

Assessing the avoidance and preference behaviour of Atlantic salmon (*Salmo salar*) to varying oxygen saturation waters

Benjamin de Jourdan¹, Anne McCarthy¹, Michael Beattie²

¹Huntsman Marine Science Centre, 1 Lower Campus Road, St. Andrews, NB, E5B 2L7, Canada

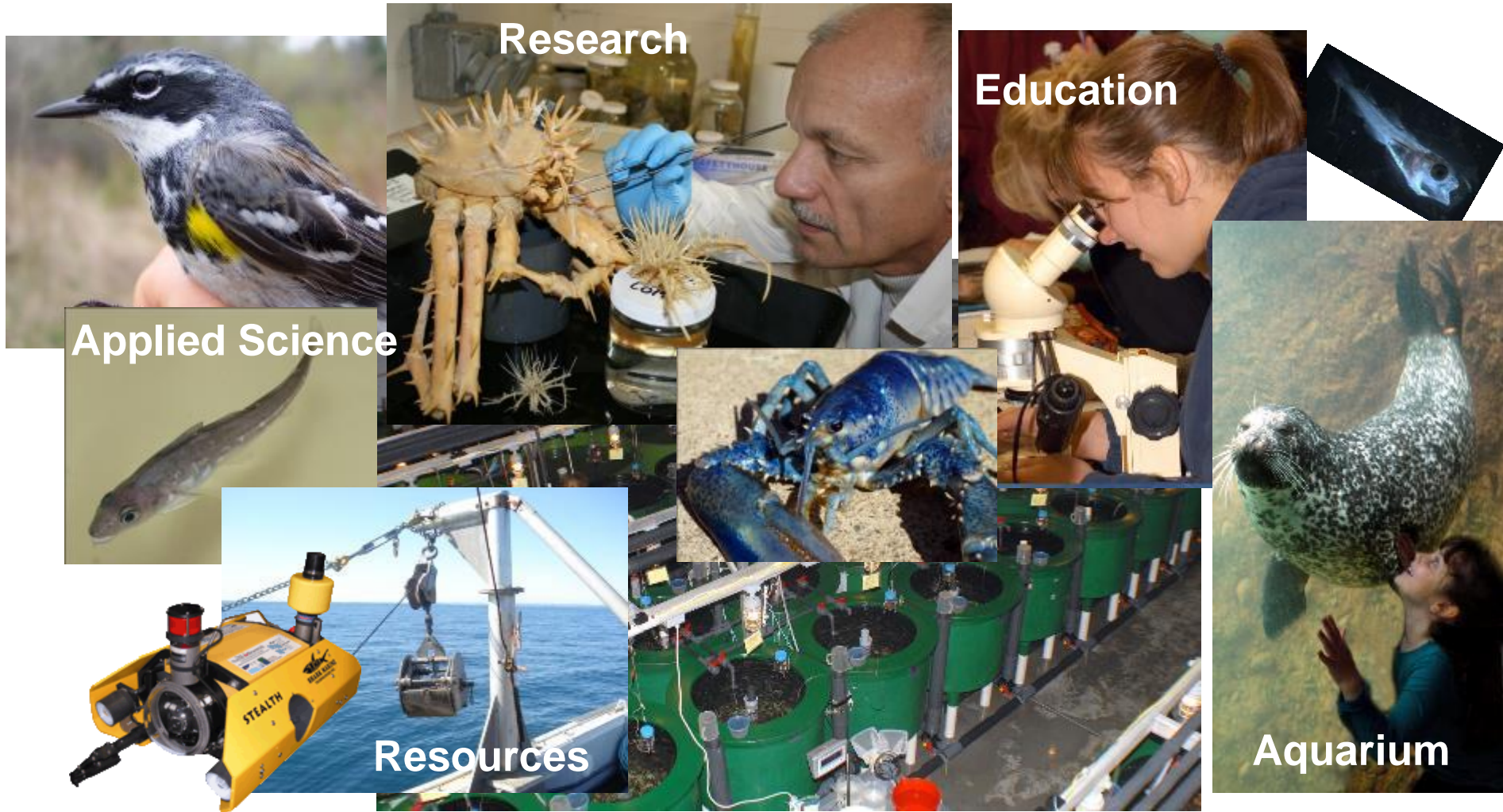
Benjamin.deJourdan@huntsmanmarine.ca

²Gas Infusion Systems, 157 Water St, St. Andrews, NB E5B 3V9, Canada

mike@gasinfusionsystems.com

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Background

Fish can sense **oxygen levels** in the water and in their blood

Temperature has a significant role in governing the metabolic rate in poikilotherms

Migration is often made more difficult by the presence of **dams**

- The presence of dams can cause increased travel times for fish, thereby increasing their risk of predation, and potentially depleting energy reserves

This study evaluated whether fish will **detect and preferentially swim towards** water that has been supersaturated with dissolved oxygen (~120% saturation)

Exposure Media Methodology



GIS Gas Infusion Systems
Inc.

Freshwater temperature was maintained at the target **8**, **10** and **12°C** ($\pm 1^{\circ}\text{C}$) for the trials

Waters of varying oxygen saturation were made up on demand using a proprietary **Gas Infusion System**

