



# Perforated plates for downstream migration

Laurent DAVID<sup>1</sup>,

Fatma LEMKECHER<sup>1</sup>, Ludovic CHATELLIER<sup>1</sup>, Dominique COURRET<sup>2</sup>

<sup>1</sup> Institut Pprime, CNRS-University of Poitiers-Isae Ensma, Pole Ecohydraulique OFB-IMFT-Pprime

<sup>2</sup> Office Français de la Biodiversité, Pole Ecohydraulique OFB-IMFT-Pprime

# Context



## Downstream migration

- Different solutions exist
- Adapted to different HPP sizes
- if the size of the fish decreases, which solution should we choose ?

Fish Protection Technologies at HPP	Concept	Type	Measure	
	Screening / Shielding and Guidance	Physical Barriers		Fine Screens
Submerged Bar Screens				
Mechanical, Behavioural Barriers			Rotary Screens	
			Eicher-Screen	
Sensory, Behavioural Barriers		Wedge-Wire-Screen		
		Barrier Nets		
Collection Systems		Skimming Walls		
		Louvers		
Conveyance	Fish Friendly Turbines		Bar-Racks	
			Plate Screens	
Fish Friendly Operation			Trash Racks	
			Light (Strobe or Mercury)	
			Low Frequency Sound	
			Popper	
			Electricity	
			Air- / Water Curtains	
			Surface Collection Pipes	
			Traveling Screens	
			Fish Pumps	
			Trap and Truck	
			Alden Turbine	
			Voith - Minimum Gap Runner	
			Alstom - Fish Friendly Kaplan-Turbine	
			Early Warning Systems	
			Weir Overflow	
			No Partial Load Operation	

# Context



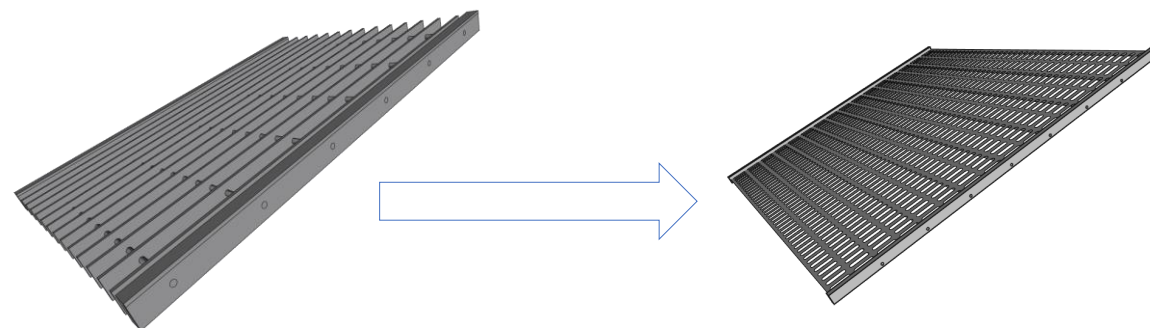
## Downstream migration

David L., Chatellier L., Courret D. Albayrak, Boes RL., 2022: Fish Guidance Structures with Narrow Bar Spacing: Physical Barriers. *Novel Developments Towards Sustainable Hydropower*. Chapter 7, 91-98, <https://doi.org/10.1007/978-3-030-99138-8>

- Physical barriers have to be adapted

Fish size ↓, bar spacing ↓  
and Head loss and clogging effects ↑

- Perforated plate with the same obstruction could be an alternative ?

