How Should Juvenile Salmonid Mortality Rate Responses to Tailrace TDG be Assessed in Evaluation of Dam Passage Options?

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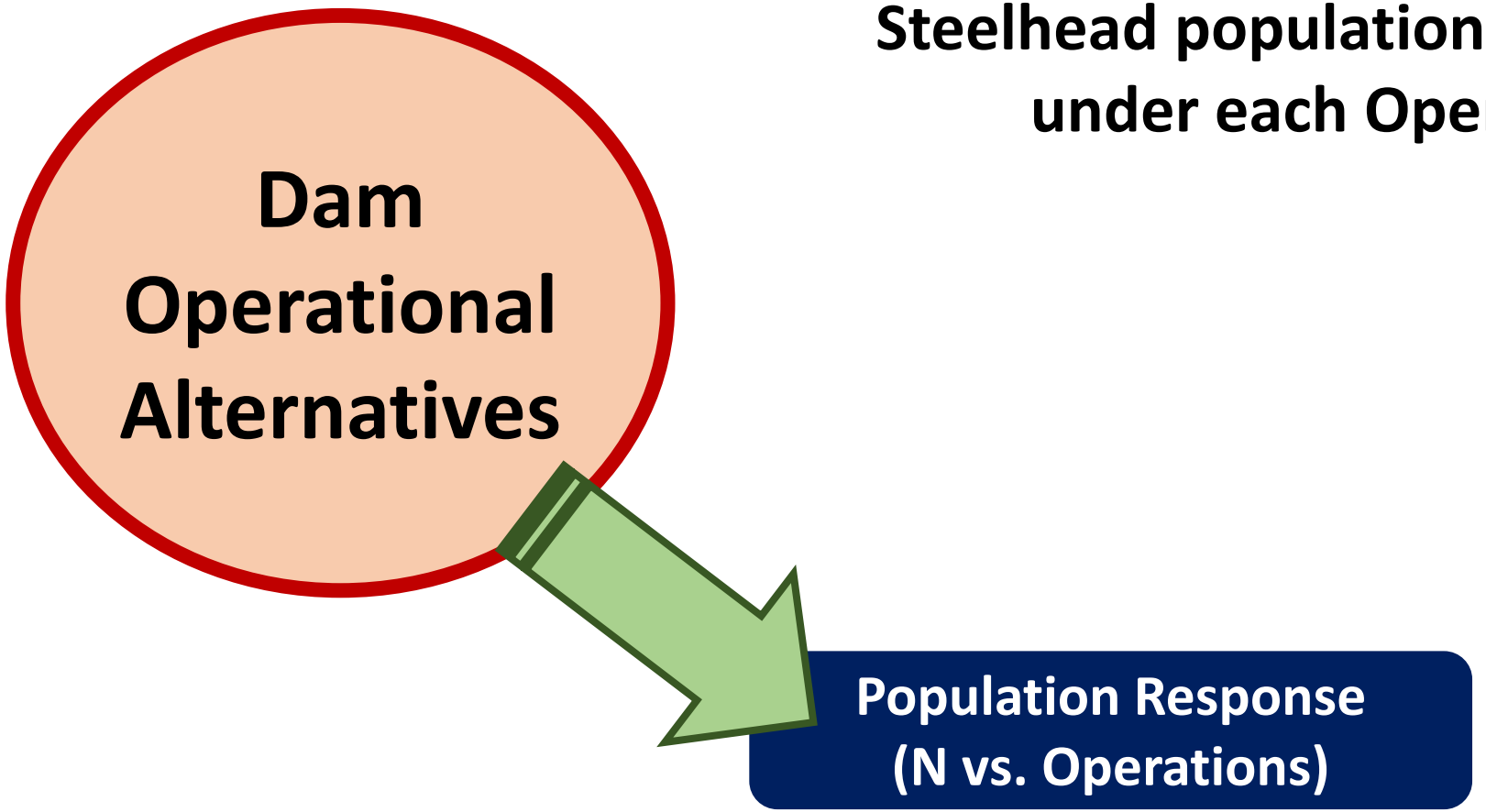
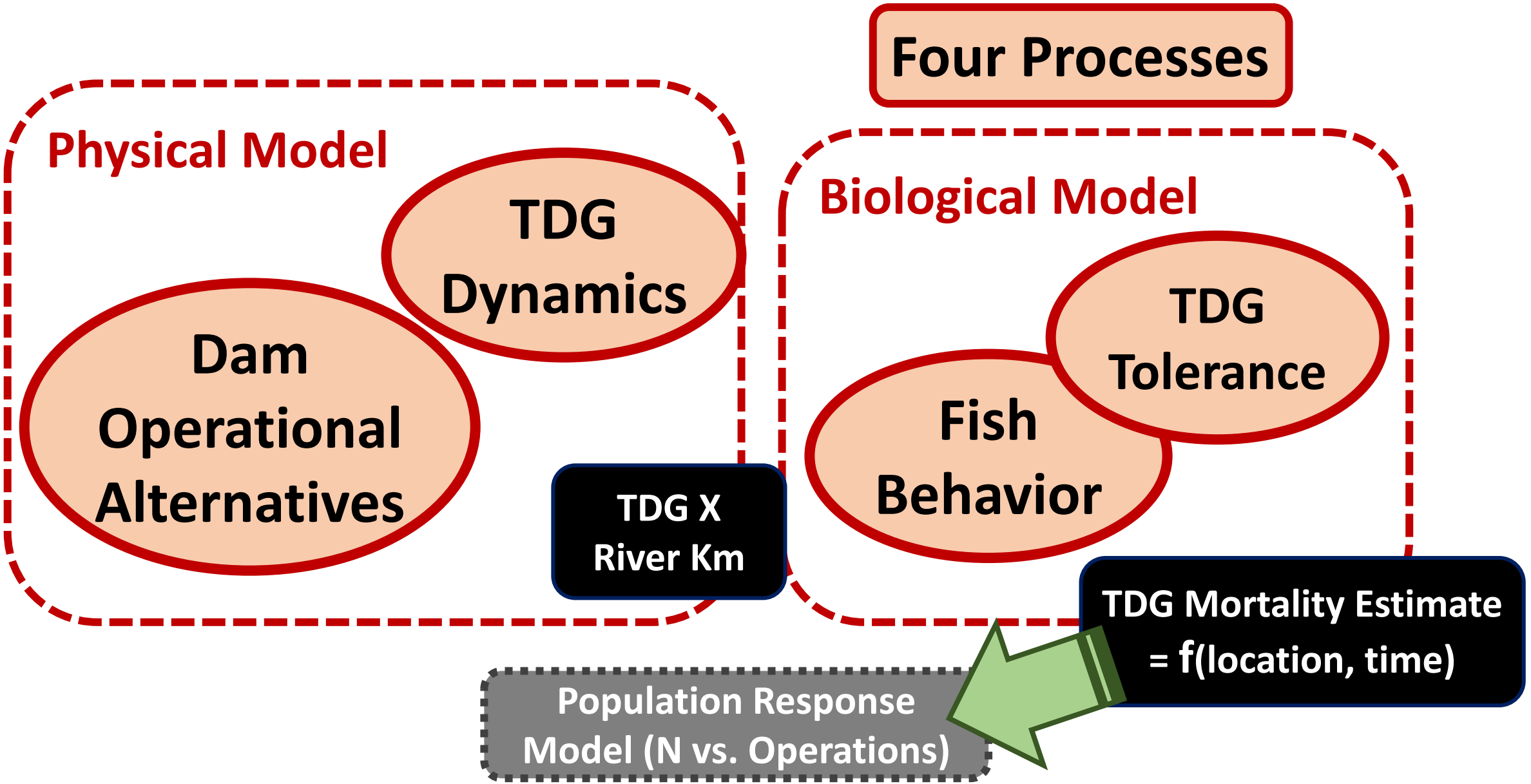
Estimating TDG Mortality: Conceptual Model

<u>Goal:</u> Estimate the response of Chinook and Steelhead populations to TDG supersaturation under each Operational Alternative