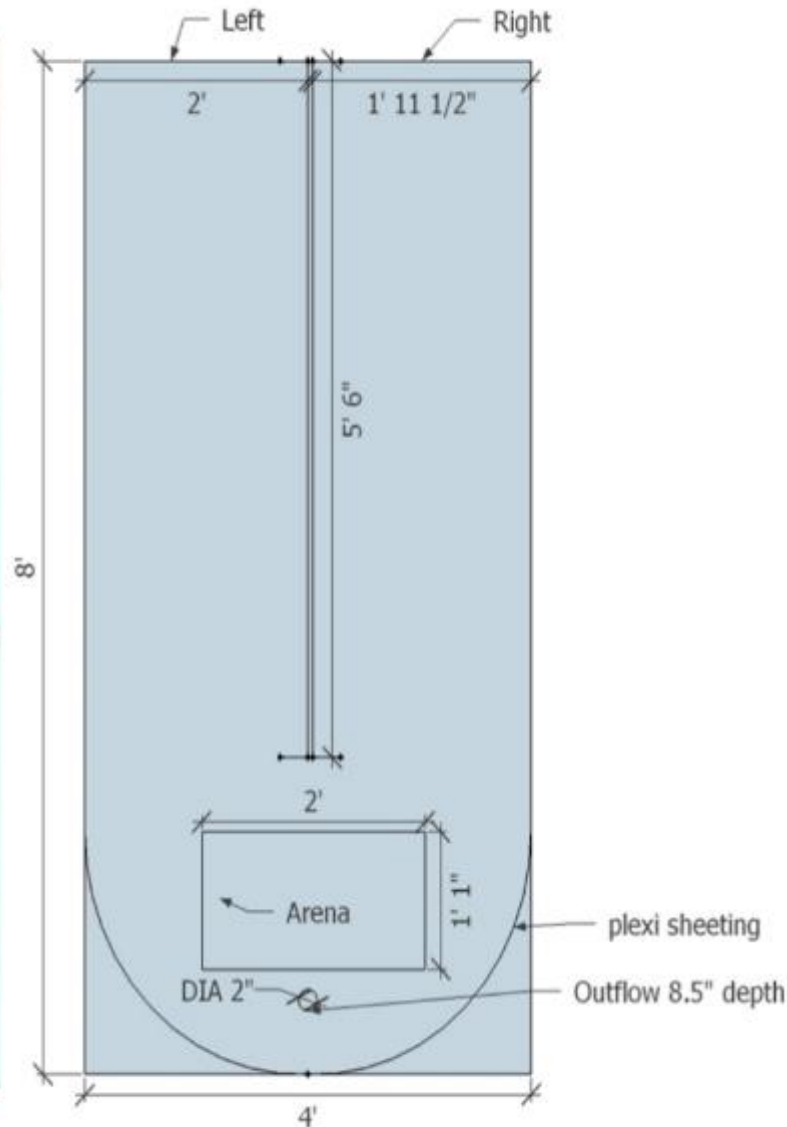
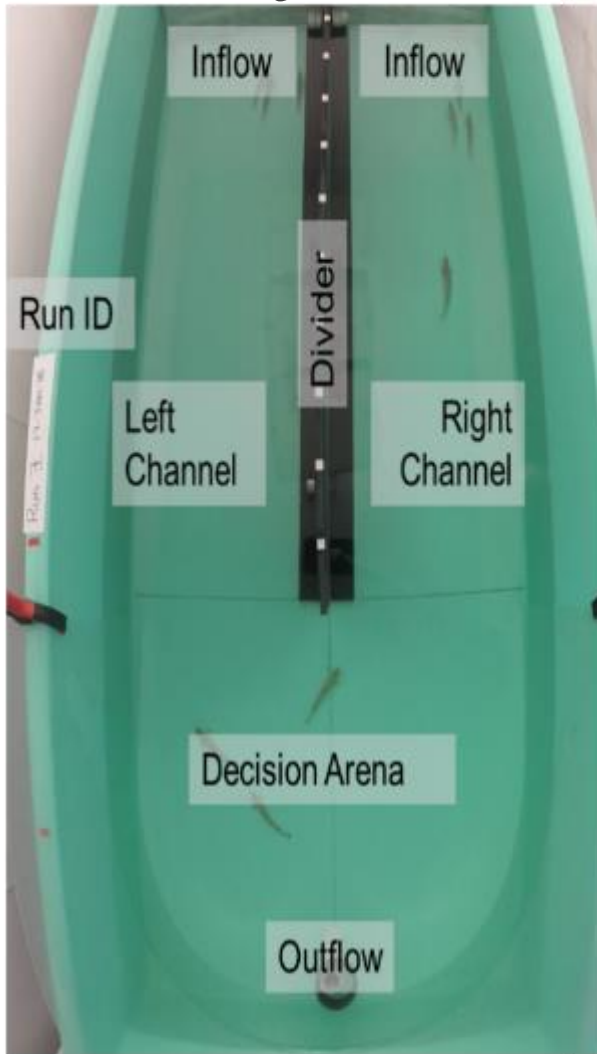
- Infuse either oxygen or nitrogen to raise or lower the measured dissolved oxygen concentrations

The three targeted saturation types were '**Low**', '**Medium**', and '**High**' oxygen

