Pacific lamprey swimming behavior and performance in relation to passage barrier velocity, distance, and turbulence

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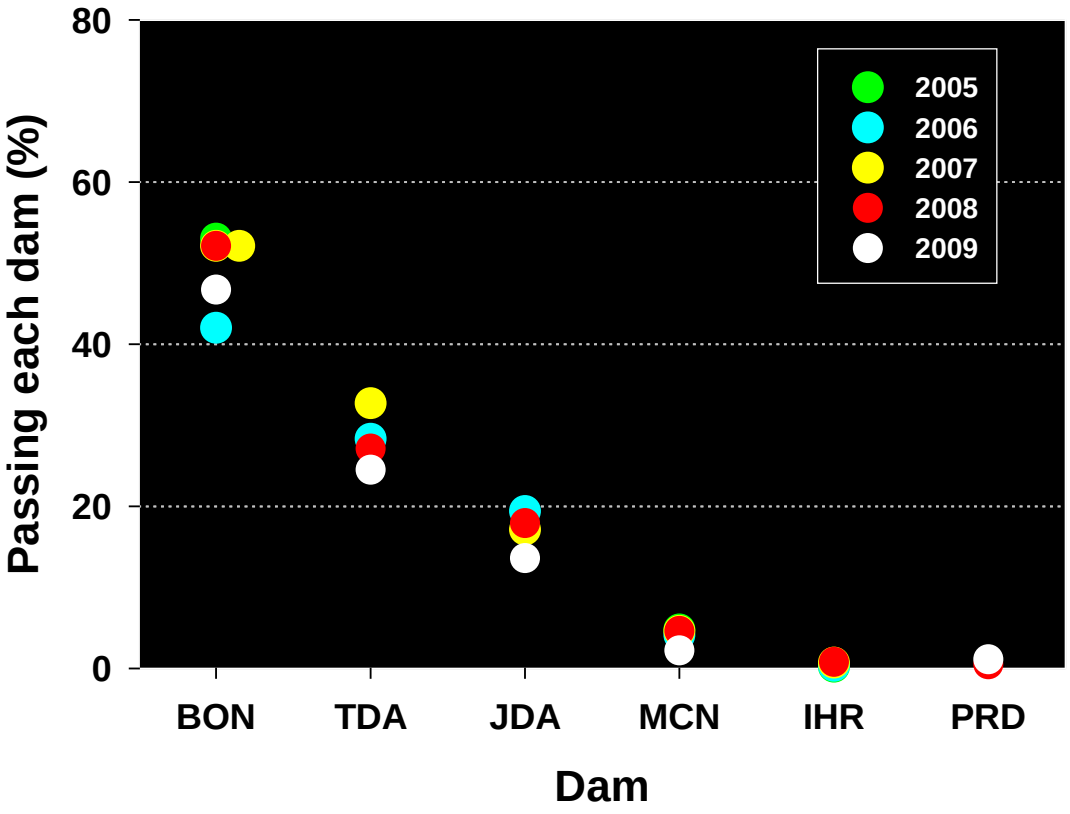
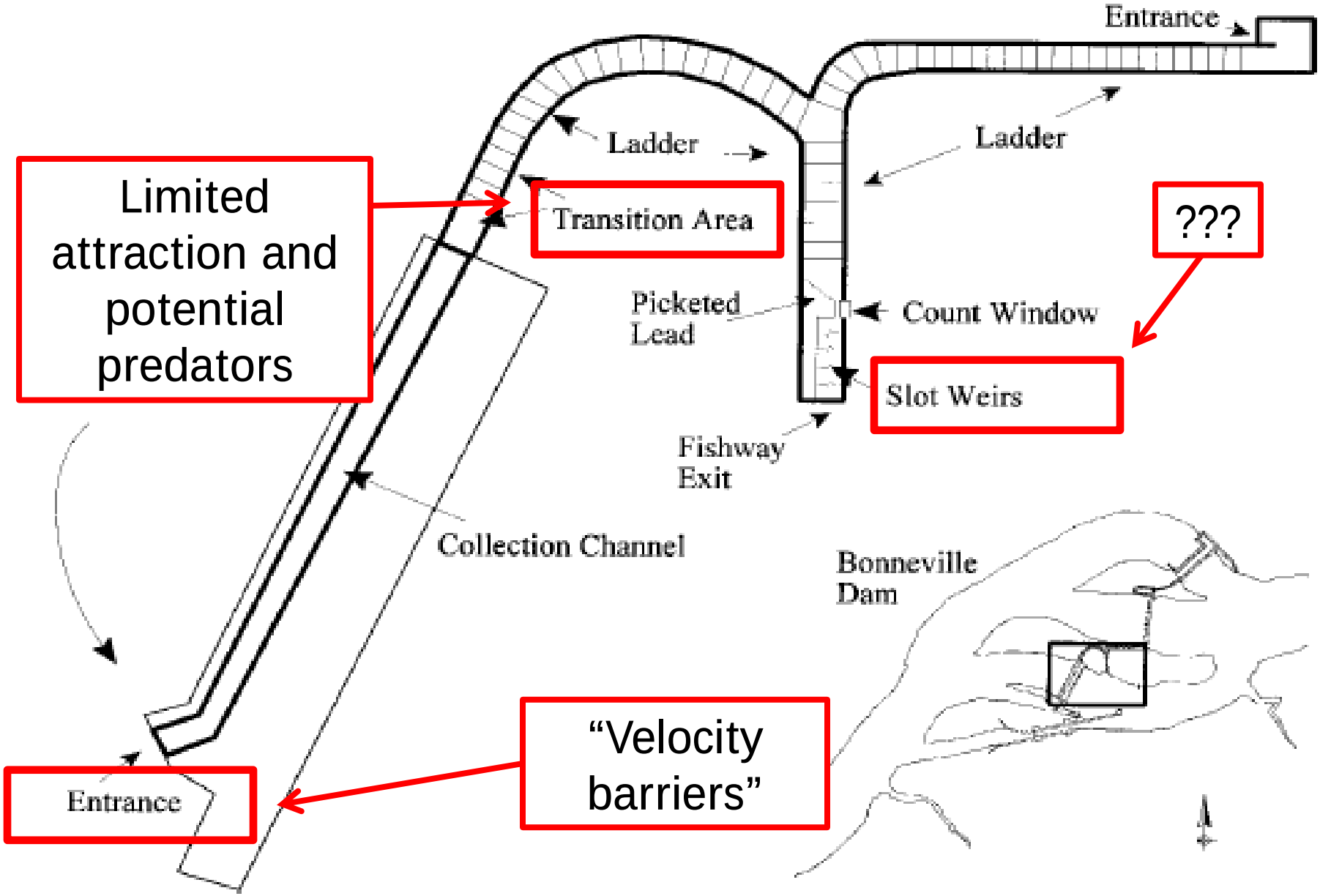
Telemetry studies of Pacific lamprey passage at Columbia River dams



