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Can vertical slot fishways (VSF) operate with less water without compromising effectiveness

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INSTITUTO SUPERIOR DE AGRONOMIA
Universidade de Lisboa

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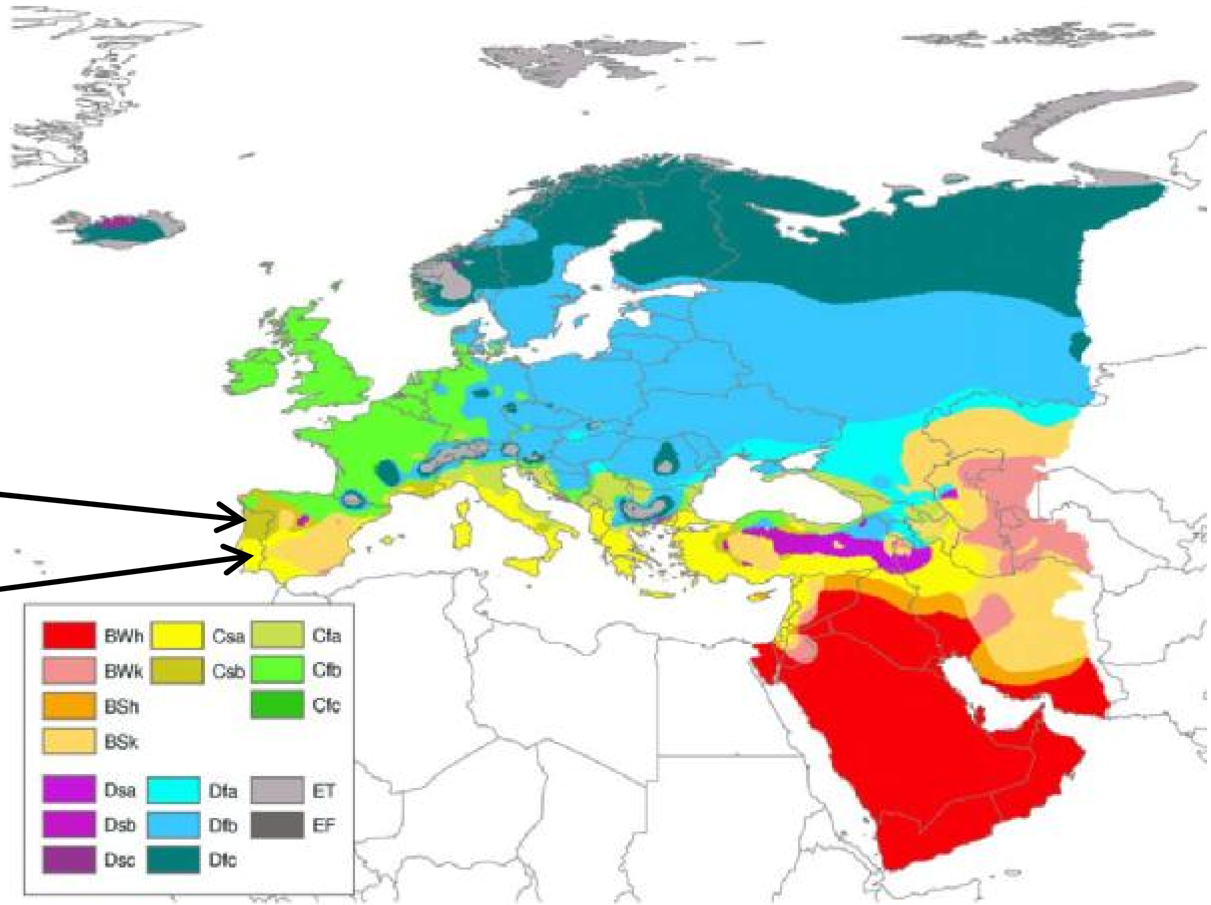
Introduction