- Medium was ambient conditions

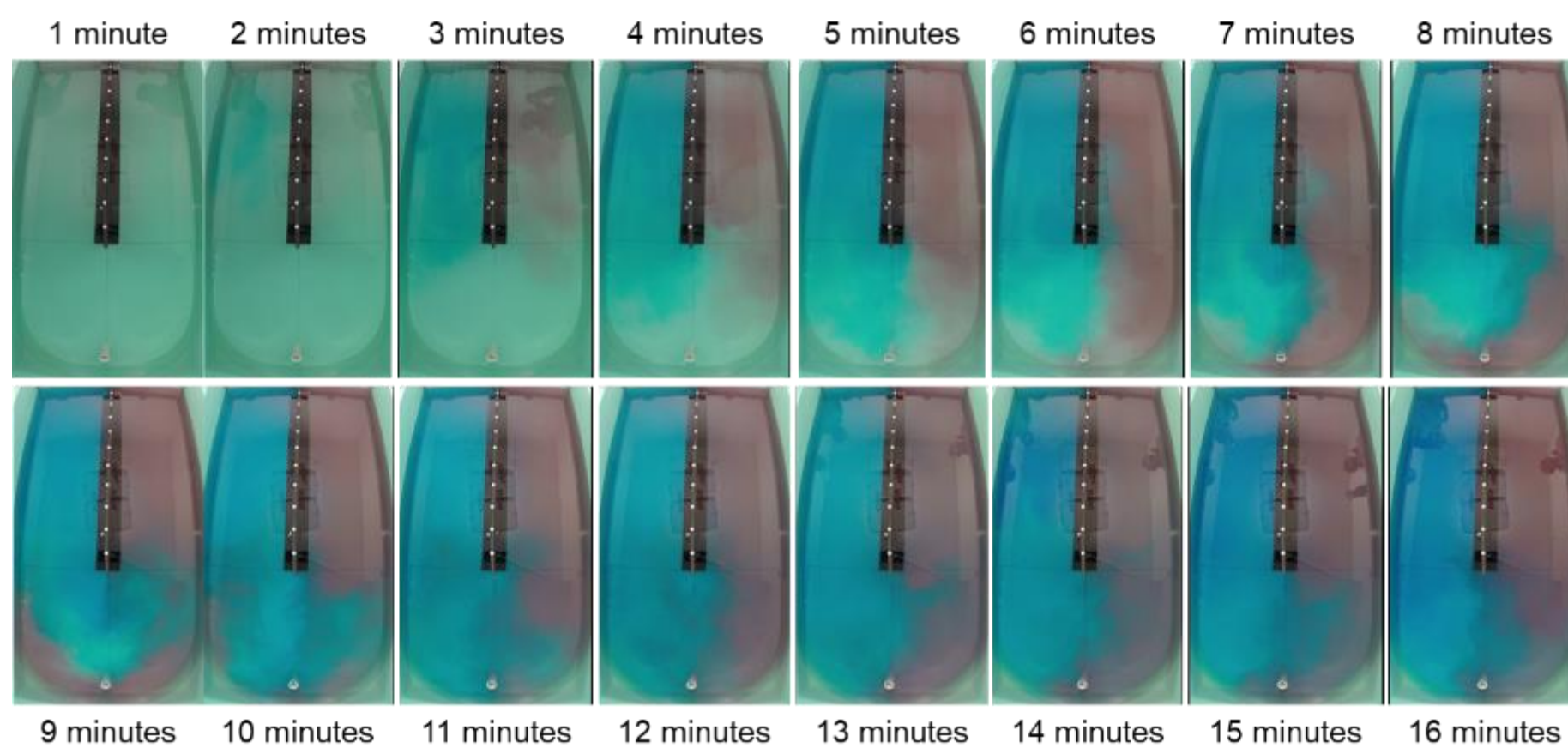


Design: Two-current flume choice system



Scientific name	<i>Salmo salar</i>
Common name	Atlantic salmon
Age/life stage	Fry
Total number	270 fish
Body mass (g)	25.0 (14.3 – 36.0)
Fork length (cm)	13.0 (10.6 – 14.6)
Condition factor	1.1 (0.9 – 2.4)
Source	Surplus Huntsman broodstock, 2016 fertilized year class

Dye Testing



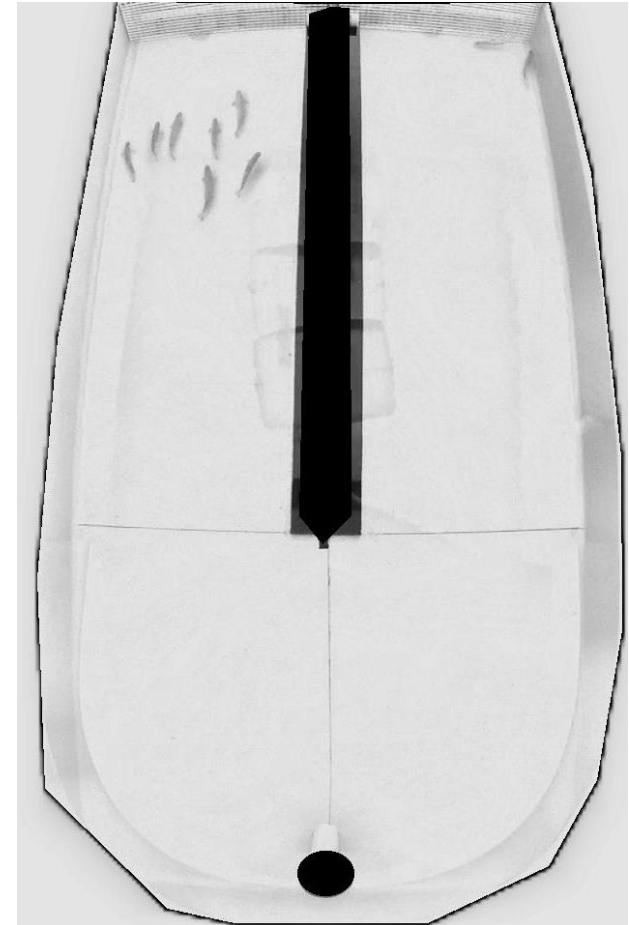
Methodology and Endpoints

Video of each run was captured using a **GoPro** (Hero 3+), then analysed using **ImageJ** (ver. 1.51v) and **ToxTrac** (ver. 2.61)

Manual counts, from *Videograms*, to determine the **gross** and **net avoidance** response for each run, and an **avoidance index**

In ToxTrac regions of interest were defined (e.g., left and right channels, decision arena), and **locomotory** and behavioural information were generated

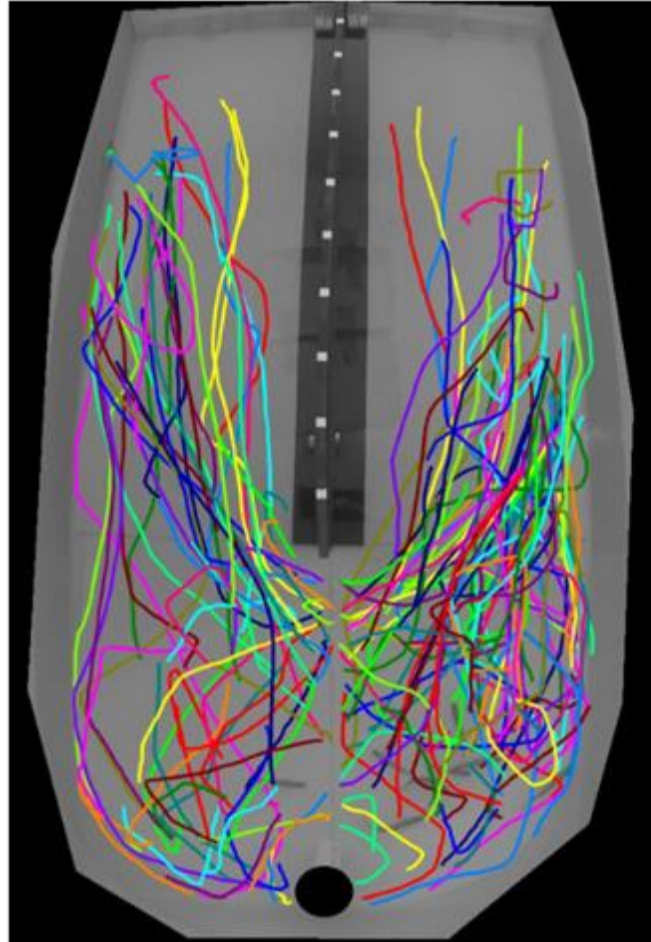
- Average speed, mobile average speed, average acceleration, mobility rate, visible frames, visible time, visibility rate, explored areas, number of areas, exploration rate, total distance, transitions in, transitions out, frozen events, total time frozen, average time frozen