Estimating TDG Mortality: Conceptual Model



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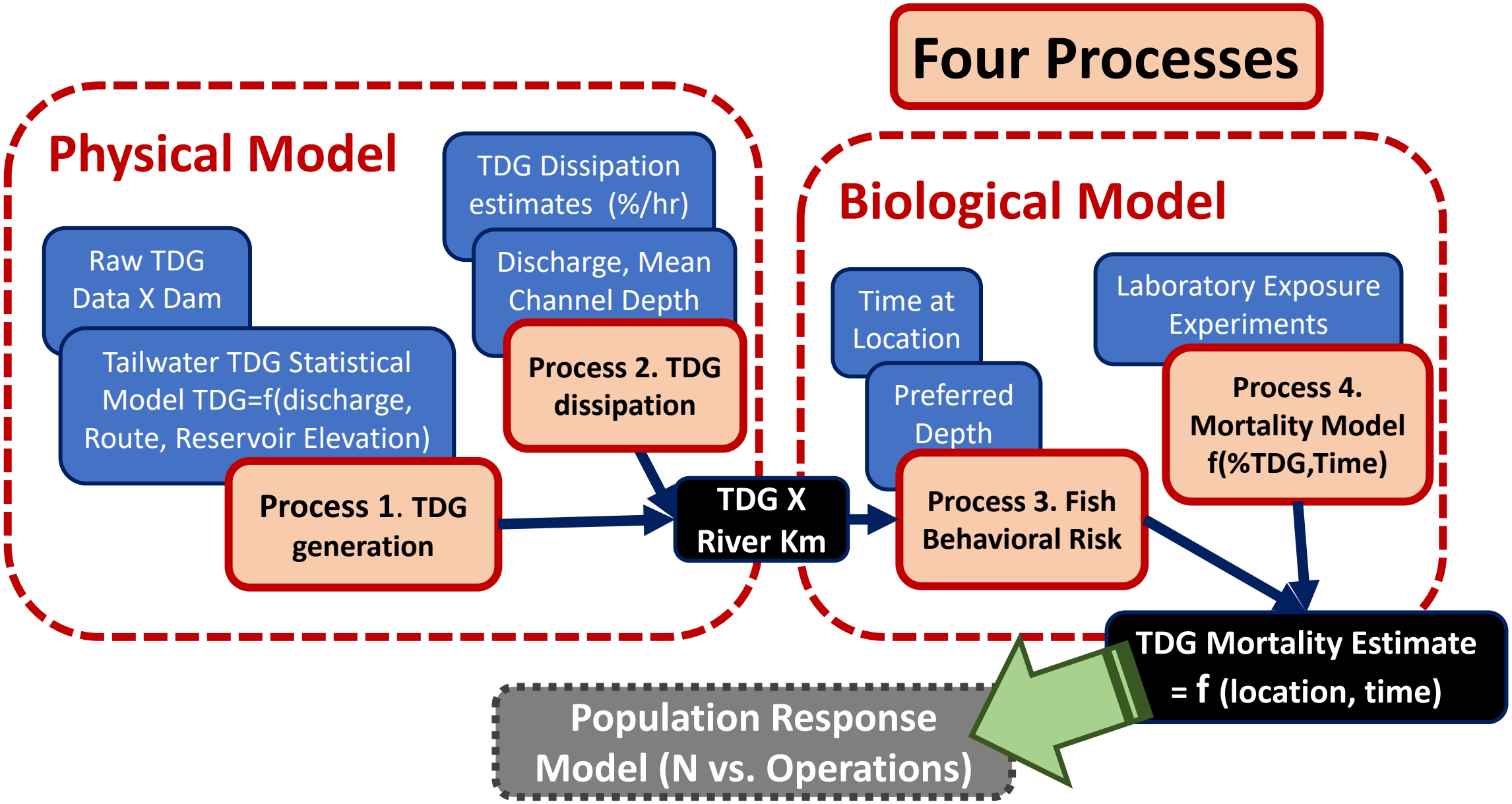
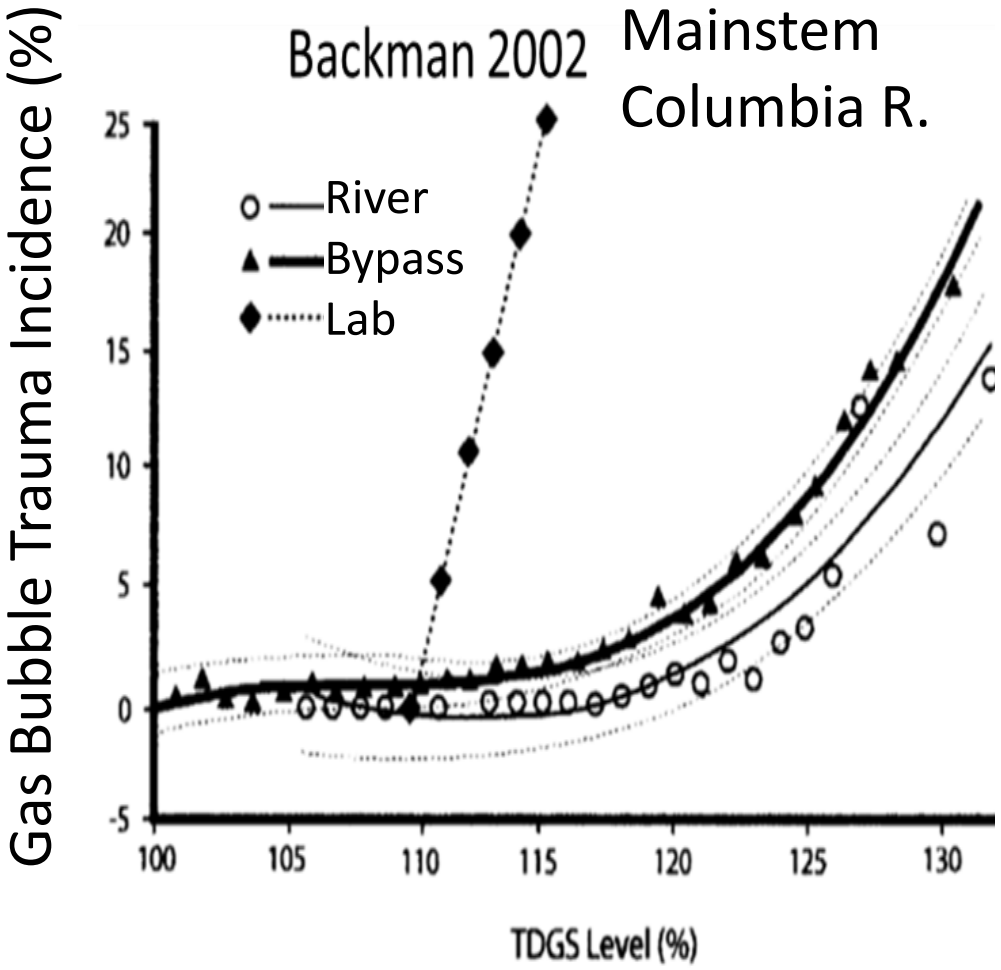
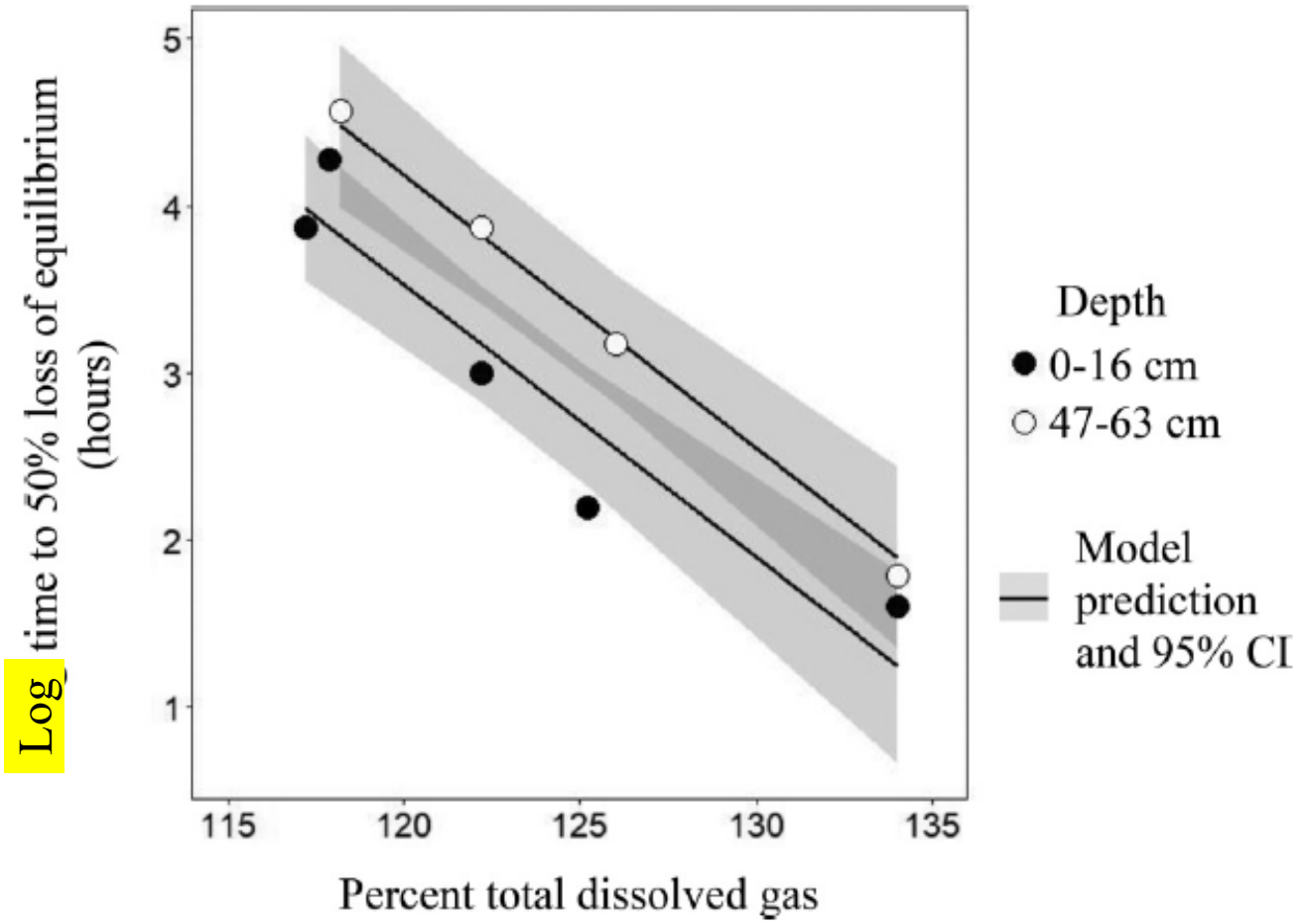


Why do this?
- Lab Risk ≠ River Risk

Pleizier et al. 2020 Fish in deeper tanks experience are not as susceptible to the effects of TDG