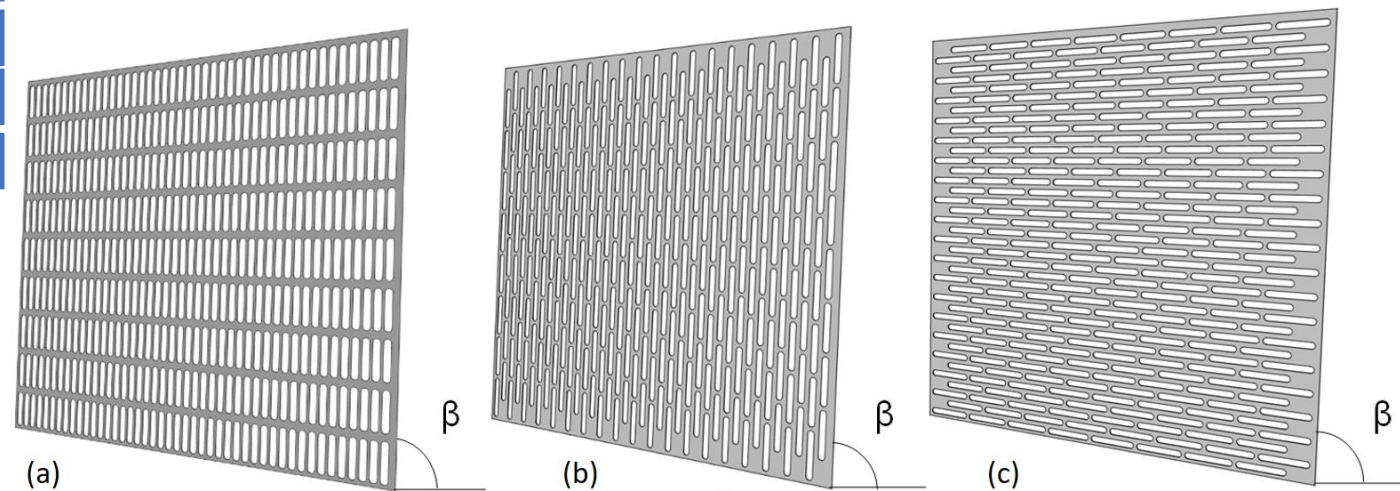
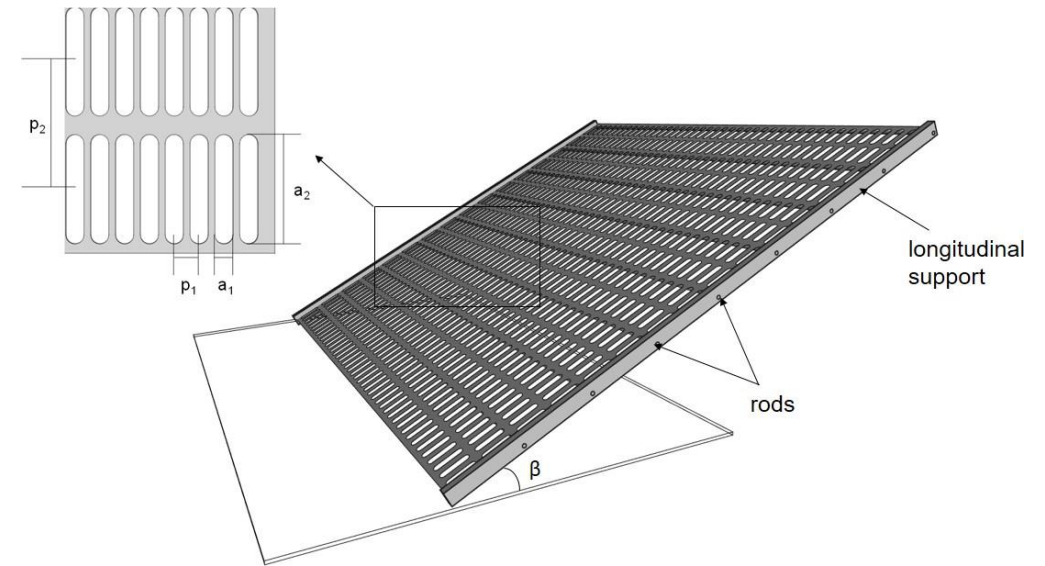


# Experimental setups

- Inclined perforated plate
- Different size of the holes with a constant obstruction of 33%

Parameters	Values	Units
Hole width $a_1$	10; 15; 20	(mm)
Hole height $a_2$	100; 150; 200	(mm)
Angle of inclination $\beta$	15; 25; 35; 45; 60; 90	(°)

- Different orientations (H/V)
- Holes distribution (A/S)