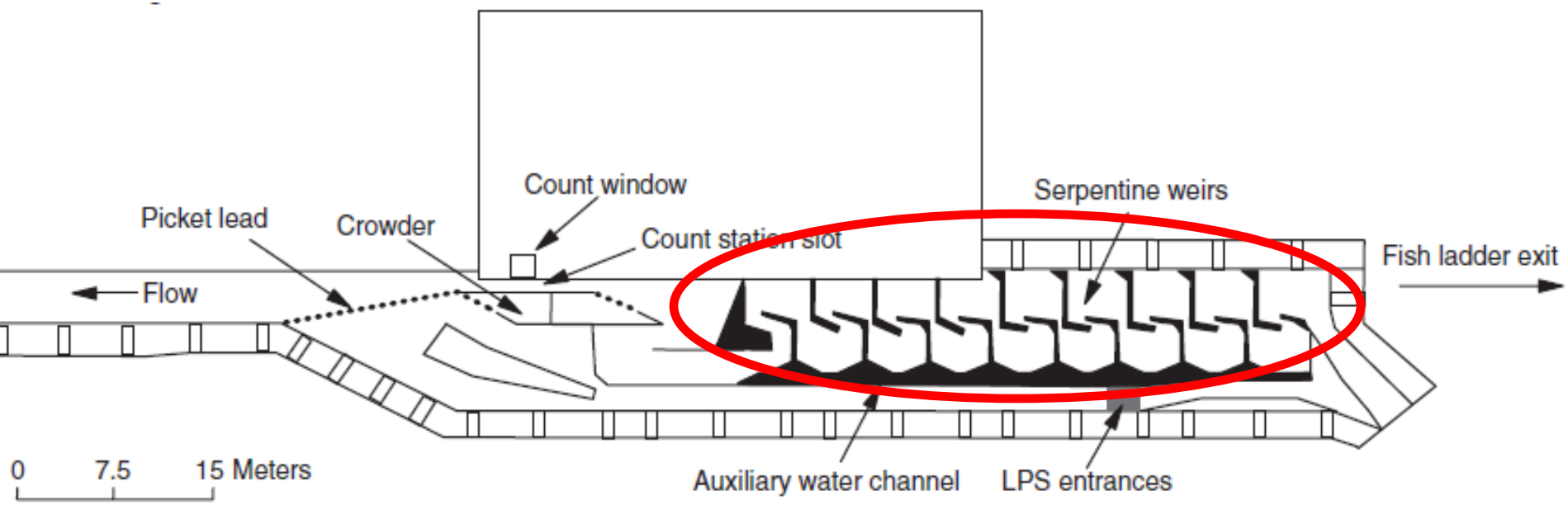
- Coarse-scale monitoring
  - Low passage rates of Pacific lamprey
- Finer-scale monitoring
  - RT studies have helped us locate fishway areas associated with poor passage
- Mechanisms of poor passage?

Observational and experimental studies

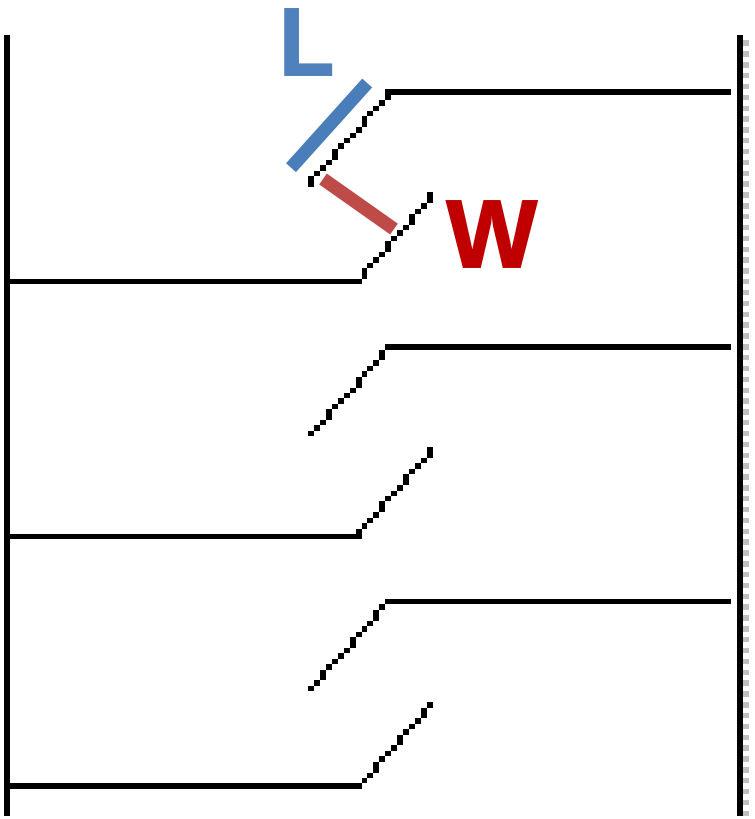


From: Moser et al. 2002

- Serpentine weirs
  - High turnaround rates
  - High failure rates
  - Important because of proximity to exit



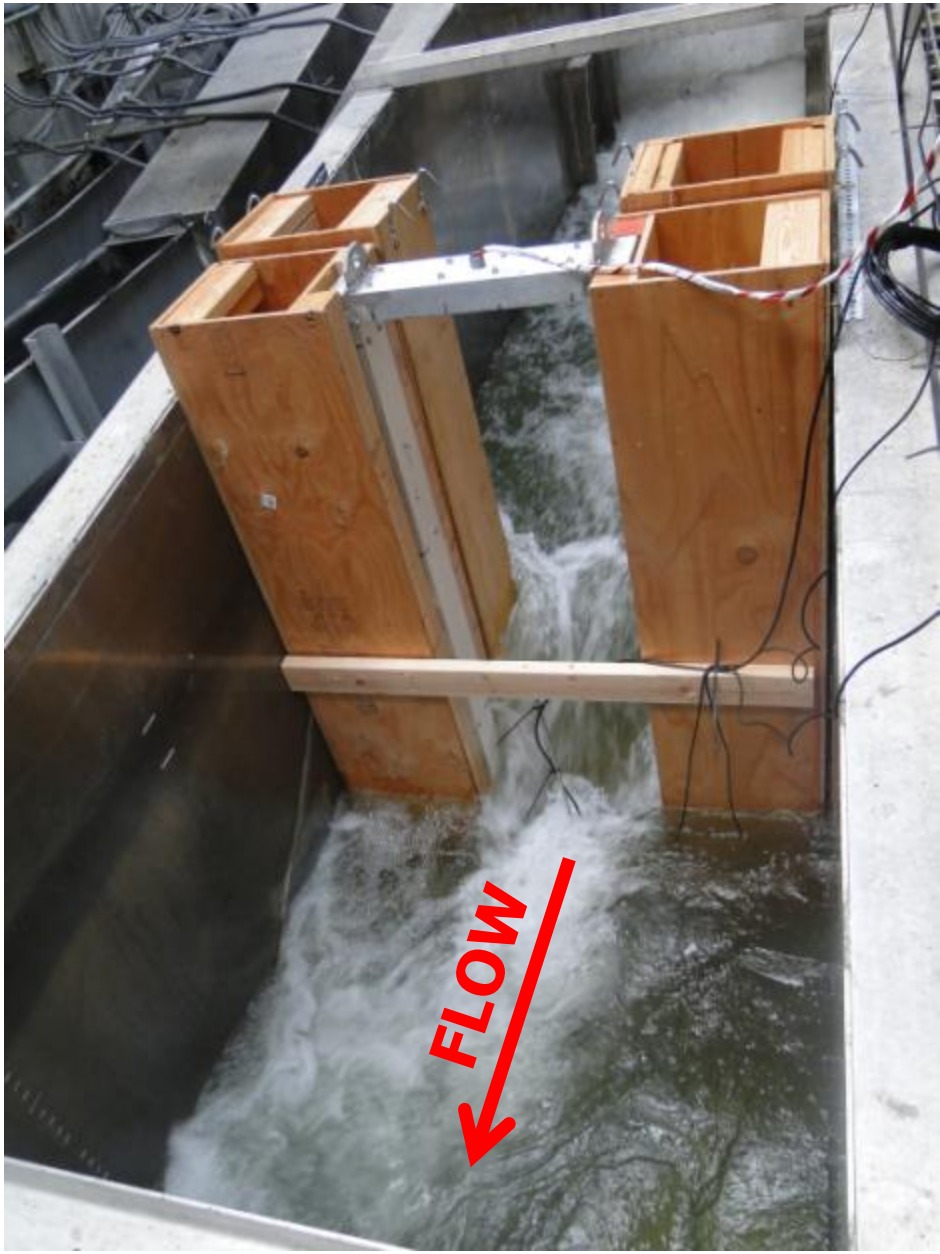
What fishway features in this section may be responsible for limited passage?



