River conservation actions

AMBER National Workshop

Connectivity improvement of instream obstacles in Mediterranean rivers: case-studies from Portugal

JOSÉ MARIA SANTOS

Forest Research Centre, School of Agriculture,
University of Lisboa, PORTUGAL
jmsantos@isa.ulisboa.pt

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cef Centro de Estudos Florestais

Hinc Patriam Sustinet INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa

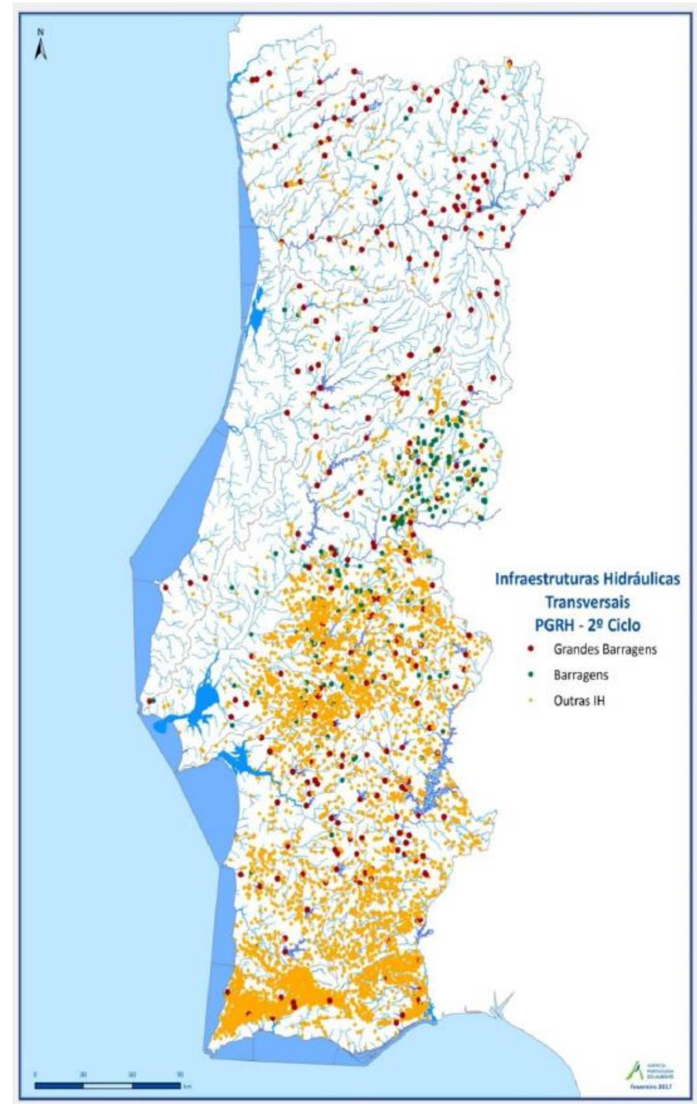
U LISBOA UNIVERSIDADE DE LISBOA

The loss of river connectivity caused by the construction of dams and weirs is one of the main causes of the decline and extinction of many fish species around the world

In Portugal there are **> 250 large dams** and c. **8000 small obstacles to migration** (From sea to Source, 2018)

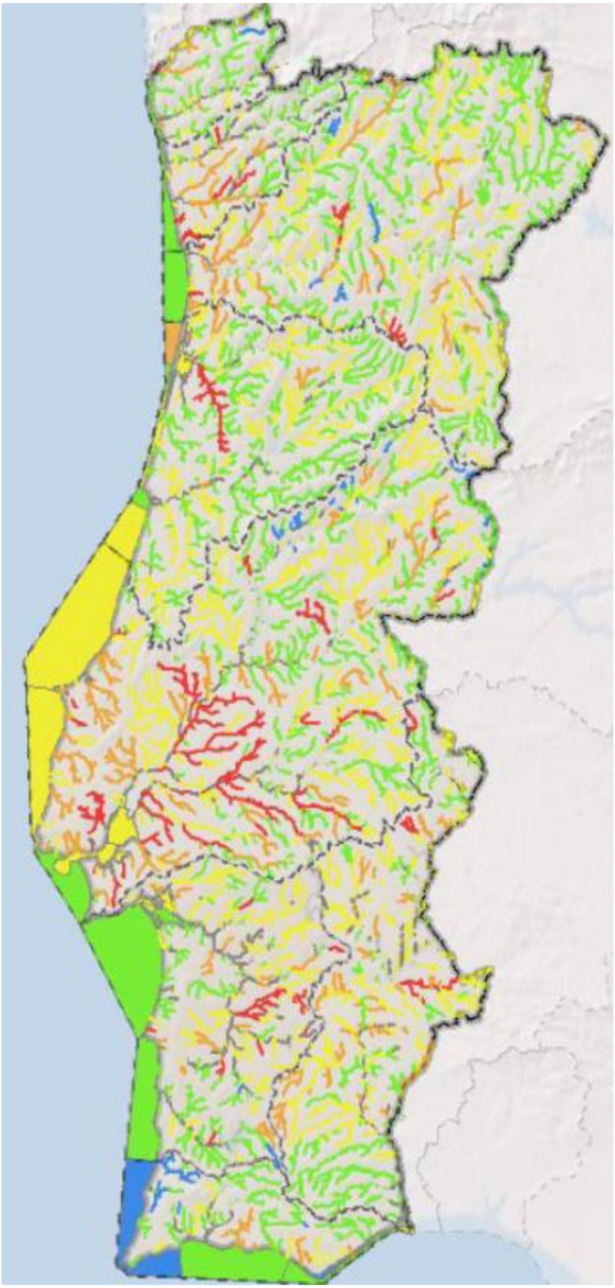
Many fish species have suffered severe declines due to habitat inaccessibility