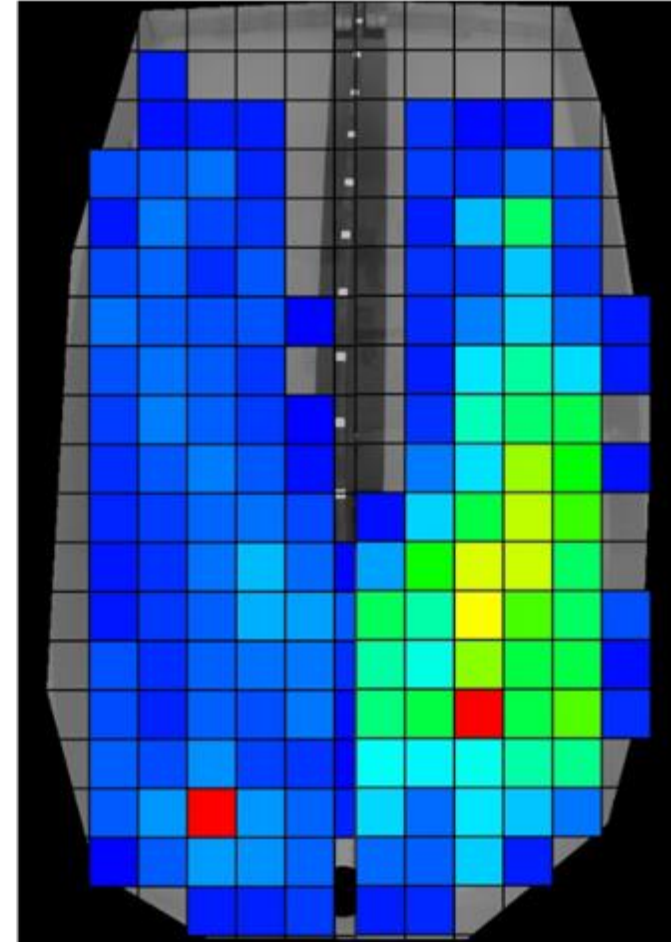
Positional Counts



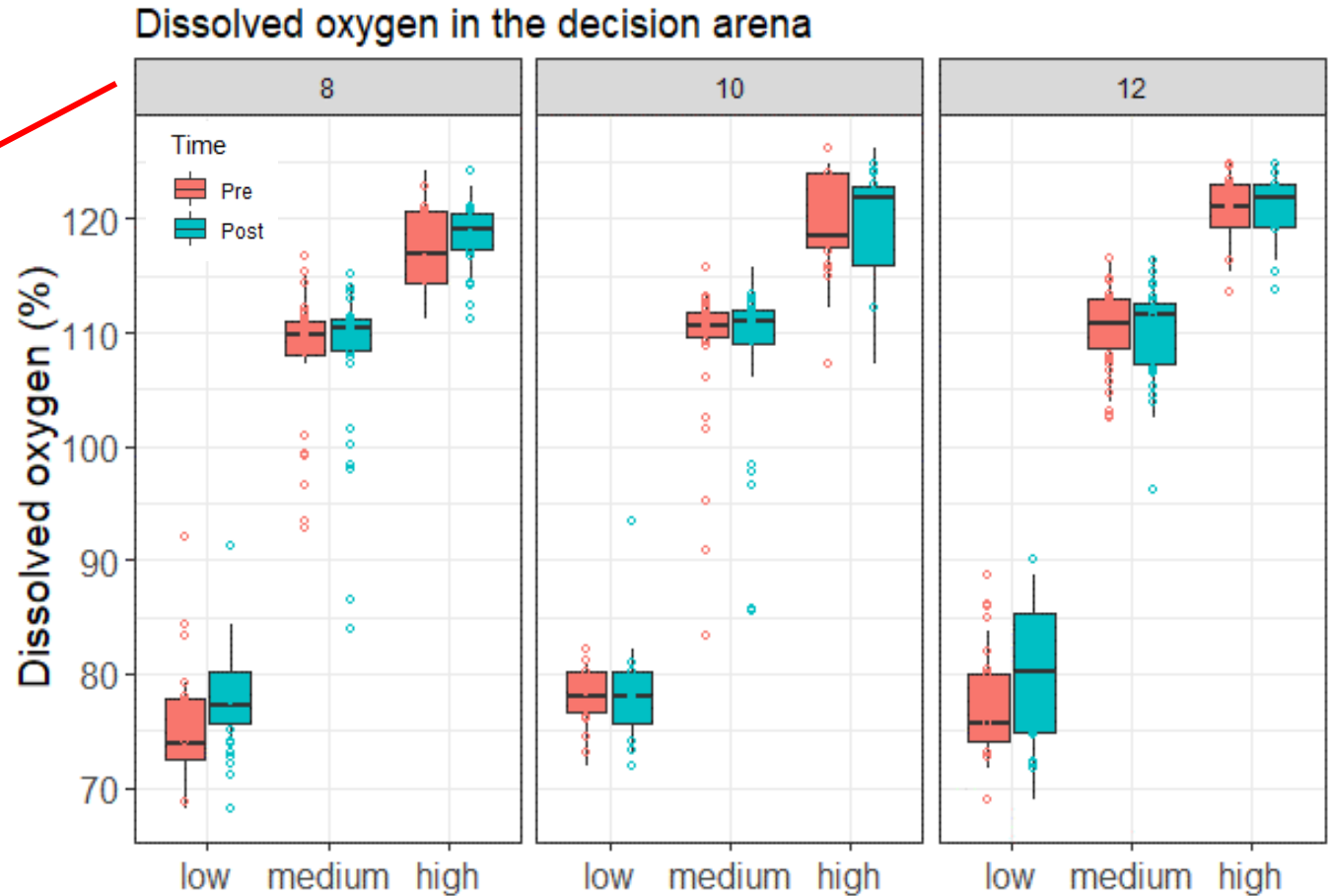
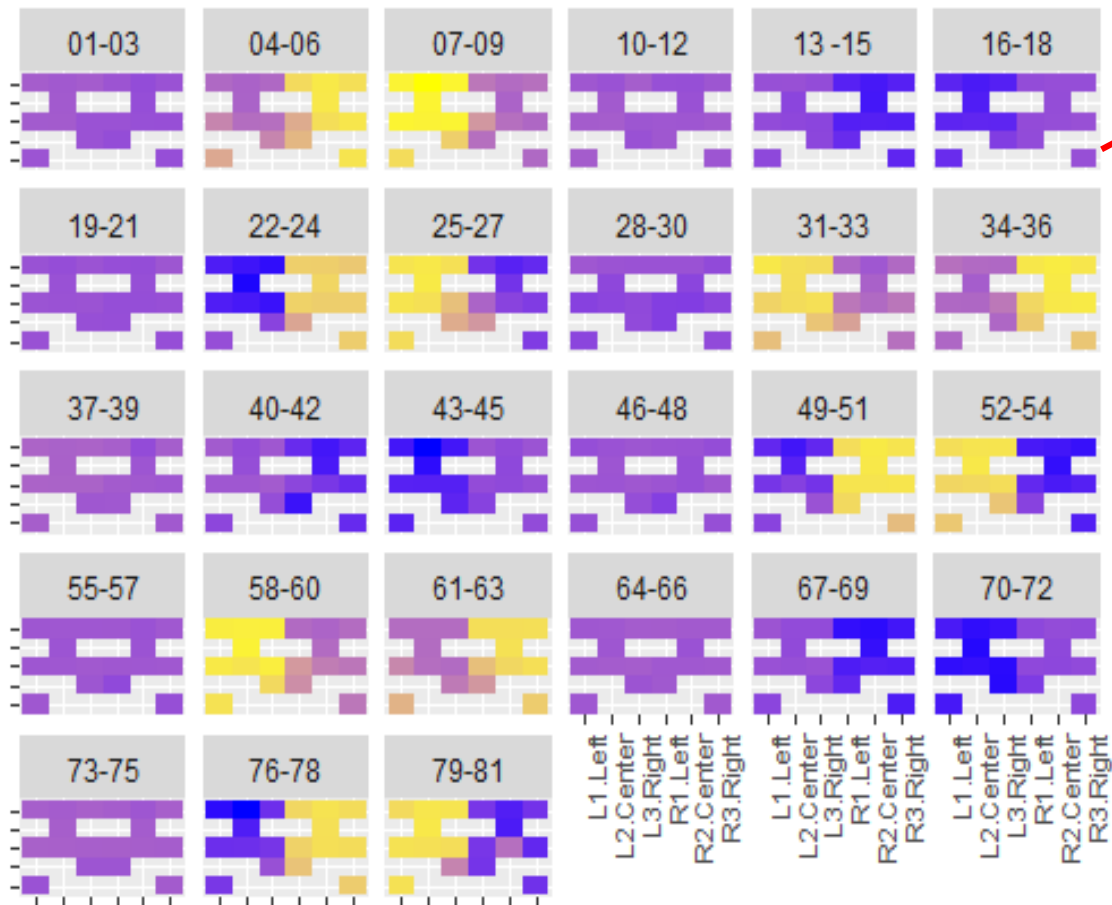
