Biological Factors Related to Sturgeon Passage

Theory and Practice

Henriette Jager

Oak Ridge National Laboratory

Joseph J. Cech

Professor emeritus, Department of Wildlife, Fish, and Conservation Biology, University of California, Davis

White Sturgeon Passage

- Theory:
  Modeling Snake River meta-populations
  Jager, funded by Idaho Power Company

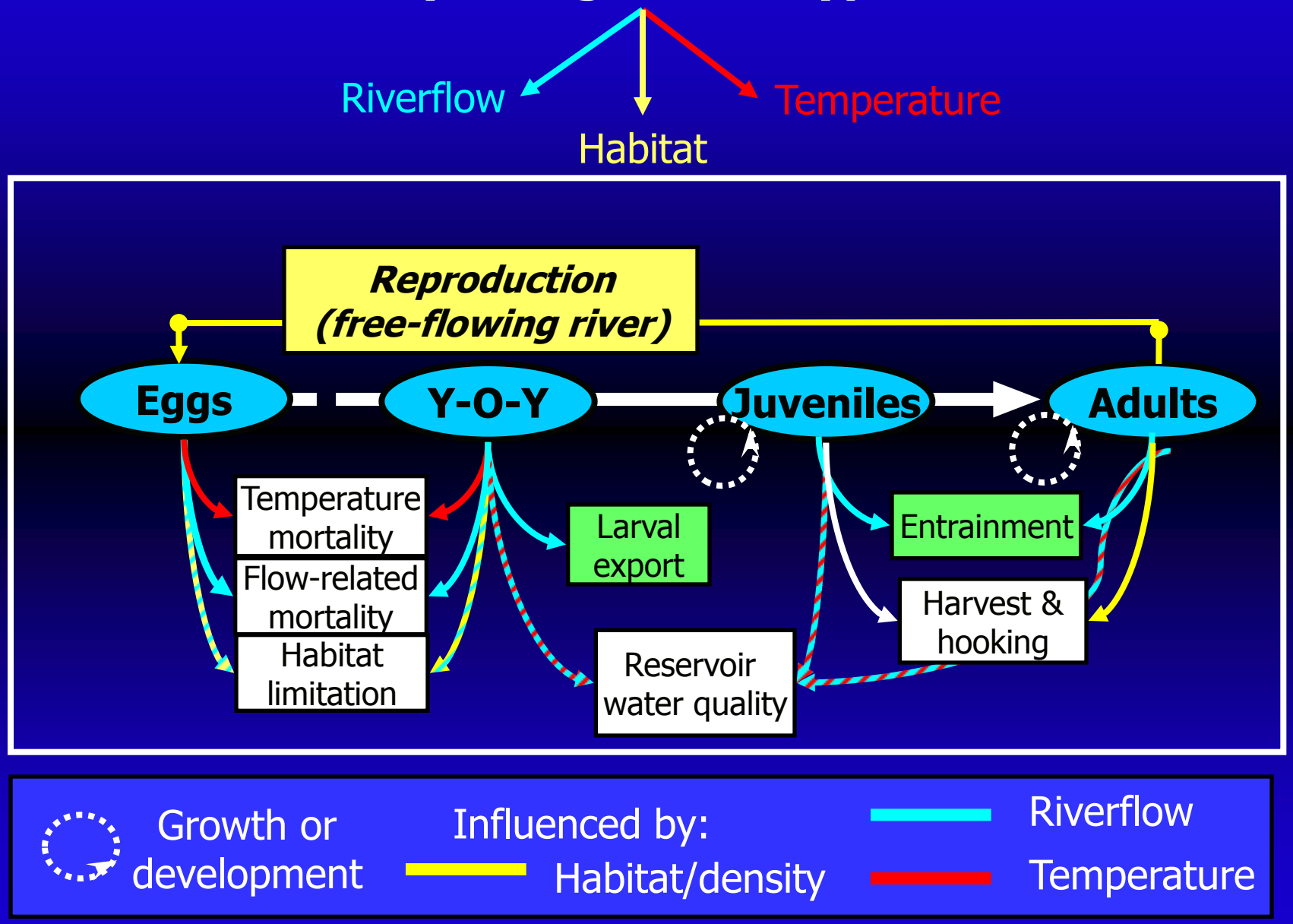
- Practice:
  Behavior, swimming, and stress responses
  Cech, funded by DWR/CALFED

PVA Modeling

Snake River White Sturgeon Fragmentation Study

How does fragmentation by dams influence persistence?

Hydrologic Year Type

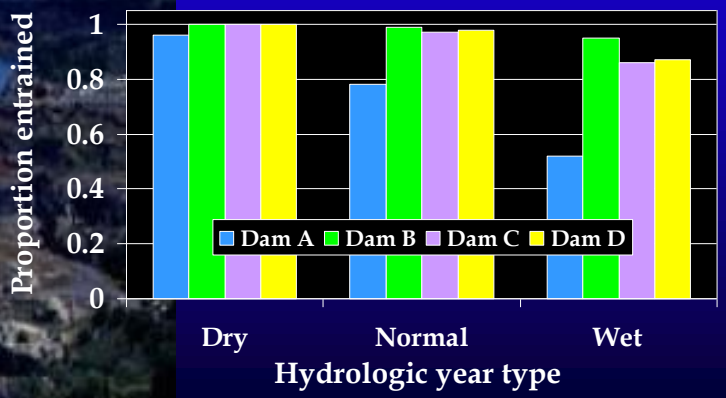


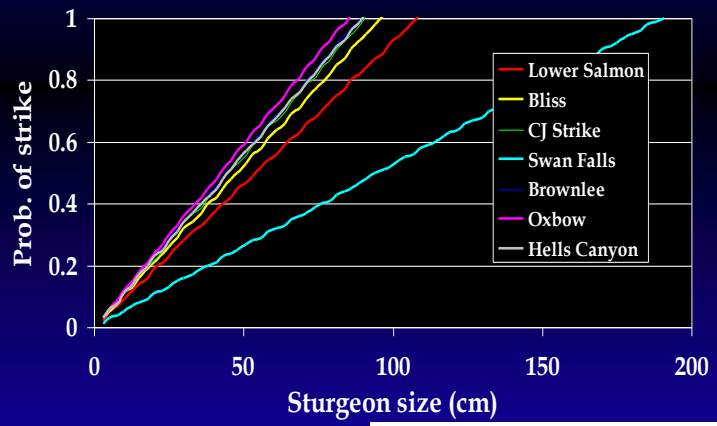
Habitat may not be available for all life stages in short segments

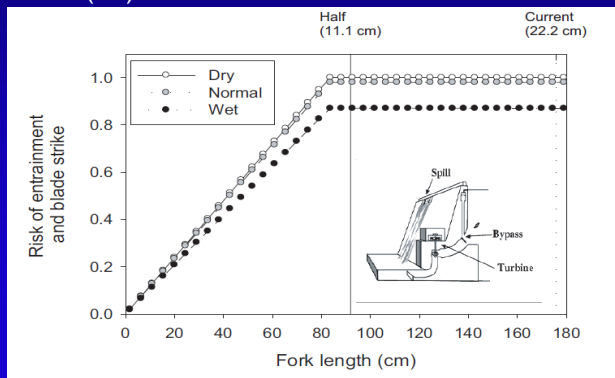
-Free-flowing habitat required for spawning
-Export of buoyant or demersal early life stages

S(export) = 1 – {Probability of reaching reservoir}
x {Probability of leaving reservoir}