Portugal

Csb – Temperate, dry and warm summer mediterranean climate

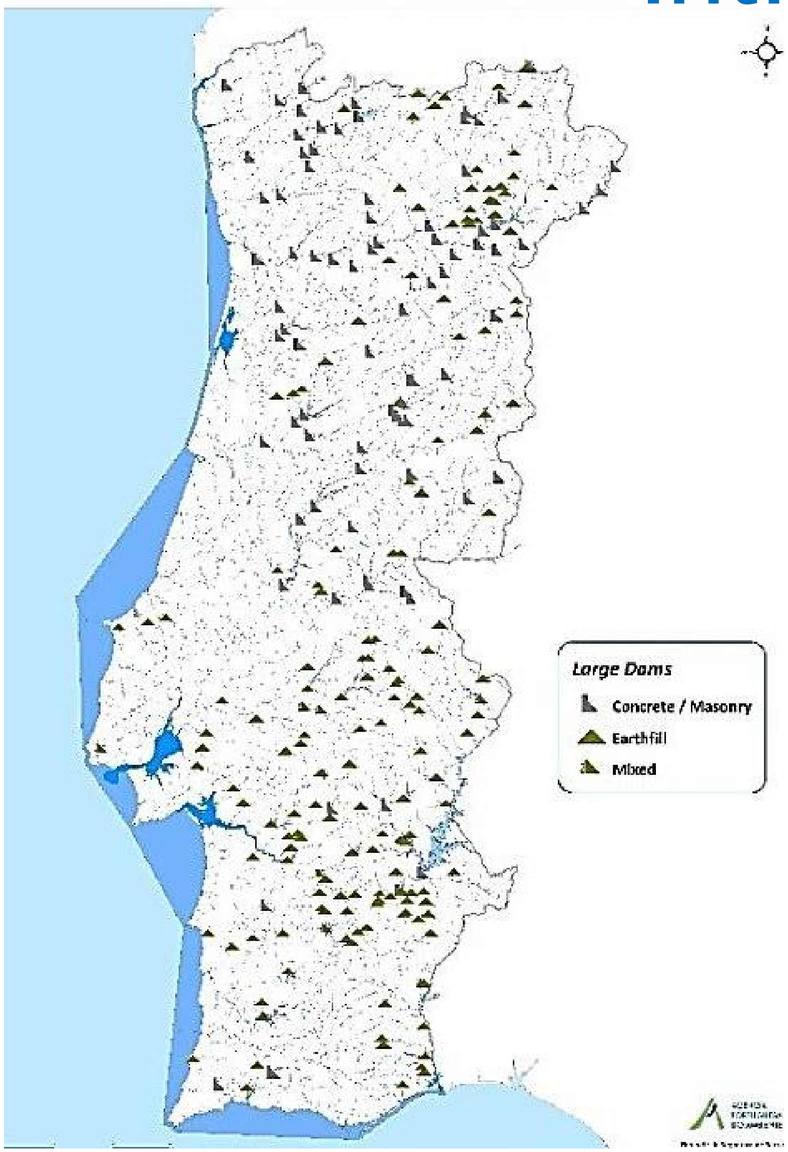
Csa – Temperate, dry and hot summer mediterranean climate

Mediterranean type river systems with extended low flow periods



Köppen-Geiger climate type map of Europe (Peel et al., 2007)

Introduction



Large dams in Portugal (APA, 2017)

250 large dams
(APA, 2017)

and more than
3000 small weirs
(Santos et al. 2004)

50 fishways
Santos et al. 2012 assessed 37
19 (51%) were found unsuitable

Introduction

Most common in Portugal - orifice/notch pool-type fishway

↓

relatively low water requirement

Fishway with notches and bottom orifices at Nunes mini-hydroelectric power plant

More recently → Vertical slot fishways (VSF)

↓

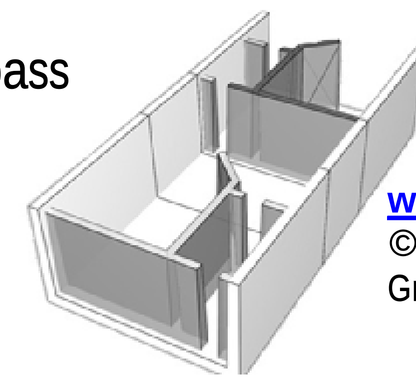
Fish can swim through the slot at any desired depth