(a) aligned vertical, (b) staggered vertical and (c) staggered horizontal

# Experimental setups

- Open flow channel at the Pprime institute

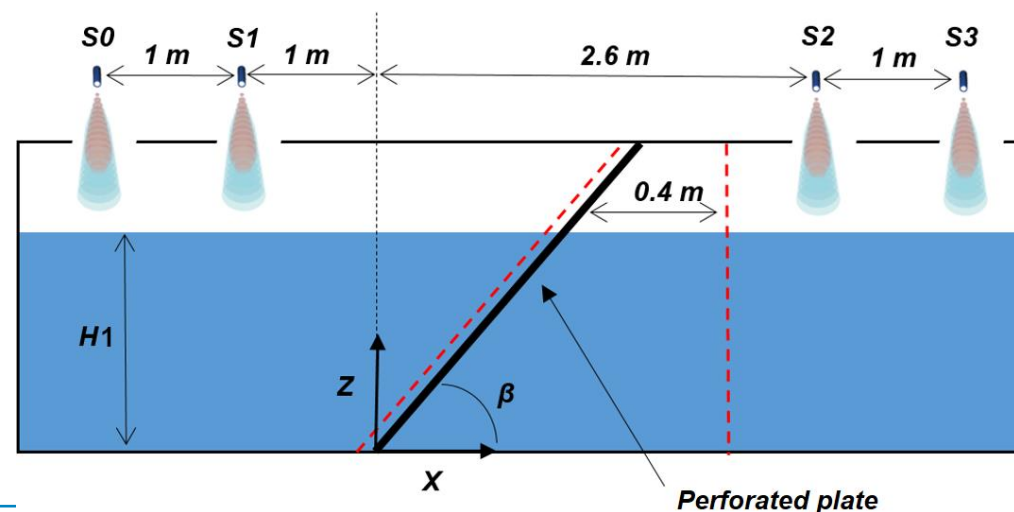


Height : 1 m  
Width : 1 m  
Length: 12 m  
Discharge: 0,22 to 0,5 m<sup>3</sup>/s

- Physical parameters

Parameters	Values	Units
Discharge Q	0.5	(m <sup>3</sup> s <sup>-1</sup> )
Upstream water depth H <sub>1</sub>	0.7	(m)
Approach velocity V <sub>1</sub>	0.72	(m s <sup>-1</sup> )
Froude number	0.27	(-)

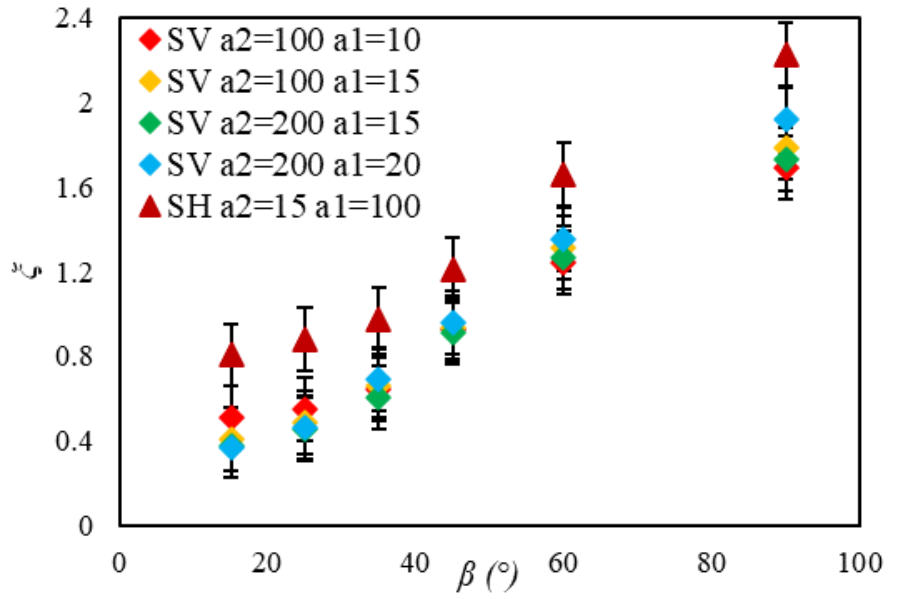
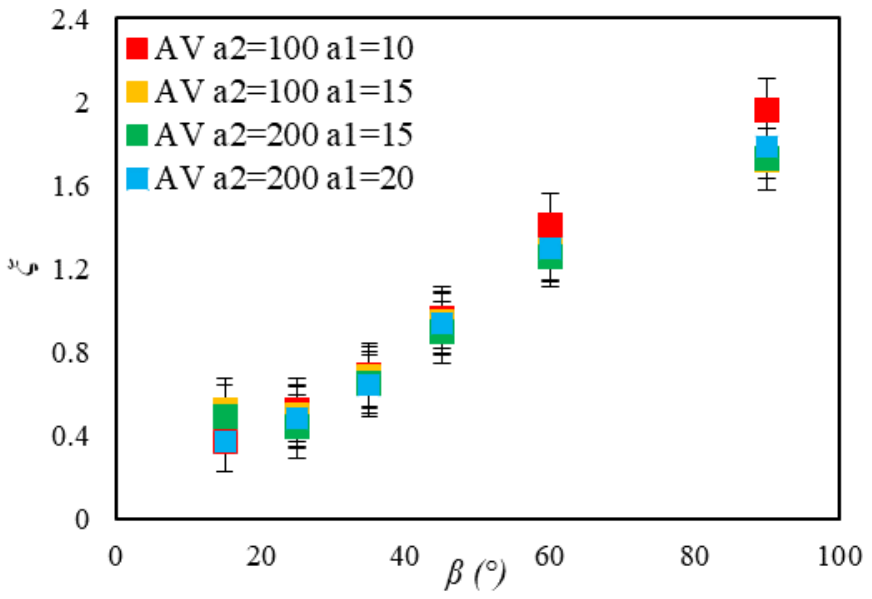
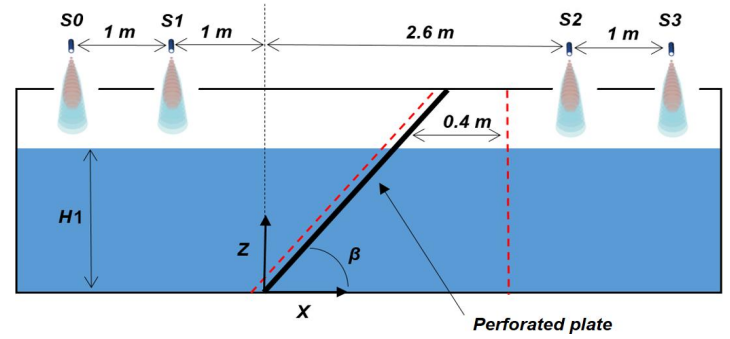
- Water depth and velocity profiles (U/D) measurements