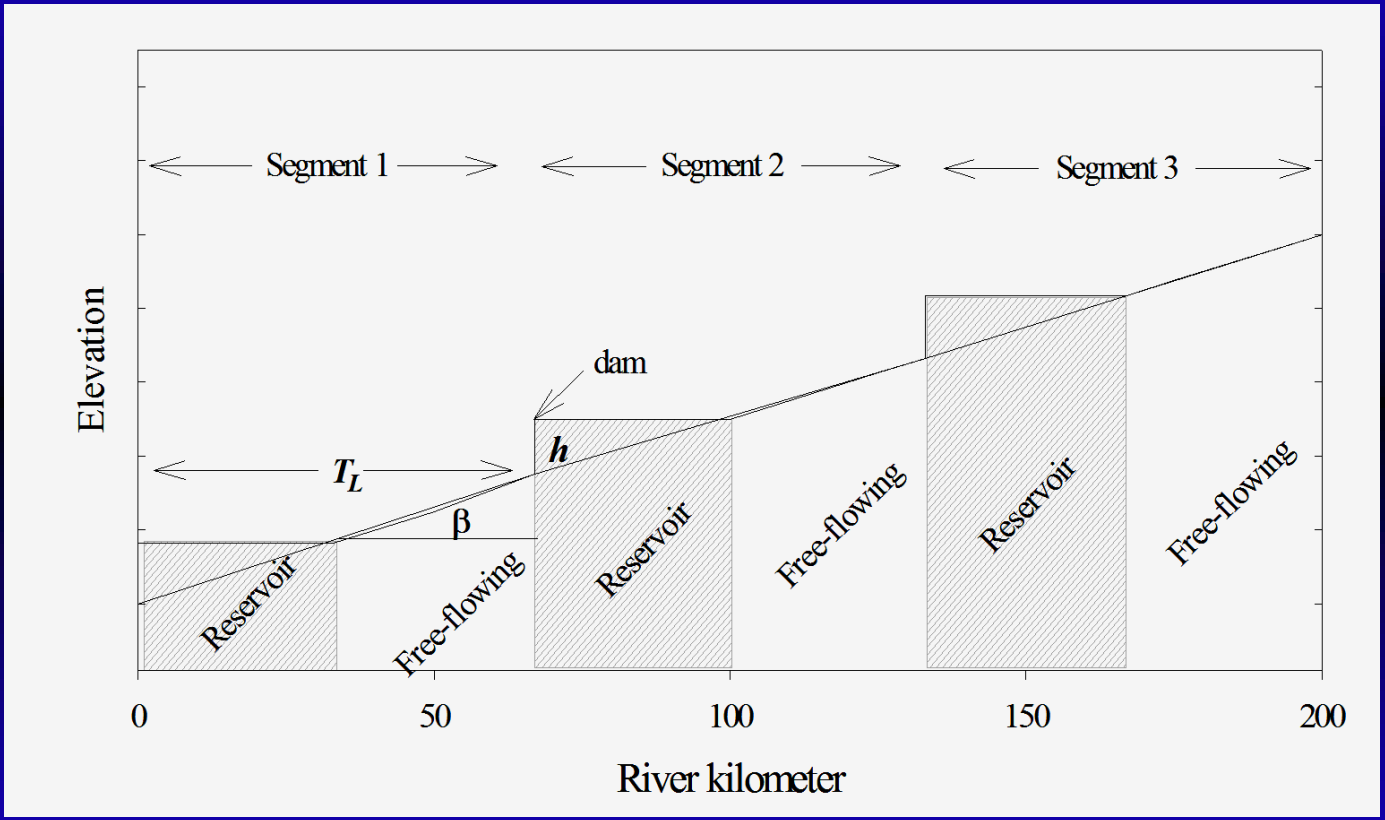
Turbine mortality depends on turbine design, flow, & sturgeon size







Closer dam spacing reduces free-flowing habitat



Simulation experiments fragmented a fixed length of virtual river by 1, 2, 3, etc. dams.

Minimum viable segment length?

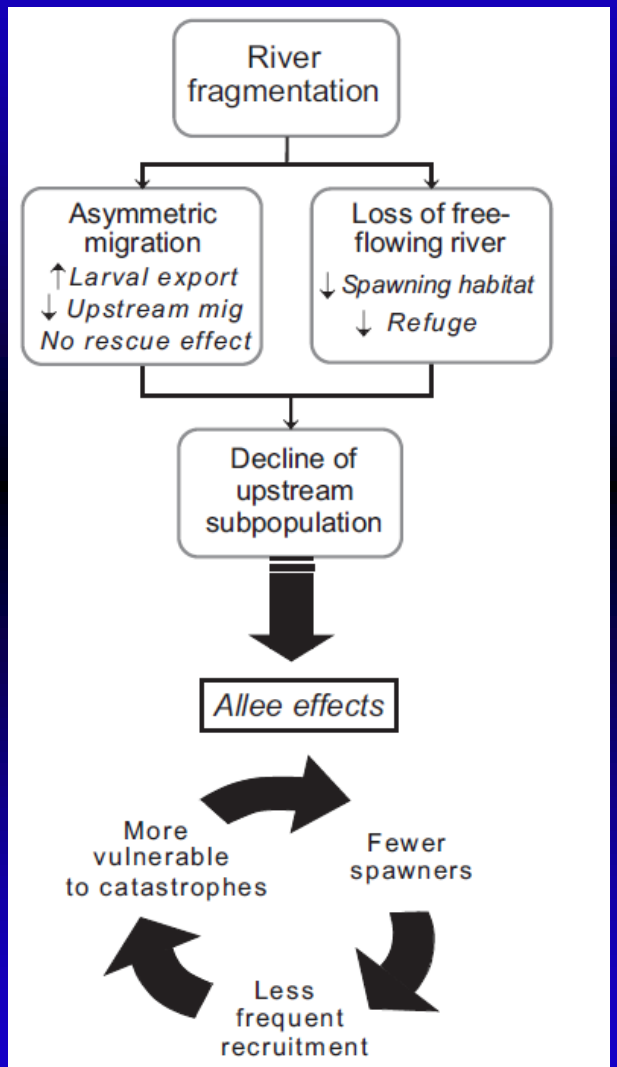
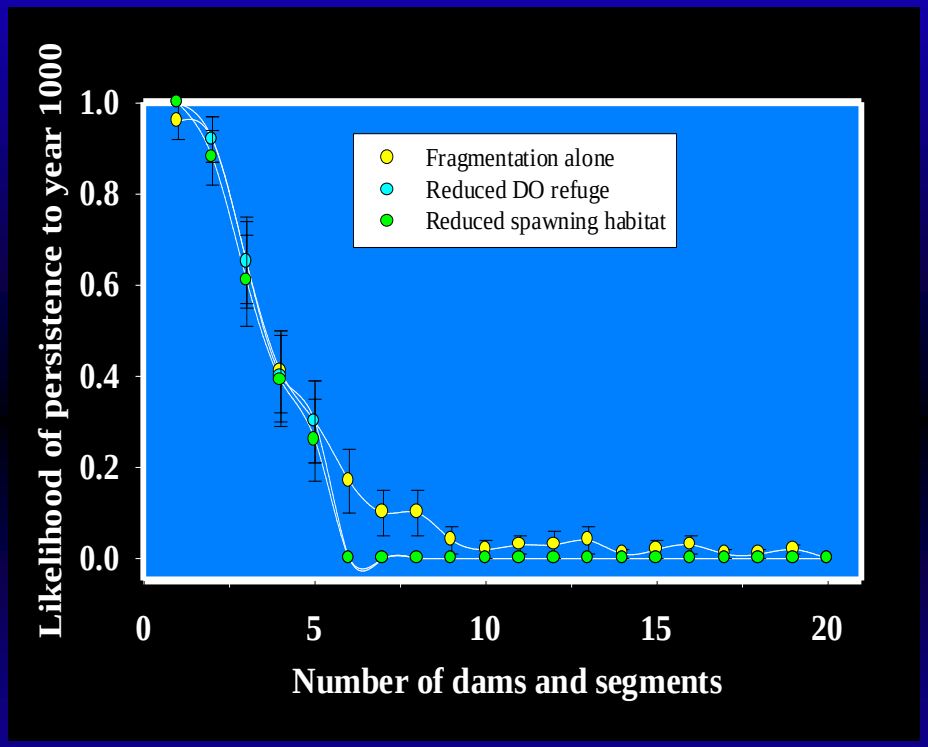
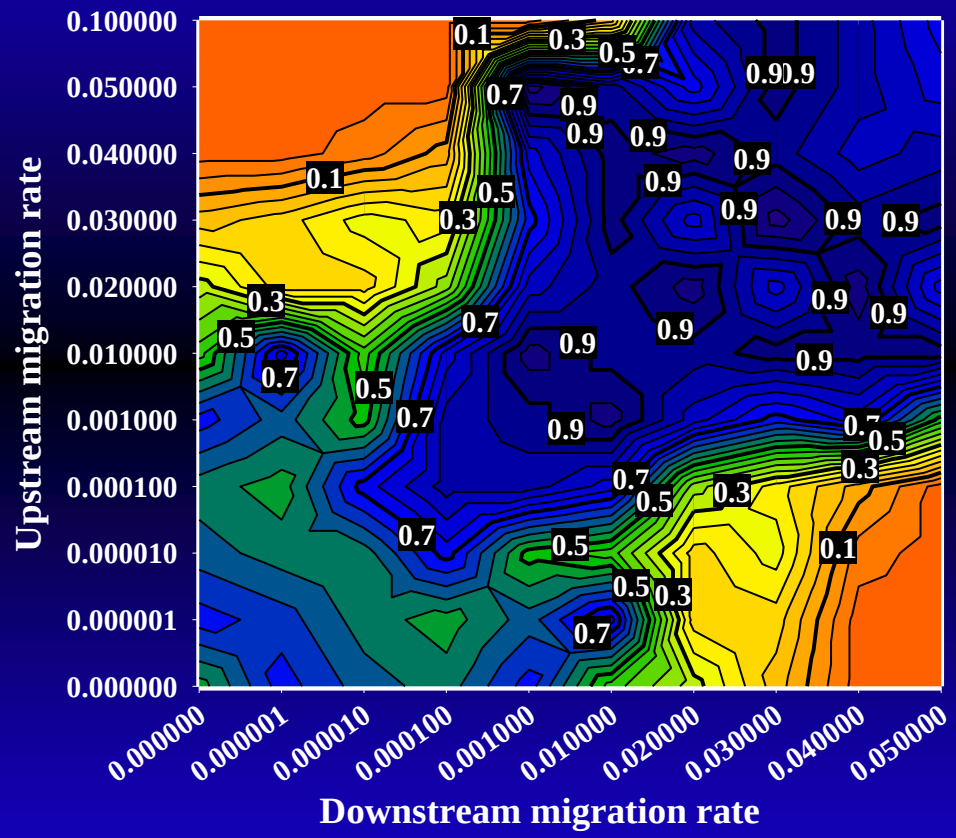