More efficient with changing water depth

VSF at Açude-Ponte Coimbra

Variation on the VSF → Enature® fish pass

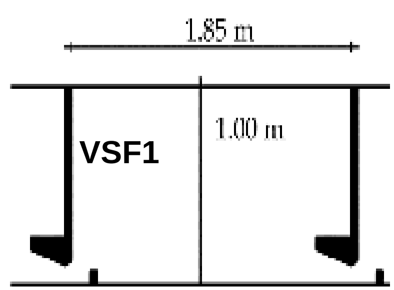
(Tauber & Mader 2009, Mader & Tauber 2010)

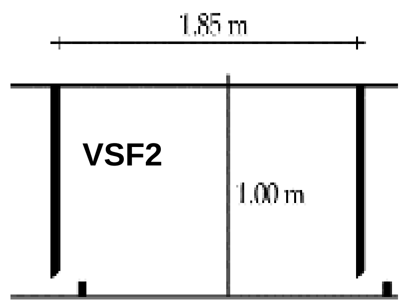


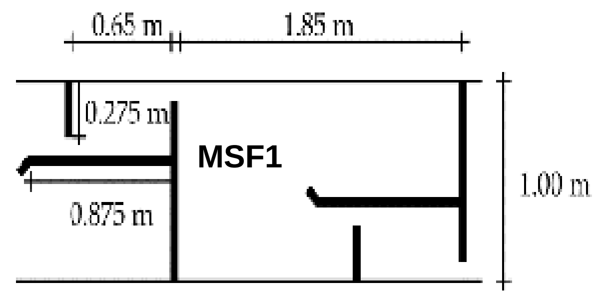
www.maba-fishpass.com; ©MABA Fertigteilindustrie GmbH

Objectives

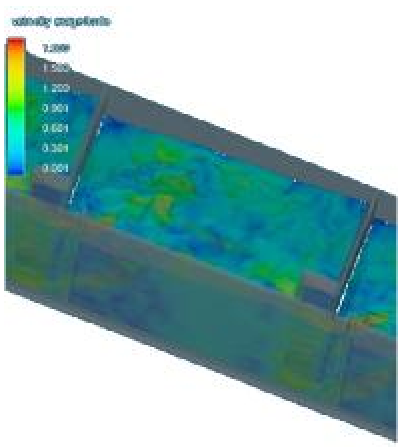
Assess the effectiveness for a cyprinid species of a MSF variant by comparing flow characteristics and passage performance

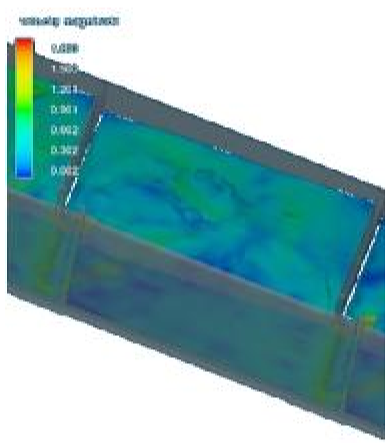


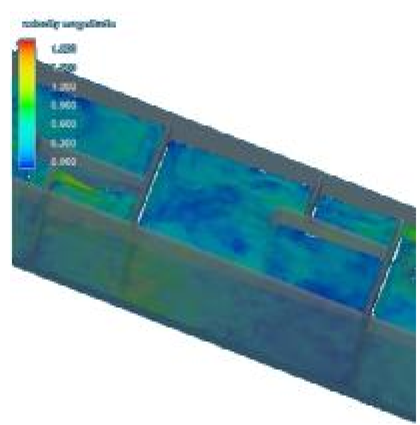




Numerical modelling with FLOW-3D®







Laboratory tests with fish

Iberian Barbel
(*Luciobarbus bocagei*, Steindachner, 1864)