# Results

- Head losses

$$\Delta H = (H_1 - H_2) + \left( \frac{V_1^2}{2g} - \frac{V_2^2}{2g} \right) + \Delta H_0 \quad \xi = \frac{\Delta H}{V_1^2 / 2g}$$



With a constant obstruction of 33%

# Results

- Modelled Head loss coefficients

Based on the law for inclined or angled bar rack

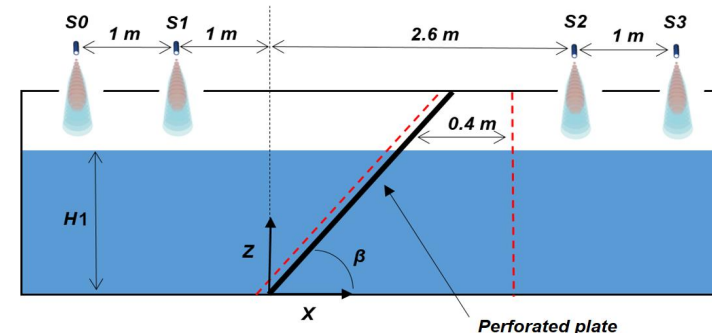
(Raynal et al. 2013, Lemkecher et al. 2022)

$$\xi = A_i \left( \frac{O_b}{1 - O_b} \right)^{1.65} \sin^2 \beta + C \left( \frac{O_{sp,H}}{1 - O_{sp,H}} \right)^{0.77}$$

$$\xi_{total} = \xi_{bars} + \xi_{spacers}$$



$$\xi_{plate} = A_i \left( \frac{O_b}{1 - O_b} \right)^{1.65} \sin^2 \beta = A_i \times K_b \times K_\beta$$