FIGURE 1. Schematic of extinction risks associated with river fragmentation.



- No clear extinction threshold
- High risk when free-flowing habitat eliminated

Asymmetric migration



Unbalanced migration decreased persistence for middle populations

River fragmentation by dams

- Closely spaced dams can turn a healthy source population into a metapopulation of sinks.
  - Insufficient free-flowing habitat for spawning or refuge
  - Export of demersal larvae
  - Allee effects
- Migration is problematic.
  - Upstream migration is prevented (asymmetric).
  - Dams impose a heavy penalty for downstream migration through turbines.

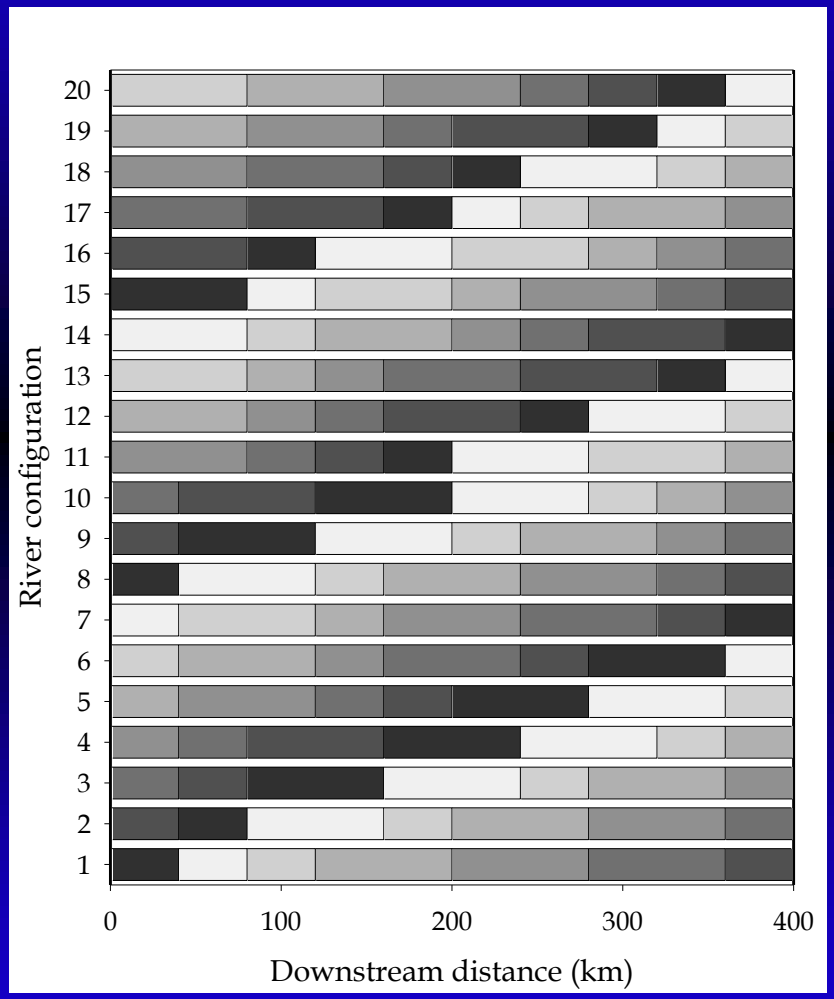
PVA Modeling

Snake River White Sturgeon Reconnection Study

Would reconnection benefit the metapopulation?

Hypothetical river configurations

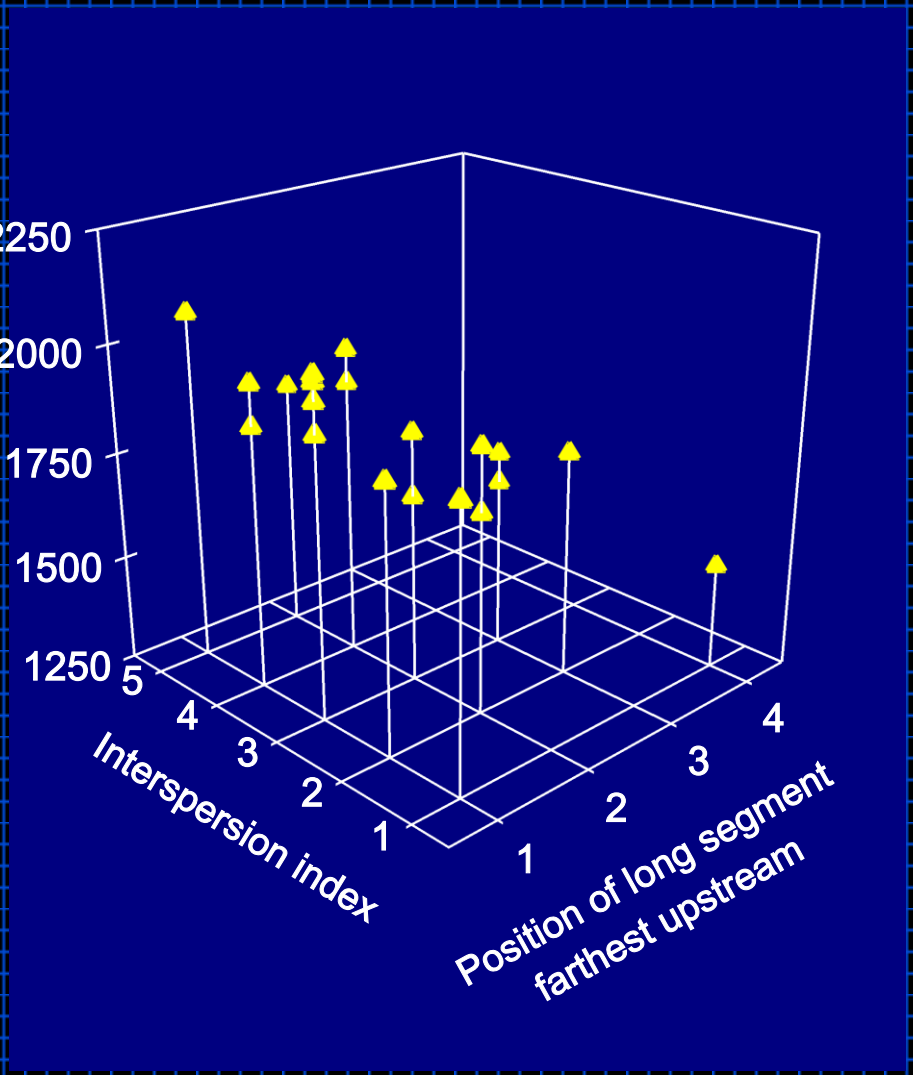
- Considering all configurations allows effect of longitudinal position to be separated from those of segment length.
- Each configuration has 3 short and 3 long segments.
- Long and short segments differ in proportion of free-flowing river habitat
- An extra segment removes boundary effects.