<u>Potential variables affecting lamprey in this section</u>

1. Turbulence (more work to endure turbulent conditions)
2. Slot lengths (0.3-1.2 m; longer barrier distances)
3. High velocities

FLOW


FLOW

Experimental design

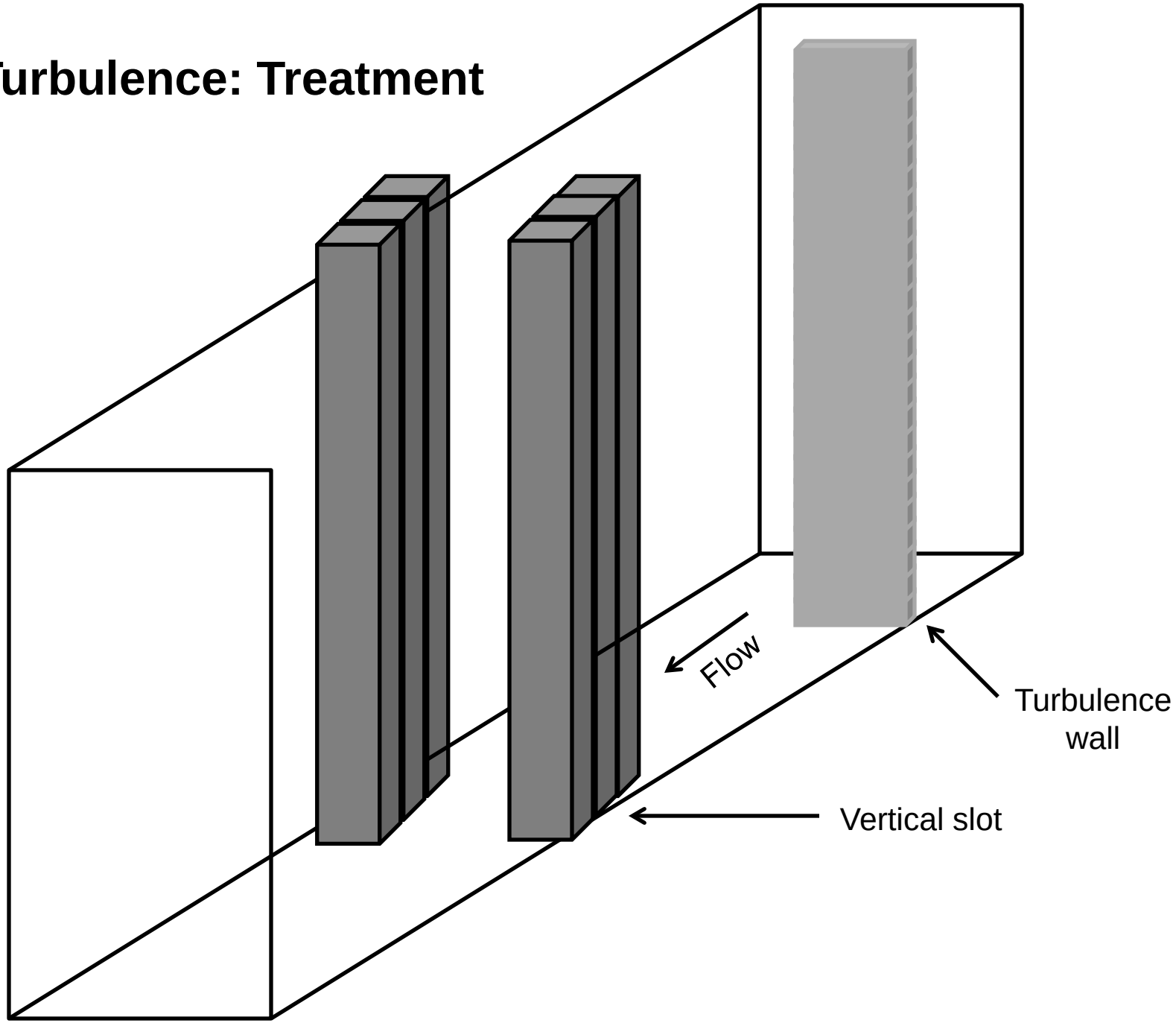
- 3 × 3 × 2 Split-split-plot design
  - Interactions between 3 variables

Velocity		Distance		Turbulence		
1.2 m/s	✖	0.33 m	✖	Control	=	18 treatment combinations
1.8 m/s		0.66 m		Treatment		
2.4 m/s		1.00 m				

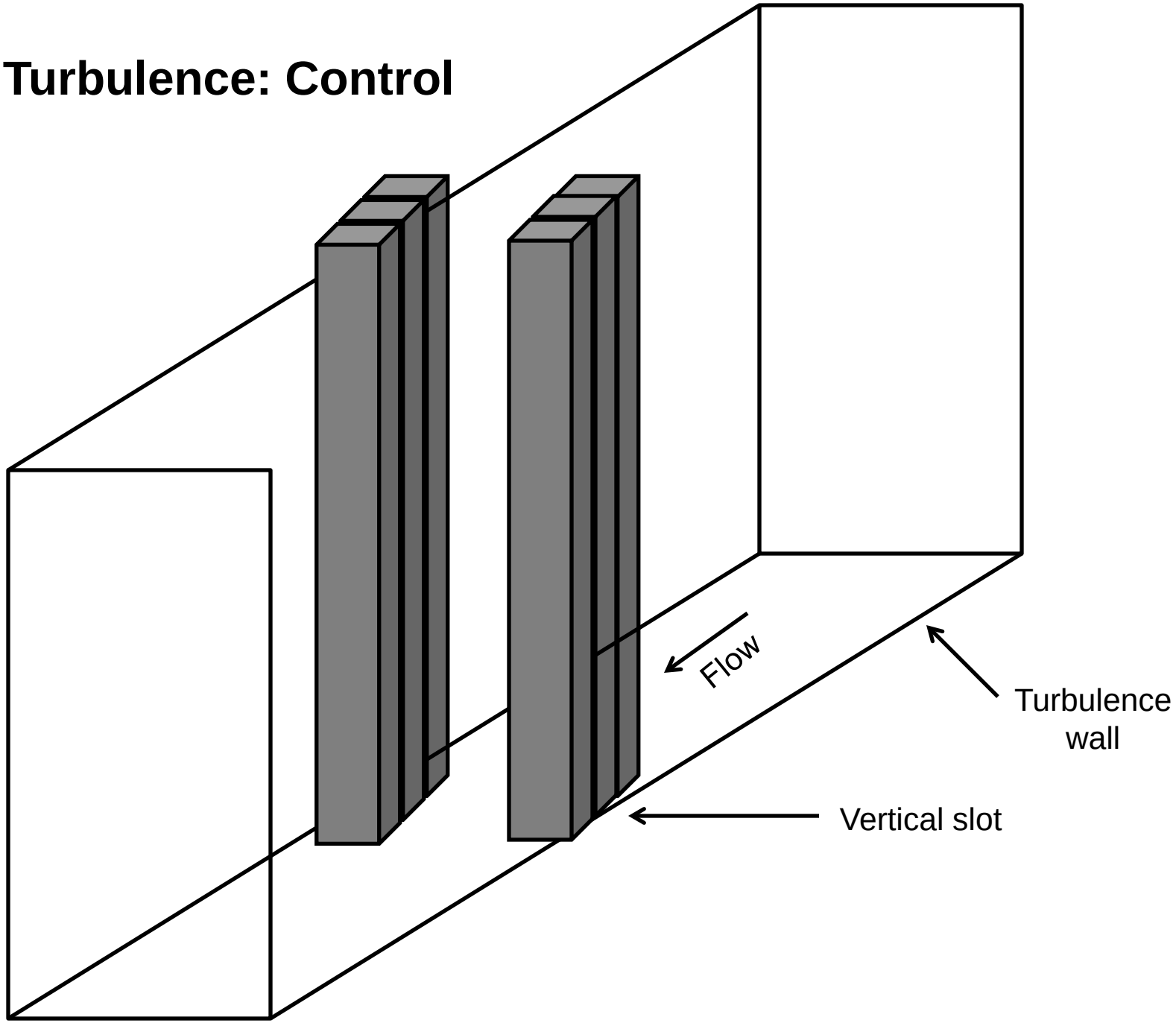
N = 300 lamprey; 6 lamprey per trial

- Hypothesis: Number of fish passing the experiment would be lower for…
  - Higher velocities
  - Higher turbulence
  - Longer distance