Mota *et al.*, 2016



The WFD aims to achieve Good Ecological Status in all water bodies, preventing any additional degradation (until 2015, 2021, 2027,…)…

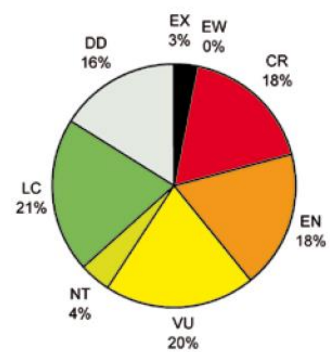
…however many of the hydromorphological pressures related to hydraulic structures need aditional mitigation measures to effectively restore rivers



MEDITERRANEAN RIVERS

☐ Characterized by sequential, seasonal, predictable flood and drought events that are variable over the years

☐ Harbour an endemic fish fauna that is among the most threatened in the world, because of a high level of endemism



Categories	No. of Species
EX Extinct	7
EW Extinct in the Wild	1
CR Critically Endangered	45
EN Endangered	46
VU Vulnerable	51
NT Near Threatened	10
LC Least Concern	52
DD Data Deficient	41
Total	**253**

Source: IUCN

☐ High demand for water, especially for agriculture

Need to improve water-use efficiency and implement integrated and sustainable water management.

SUSTAINABLE DEVELOPMENT GOALS
KNOWLEDGE PLATFORM

SUSTAINABLE DEVELOPMENT GOAL 6

Ensure availability and sustainable management of water and sanitation for all

TARGETS:

(…)

By 2030, substantially **increase water-use efficiency** across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity

By 2030, **implement integrated water resources management at all levels**, including through transboundary cooperation as appropriate

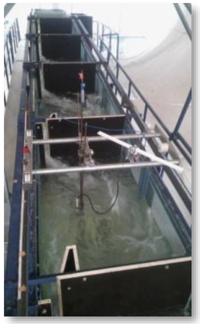
By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

Many river restoration actions (fishways, environmental flows) are related to the negative impacts of dams

However, some of the impacts of dams (generation of reservoirs, sediment retention) are difficult (if not impossible) to mitigate

Barrier removal and retrofitting

Development of effective fishways



Effective actions to restore fragmented rivers

BARRIER REMOVAL AND RETROFITTING

2017 – Ministerial order (15/MAMB/2016) to create a Working Group:

National Strategy for the Removal of Obsolete Hydraulic Infraestructures

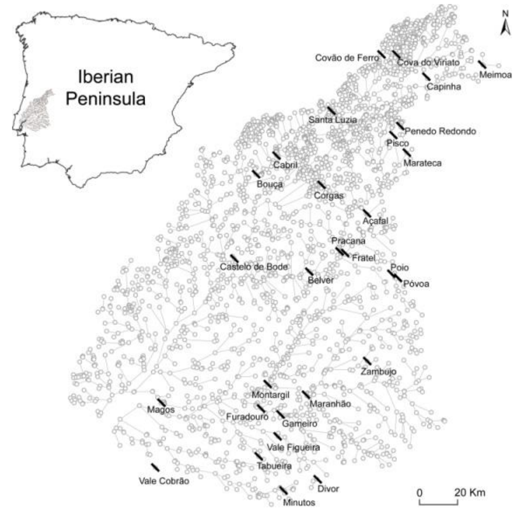
GOAL: identifying and studying dams and weirs and to purpose a removal plan for the infrastructures that are considered obsolete

- ☐ The ministerial dispatch indicated that 8 obsolete dams would be "immediatly" removed

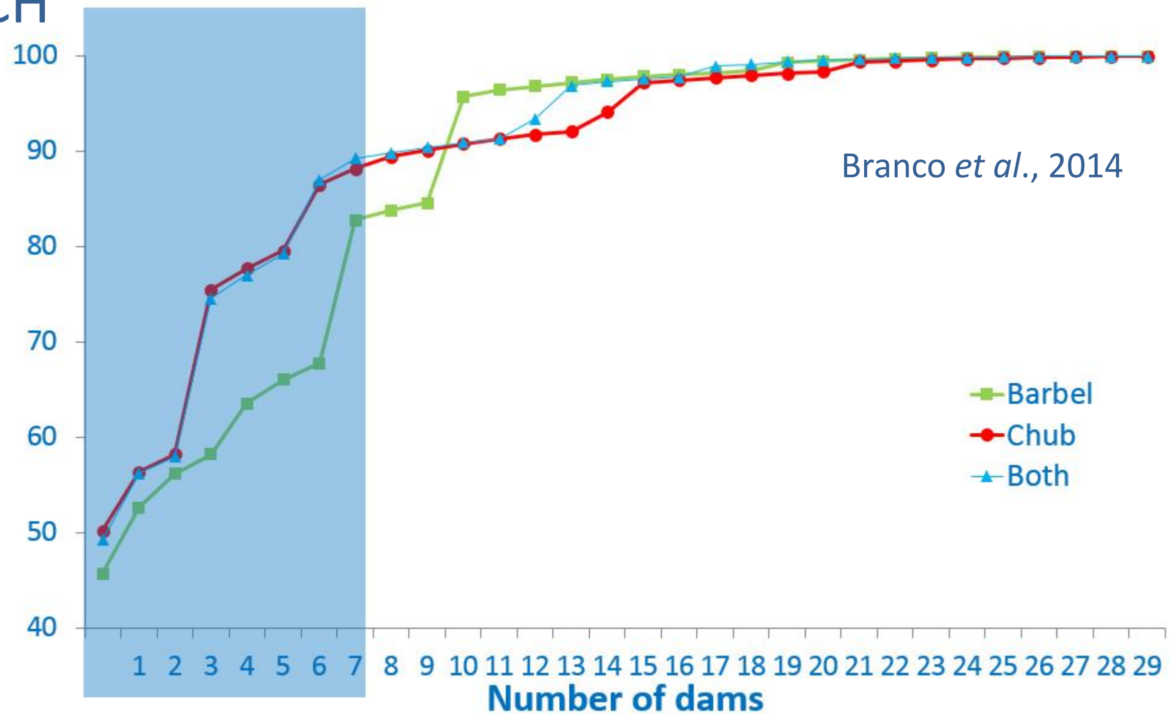
- ☐ **Until now, only 3 earth dams were removed by the initiative of the owners**