Experimental setup

Indoor full scale pool-type fishway

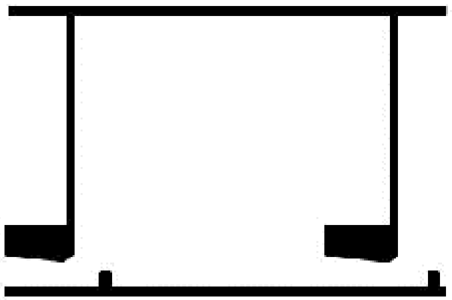
10 m long ; 1 m wide ; 1.2 m high

hydraulic measurements and tests with fish

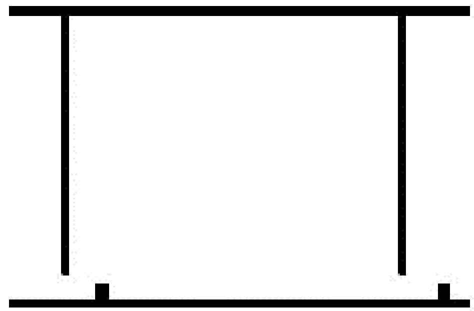
Fish Trials

- Iberian Barbel (*Luciobarbus bocagei*, Steindachner, 1864)
- School of five fish
- Total 15 trials (5 trials x 3 configurations)
- Acclimation period of 30 minutes
- Experiments lasted 90 minutes per trial
- Visual and video monitoring
- Number of upstream movements
- Number of successes (number of fish ascending to the top of the fishway)

Hydraulic measurements



VSF1



VSF2

ü **6 pools** - 1.85 m long x 1.00 m wide x 1.20 m high

ü **Cross-walls equipped with aligned slots** (0.10 m wide)

Ø s = 8.5%; $\Delta h = 0.16$ m; $h_m = 0.80$ m

Ø Q (VSF1) = 110 L/s Q(VSF2) = 81 L/s

ü **3D velocity components** (*u, v, w*) measured with ADV in the 2nd pool

ü **2 planes parallel to the bottom :** h_1 (0.50 m) and h_2 (0.625 m)

Romão et al. 2017

ADV measurements

Numerical model

- **FLOW-3D®**
- **Calibration**: comparing the measured **discharges** and **flow depths** in VSF1 and VSF2 with the numerical model results
- **Meshing**:
  - **4 cm** mesh for the entire flume,
  - **2 cm** mesh for the cross-walls and the 2nd - 4th pool,
  - **1 cm** mesh for the VSF slots
- Turbulence model: **Large eddy simulation (LES)**
- Second order monotonicity preserving

Numerical model application to MSF

Fishway configuration	Pool mean water depth (m)			Discharge (Ls^{-1})		
	Experimental	Numerical model	Relative difference (%)	Experimental	Numerical model	Relative difference (%)
VSF1	0.80	0.80	0.1	110	112	2.3
VSF2	0.80	0.81	1.8	81	80	-1.3
MSF1	0.80	0.83	4.2	56	58	3.3

The numerical model calibrated with VSF1 and VSF2 configurations, performs quite well for MSF