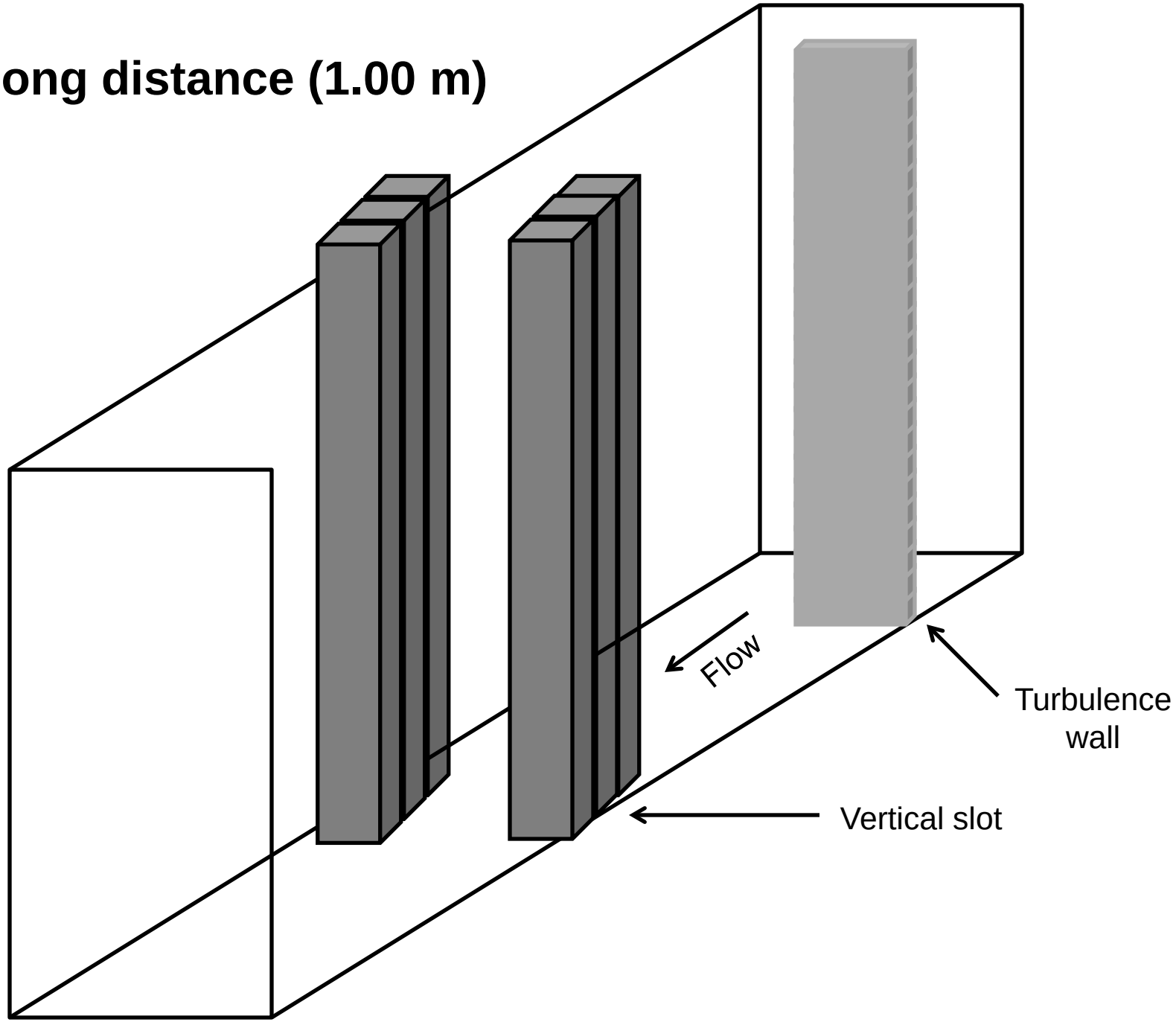
Turbulence: Treatment



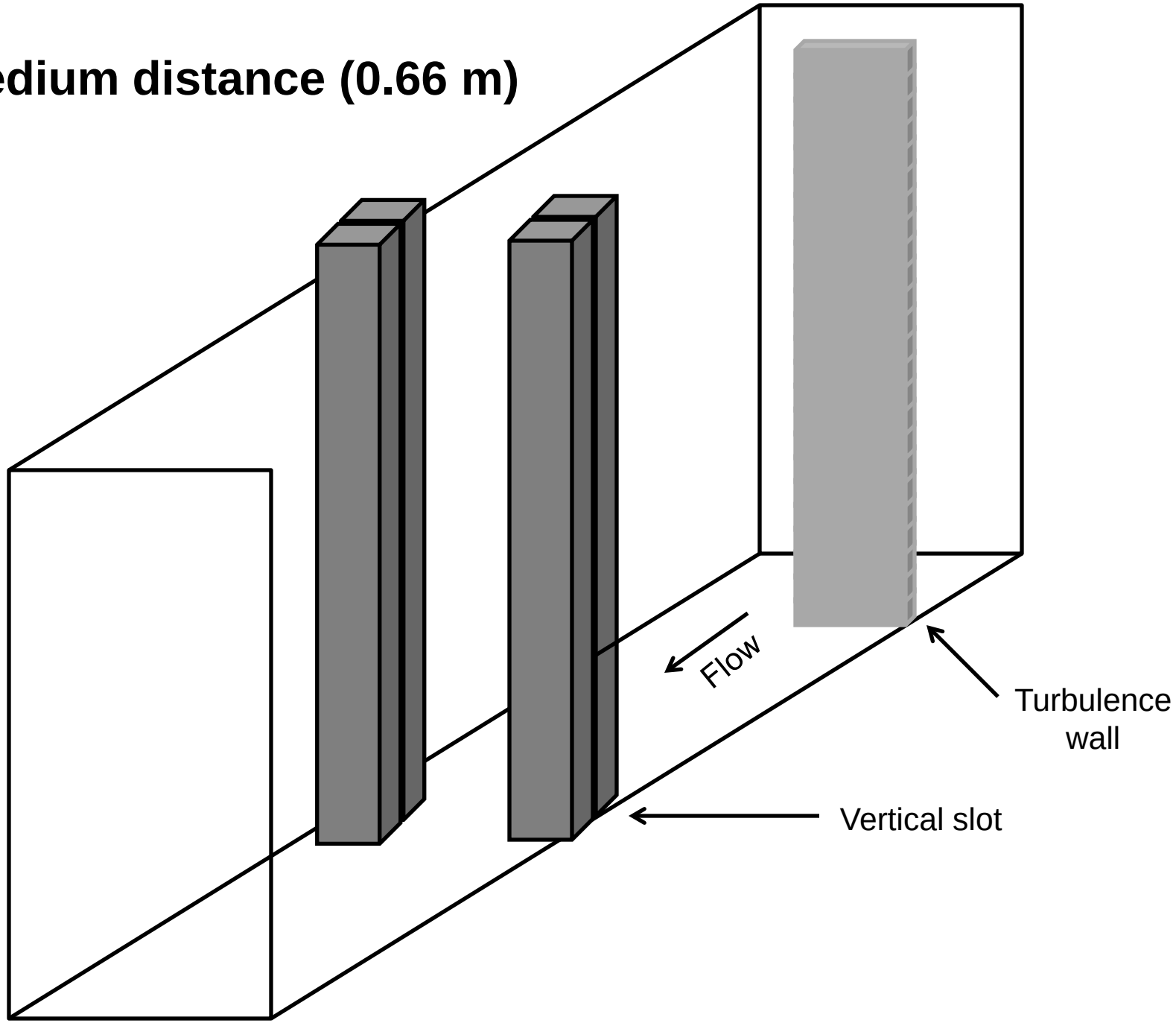
Turbulence: Control



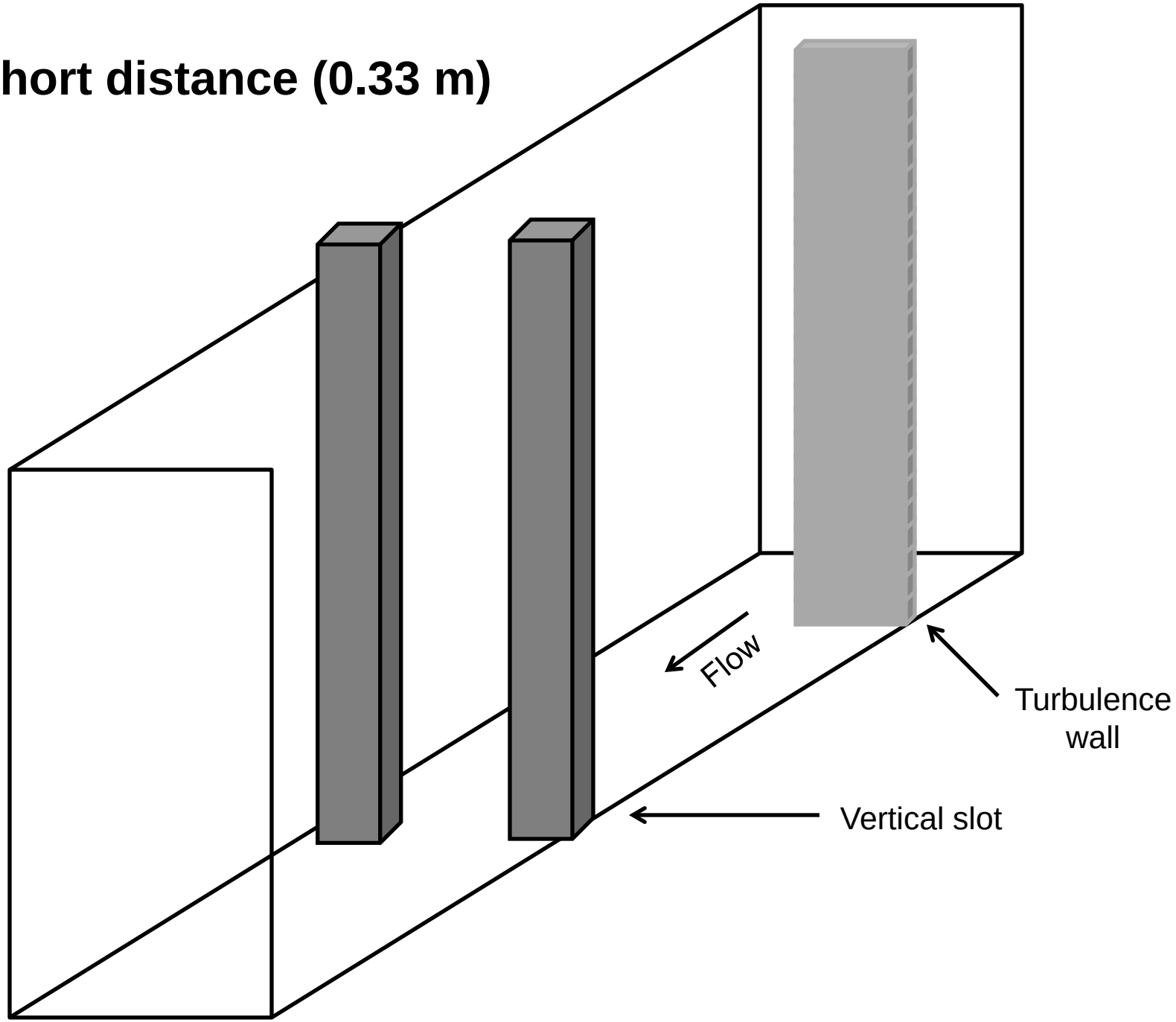