Need to prioritize dam removal at large spatial scales

SPATIAL GRAPH APPROACH



2542 river segments, 456 sampling points



Percentage of change in the overall connectivity (IIC) of the Tagus River network following the barrier removal sequence defined by a stepwise procedure

Habitat suitability models (BRT)

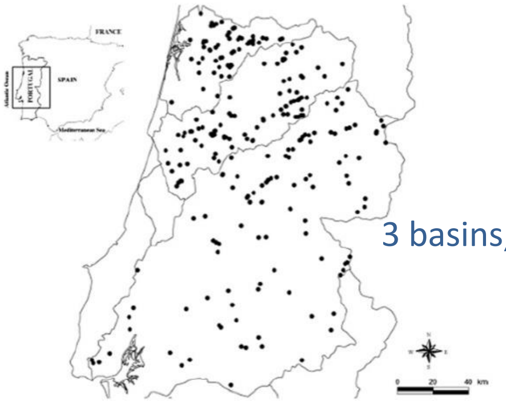
Barbel

Chub

- Aid decision-making process by prioritizing actions to promote overall connectivity increase
- Useful tool for determining new barrier placement with less impact

Branco *et al.* (2014). *Journal of Applied Ecology* 51: 1197-1206

However, fish species distribution is not always affected by longitudinal connectivity losses



3 basins, 196 sites

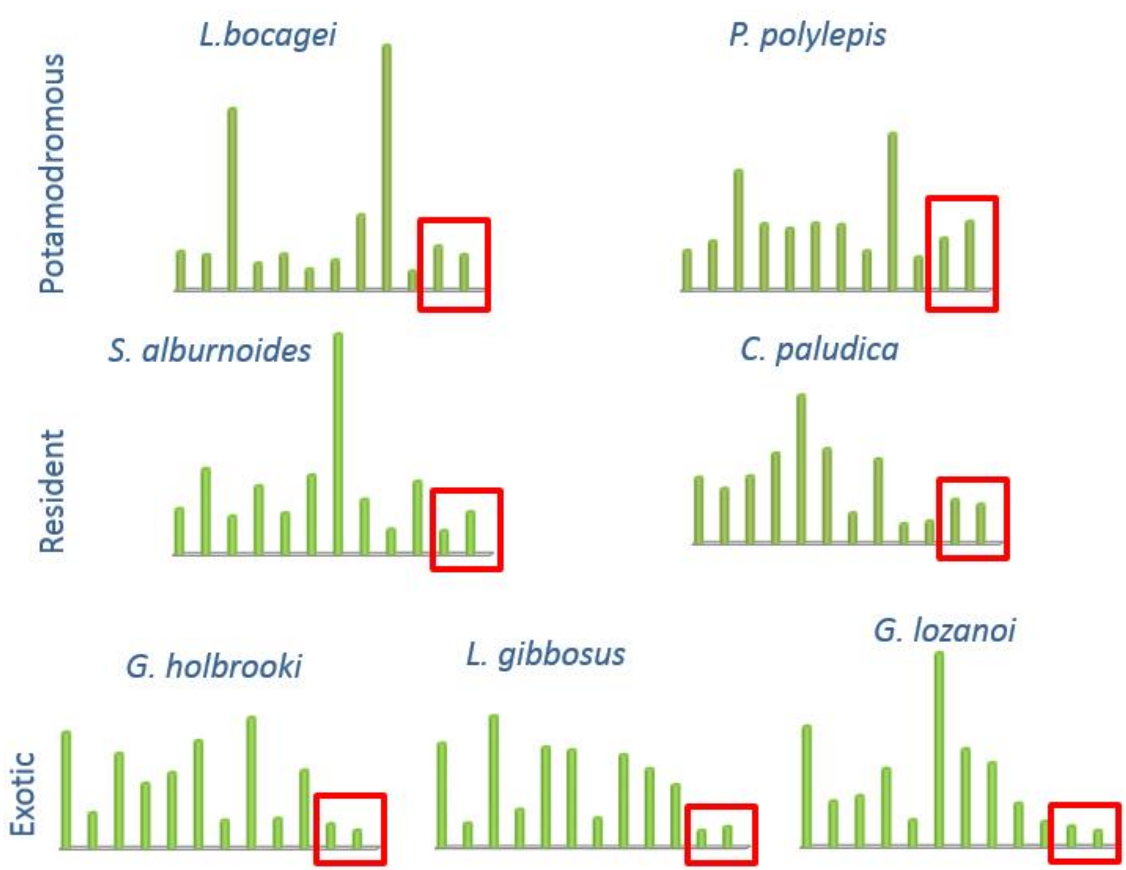
Connectivity variables were not important in explaining species distribution