Trajectory



Exploration

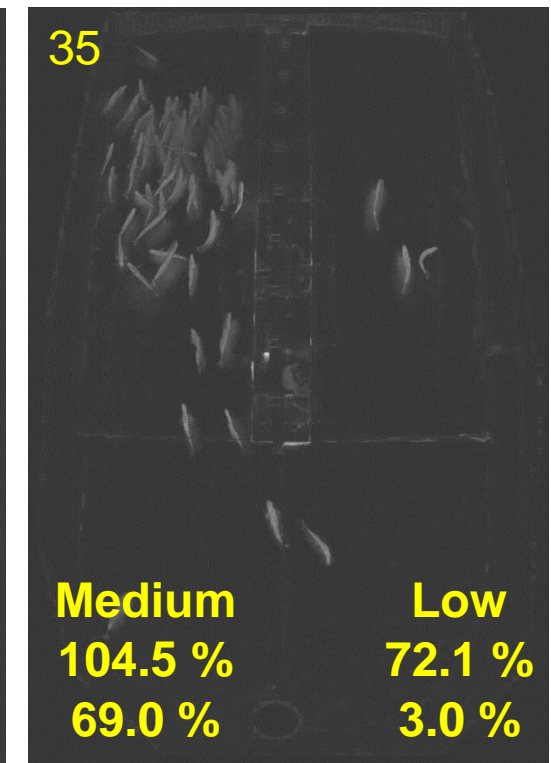
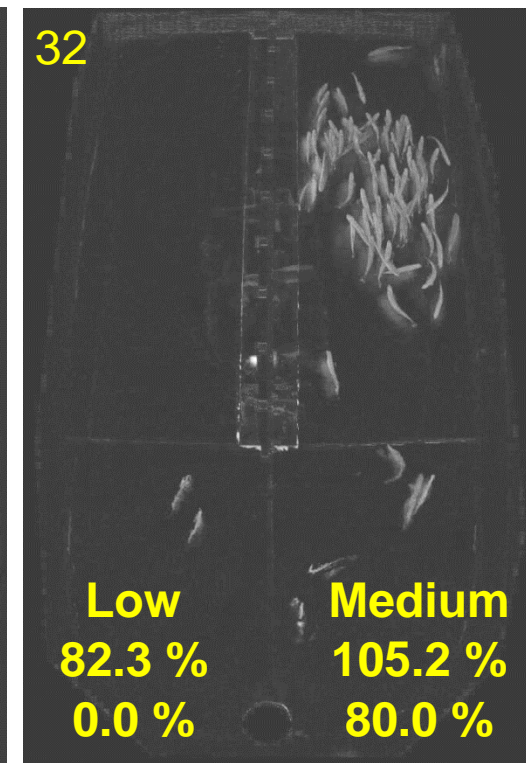
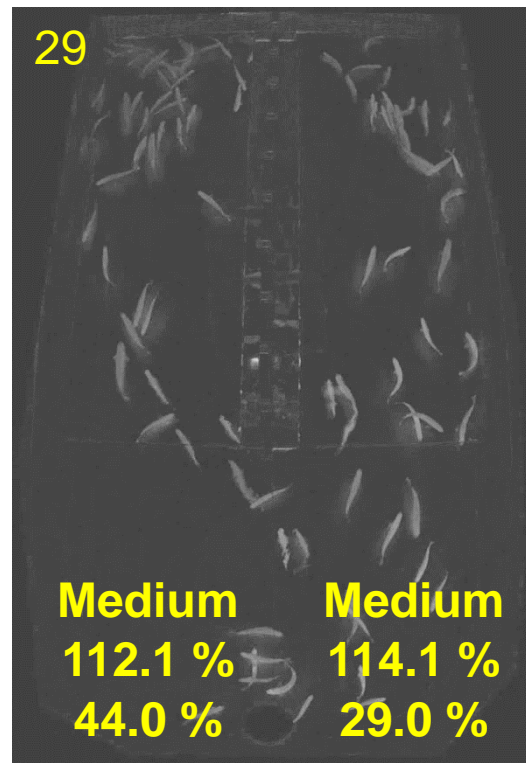