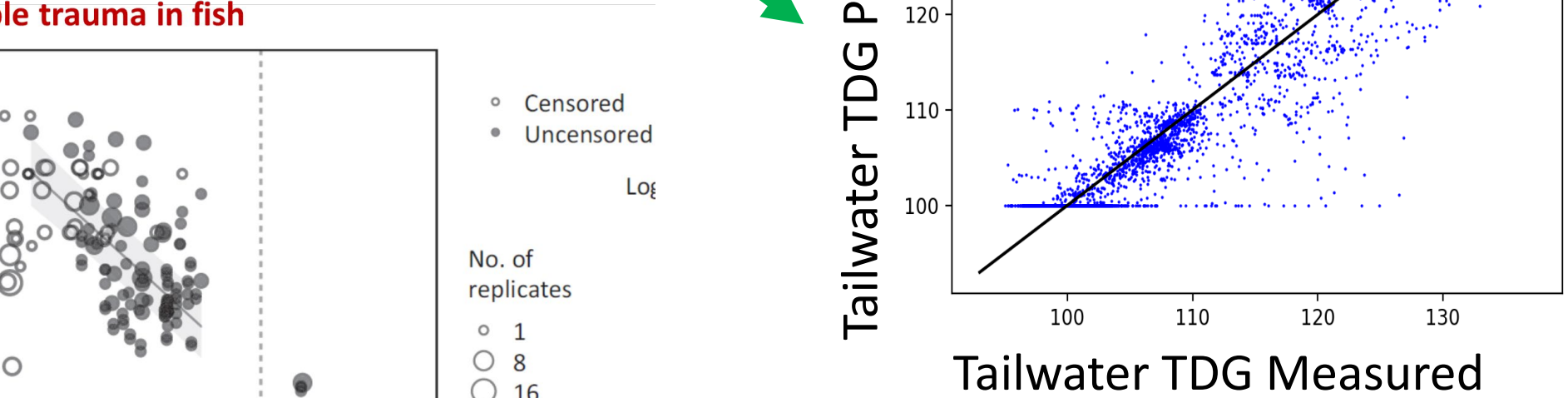


Four Processes: Two are well documented

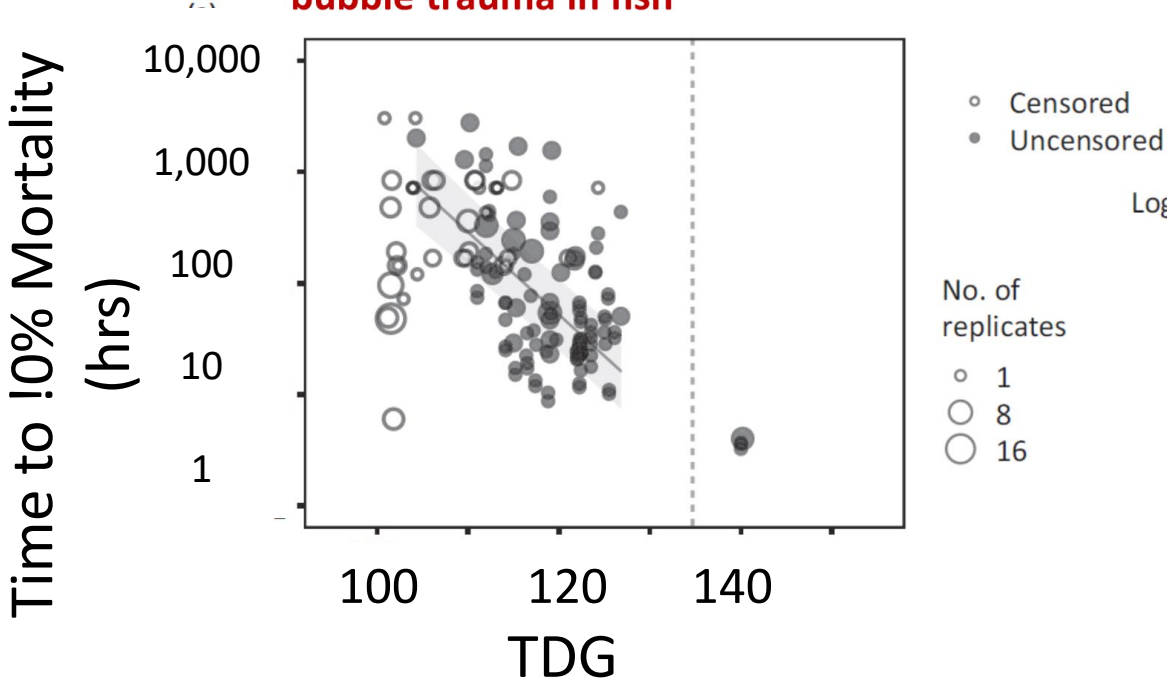
1. **TDG Generation**
2. TDG Dissipation
3. Fish Behavior
4. Lab tolerance

USACE 2022. EIS, Appendix D: Water Temperature & TDG Methods

$$\%\boldsymbol{TDG} = \text{f(discharge)} = \boldsymbol{a} + \boldsymbol{be}^{\boldsymbol{cQ_s}}$$



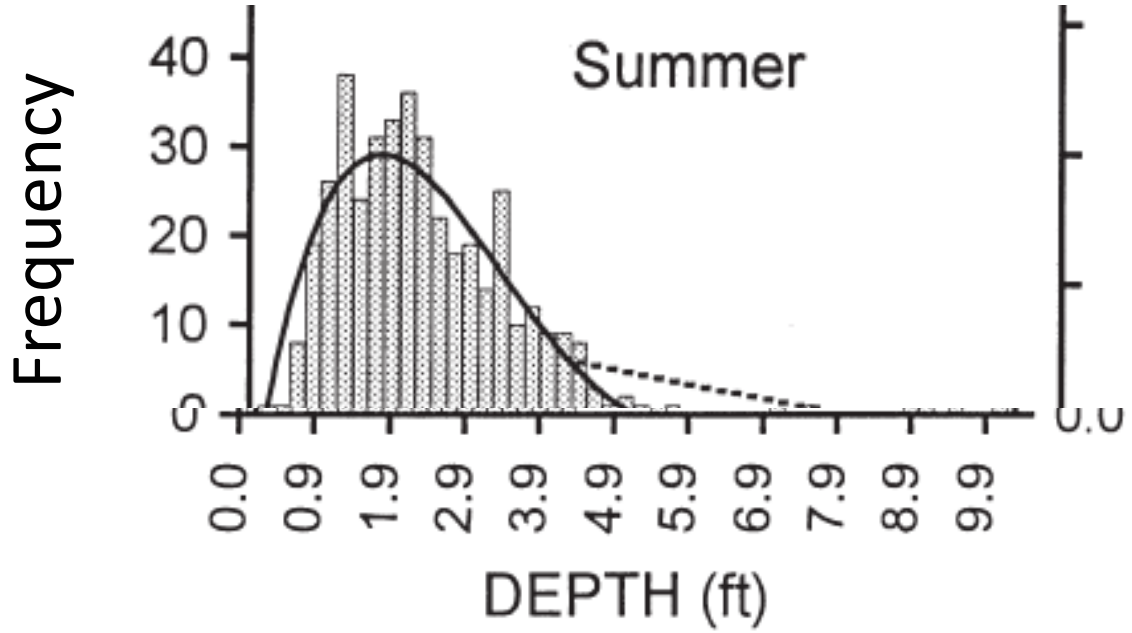
Pleizier et al. 2020 A meta-analysis of gas bubble trauma in fish



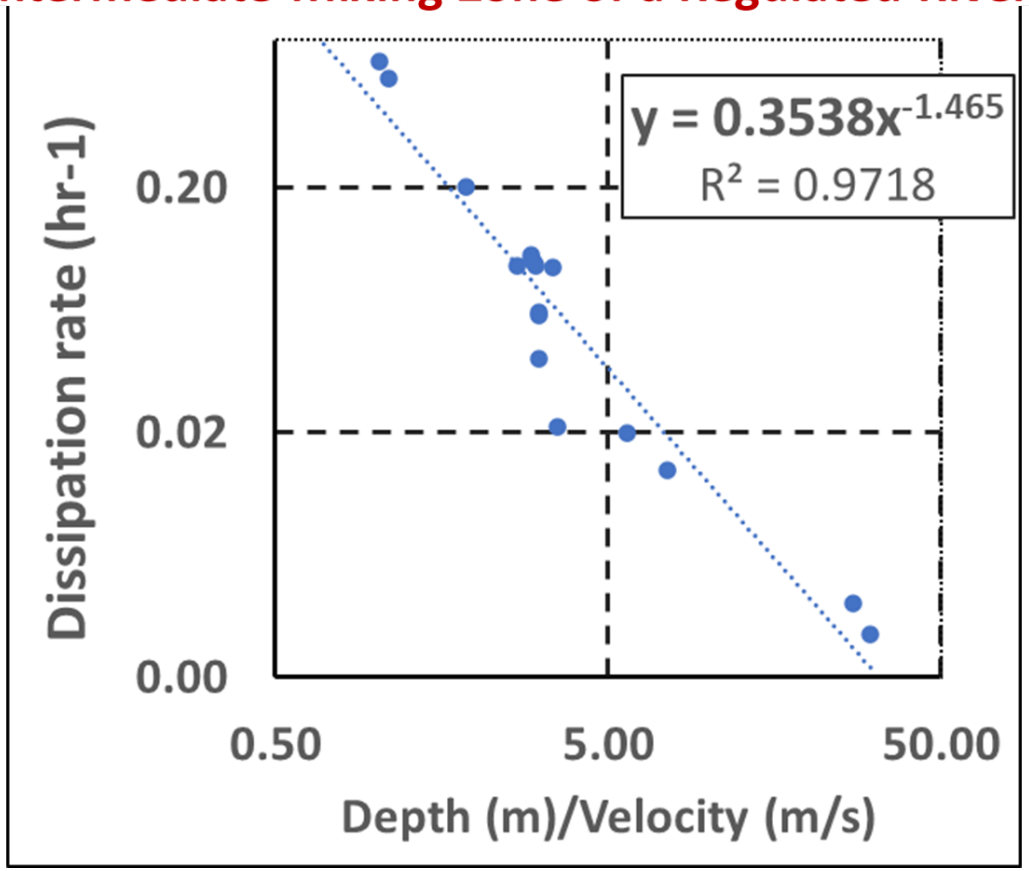
Four Processes: Two Are Not well Documented

1. **TDG Generation**
2. TDG Dissipation
3. Fish Behavior
4. Lab tolerance

Allen 2000 Seasonal Microhabitat Use by Juvenile Spring Chinook in the Yakima R

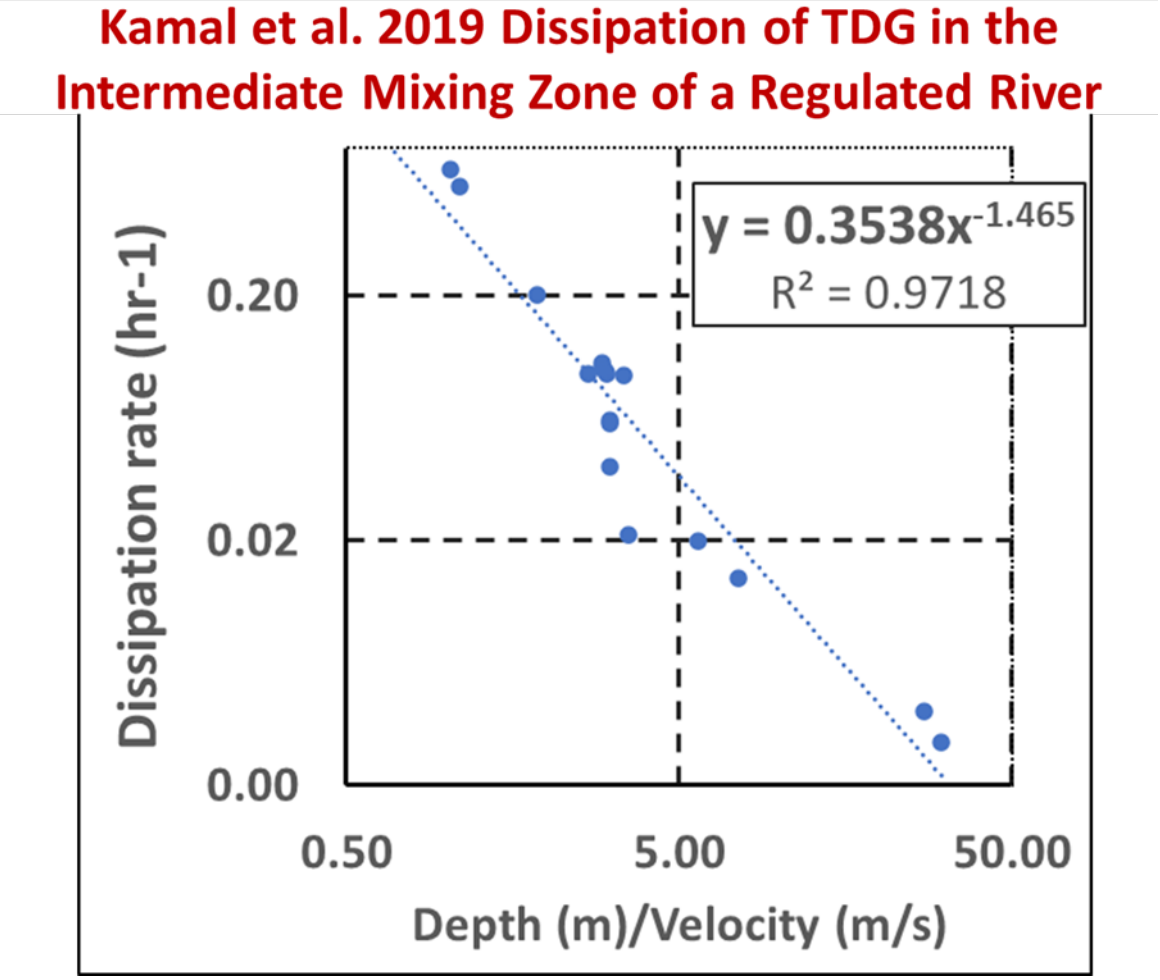


Kamal et al. 2019 Dissipation of TDG in the Intermediate Mixing Zone of a Regulated River