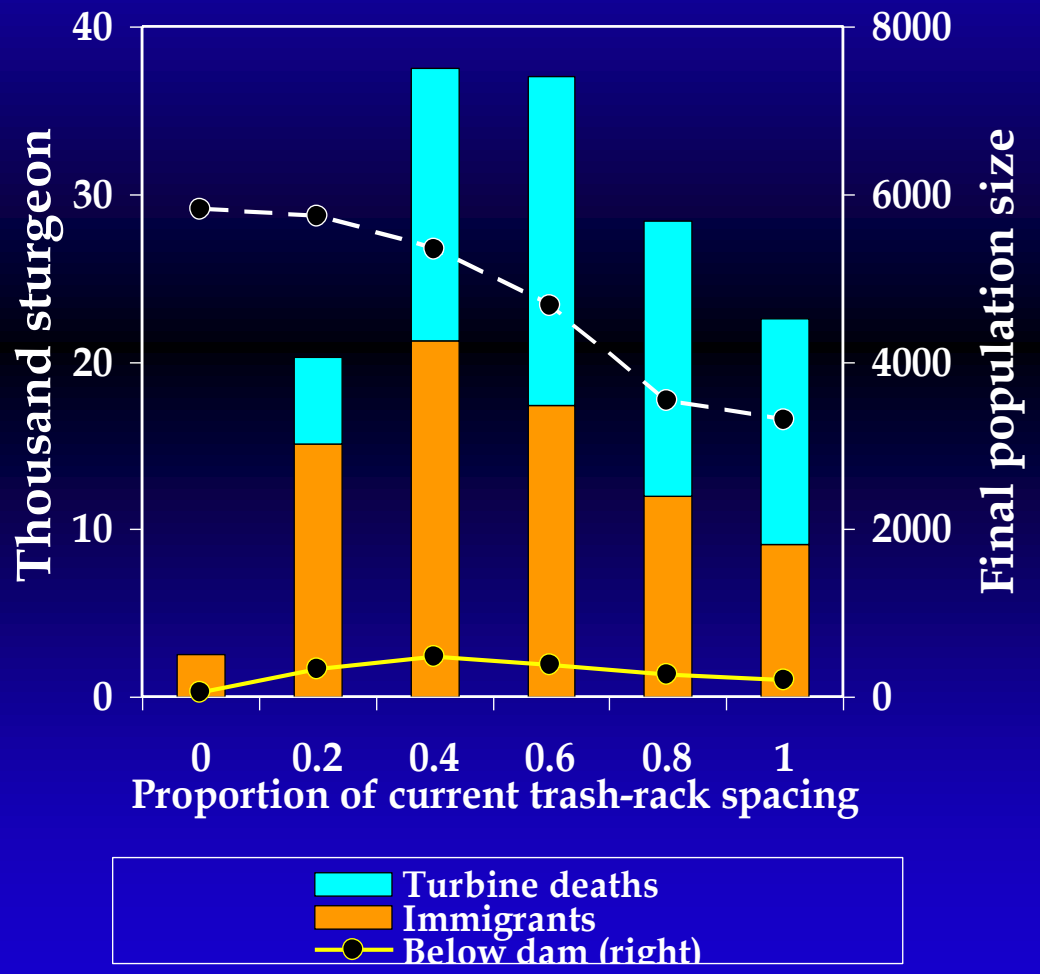
Metapopulation status

- NT500 is an index I devised to measure demographic status.
  - Sum of final population sizes, each truncated at 500.
  - NT500-7 includes the extra, 7th, segment.
- Genetic indices:
  - Gst is Nei's index of genetic subdivision – low values=more homogenous
  - Nall, a measure of introgression, is the average number of alien alleles (initially private to another population) in the final metapopulation.

Status highest for configurations with upstream long segment and high interspersion



Simulated effects of narrowing space between trashrack bars

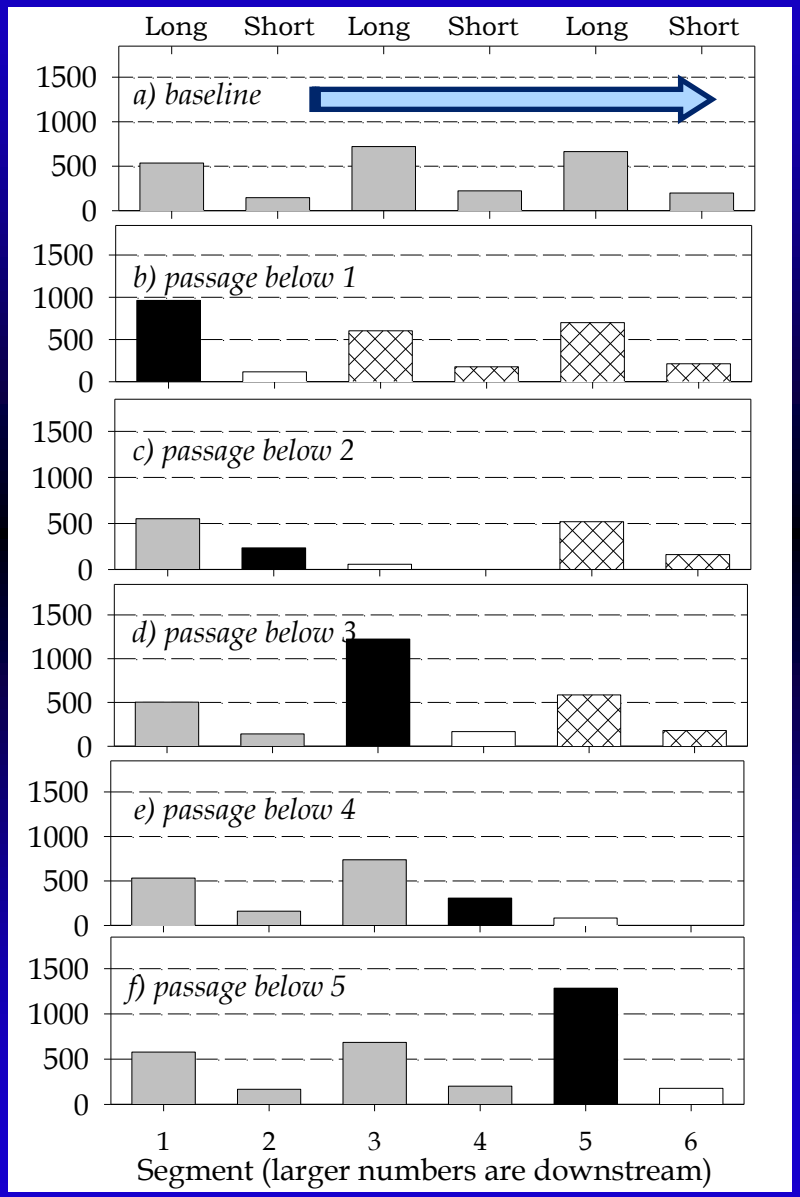


- We simulated different proportional reductions in trash-rack spacing.
- The population above the dam (white line) did best with no space between trashracks.
- The population below the dam (yellow line) did best with intermediate spacing that maximized subsidy by upstream emigrants.

Reconnection options

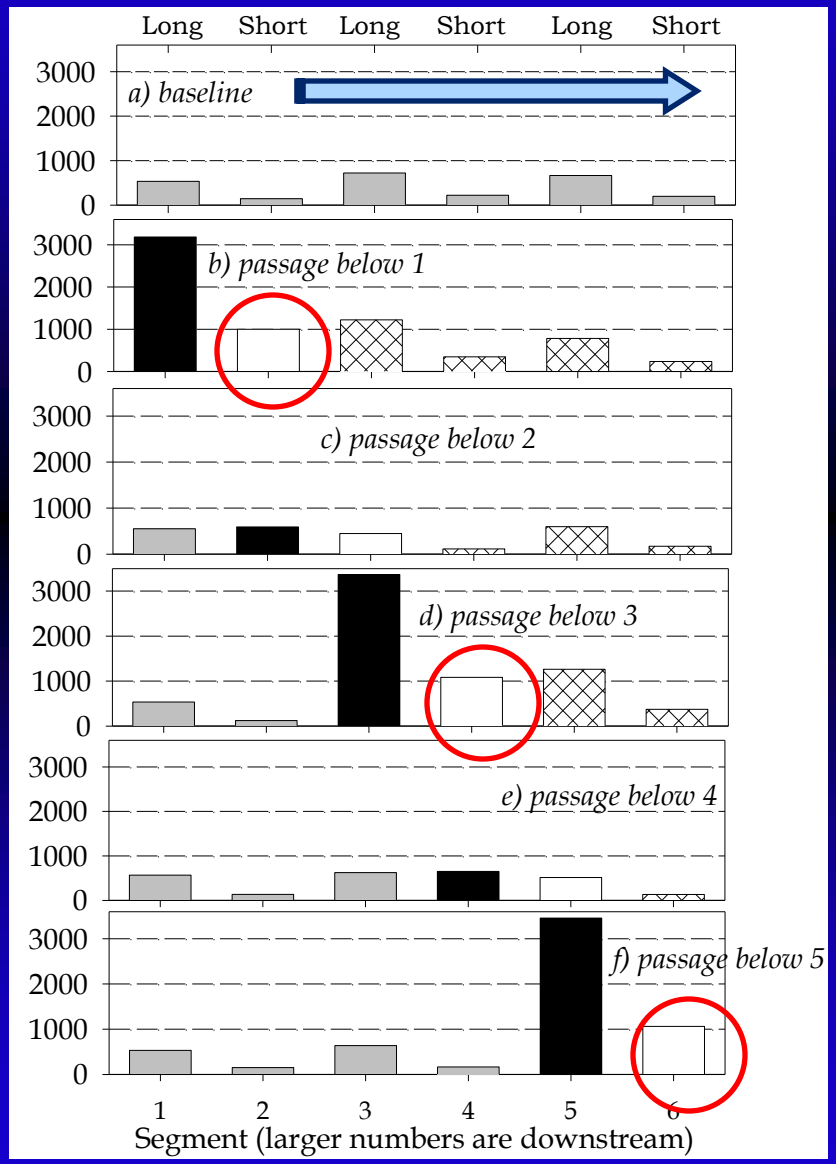
- Upstream passage
  - Current trashrack spacing (wide screening)
  - Halved trashrack spacing (narrow screening)
  - Downstream passage