Results: Dissolved Oxygen Concentrations



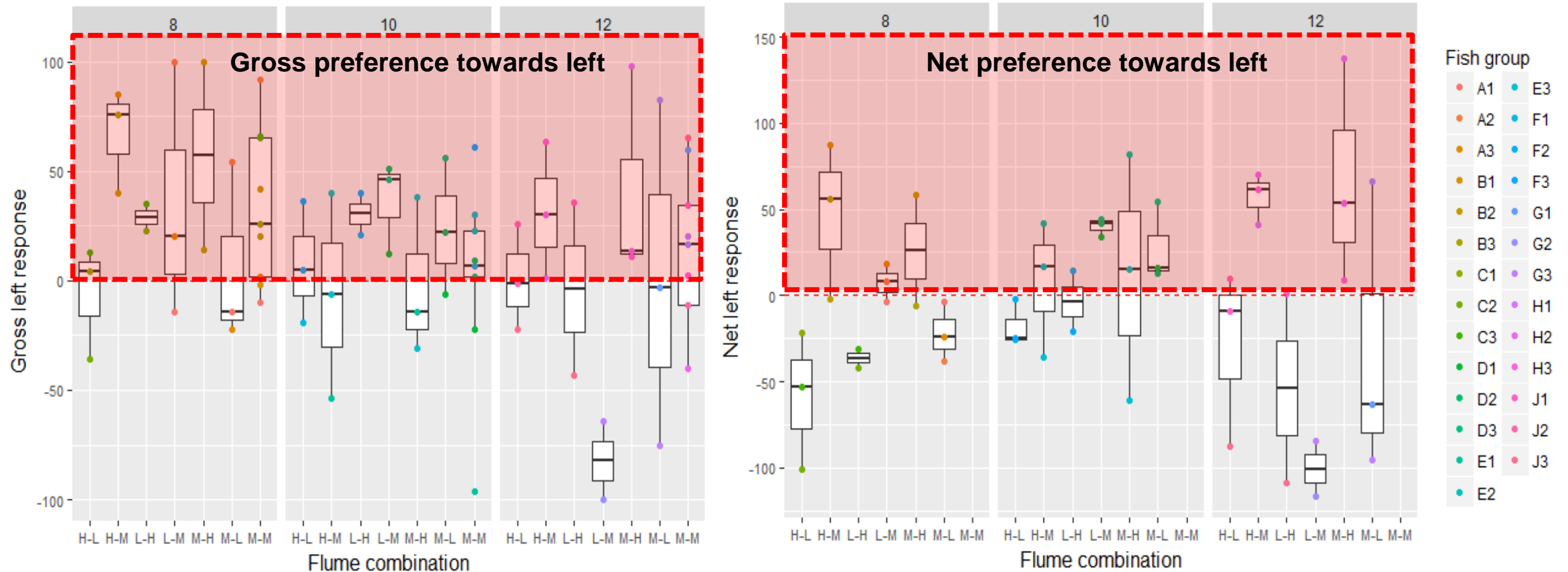
Temperature (8 °C)						
	Left	Right	Left	Right	Left	Right
Trial A	Replicate A1		Replicate A2		Replicate A3	
	Medium	Medium	Medium	Medium	Medium	Medium
	Low	Medium	Low	Medium	Low	Medium
Trial B	Replicate B1		Replicate B2		Replicate B3	
	Medium	Medium	Medium	Medium	Medium	Medium
	Medium	High	Medium	High	Medium	High
Trial C	Replicate C1		Replicate C2		Replicate C3	
	Medium	Medium	Medium	Medium	Medium	Medium
	High	Low	High	Low	High	Low
Temperature (10 °C)						
	Left	Right	Left	Right	Left	Right
Trial D	Replicate D1		Replicate D2		Replicate D3	
	Medium	Medium	Medium	Medium	Medium	Medium
	Low	Medium	Low	Medium	Low	Medium
Trial E	Replicate E1		Replicate E2		Replicate E3	
	Medium	Medium	Medium	Medium	Medium	Medium
	Medium	High	Medium	High	Medium	High
Trial F	Replicate F1		Replicate F2		Replicate F3	
	Medium	Medium	Medium	Medium	Medium	Medium
	High	Low	High	Low	High	Low
Temperature (12 °C)						
	Left	Right	Left	Right	Left	Right
Trial G	Replicate G1		Replicate G2		Replicate G3	
	Medium	Medium	Medium	Medium	Medium	Medium
	Low	Medium	Low	Medium	Low	Medium
Trial H	Replicate H1		Replicate H2		Replicate H3	
	Medium	Medium	Medium	Medium	Medium	Medium
	Medium	High	Medium	High	Medium	High
Trial J	Replicate J1		Replicate J2		Replicate J3	
	Medium	Medium	Medium	Medium	Medium	Medium
	High	Low	High	Low	High	Low