TDG Dissipation:

Calibrate Kamal et al. 2019 to Willamette Tributaries



North Santiam at Niagara					
At Discharge = 42.5 cms					
	Velocity m/sec	Depth m	Depth /Velocity	inst k min-1	% retained
Sement 1	1.24	0.53	0.42	0.03	99.2%
Sement 2*	1.90	0.31	0.16	0.09	94.9%
Sement 3	1.14	0.52	0.46	0.02	97.0%

*** High Dissipation Segment**

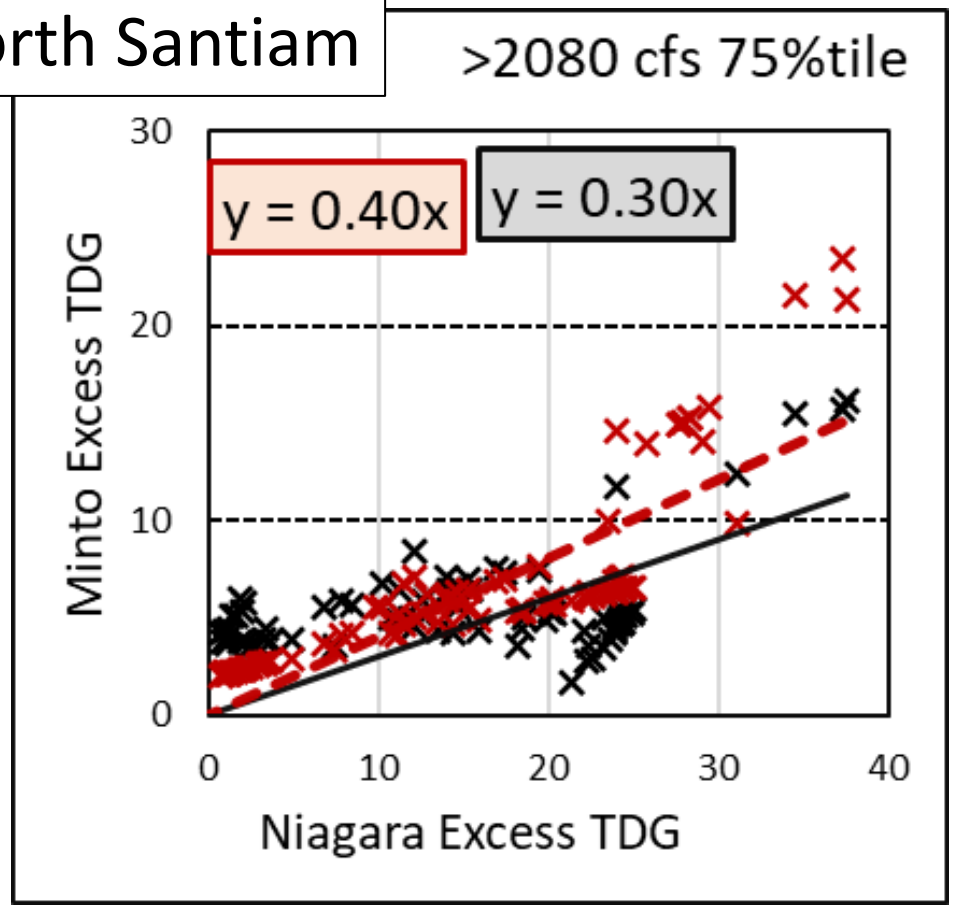
Reach TDG Retention
= Product (segment retentions)

Note: Low downstream TDG = High Dissipation

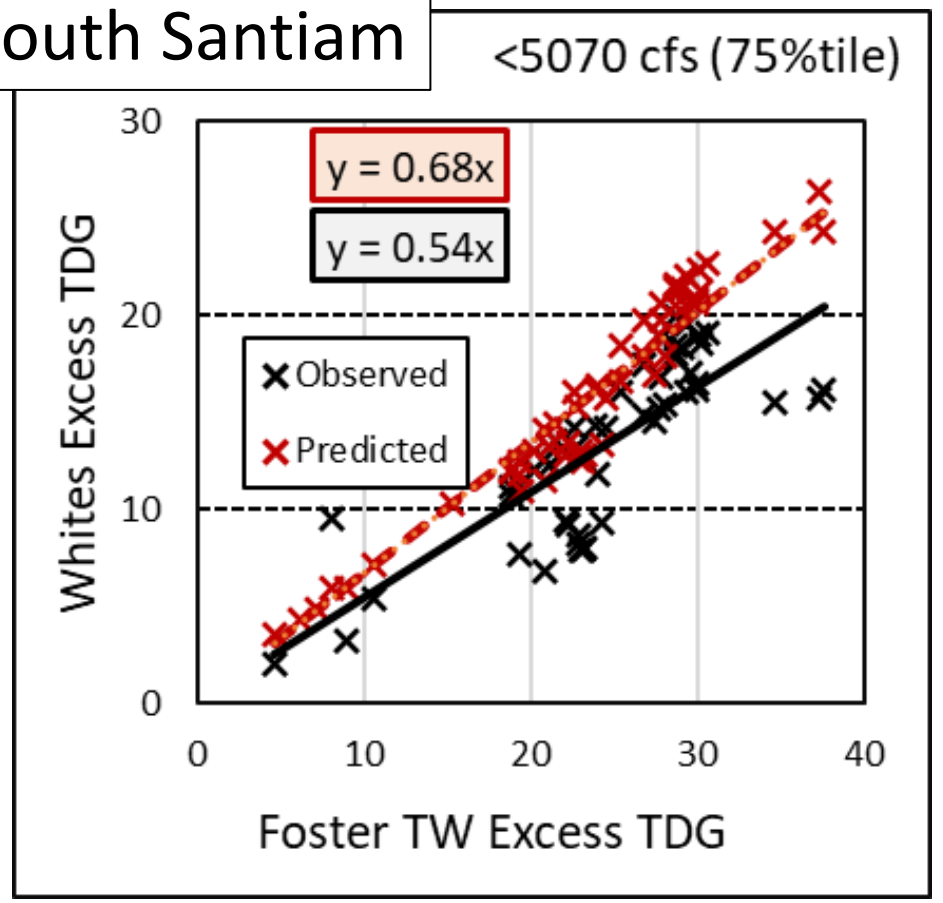
Predictions:

- Dissipation is faster in the North Santiam
- Predicted TDG is higher than Observed especially at high TDS
  - Note: Low downstream TDG = High Dissipation