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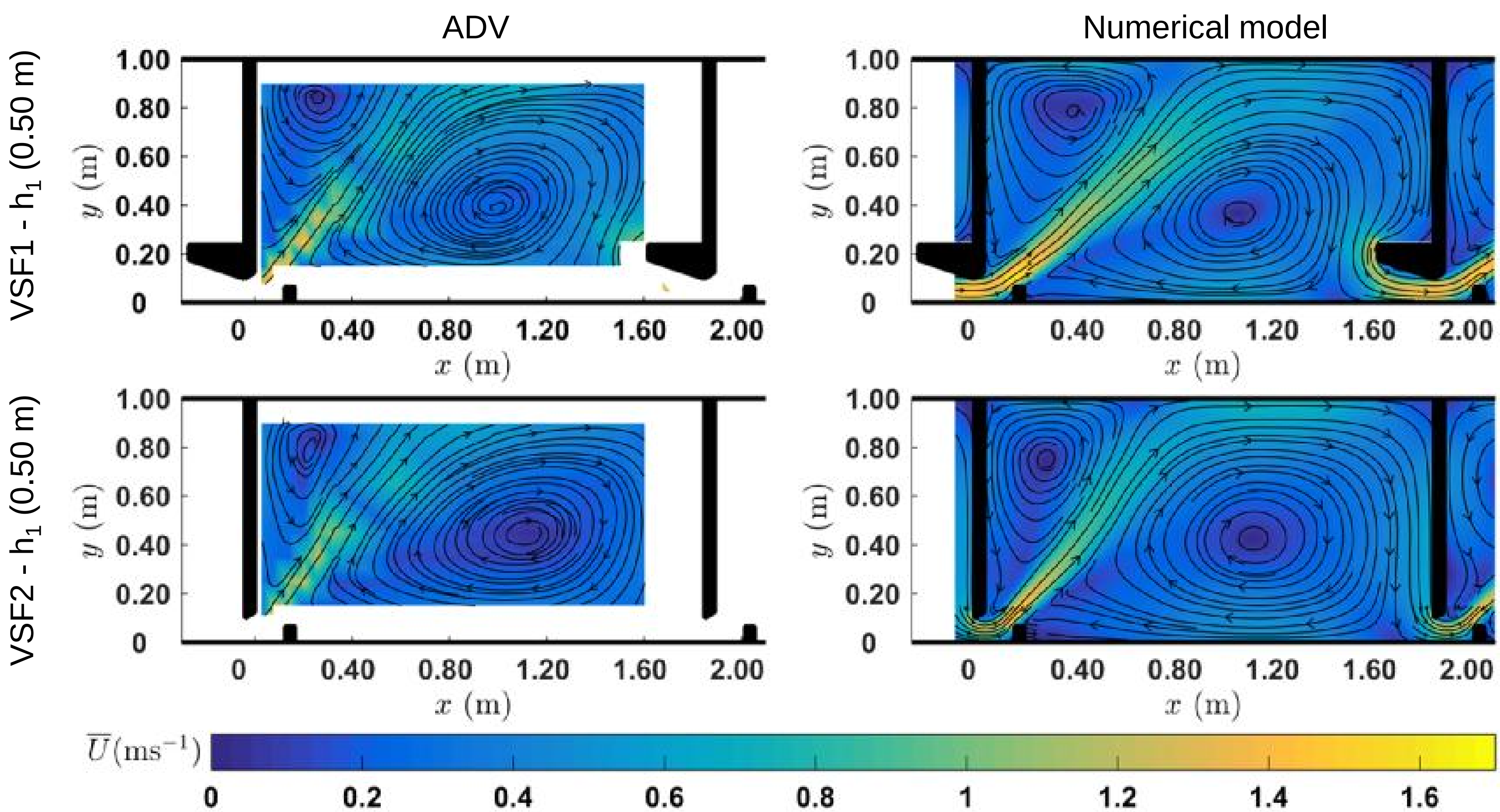
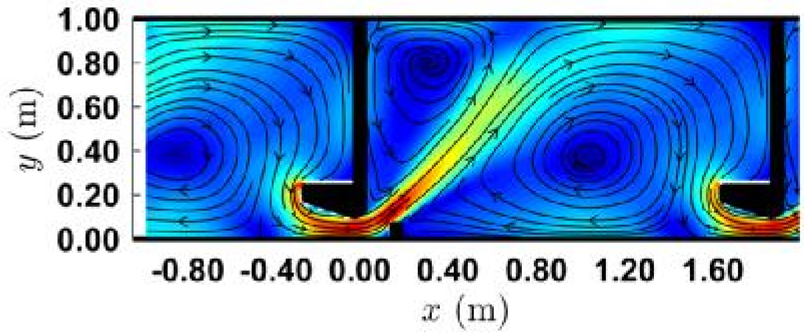
Numerical model validation



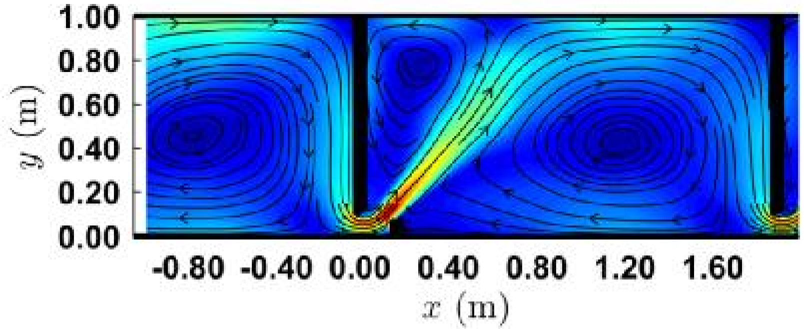
Maximum relative differences of 5% for maximum and average mean velocity magnitude in both VSF configurations