Upstream passage alone



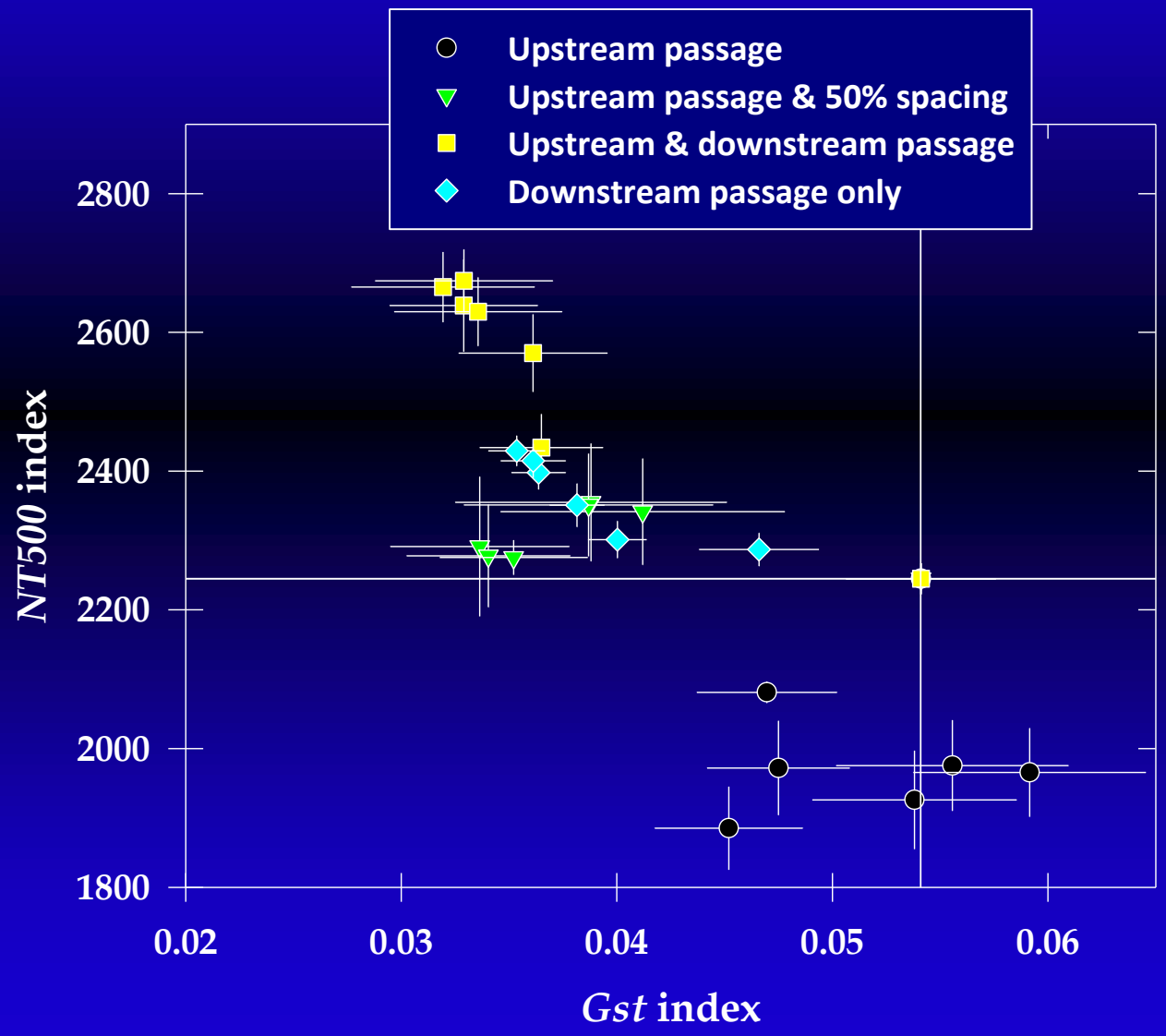
- Simulated the effects of providing upstream passage for river configuration #15.
- Donor populations below the dam with passage (open bars) decreased.
- Recipient populations above the dam (black) increased.
- No “trickle-down” benefits are evident.

Up & downstream passage combined

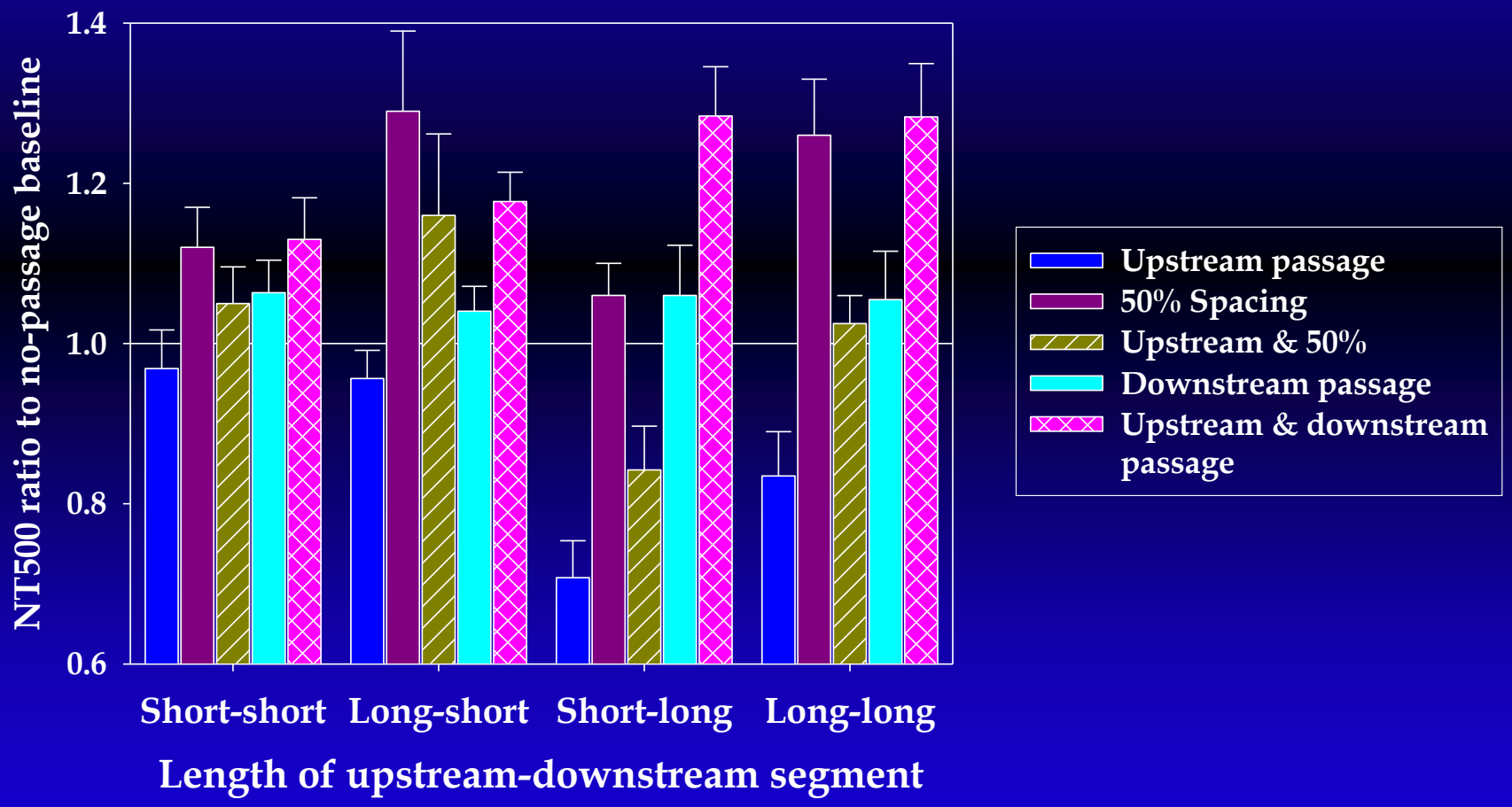


- How does providing downstream passage affect things?
- Donor populations below the dam with passage (open bars) decreased.
- Recipient populations above the dam (black) increased, especially if the segment is long.
- Now, we see trickle-down benefits when recipient segment is long.