North Santiam



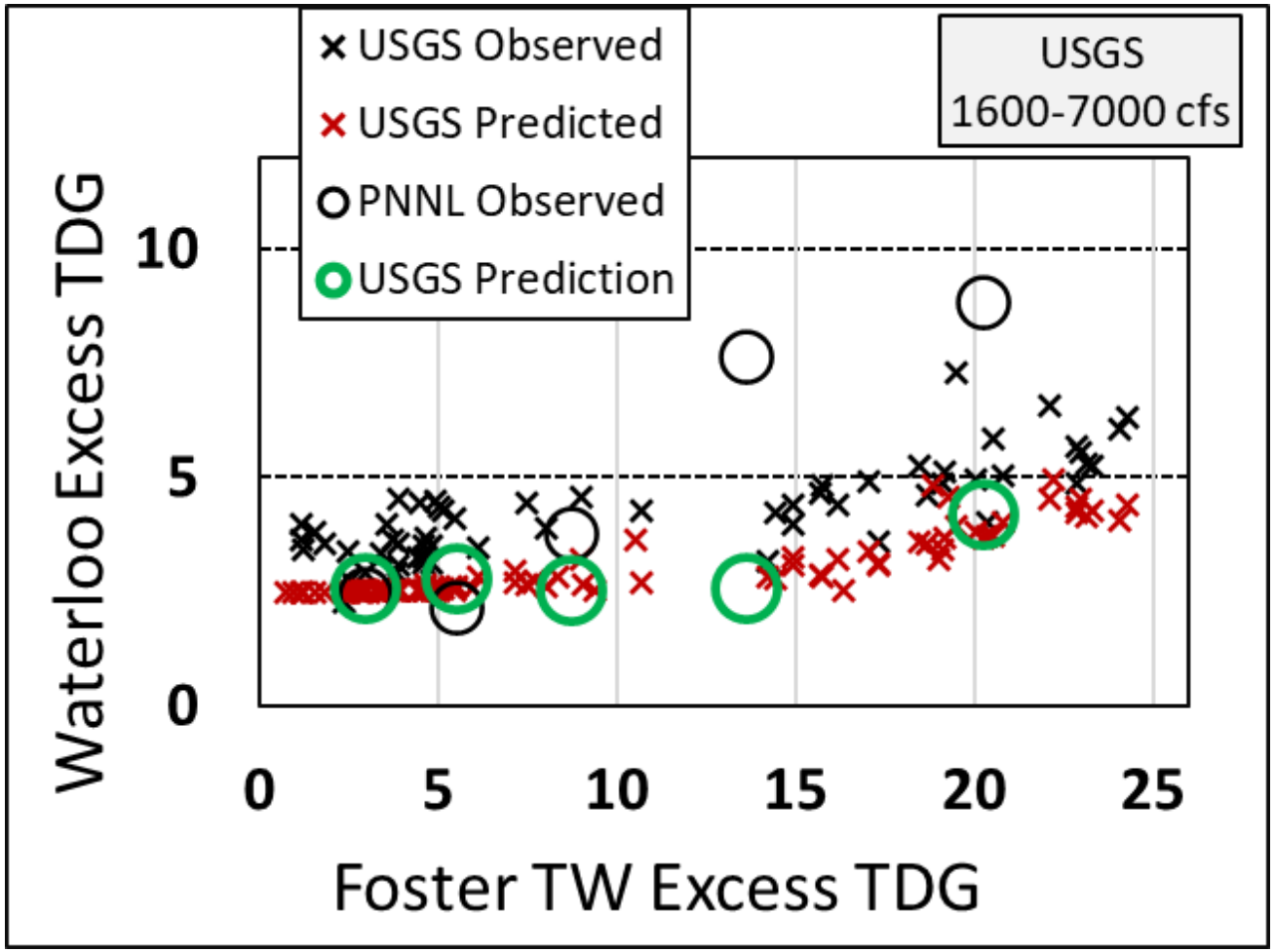
South Santiam



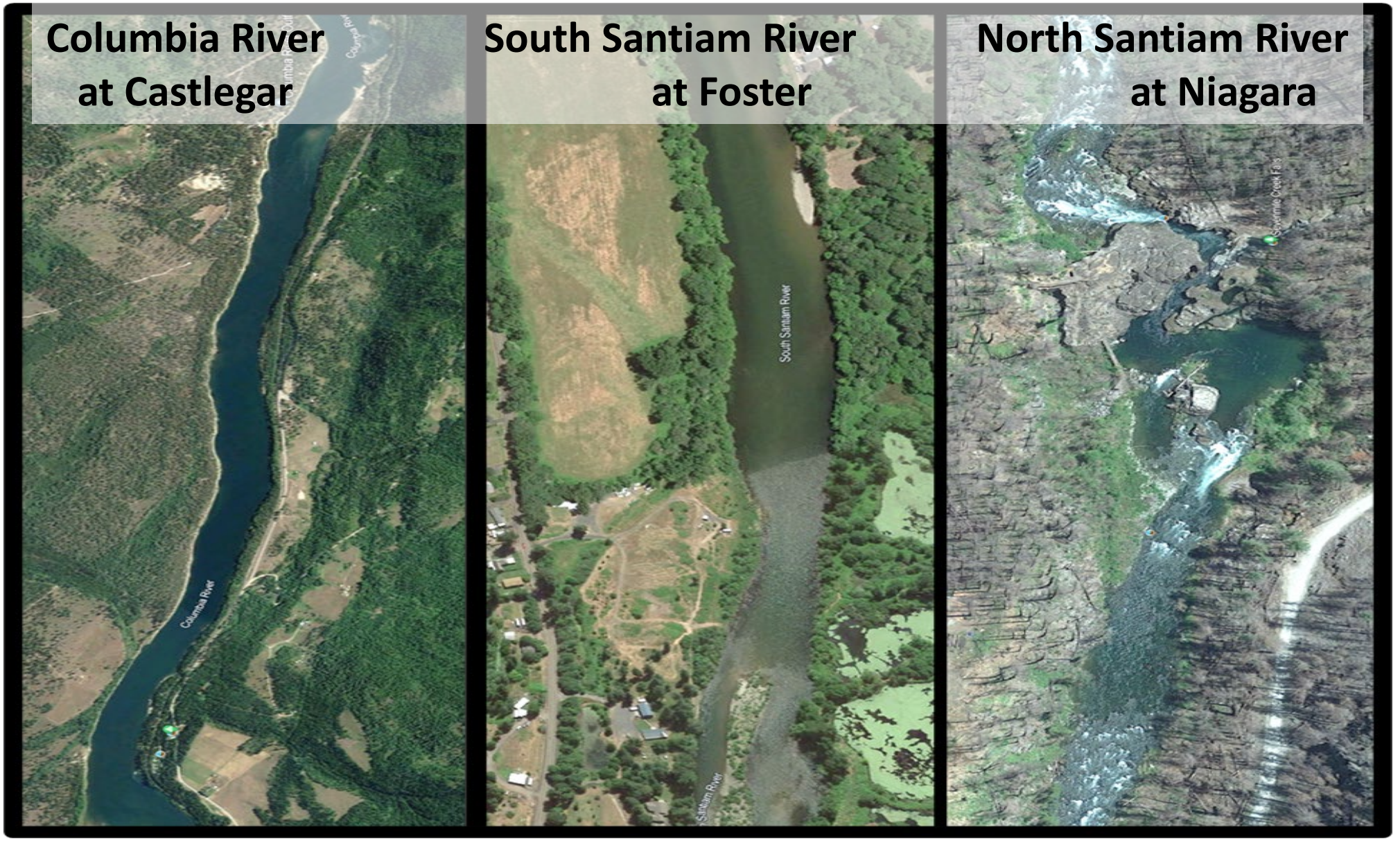
USGS data vs. PNNL 2016-17; South Santiam River

- Observed dissipation is lower than for the USGS data set*
- Compare 5 data points with USGS at a similar discharge range
- PNNL data: Similar predictions, higher observed
  - Implies that dissipation was low during the PNNL study

*Low TDG = High Dissipation



Bubble and Turbulence Effects?



Four Processes

1. TDG Generation
2. TDG Dissipation
3. **Fish Behavior**
   - **– Depth Choice**
4. Lab tolerance

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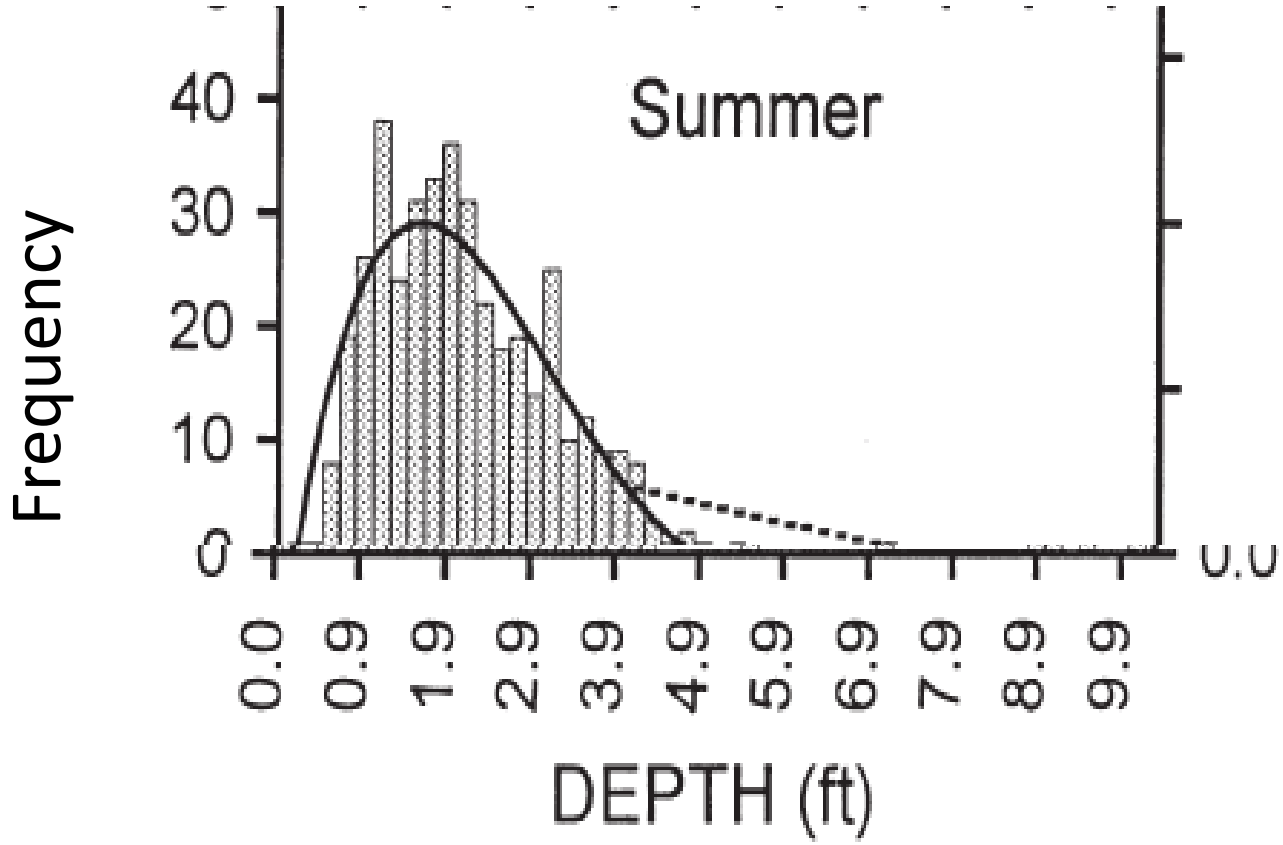


Fish Behavior and Depth Compensation

In deep water, dissolved gases remain in solution under pressure

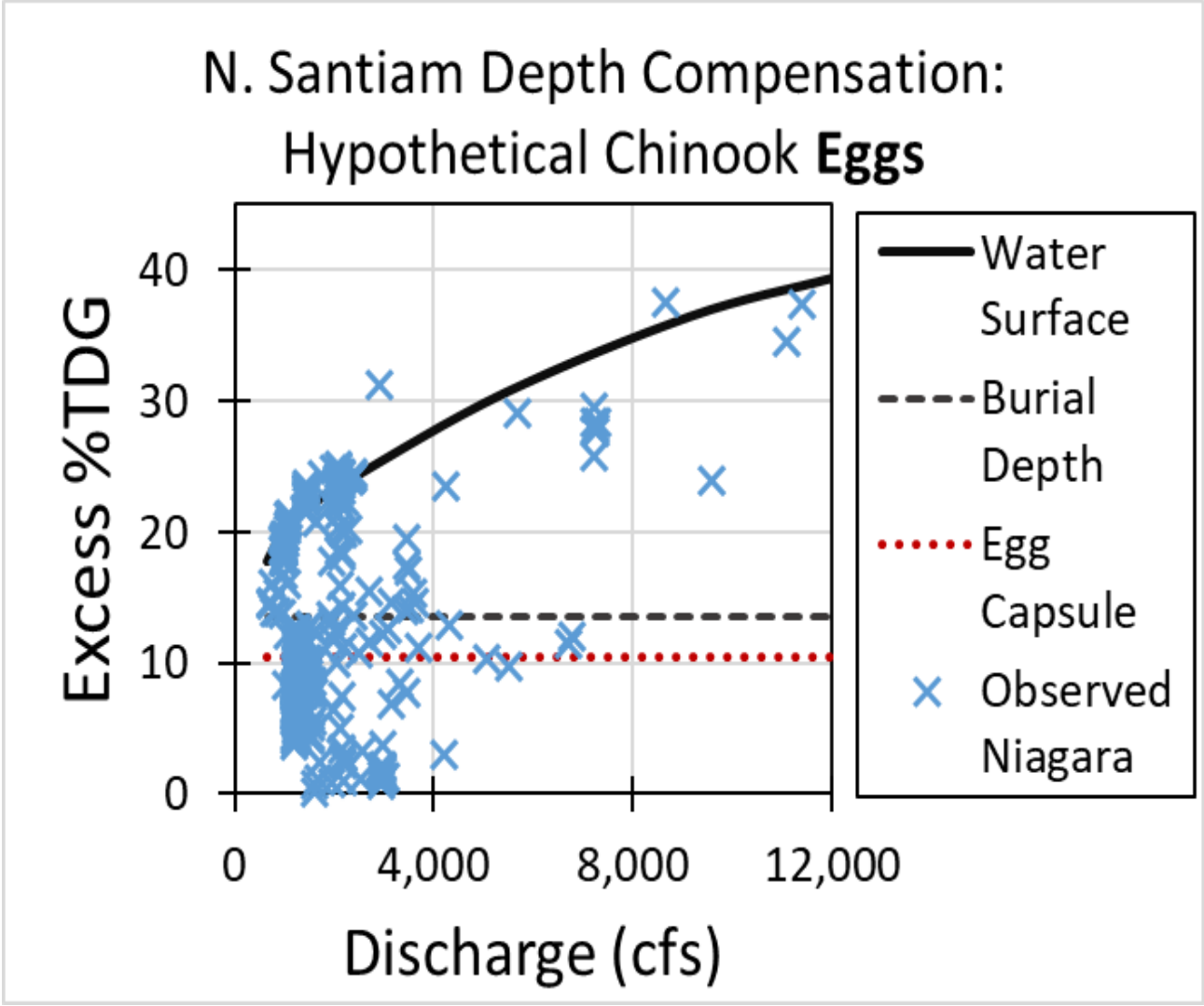
- There is a similar issue with Scuba divers ("*the bends*")
- **About 10% TDG Compensation for 1 meter** in depth or **3% per foot**
- Highest TDG are at high flows
- Fish potentially have a depth refuge, especially at high flows

- Do they use it? Experiments have had mixed results.
- Fish do not seem to detect TDG concentration directly.