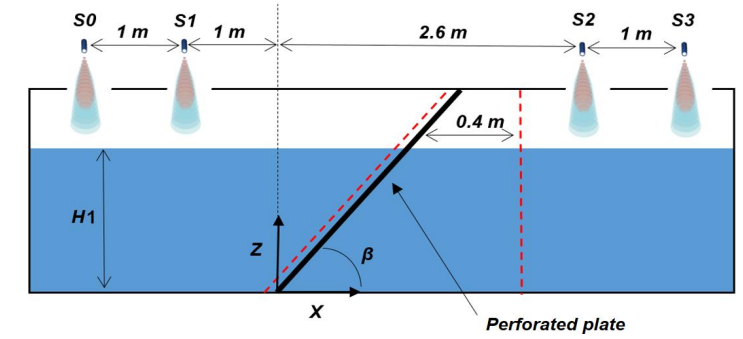
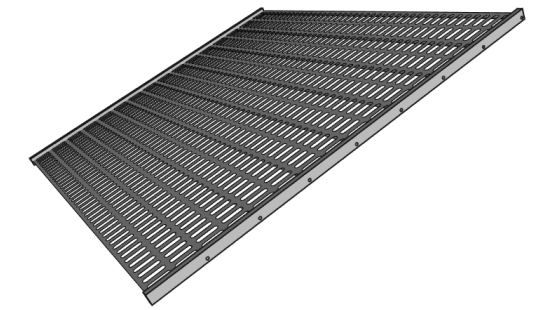
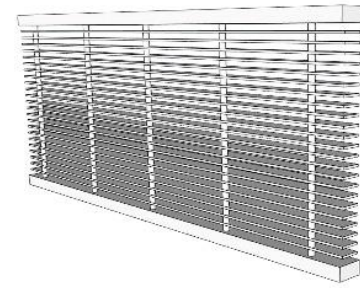
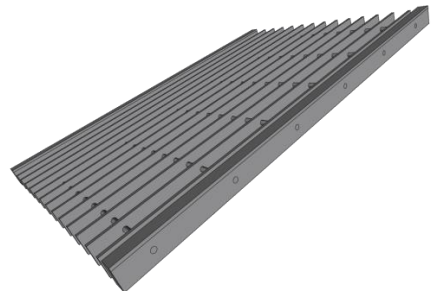
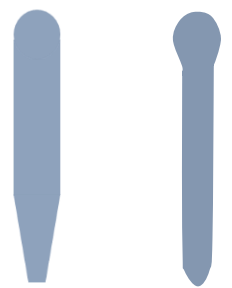
Type	Aligned Vertical				Staggered Vertical				Staggered Horizontal
a <sub>1</sub> (mm)	10	15	15	20	10	15	15	20	100
a <sub>2</sub> (mm)	100	100	200	200	100	100	200	200	15
A <sub>i</sub>	3.74	3.27	3.28	3.35	3.20	3.40	3.29	3.66	4.27
R2	0.997	0.994	0.992	0.998	0.993	0.998	0.998	0.998	0.987
Global A <sub>i</sub>	3.33 with R2 = 0.964								4.27

Raynal S., Courret D., Châtellier L., Larinier M., David L., 2013 : An experimental study on fish-friendly trashracks- Part 1: Inclined trashracks. *Journal of Hydraulic Research*, 51:1, 56-66.

Lemkecher F., Chatellier L., Courret D., David L., 2022. Experimental study of angled fishfriendly trashracks with horizontal bars. *Journal of Hydraulic Research*, 12p.

# Results

- Comparison with a bar rack system

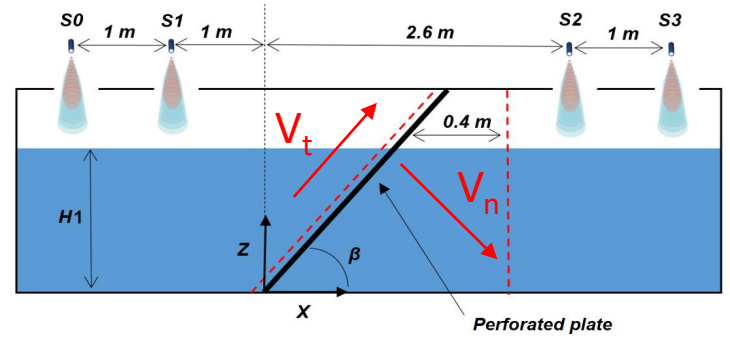


$\Delta H$ (mm)	Vertical Inclined Bar Rack or horizontal angled Bar Rack $b = 7$ mm				Perforated Plate	
Angles ( $^{\circ}$ )	15		25		15	25
Shape	Hydrodynamic	Tadpole 8	Hydrodynamic	Tadpole 8	-	-
e=10 mm	7,3 mm	7,3 mm	11,2 mm	8,6 mm	3 mm	7,9 mm
e=15 mm	6,8 mm	6,8 mm	8,8 mm	7,4 mm	3 mm	7,9 mm
e=20 mm	6,8 mm	6,8 mm	7,9 mm	7,1 mm	3 mm	7,9 mm