Long distance (1.00 m)



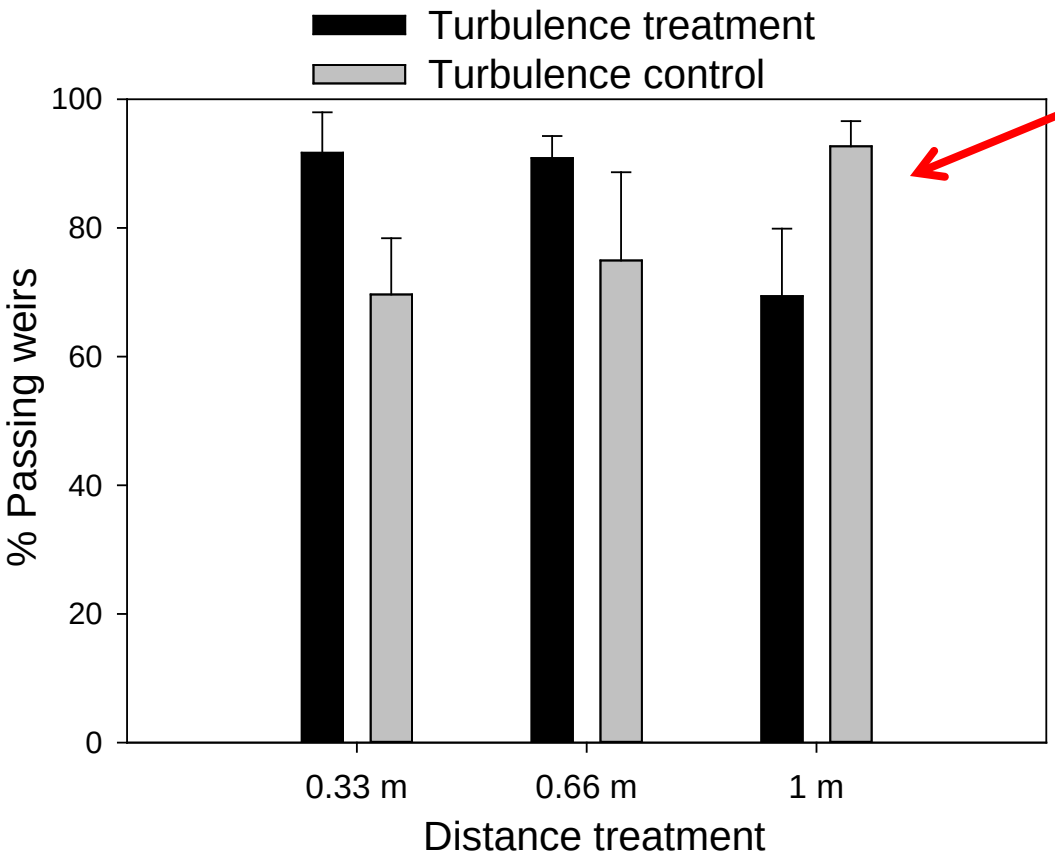
Medium distance (0.66 m)



Short distance (0.33 m)



% Passing weirs each trial (# fish passed/# fish approached)