Depth Compensation:

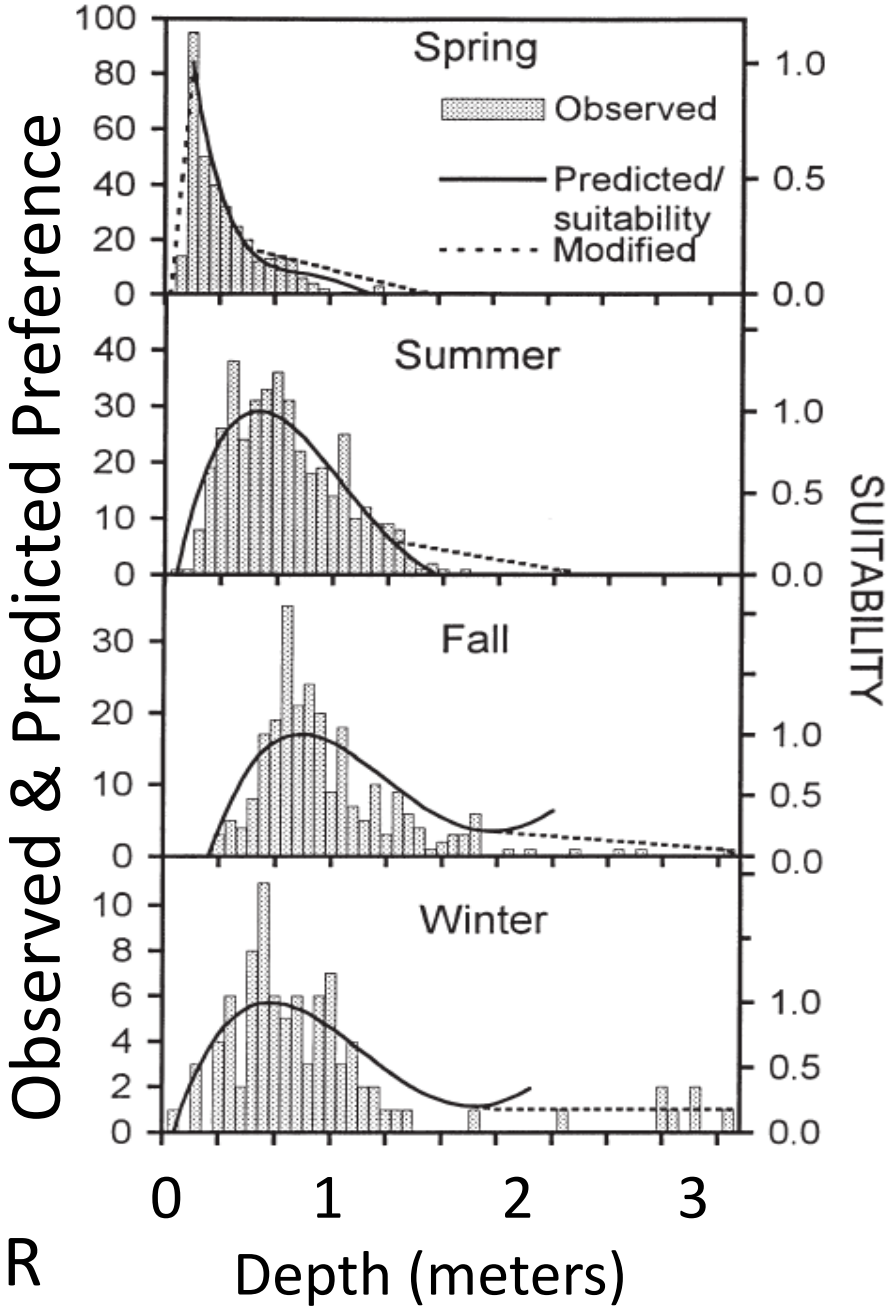
e.g. Chinook Eggs below Big Cliff Dam

- Egg Capsule Pressure(before hatching):7-12% TDG
  - Alderdice and Jensen 1985
- Burial depth: 19-40 cm (2-4% TDG)
  - DeVries 1997
- Spawning Depth: 30-60 cm (3-6%)
  - Raliegh 1986
- **Increase in water depth with discharge: 0-2.5m (0-24%)**
  - Hydraulic modeling & Pleizeir et al. 2020



Fish Behavior: Depth Choice

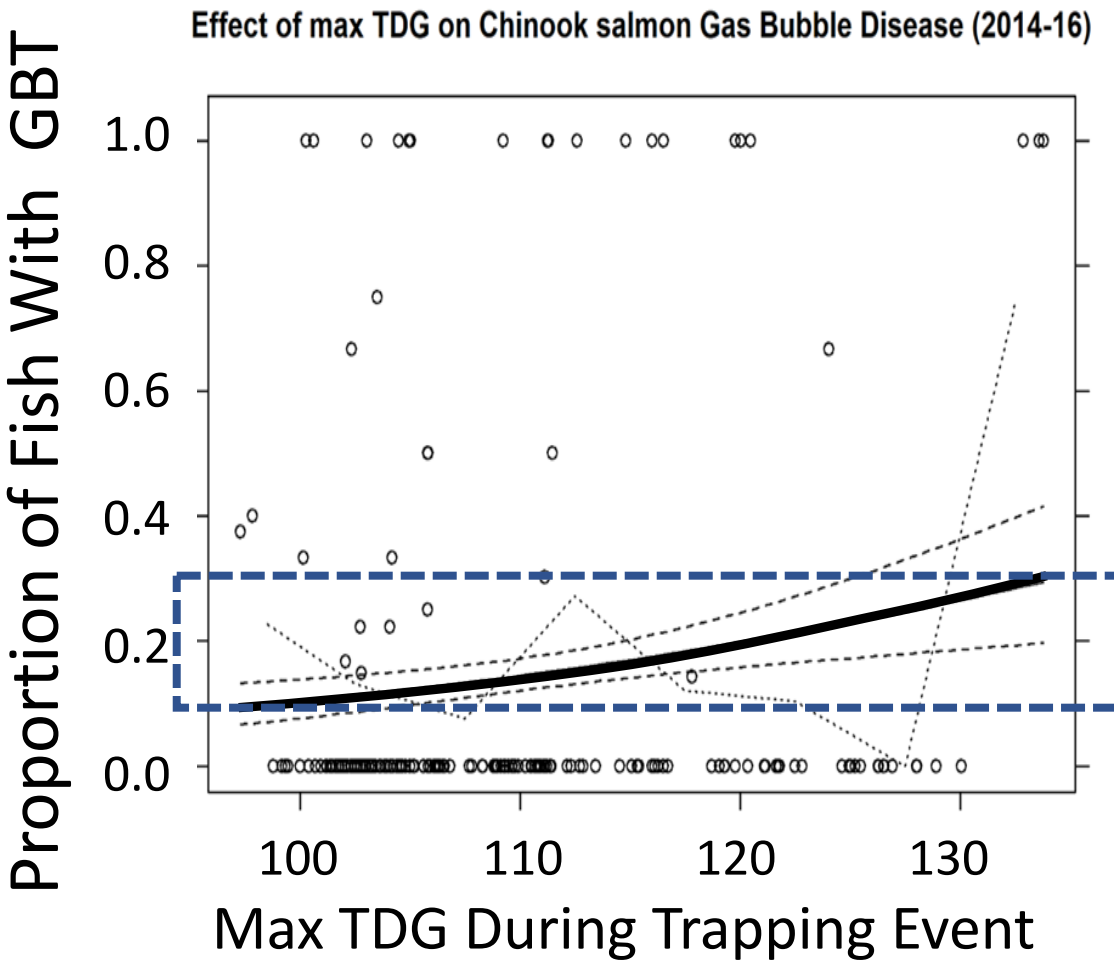
- **Small Chinook generally use shallow water**
  - 0.0-1.5 m, deeper in fall & winter
  - 0-15% TDG depth compensation
- **Are there exceptions to this rule**
  1. Observations in Willamette Basin traps
  2. High Flow events
  3. Migration
  4. Buoyancy cues
  5. Physical displacement downstream or to deeper water?



Allen 2000 Yakima R

Exceptions: Observed TDG Incidence:

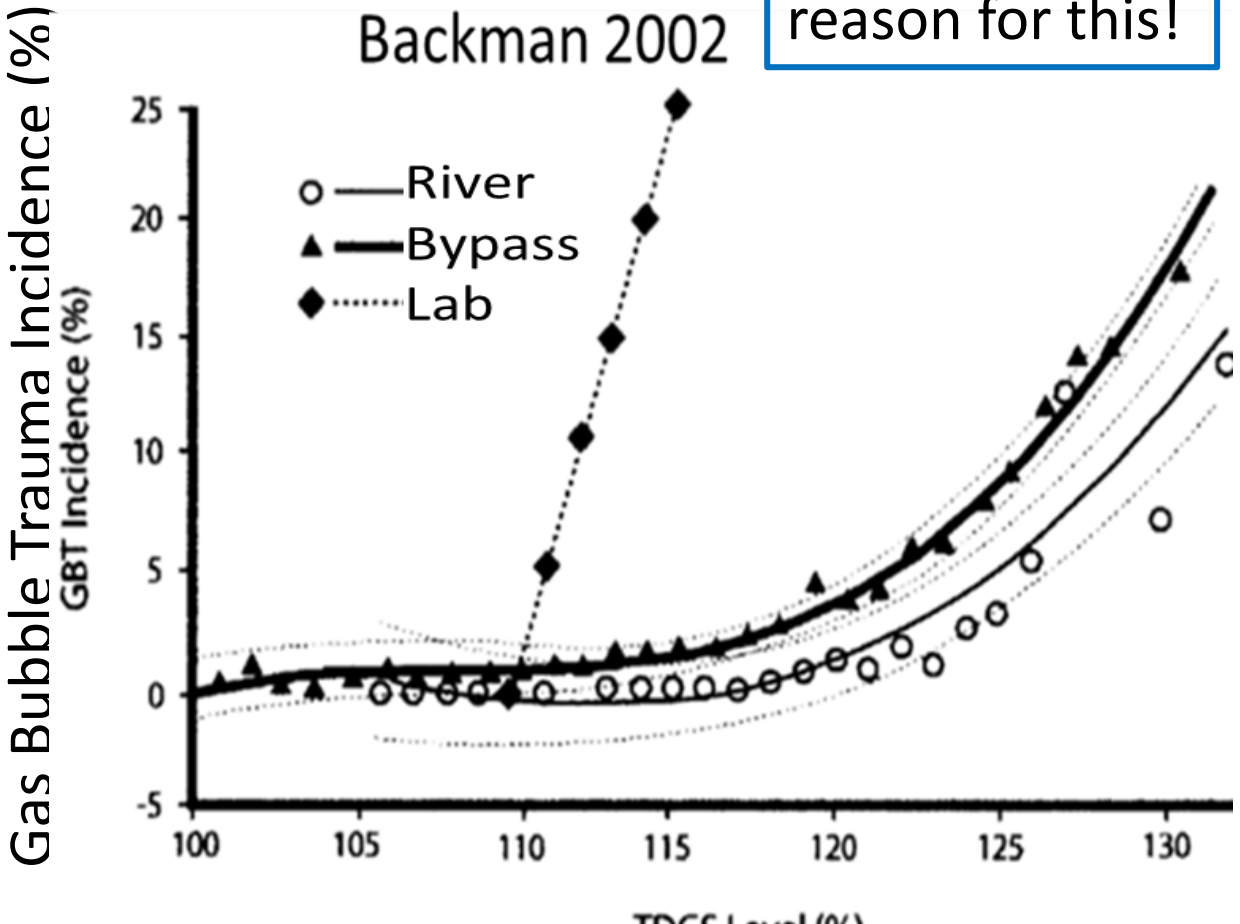
- Rotary screw trap (RST) data from below Big Cliff dam has gas bubble trauma (GBT) incidence
- Binomial Regression: GBT incidence =f(hydrological variables)
- **No effect of mean TDG during trap events**
- **Significant effect (+20%) with maxTDG during driven by TDG values >130%**
- RST data are worst case scenario as fish are held at surface so cannot depth compensate