Effects of environment exceeded the isolated effect of connectivity

Insignificant barrier effects on species distribution

For some barriers effect is only temporary

HIERARCHICAL VARIATION PARTITIONING

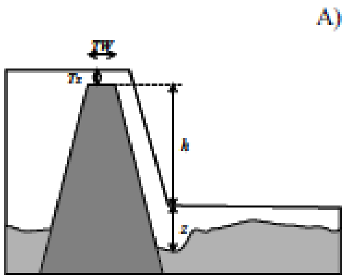


Branco *et al.* (2012). *Ecological Engineering* 48: 70-78

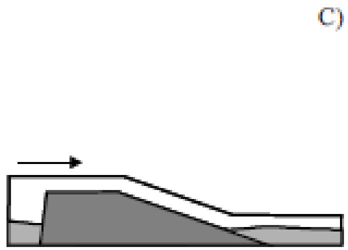
SMALL WEIRS (> 8000)

Different types:

Solà *et al.* (2011)



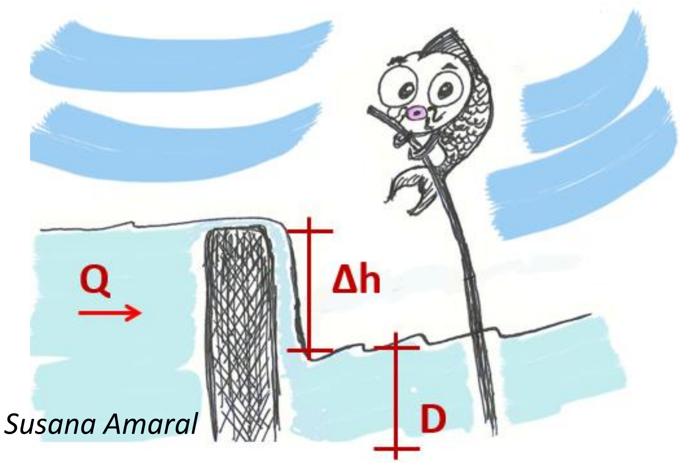
broad-crested weir
creates small waterfall

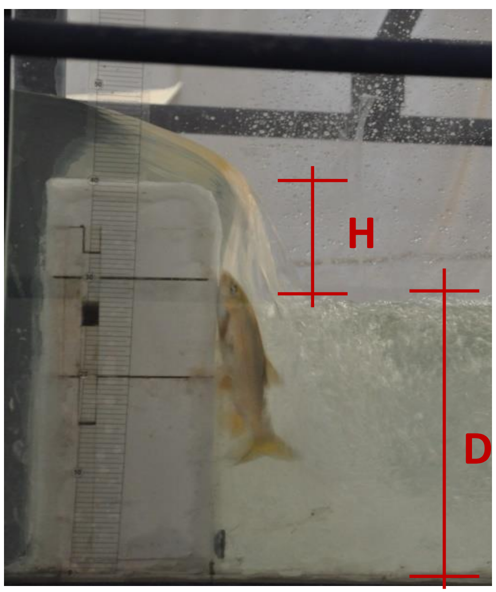


low slope weir
water passes over with no waterfall

Solà *et al.* (2011). *Limnetica 30*: 273-292

1. Influence of key-hydraulic parameters on passage performance by potamodromous cyprinids





Amaral *et al.* (2016)