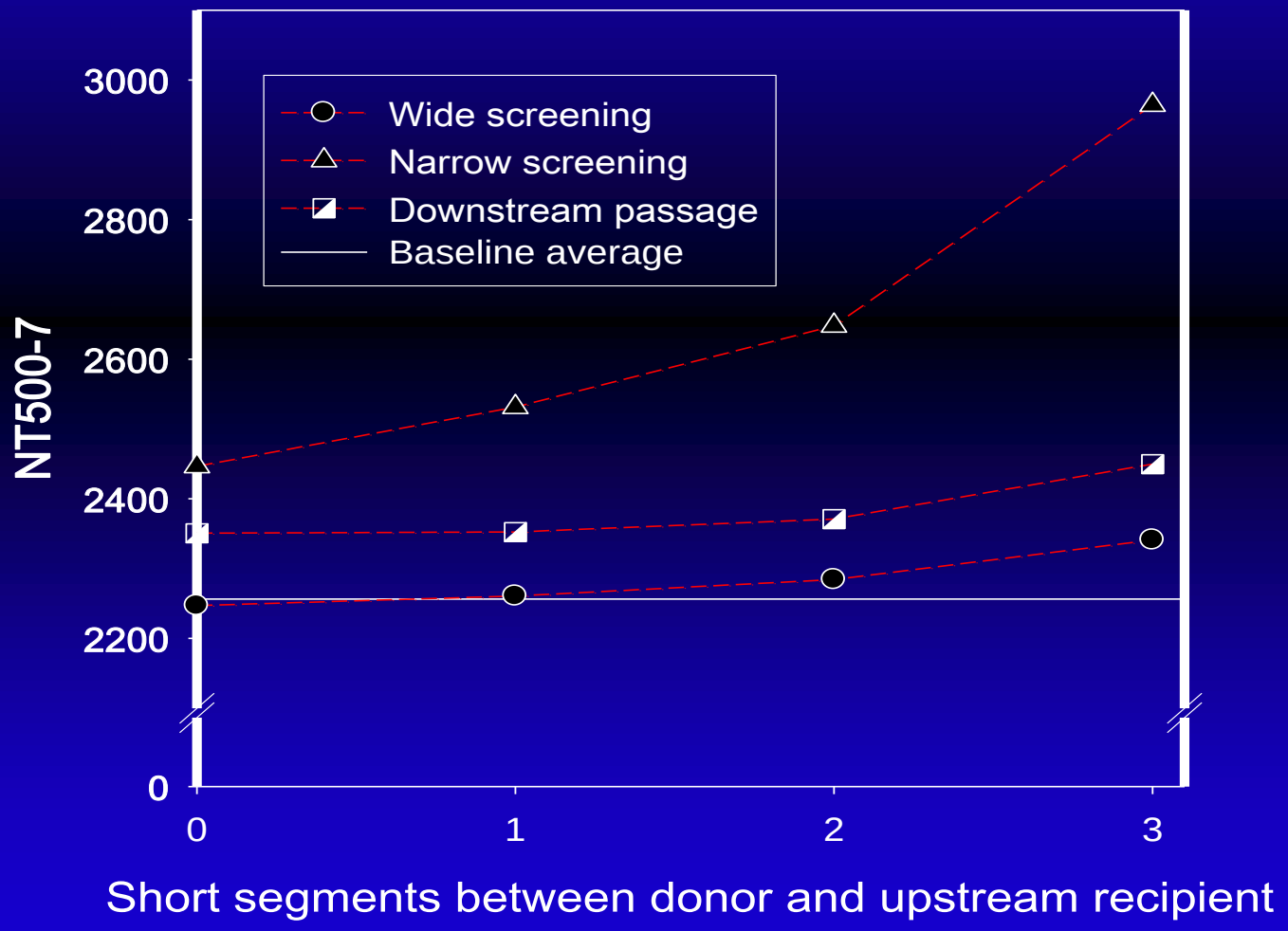
Simulated demographic and genetic responses averaged over river configurations



Best passage option depends on attributes of the segments



Narrow screening enables an upstream recipient to support downstream sink populations



Conclusions for upstream passage

- Upstream passage provided a net demographic benefit:
  - When combined with reduced entrainment mortality
  - When upstream segment is long, downstream short
- Combining two segments (up and downstream passage) was best when the downstream segment was long.
- Screening was very effective alone or combined with upstream passage, especially for long segments above short segments.

Conclusions

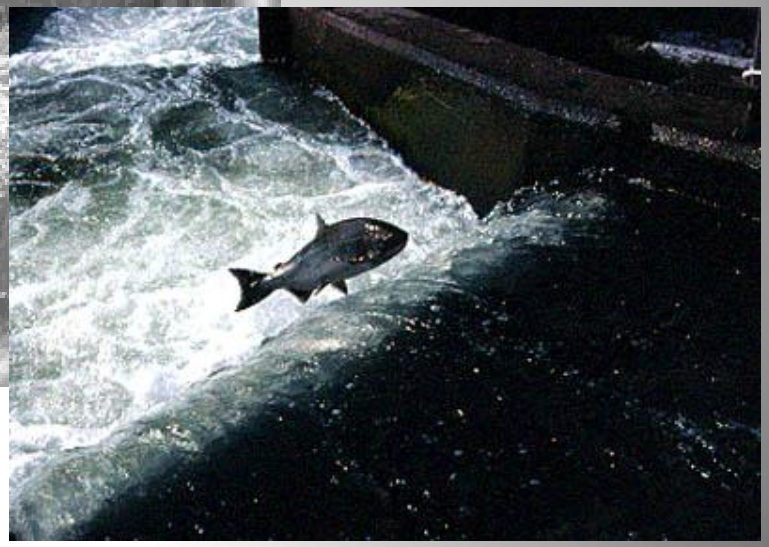
- To benefit metapopulatons, reconnection should be accompanied by:
  - Low entrainment mortality risk following upstream migration.
  - Minimal impact on the donor population (and trickle-down effects downstream of the donor).
- Situations in which reconnection is beneficial:
  - Screening with passage to a long segment with short downstream sinks.
  - Upstream connection with downstream connection at intervening dams.
- Mitigation of entrainment mortality is important.
- Protect the donor population
  - Set translocation policies based on capture effort.
  - Monitor donor populations – the response of the donor indicates net metapopulation response.

Behavior Study

White Sturgeon Passage Behavior, Swimming, and Stress Responses

How do adults respond to passage structures?

Can sturgeon pass barriers, using ladders intended for salmonids?



Objectives

- Design and test a “sturgeon-compatible” fish ladder.
- Concentrate studies on a “random mid-section” of such a ladder.
- Measure hydraulic characteristics, adult white sturgeon passage success, and stress responses associated with passage.