Results

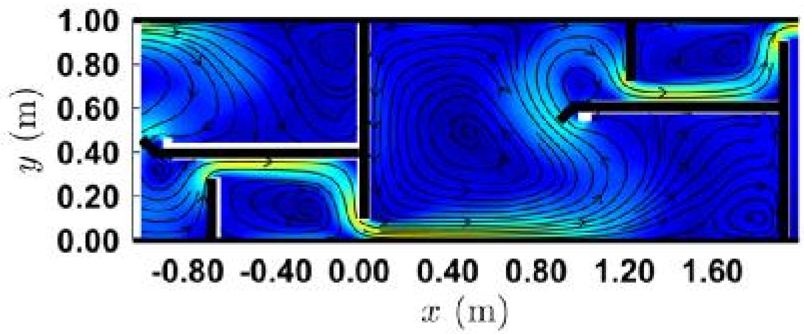
VSF1 – 50%h_m (0.40 m)



VSF2 – 50%h_m (0.40 m)



MSF1 – 50%h_m (0.40 m)

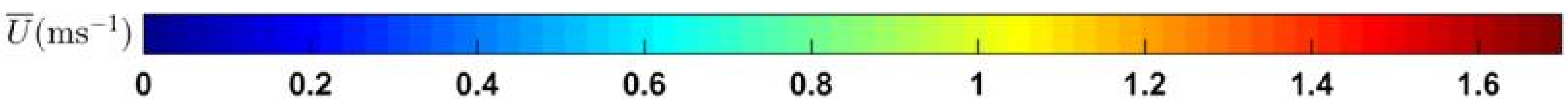


Mean velocity magnitude in the pool ($\overline{U}$)

VSF1 $\overline{U}_{average}$ = 0.58 ms^{-1}

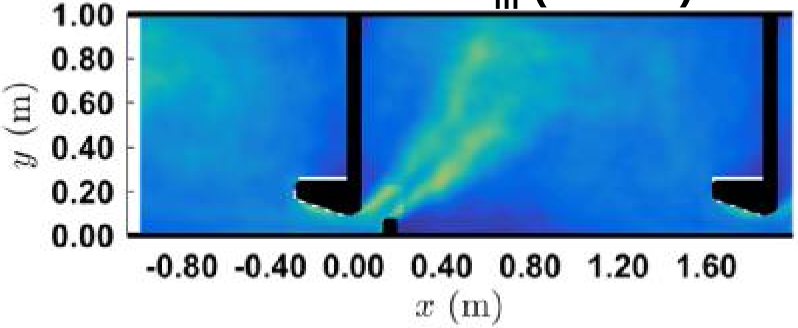
VSF2 $\overline{U}_{average}$ = 0.35 ms^{-1}