16 Combinations of D x H

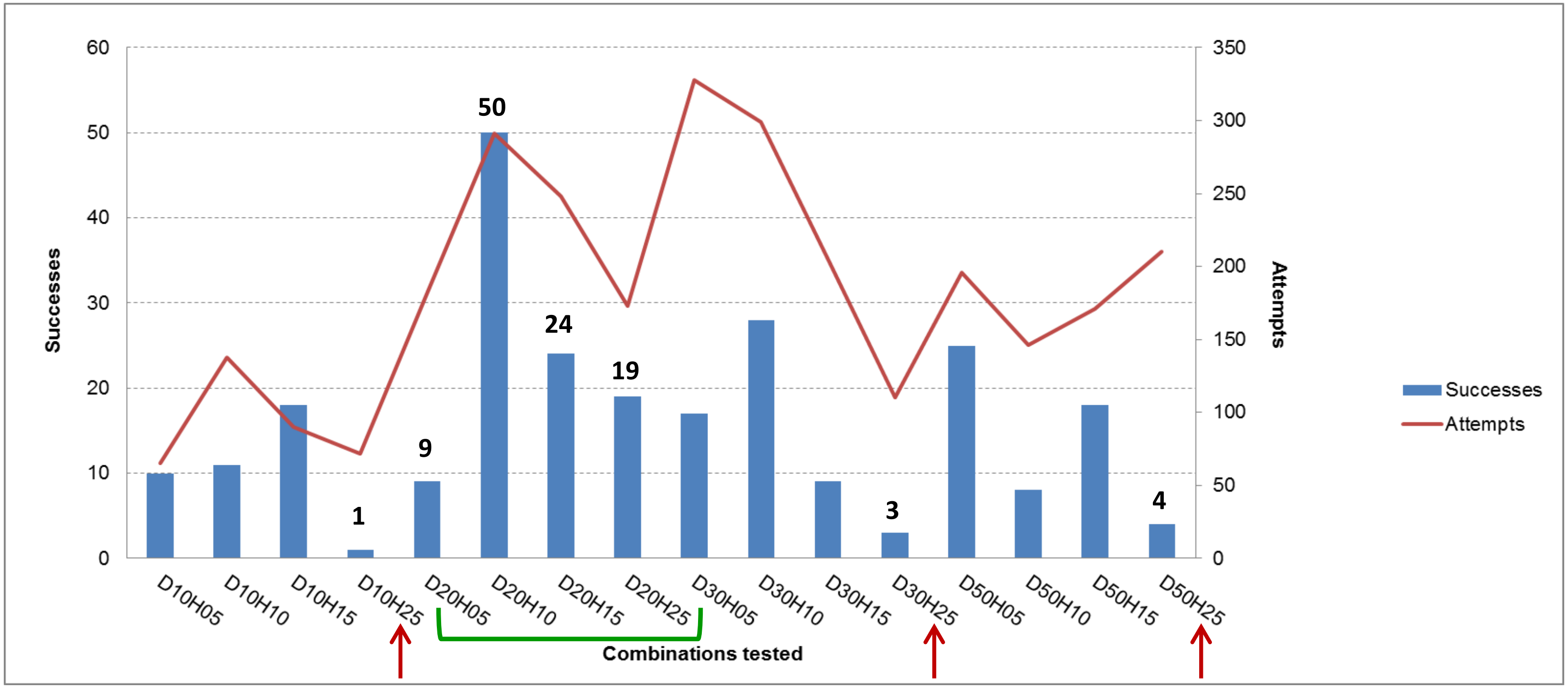
D		H
10 cm		5 cm
20 cm	X	10 cm
30 cm		15 cm
50 cm		25 cm

Source	d.f	SS	MS	*F*	*P*
D	3	160.30	53.43	5.46	**0.004**
H	3	137.30	45.76	4.68	**0.006**
D x H	9	266.02	29.55	3.02	**0.005**
Residuals					

(PerMANOVA, $p < 0.01$)

✓ **20 cm (D20): the highest number of successes**

X **25 cm (H25): the lowest number of successes**

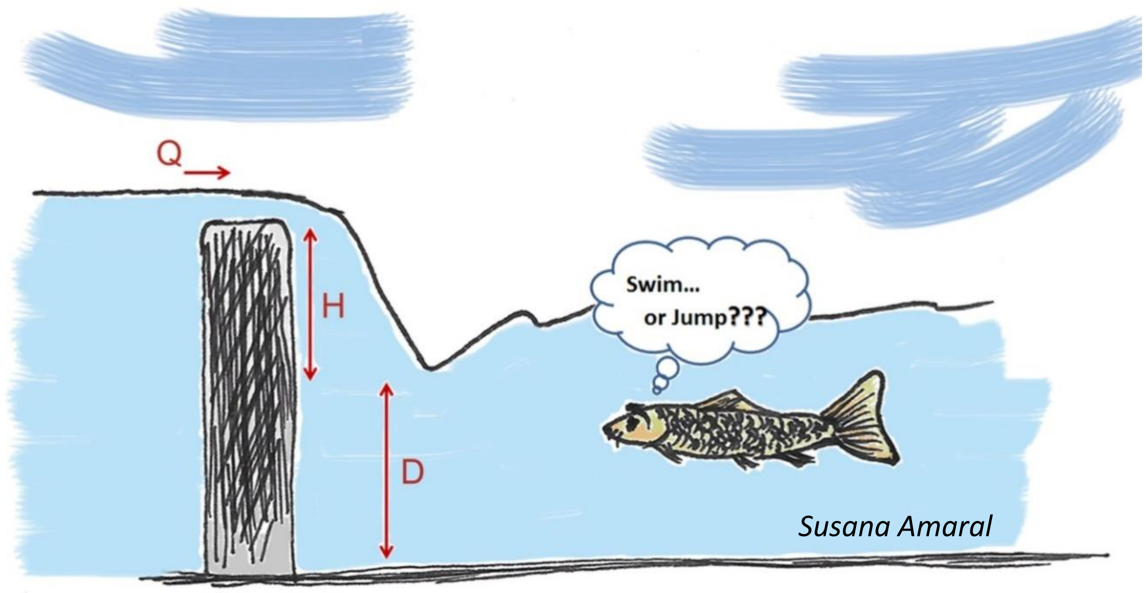


2-way PerMANOVA**: effects of D, H e D x H on number of successes**

- Passage inhibited by shallow plunge pool depths, high waterfall heights and high flow discharges
- Increased passage did not occur at higher plunge pool depths in association with lower heights
- Successful negotiation of the weir seems to be a complex phenomenon dependent on the interplay of different hydraulic variables and their interaction