Temperature (12 °C)			
	Left	Right	
Trial G	Replicate G3		Run #
	Medium	Medium	29
	Low	Medium	32
	Medium	Low	35



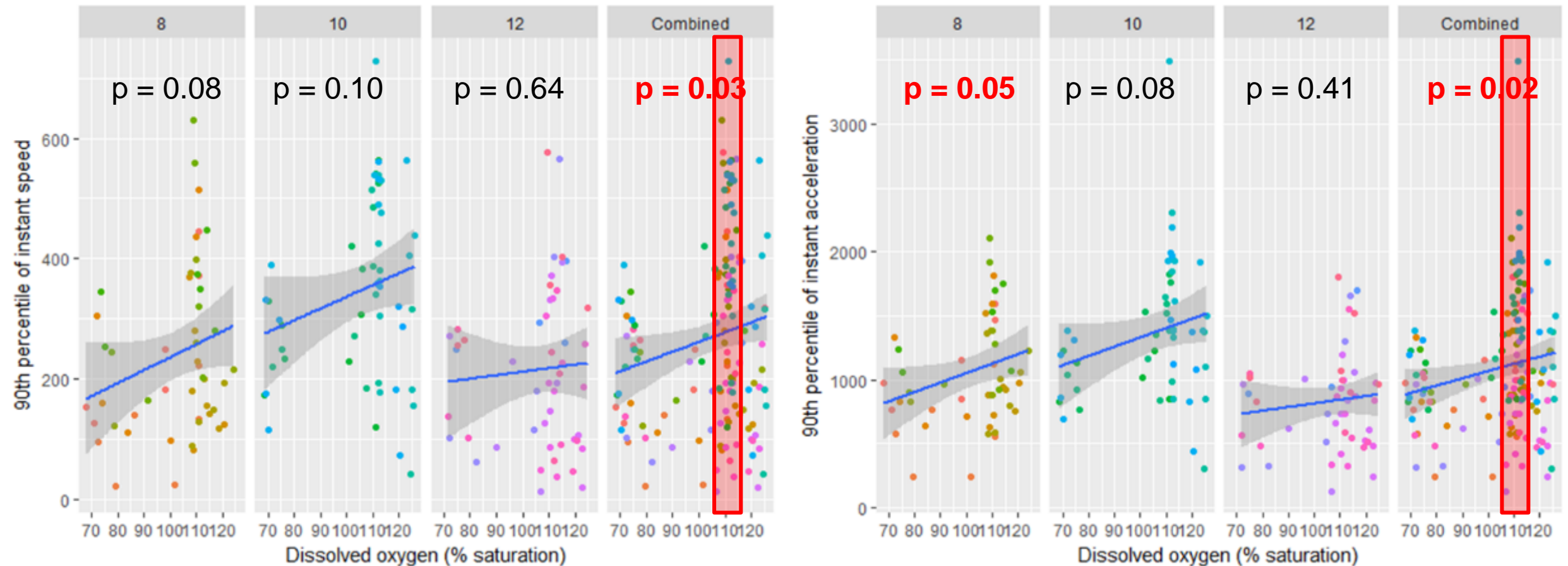
DO
Time

Side and Treatment Preference



Locomotory Endpoints

Maximum speed and
acceleration at
~ 110% saturation



Field trial

Deploy GIS Container Unit at Dam

- 6000 LPM – 18,000 LPM water flow
- 250 gpm – 750 gpm Oxygen

Trial Objective

- Provide oxygen gradient for fish attraction/ladder movements
- Extension of attraction zone at the basin level (for lifts incl. head pond)
- Direct fish to the mouth of the lift/fish ladder and away from turbine outputs
- Direct fish away from turbulent water (avoid high TGP levels/gas bubble disease)