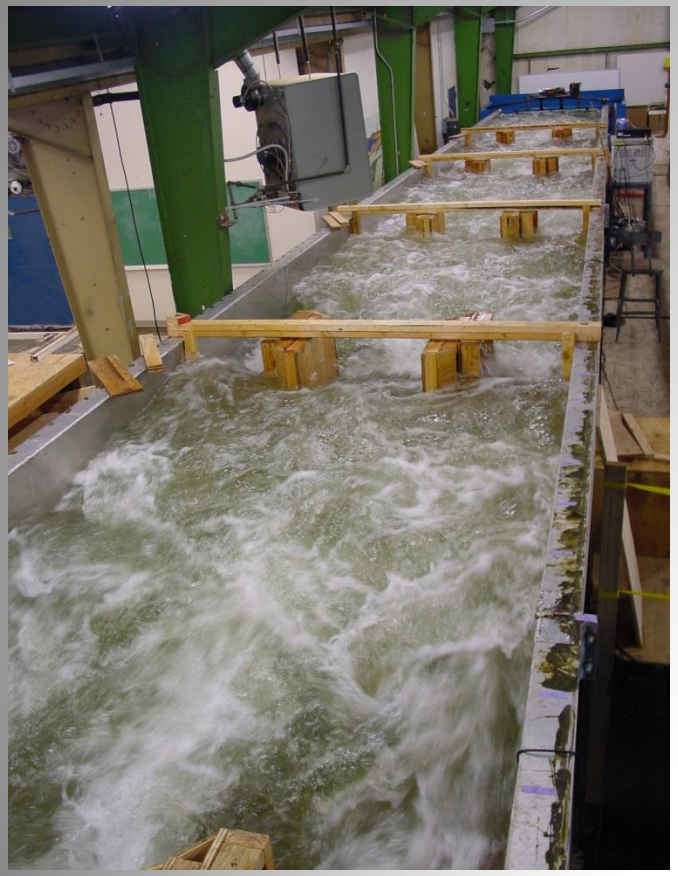
Sturgeon Collection

- Winter - Spring 2003 – 05
- San Francisco Bay Estuary (hook-and-line)
- Yolo Bypass toe drain (fyke trap)

Five-baffle CSE Sturgeon Passage Structure (Flume) of Aluminum

- CSE = Contraction, Straightening, and Expansion
- 31-35 cfs (0.88-0.99 m^3/s) flow through
- 4% bed slope over 24.4-m length
- 81.3 cm - 91.4 cm tail-pool depth treatments

Five-baffle CSE Sturgeon Passage Structure



High tail-pool depth treatment

Low tail-pool depth treatment

Sturgeon Experiments

- Sturgeon held for 3 d after capture before 1st experiment, and held 2 d between experiments.
- Examined for pre-test injury
- Given 30-min acclimation before 1-h experiment
- Fish only allowed two, prolonged (30 s) impingements, shortening experiment to <1 h duration.
- Two standard treatments, with low (S1) and high (S2) tail-pool water heights.

Passage/flume behavior

- Showed burst swimming (mean: < 1.6% of experiment time between the 1st and 5th baffle).

- Passage swimming depth related to tail-pool water depth:

  Low depth: pass near/touching flume floor

  High depth: pass near bottom to mid-water

- Sturgeon can "anchor" position in velocities < 1.07m/s (straight flume), and they often searched for low-velocity refuges in tail pool.

Passage/flume behavior

- Second passage, after failed 1st attempt, occurred in only 18% of fish.

- Incomplete experiments due to 2nd impingements:
  - Low tail-pool depth: 52%
  - High tail-pool depth: 10%

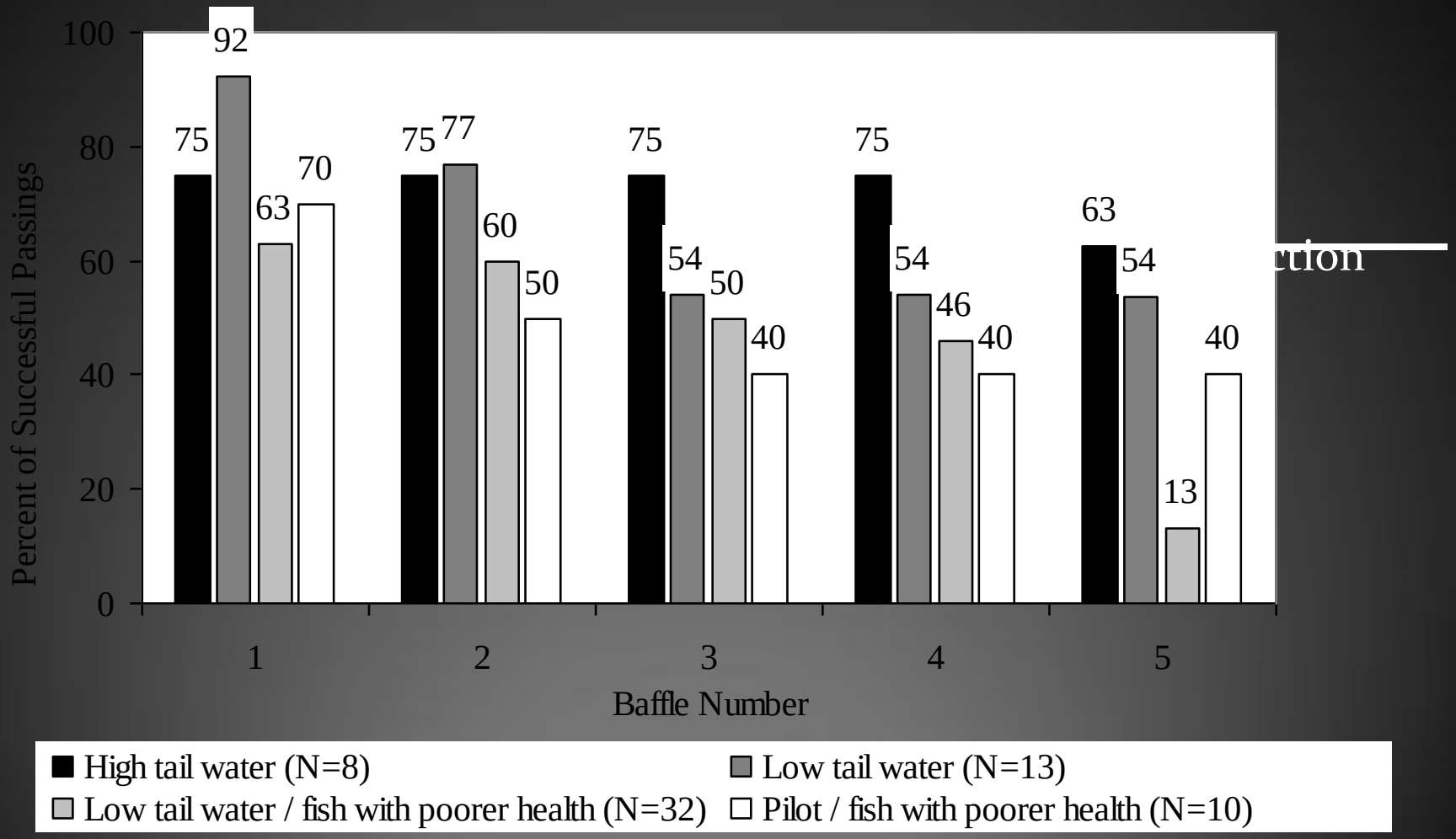
- Downstream movement after failed passage:
  - Low tail-pool depth: pass using + rheotaxis
  - High tail-pool depth: pass using – rheotaxis

1st Baffle Passage Video

Swimming Performance

- Attraction flows: ≥ 0.45 m/s (2003)
- Mean swimming velocity: 2.57 m/s (8.55 ft/s) at 1st baffle (Peak™ motion-tracking software).
- Passage improved when baffle slots were aligned.
- Time to pass five baffles:
  - Low: 11-45 s
  - High: 45-131 s