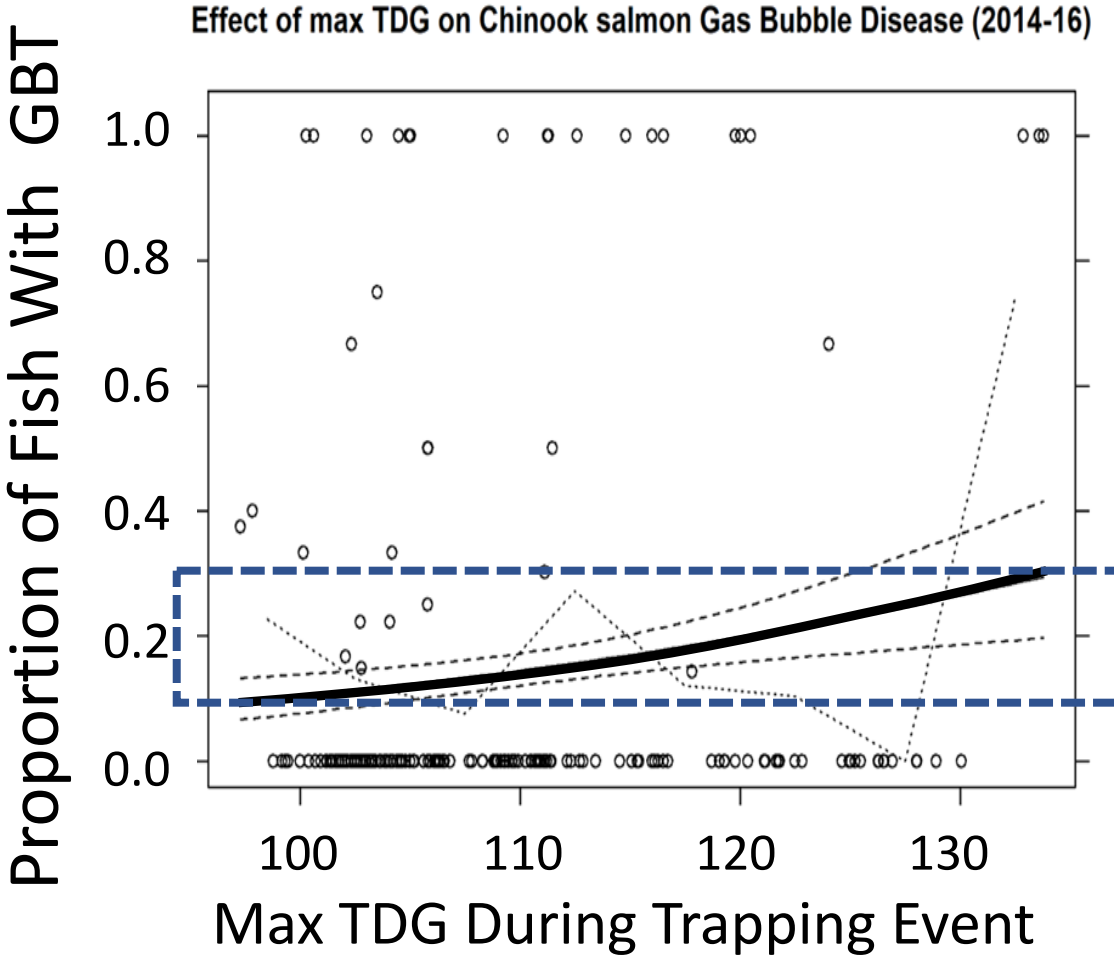


Exceptions: Observed TDG Incidence:

Compared with Columbia River data

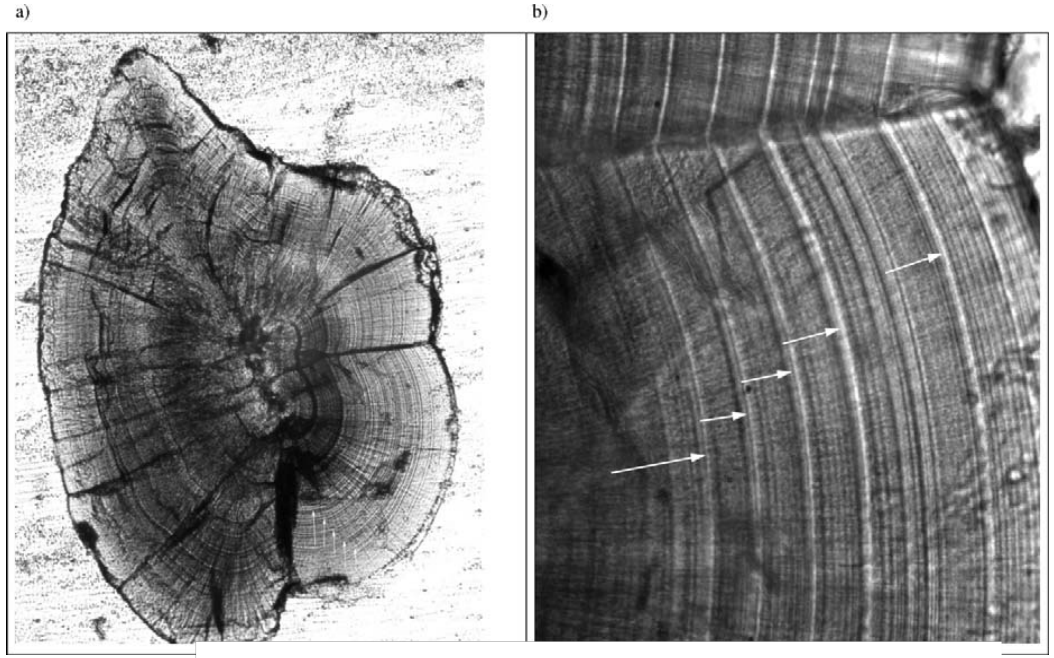
We know the reason for this!



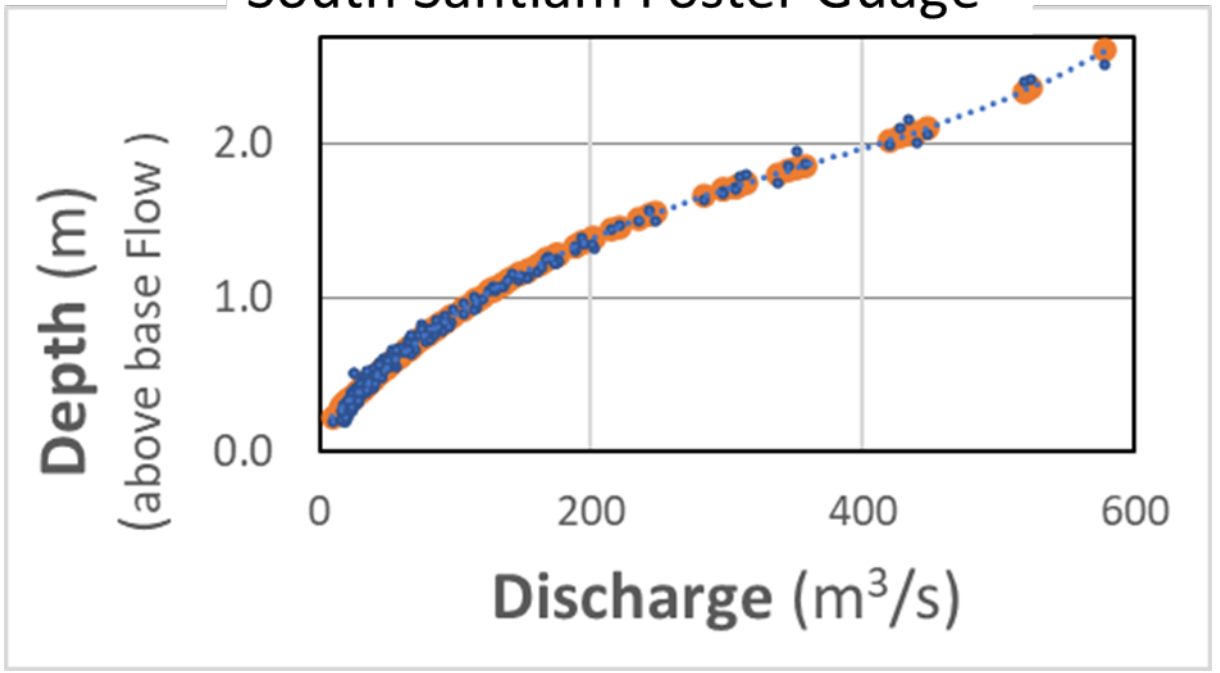


Exceptions: High Flow Events:

- Hydro peaking
  - Korman and Campana 2009, 2011: Colorado River Rainbow Trout on low angle habitat do not move at peak flows
  - Pert 1994: 2 patterns; Some rainbow move, some stay deep
- Natural flow variation
  - In a small stream, coho or chinook used similar depths at 4X higher flows (Shirvell 1994)



