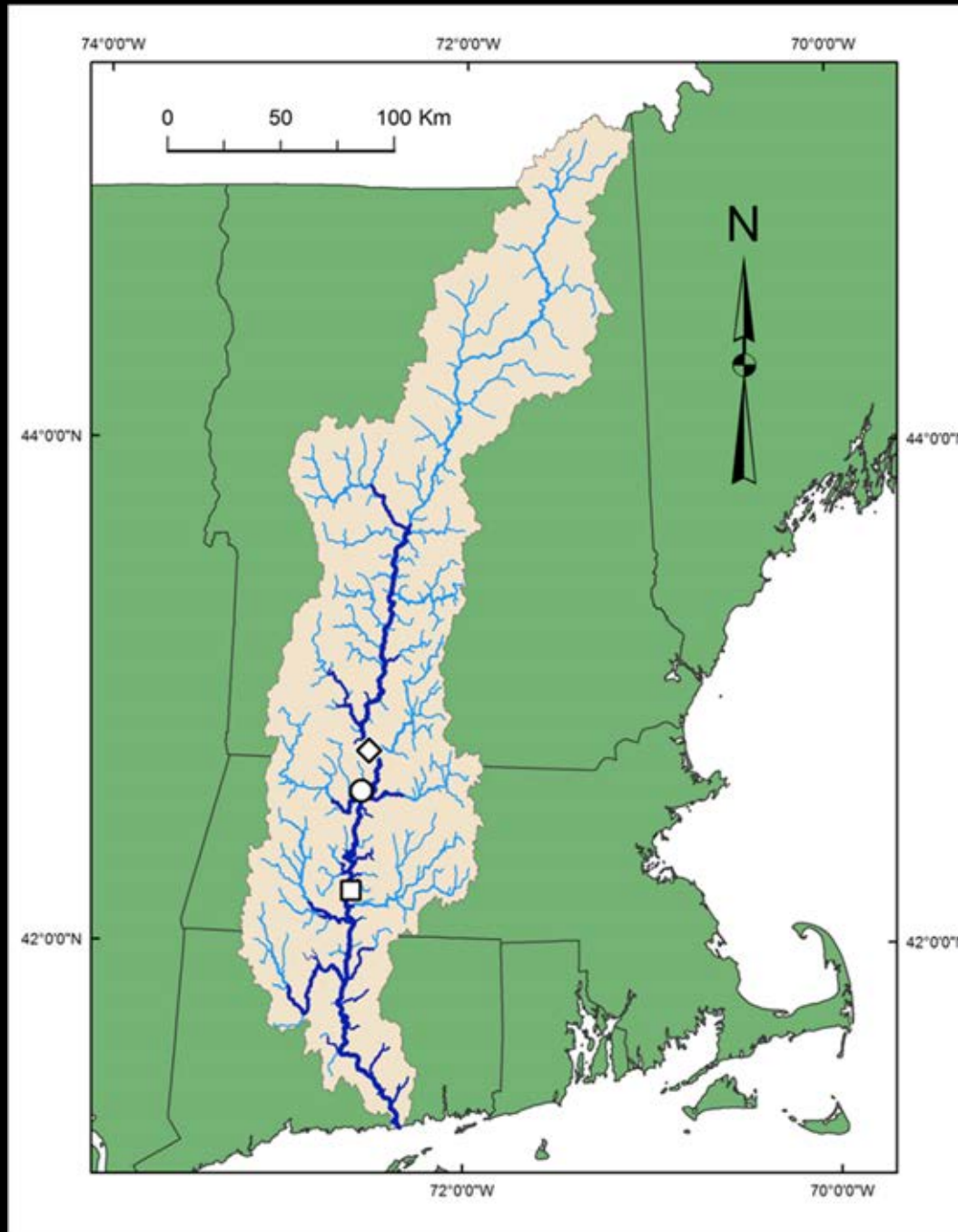


Passage and failure rates