MSF1 $\overline{U}_{average}$ = 0.26 ms^{-1}

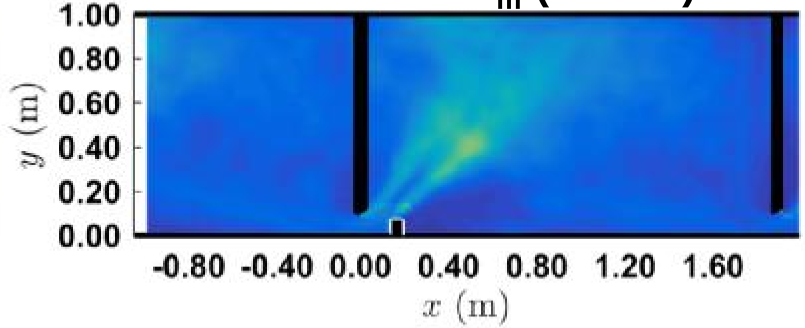


Results

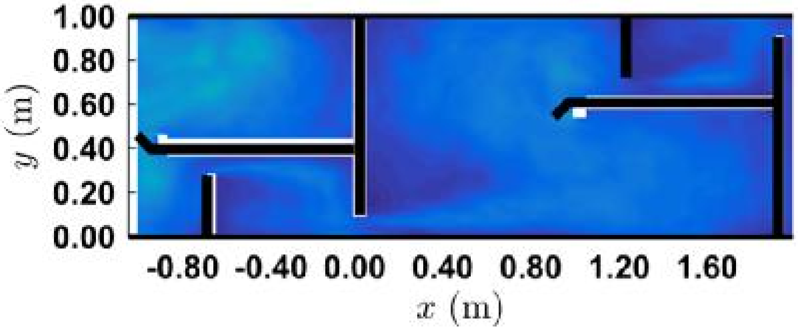
VSF1 – 50%h_m (0.40 m)



VSF2 – 50%h_m (0.40 m)



MSF1 – 50%h_m (0.40 m)

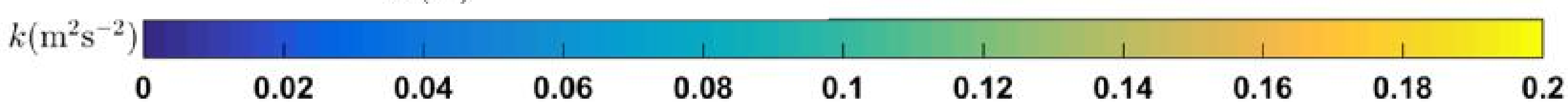


Turbulent kinetic energy in the pool (*k*)

VSF1 $k_{average}$ = 0.054 m^2s^{-2} k_{max} = 0.34 m^2s^{-2}

VSF2 $k_{average}$ = 0.042 m^2s^{-2} k_{max} = 0.35 m^2s^{-2}

MSF1 $k_{average}$ = 0.026 m^2s^{-2} k_{max} = 0.12 m^2s^{-2}



Reynolds shear stress (τ_{uv})

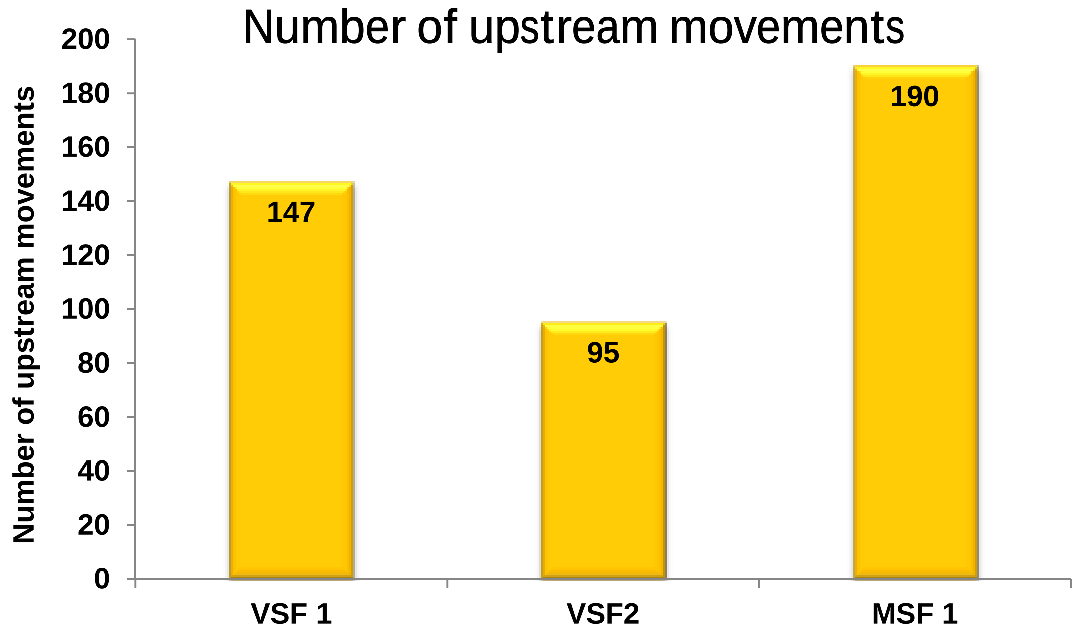
VSF1 $|\tau_{uv}|_{average}$ = 10 Pa $|\tau_{uv}|_{max}$ = 145 Pa