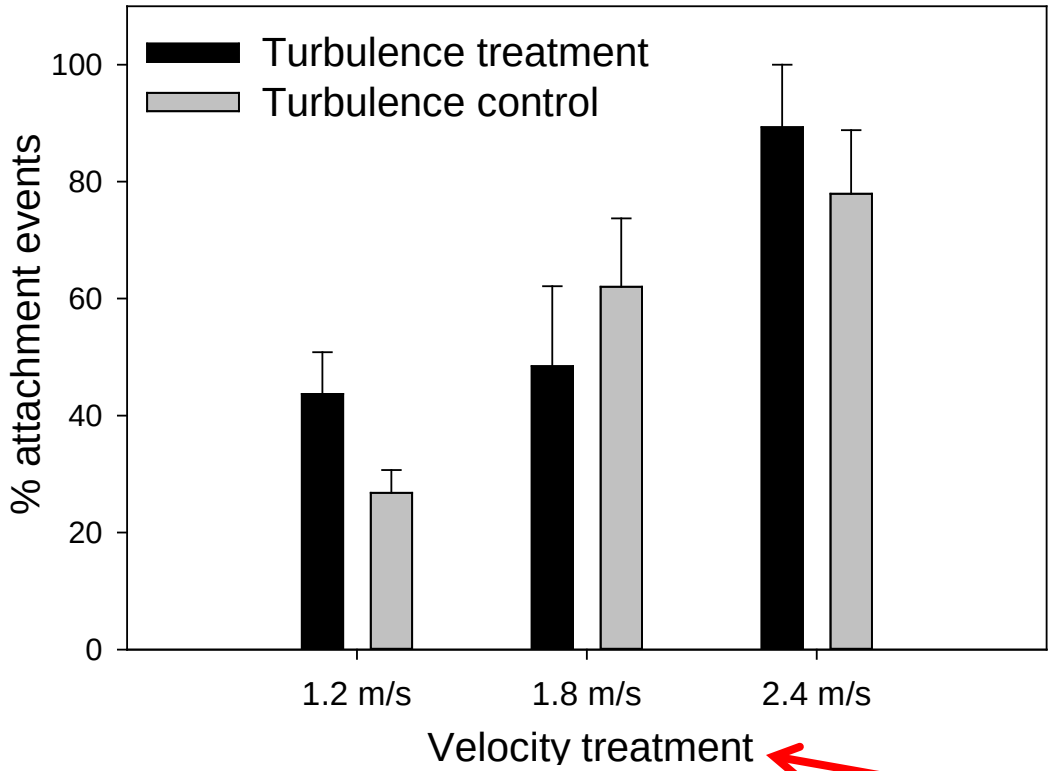


Crisscross in turbulence groups

ANOVA Table		
Source	*F*	*P*
Distance	0.10	0.908
Turbulence	0.53	0.474
Velocity	1.31	0.284
D*T	**4.35**	**0.021**
D*V	1.08	0.384
T*V	0.533	0.592
D*T*V	0.20	0.936

Note: high passage rates for lamprey

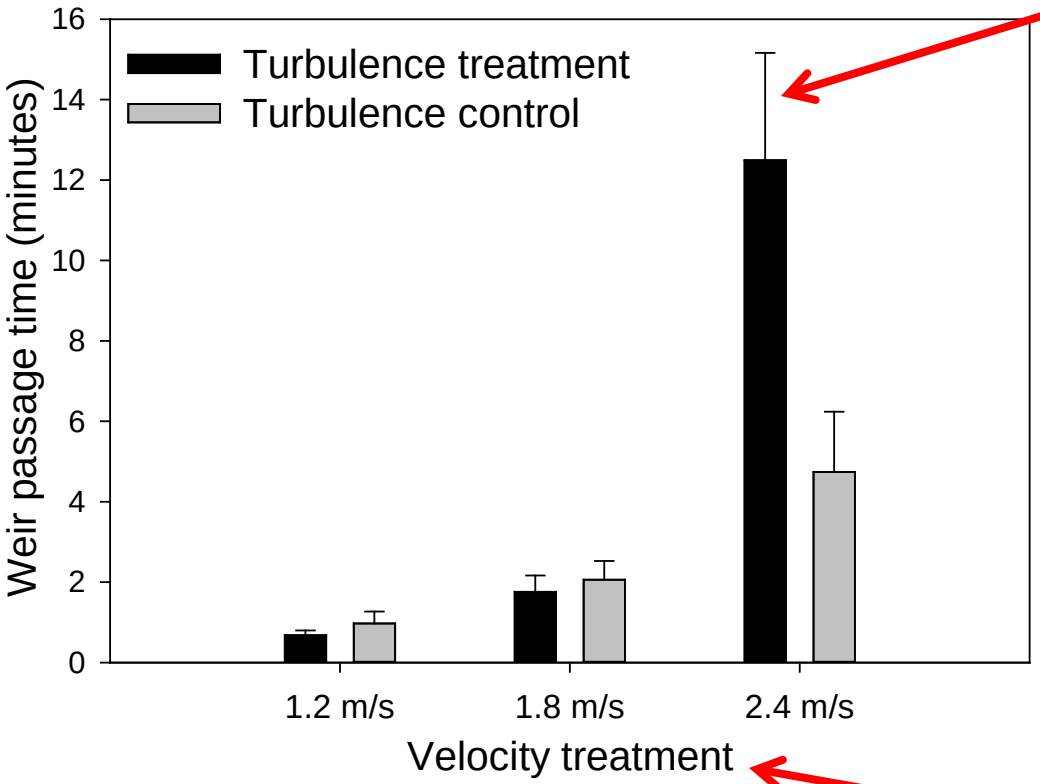
% of attachment events in each trial (# of events with an attachment/total # events)



ANOVA Table		
Source	*F*	*P*
Distance	1.33	0.28
Turbulence	0.45	0.50
Velocity	**14.54**	**<0.001**
D*T	0.43	0.66
D*V	1.71	0.17
T*V	0.76	0.47
D*T*V	1.61	0.19

Positive relationship

Weir passage times for individual fish (i.e., attachment time)