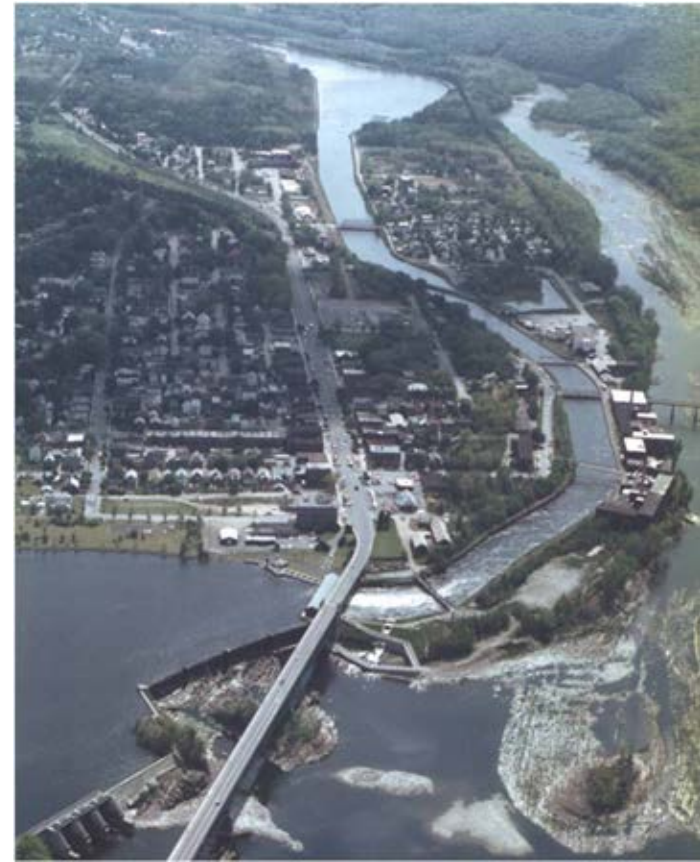
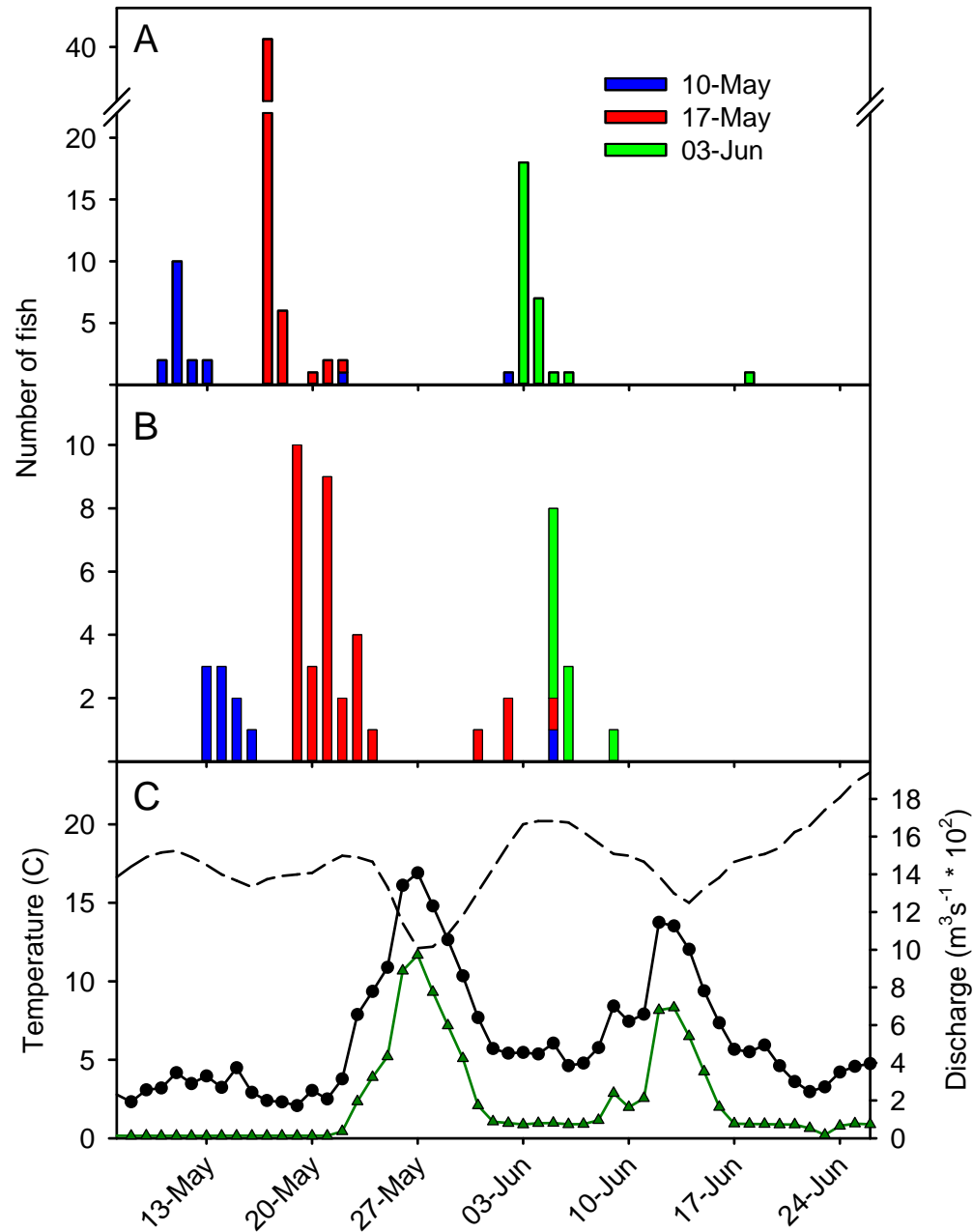