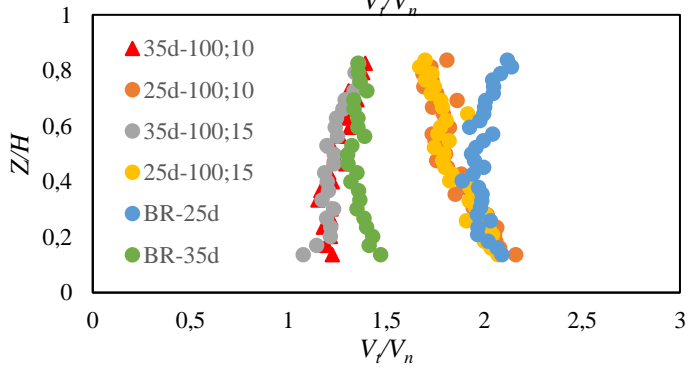
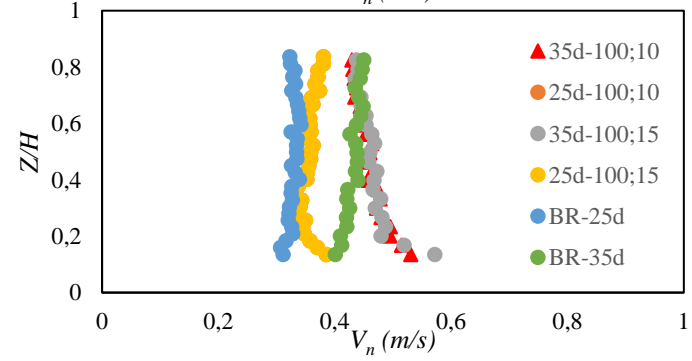
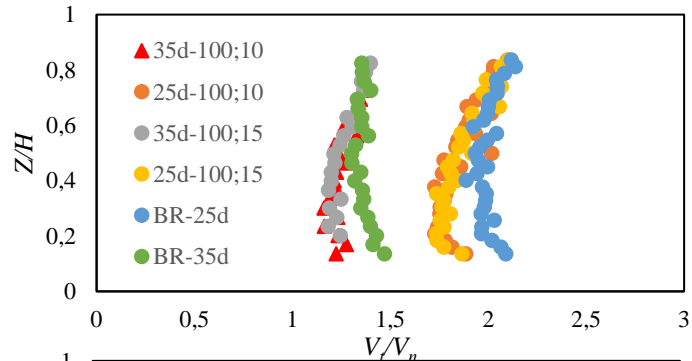
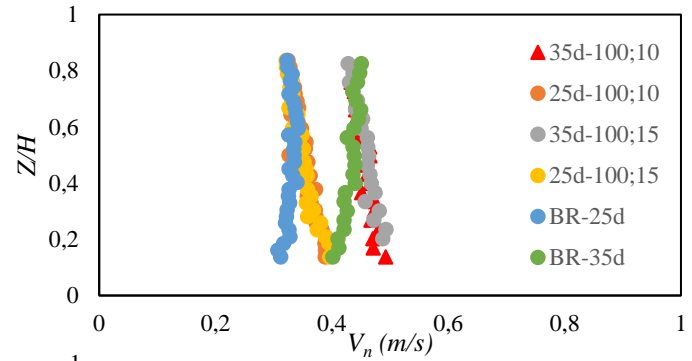
# Results