Amaral *et al.* (2016). *Journal of Ecohydraulics* 1: 79-89

2. Passage by swimming or jumping?

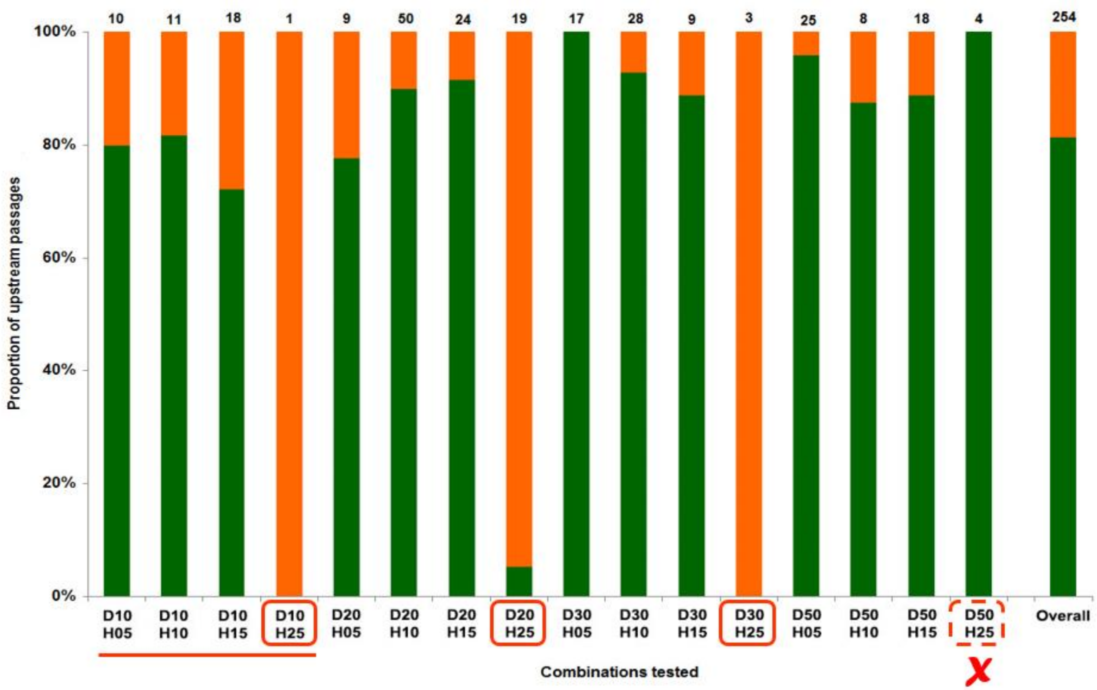


Amaral *et al.* (2018a)

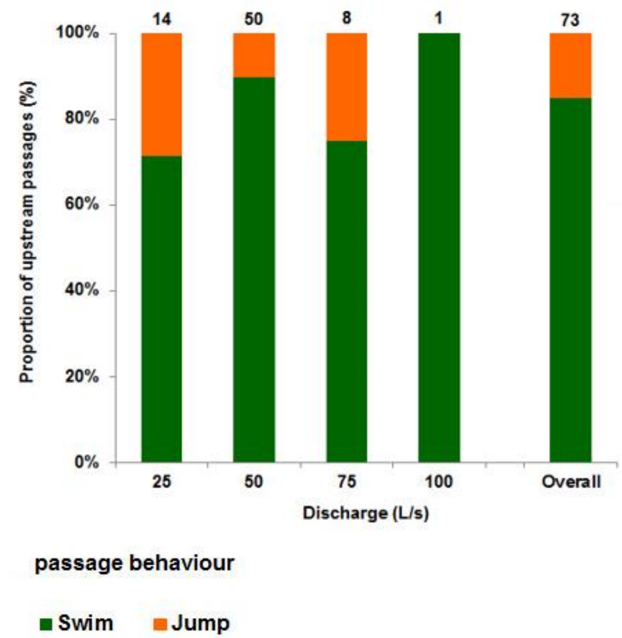
224 passages by Swimming (81%)

53 passages by Jumping (19%)