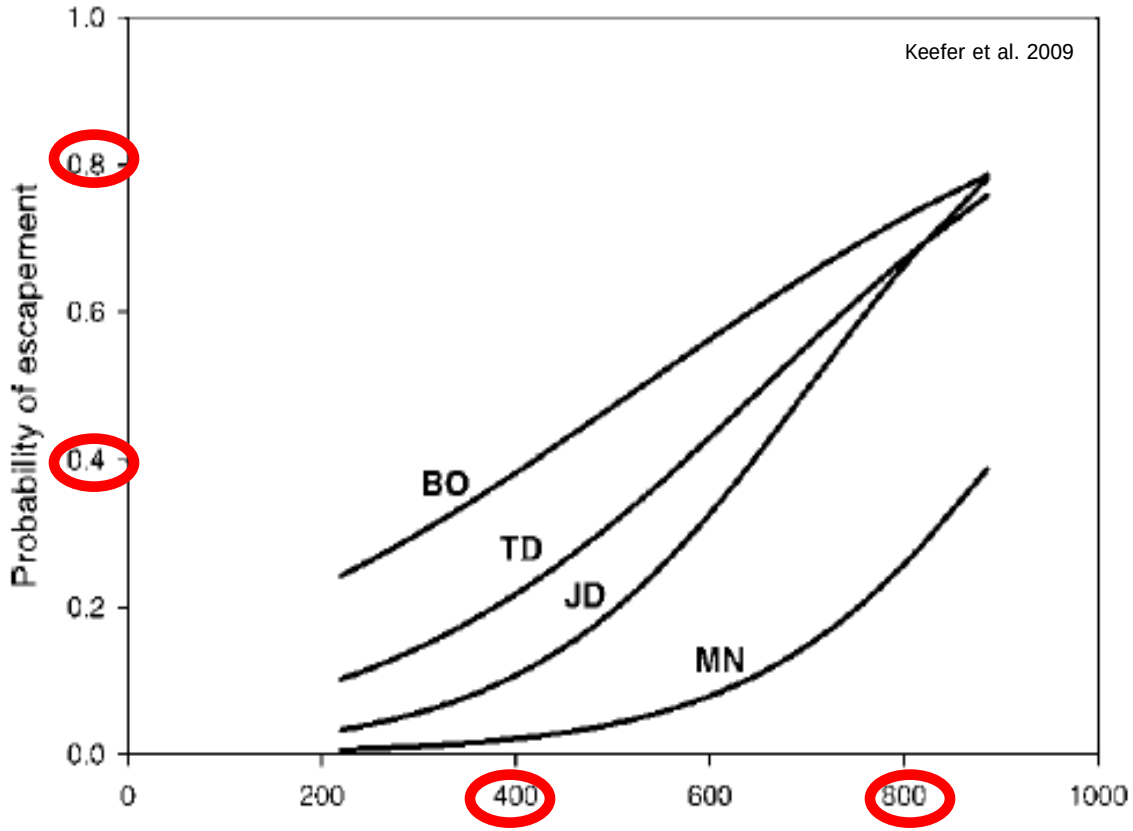


2.5× increase

ANOVA Table		
Source	*F*	*P*
Distance	0.24	0.80
Turbulence	0.13	0.74
Velocity	**23.11**	**<0.001**
D*T	1.24	0.37
D*V	1.01	0.41
T*V	**5.85**	**0.004**
D*T*V	1.78	0.16

Positive relationship

Effects of Body Size



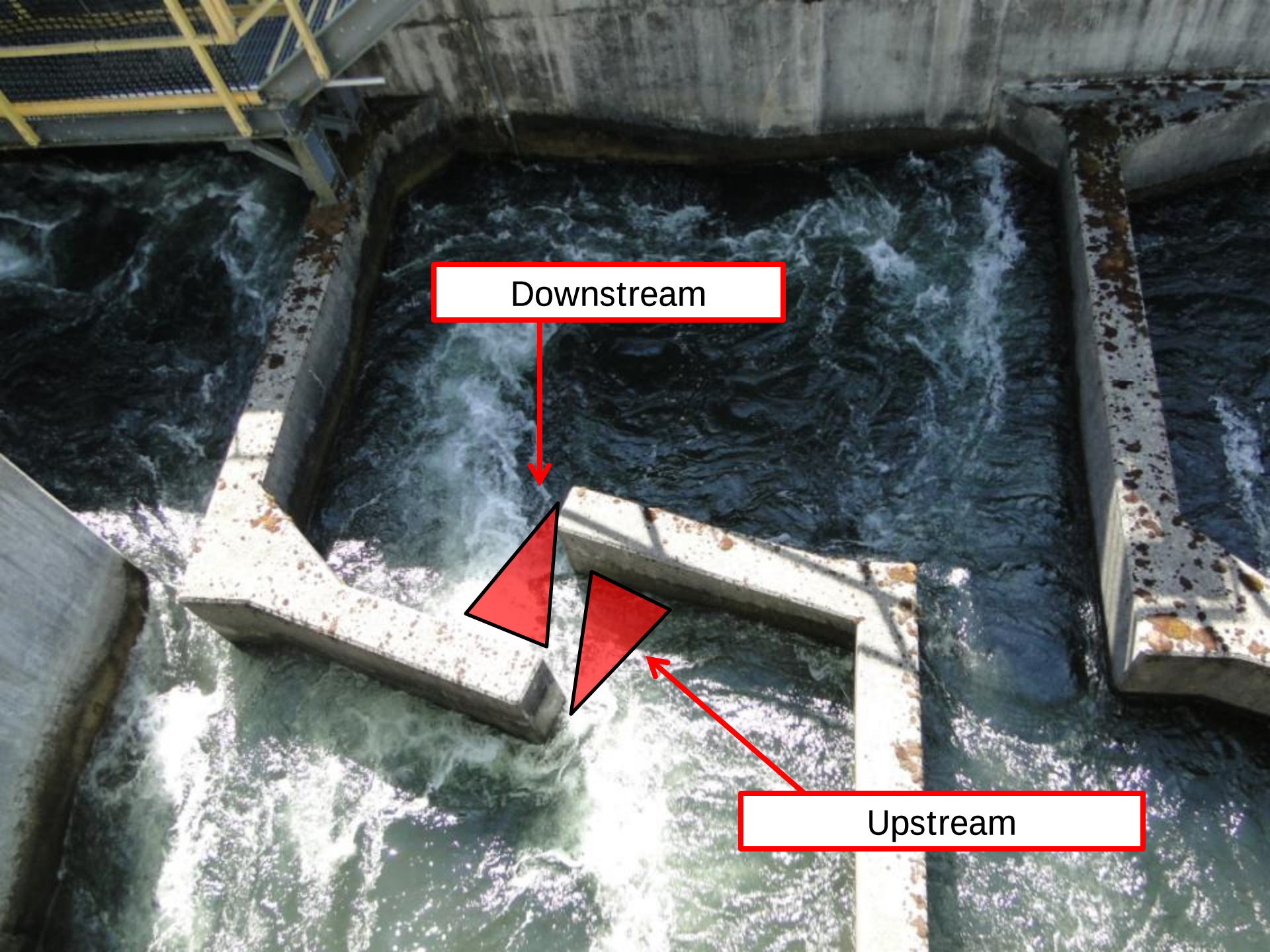
Do larger lamprey have a higher probability of passage under experimental conditions?

Multiple logistic regression

Factor
Weight
“Condition”
Dorsal distance
1 m – 0.66 m
1 m – 0.33 m
1.2 m/s – 2.4 m/s
1.8 m/s – 2.4 m/s
Treatment - Control
Late-Early run date
Mid-Early run date

Question: How does high experimental passage translate into poor passage observed in fishway?