VSF2 $|\tau_{uv}|_{average}$ = 8 Pa $|\tau_{uv}|_{max}$ = 147 Pa

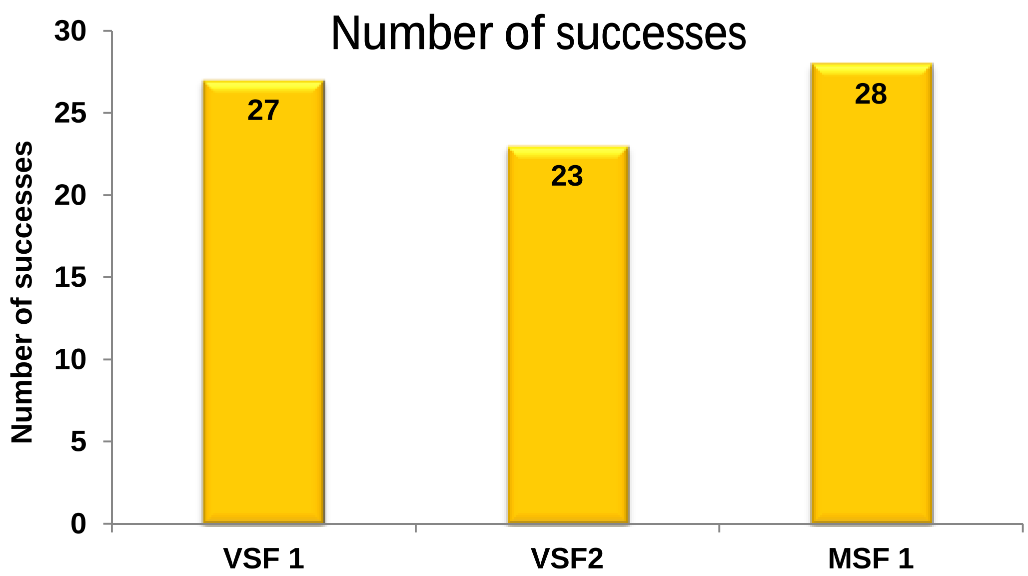
MSF1 $|\tau_{uv}|_{average}$ = 5 Pa $|\tau_{uv}|_{max}$ = 52 Pa

Results

Fish trials



Higher number of upstream movements in MSF



No significant differences were detected

Conclusions

- MSF require lower discharges to operate than VSF1 or VSF2, for similar flow depths.
- Consequently, $\overline{U}$, k, and τ_{uv} values in MSF are lower than in the two tested VSF.
- MSF seems suitable for Iberian barbel comparatively to the two tested VSF configurations.

Although further testing with fish are needed (e.g. other cyprinid species), tested MSF seemed to be adequate for the (Iberian barbel, allowing to save water for the same basin size and head drop.

Acknowledgments

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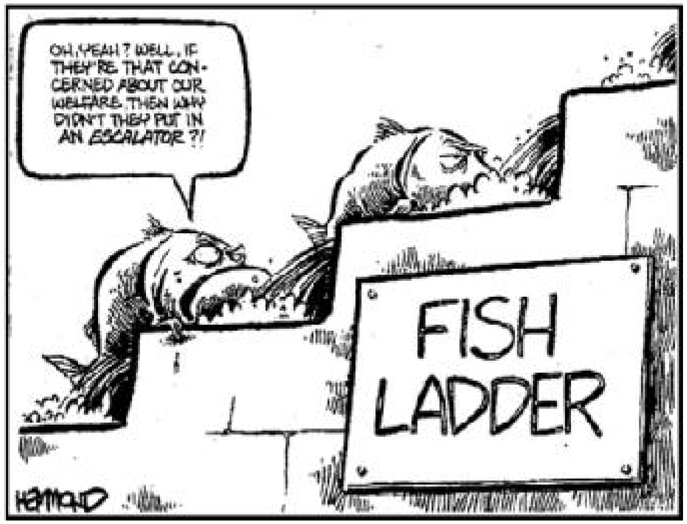
Thank you!



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