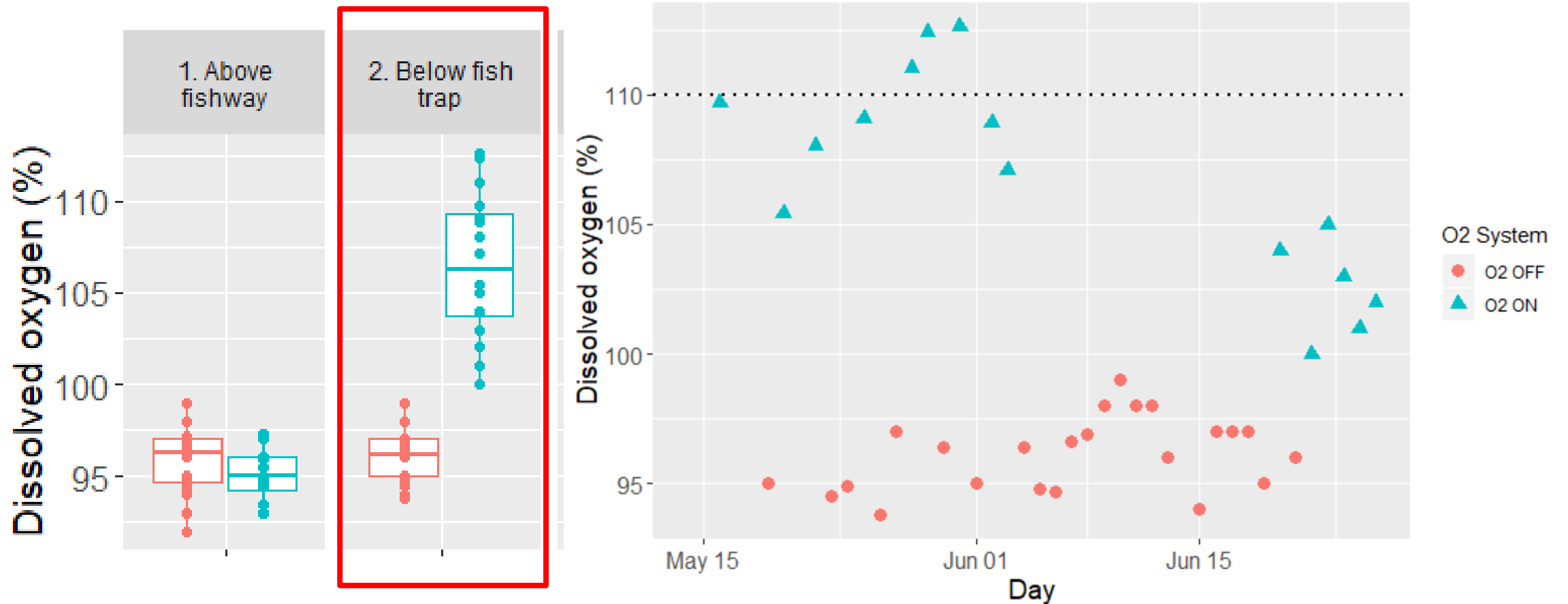
Overall Goals

- Improve ladder climb percentage
- Reduce turn around effects
- Increase fish returns (< mortalities)
- Reduce stress (immuno-compromised)

Assess daily returns with and without O2 treatment



Field trial results: Oxygen infusion



Discussion

The data *did not support* a preference or avoidance related to freshwater oxygen saturation within the tight concentrations tested (**80-120%**)

- There was a notable bias towards the left channel; Net and avoidance index responses were inconsistent
- Below 60% saturation, Atlantic salmon will alter their migratory behaviour (Priede et al. 1988)

There was a positive relationship between locomotory endpoints and freshwater oxygen saturation within each temperature

- Peak performance observed **~110% saturation**
- With caged salmon, swim speeds were 1.5 to 2.7 times slower during times of lower dissolved oxygen (Oldham et al. 2017)

Social behaviour dynamics may override preference/avoidance response under these testing conditions

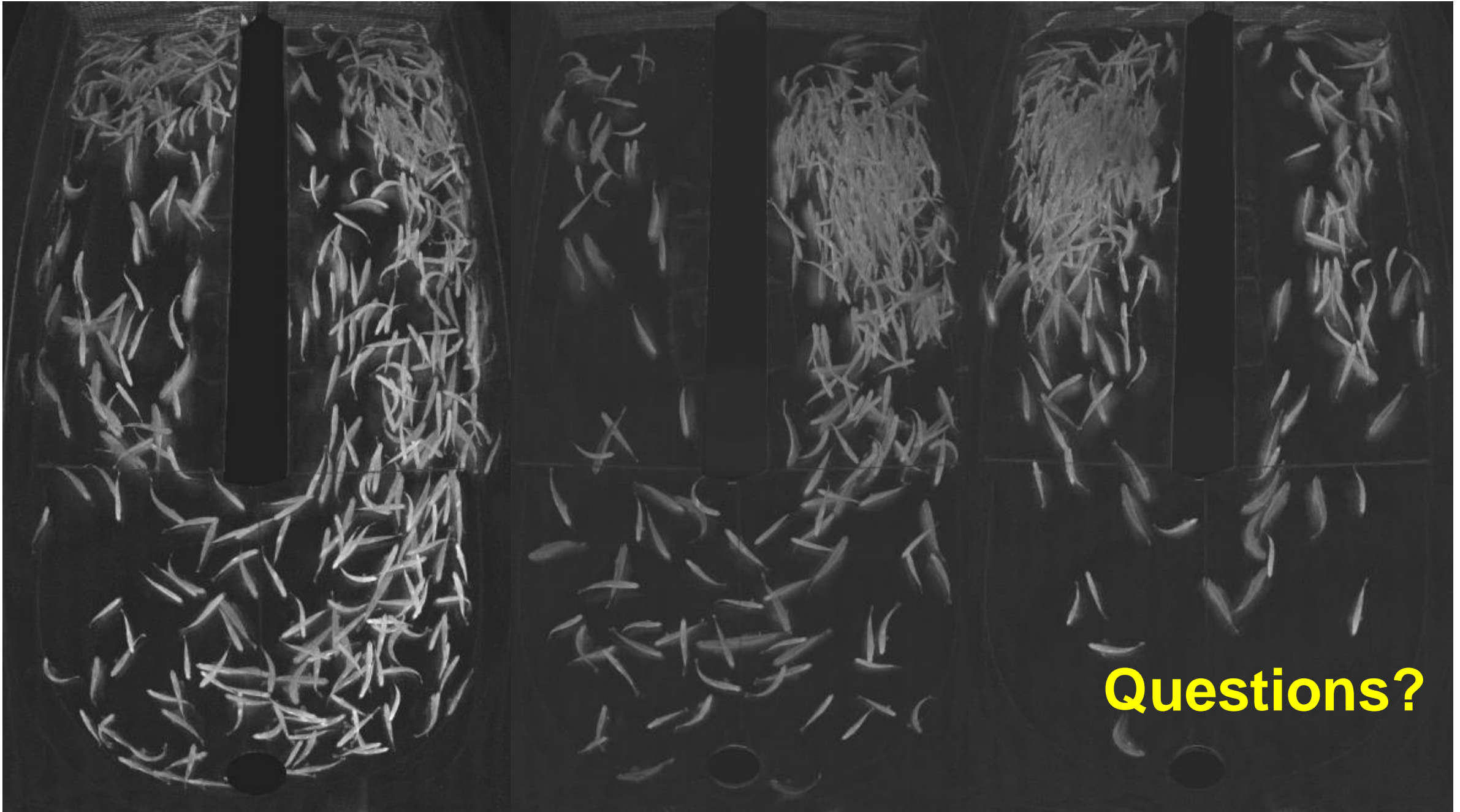
Oxygen infusion creates increased dissolved oxygen concentrations within the surrounding areas in large scale field studies

- Changes in concentration are rapidly observed and are stable once system is engaged, reaching **~110% saturation**

Preliminary field findings, when >10,000 fish per day;

- **Without** O2 system: DO in the fish trap can drop to < 80%; **up to 100 fish mortalities**
- **With** O2 system: No DO drop (>100%); **maximum of 12 fish mortalities**

Priede, I.G. et al. 1988. *J. Fish Biol.* **33**, 133–139
Oldham, T. et al. 2017. *Aqua. Environ. Interact.* **9**, 145–153



Questions?