Effects of D and H

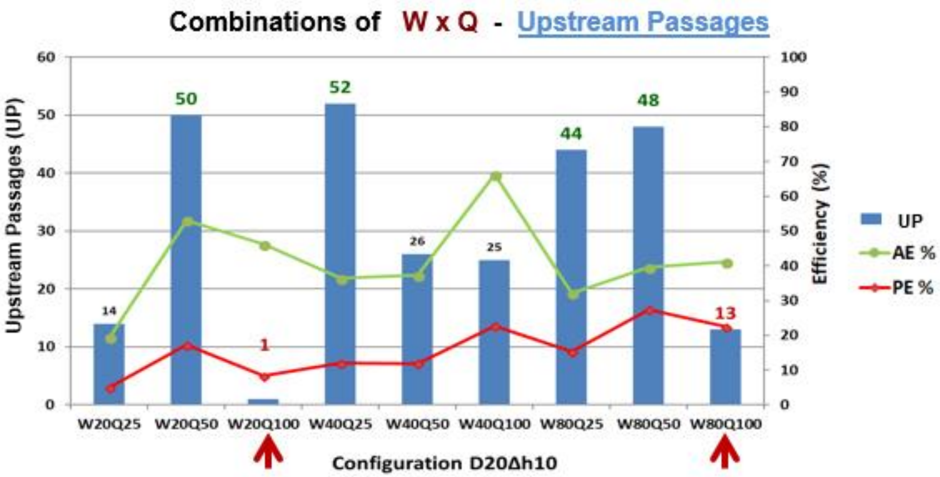


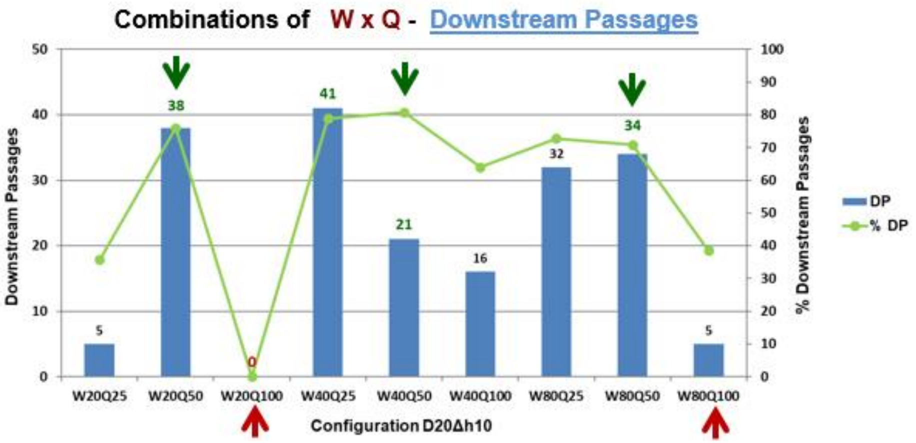
Effect of Q



- Passage behaviour highly conditioned by the hydraulic environment
- Swimming mode prevails… but higher waterfalls stimulated a switch from swimming to jumping
- Passage behaviour was not flow-related

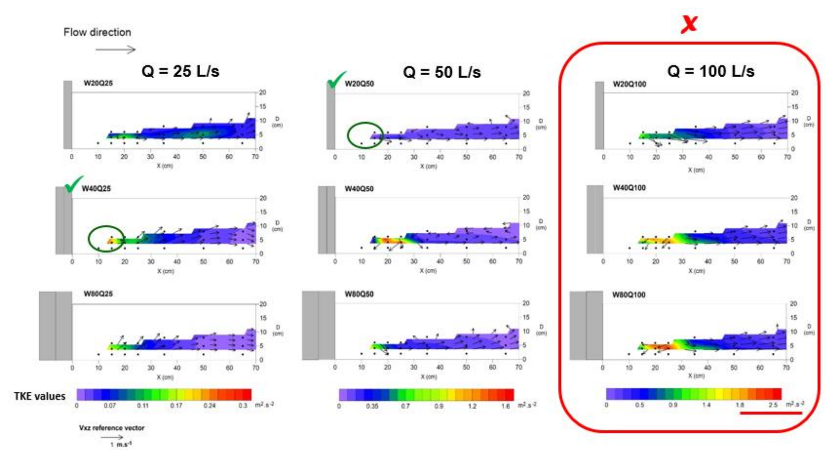
Amaral *et al.* (2018a). *River Research and Applications* 34: 174-182





- Discharge was preponderant on both up- and downstream passages, proving that fish movements may be hampered by increasing discharges.

- Width of the weir crest only significantly influenced downstream passages, showing that strong velocity gradients experienced on narrower widths of the weir crest may discourage downstream movements

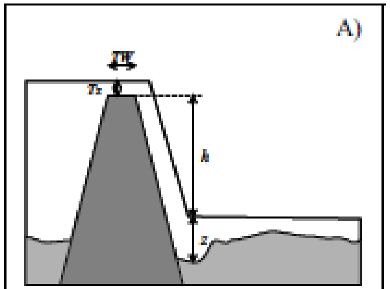


Amaral *et al.* (2018b). *Marine and Freshwater Research* 69: 1795-1804

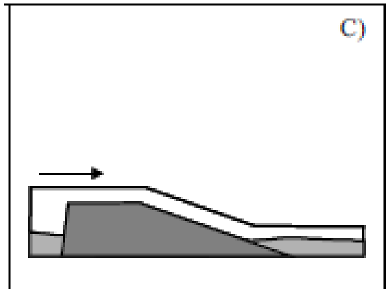
SMALL WEIRS (> 8000)

Different types:

Solà *et al.* (2011)