Passage and failure rates

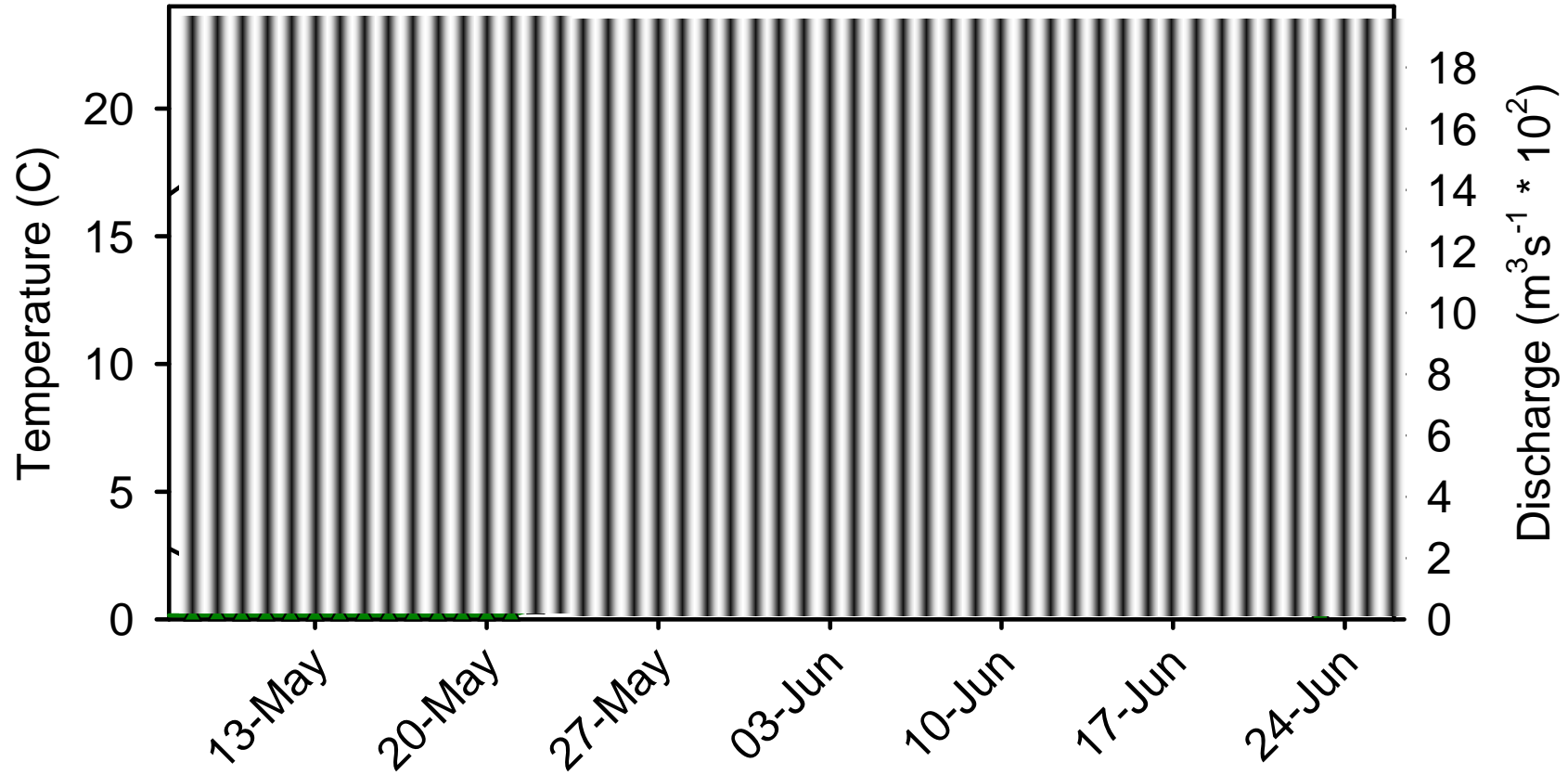




The case for Cox regression



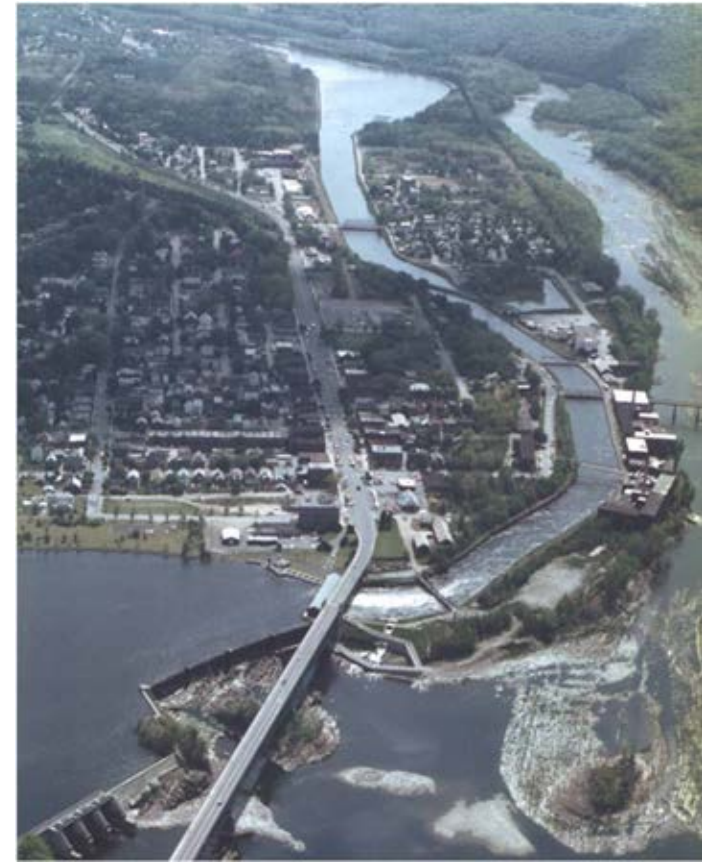
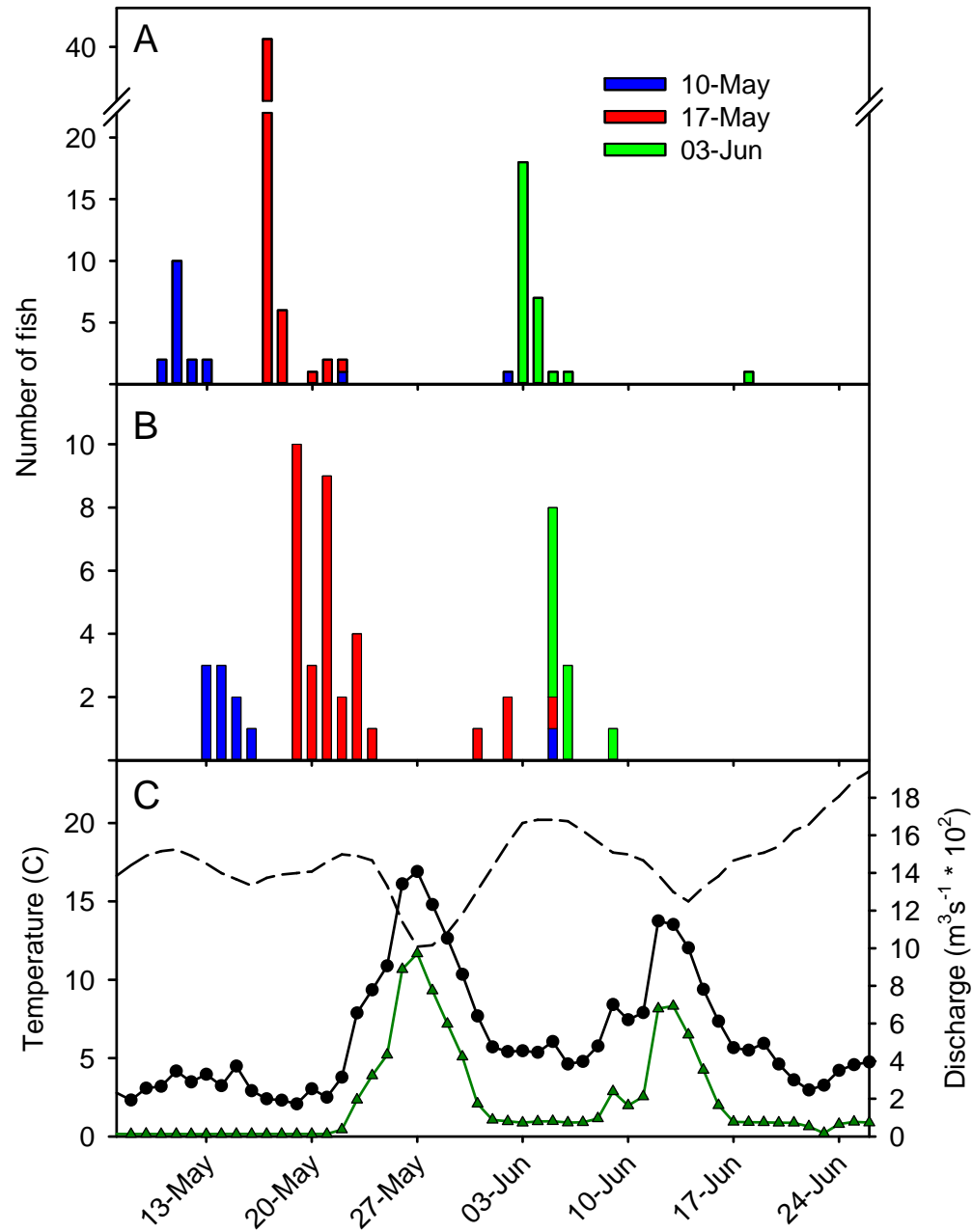
Covariates that change over time



Rates of Fishway Entry: Cox Regression Results (Hazard ratios)

Parameter	Turners Falls	Cabot	Spillway	Canal
Fishway (Cabot)	2.01	---	---	---
Day/Night	-0.58	-0.96	---	-0.99
Q_{tot}	1.87	---	---	-0.07
Q_{Cabot}*Day/Night	---	2.08	---	1.10
Q_{Bypass}	---	---	11.65	---
Temp (°C)	-0.30	---	---	2.29
Nevents	45	31	14	17
Ncensored	220	234	251	51

The case for Cox regression





Conclusions



- Variability in performance means existing designs not reliable
- Plethora of structures demands widespread evaluation
- Appropriate units are rates-based: %/time
- Competing risks are a fact of life
- Cox Regression is a powerful tool, but all survival analysis methods are useful.
- Adaptive management is possible