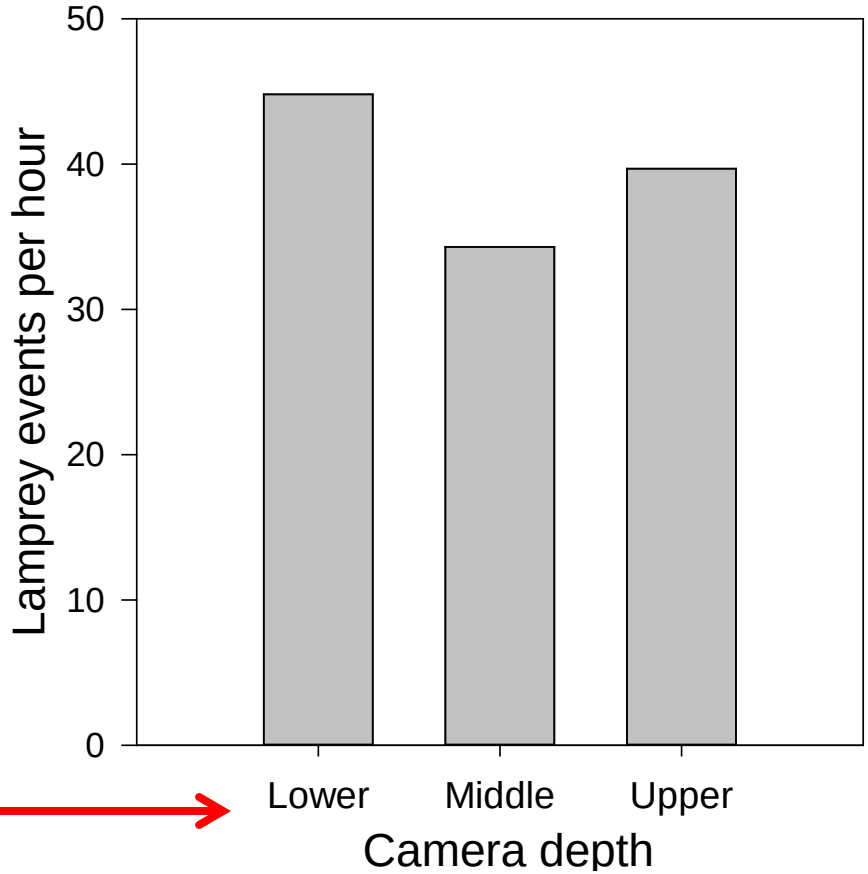
Complementary Field Study


Downstream
Upstream

Behavioral comparisons

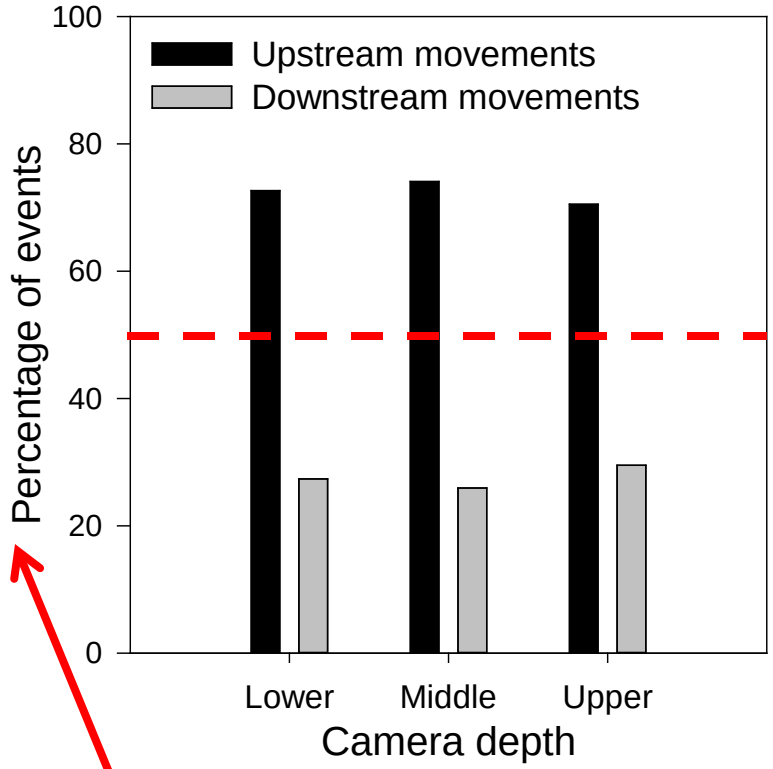
In contrast, 85% of events occurred near the flume floor

No strong demersal orientation

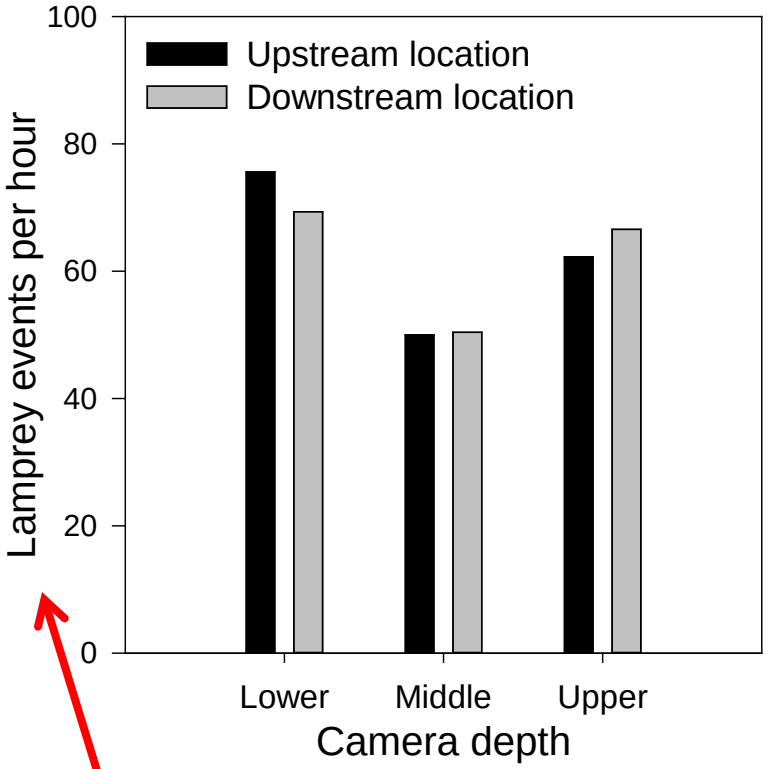


- Fewer attachment events in field than experiments (20% vs. 40%, respectively)

Movement rates at the weir



~20% net upstream

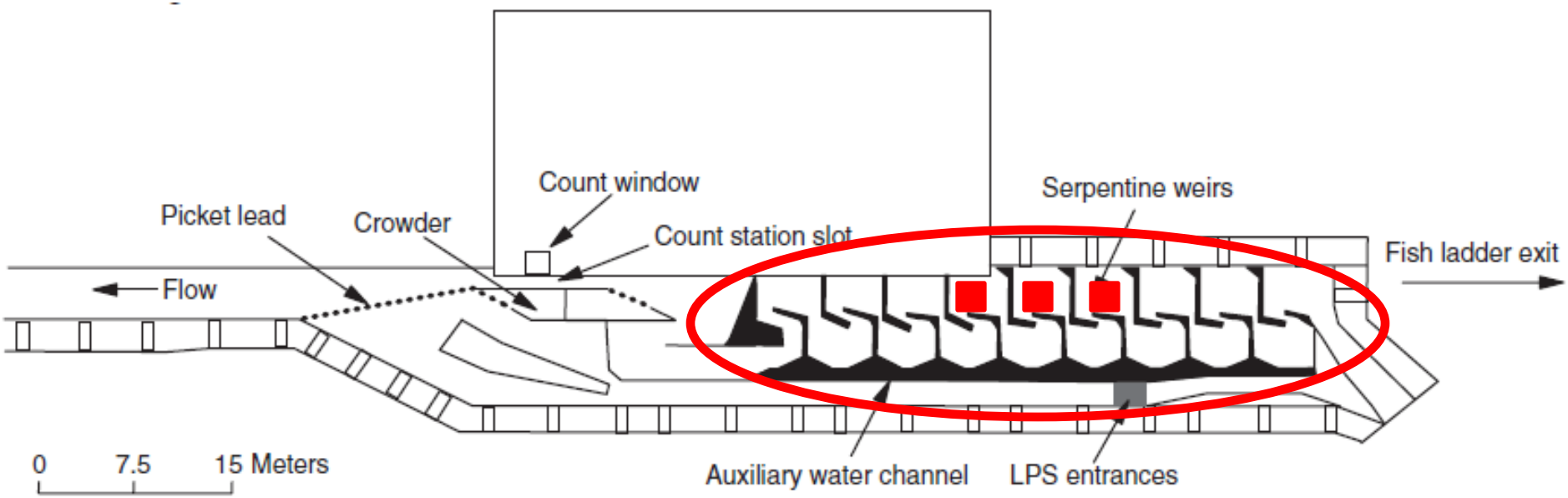


Fish passing through the slots easily

Take-home: Passage through individual weirs good

Alternative Hypotheses for Poor Passage

- <u>Alternative Hypothesis #1</u>: Endurance-based hypothesis
  - Evaluate attrition from July camera deployments
  - Predict event rates decline from downstream to upstream



From: Clabough et al. 2012

- <u>Alternative Hypothesis #2</u>: "Turning-radius" hypothesis
  - 90° and 180° sharp turns = ~1900° in turns
  - Difficulty in orientation for lamprey

Conclusions

- High passage rates (~80%)
  - 80% passage per weir × 15 weirs = 96% attrition to exit
- Test “Endurance-based” hypothesis from video’s
- Minimal effects of velocity, distance, or turbulence on passage rates at a single weir
  - Turbulence affects behavior = attachment duration

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