- Upstream velocity profiles



staggered vertical holes

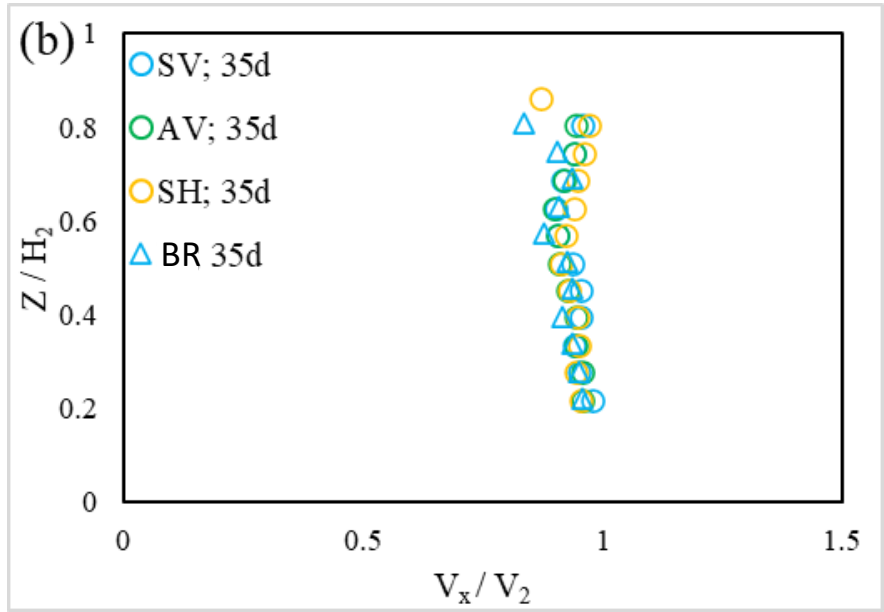
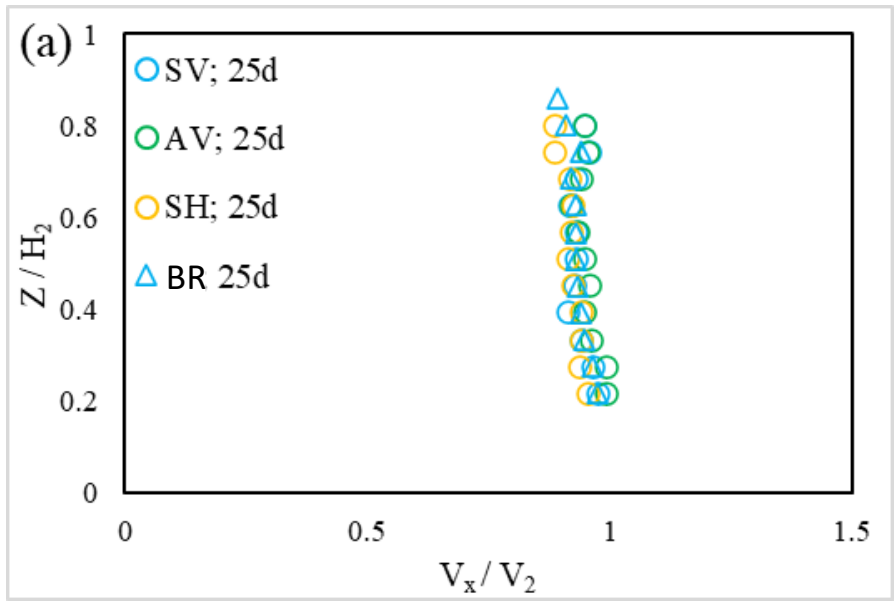
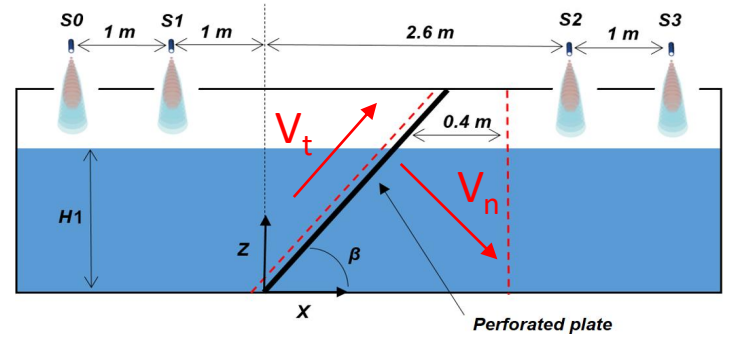
aligned vertical holes



Criteria  $V_n < 0.5 \text{ m/s}$  and  $V_t/V_n > 1 \text{ to } 2$

# Results

- Downstream velocity profiles



No asymmetric

# Conclusion

- Perforated plates are a good solution for downstream migration
- Less head-losses for perforated plate than rectangular bar
- For small fish size, it allows to obtain same head losses with a same obstruction even if the hole size is decreasing
- Fish friendly criteria are respected ( $V_n$  and  $V_t/V_n$ )
- Downstream, streamwise component is uniform
  
- Good alternative to bar rack system but has to be tested in the field !

# Thank you for your attention



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