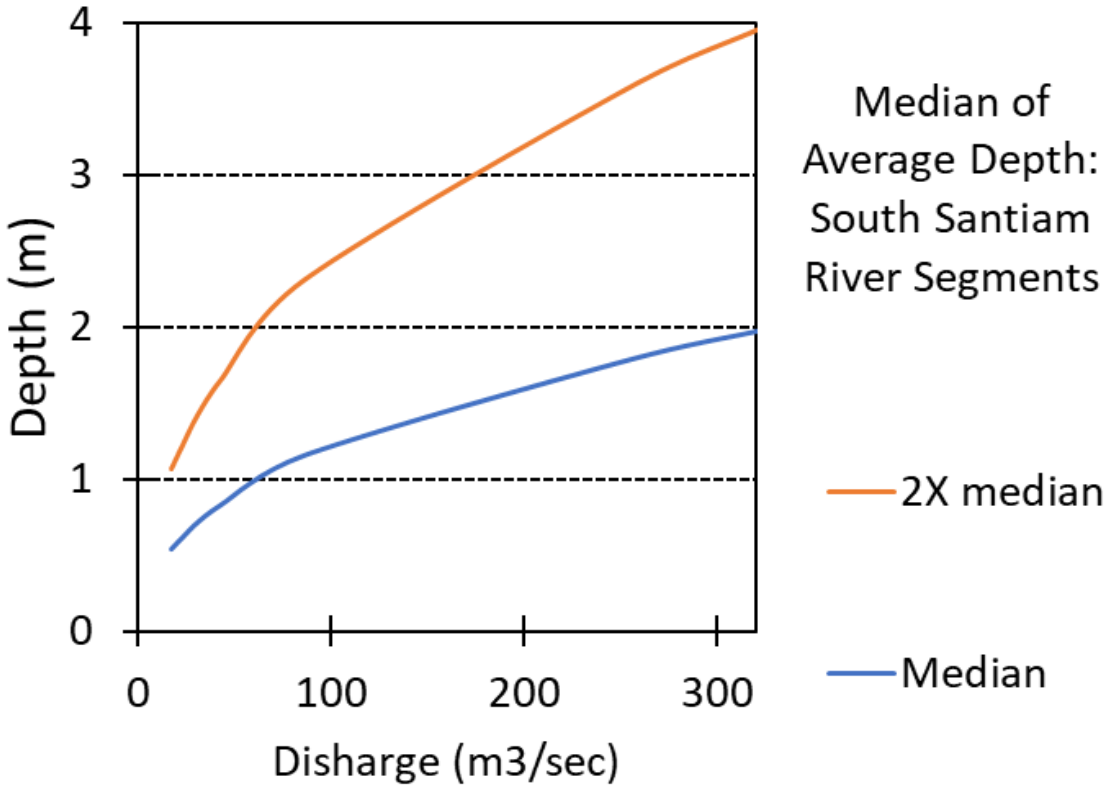
South Santiam Foster Guage

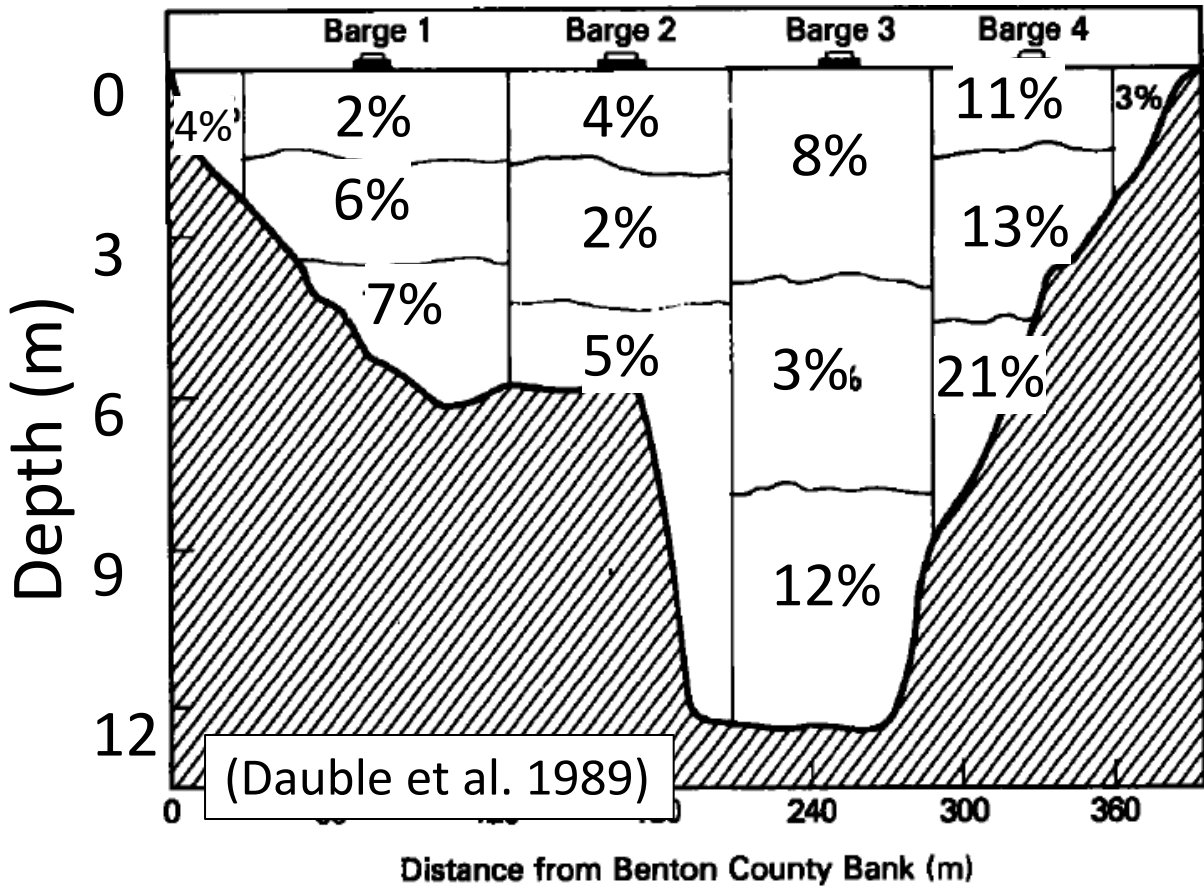


Exceptions:

Migration vs Rearing Depth Preference

Deep water appears to be available in many Segments

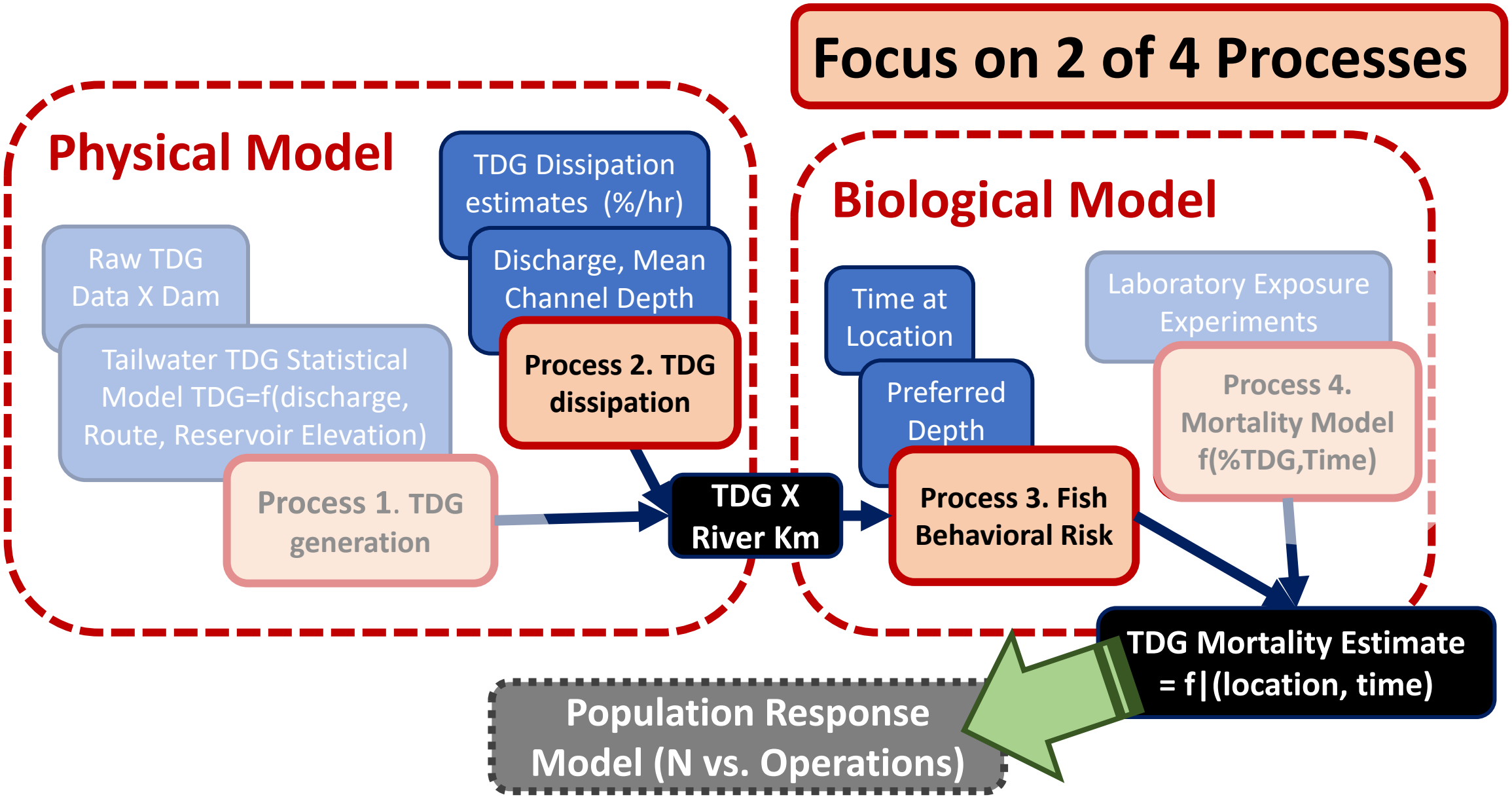




Exceptions:
Buoyancy and the Detection of TDG by Fish

- Pleizier 2021: Measured short term avoidance in <u>shallow</u> flumes. Choice was 100% versus 145% TDG
  - *"**fish cannot detect and avoid harmful TDG supersaturation** using lateral movements during an acute exposure.."*
- Pleizier 2021 also reviewed 19 previous studies of which 15 showed some avoidance behavior. Differences seem to be due to:
  - Avoidance may occur after 1-3 days of exposure
  - ***In high-TDG, deep tanks, fish detect positive buoyancy and move deeper (Shrimpton 1990)***

Estimating TDG Mortality: Conceptual Model



Summary

- **TDG prediction looks promising**
  - **A dissipation model is essential in modeling spatial differences in exposure**
  - Used to estimate mortality at different locations
- The depths available in the North and South Santiam could be used by fish to avoid Gas Bubble Trauma
  - **It is not clear if fish actually depth compensate**
  - At low flows, small Chinook and Steelhead clearly prefer shallow water
  - Quantifying depth distributions at moderate to high flow requires telemetry data
  - GBT data from screw traps is puzzling
    - lower than expected incidence
    - High TDG does not necessarily mean High GBT

Depth Compensation:

Chinook after hatching below Big Cliff Dam

- Burial depth: 19-40 cm (2-4% TDG)
  - DeVries 1997
- Spawning Depth: 30-60 cm (3-6%)
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