Passage Efficiency

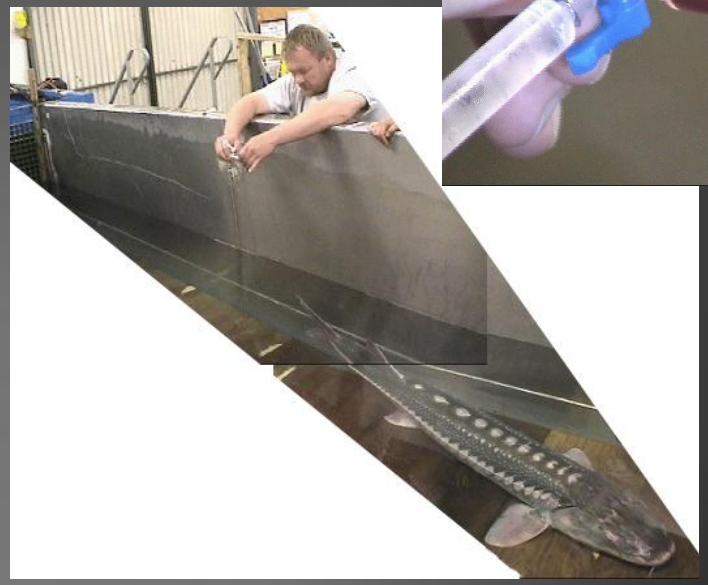


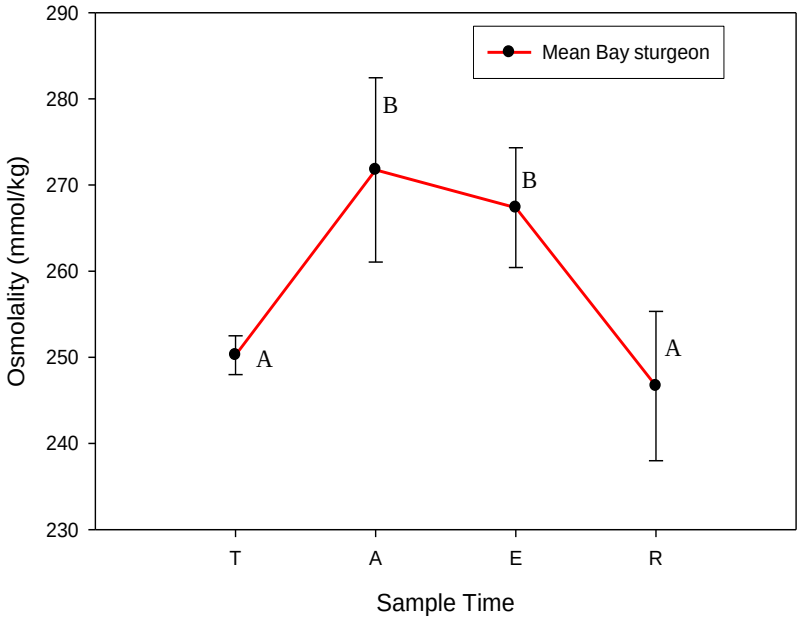
Passage Efficiency

- Pre-test health (HAI) condition and holding time significantly affected passage rates.
  - (-) HAI $p = 0.0002$, GLM
  - (+) holding time $p = 0.01$, GLM
- Fish with 13% passage rate (low tailpool depth); success increased to 40% when tested in a high tail pool depth treatment.
- Hydraulic conditions seem to have a greater effect on passage than the sturgeon's pre-test health.

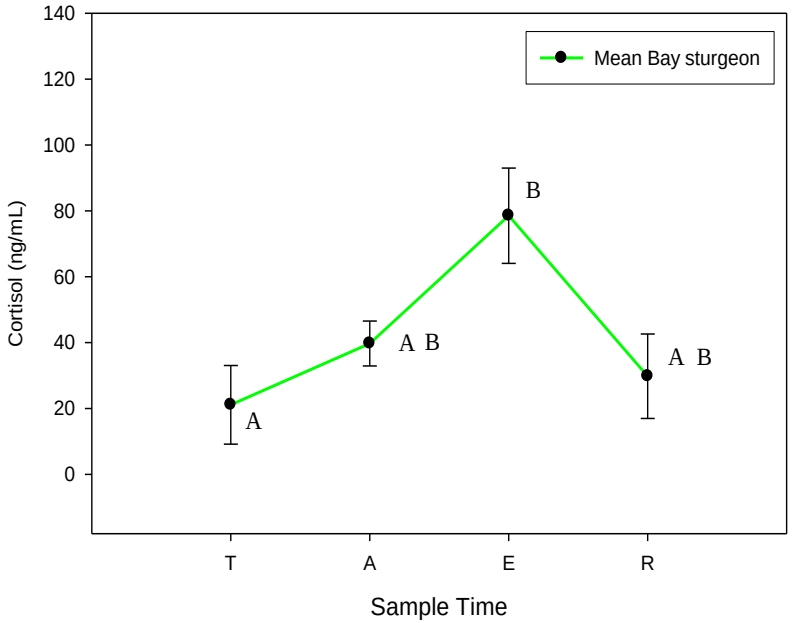
Stress Response

- Physiological stress responses to passage were assessed by measuring blood hematocrit, and plasma pH, cortisol, osmolality, and lactate concentrations.
- Sampled via in-dwelling cannula in the caudal vein

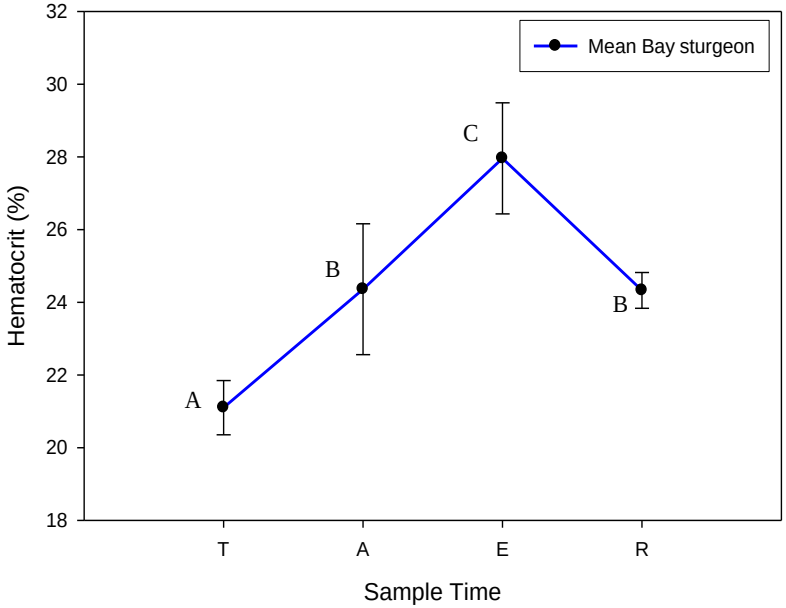




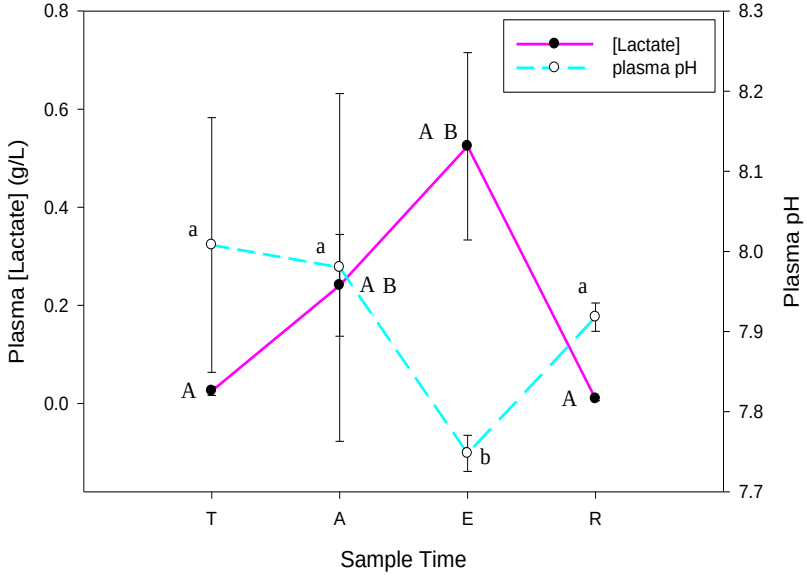
(T-Tank, A-End acclimation, E-15 min post-experiment, R-24 h post-experiment)



(T-Tank, A-End acclimation, E-15 min post-experiment, R-24 h post-experiment)



(T-Tank, A-End acclimation, E-15 min post-experiment, R-24 h post-experiment)



(T-Tank, A-End acclimation, E-15 min post-experiment, R-24 h post-experiment)

Stress Response Conclusions

- Sturgeon showed significant, and typical, physiological responses to handling and passage.
- Sturgeon apparently recruited (anaerobic) white muscle fibers to ascend the flume. These powerful bursts required the fish to rest, to clear accumulated H^+ and $lactate^-$ and to restore muscle glycogen stores.
- 24-h post-swimming exercise data often were not significantly different than pre-exercise levels.

Overall Conclusions

- Adult white sturgeon can negotiate a random mid-section of an CSE-type passage structure with peak water velocities up to 2.57 m/s, over 24.4 m at a 4% bed-slope.
- Sturgeon passage is improved with aligned passage slots and deeper tail pool depths (independent of water velocity), as is control of swimming direction.
- Future Research Questions:
  - How do sturgeon negotiate passage entrances and exits?
  - What role does substrate play in passage success?
  - How does upstream passage affect reproduction?

For more information on fish modeling,

see www.esd.ornl.gov/~zij/

For more information on behavioral studies, see

http://wfcb.ucdavis.edu/www/Faculty/Joe/treadmill/