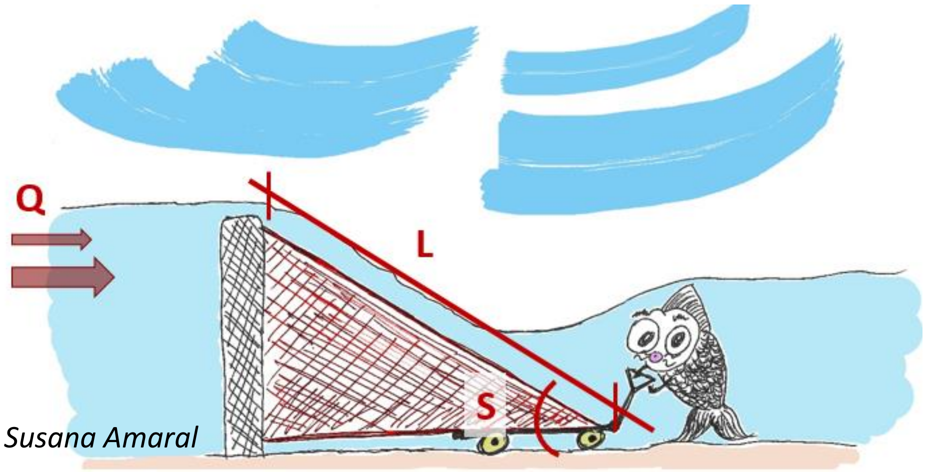


broad-crested weir
creates small waterfall



low slope weir
water passes over with no waterfall

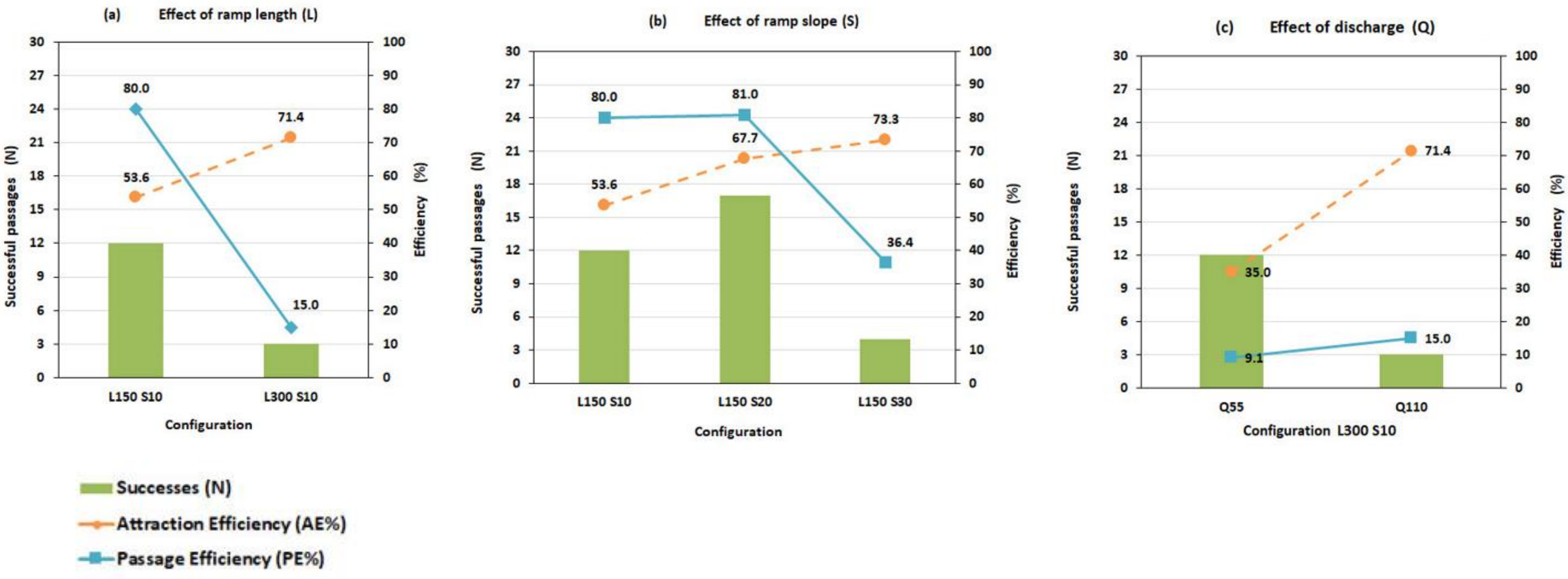
4. Fish passage performance over low-head ramped weirs



Configuration	Ramp Length cm	Slope %	Discharge L/s	Substrate
L150 S30	150	30	110	No
L150 S20	150	20	110	No
L150 S10	150	10	110	No
L300 S10	300	10	110	No

+ 1 new Discharge → Q = 55 L/s
configuration with the lowest number of successful passages

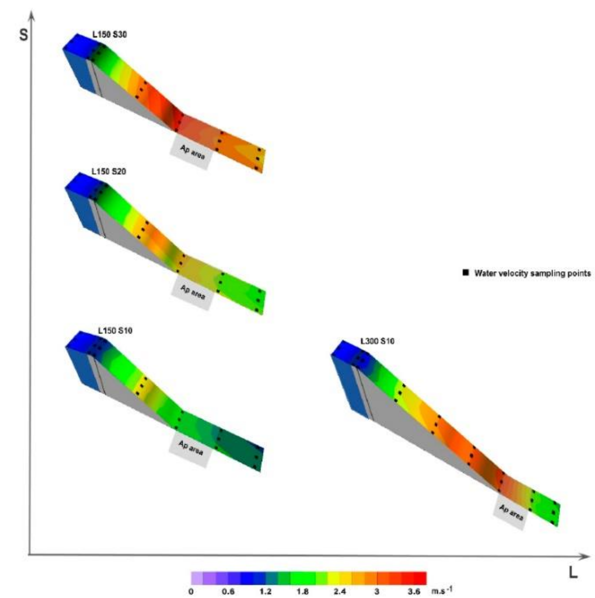
Amaral *et al.* (2019)



➢ Successful passage was conditioned by the increase of slope and ramp length

➢ The number of successful passages increased significantly in response to discharge reduction

➢ Hydrodynamics downstream and over the ramp may have influenced successful passages



Amaral *et al.* (2019). *Sustainability* 11(5), 1456

Currently working on…

Retrofitting the poorest configurations to improve fish passability

Large offset blocks

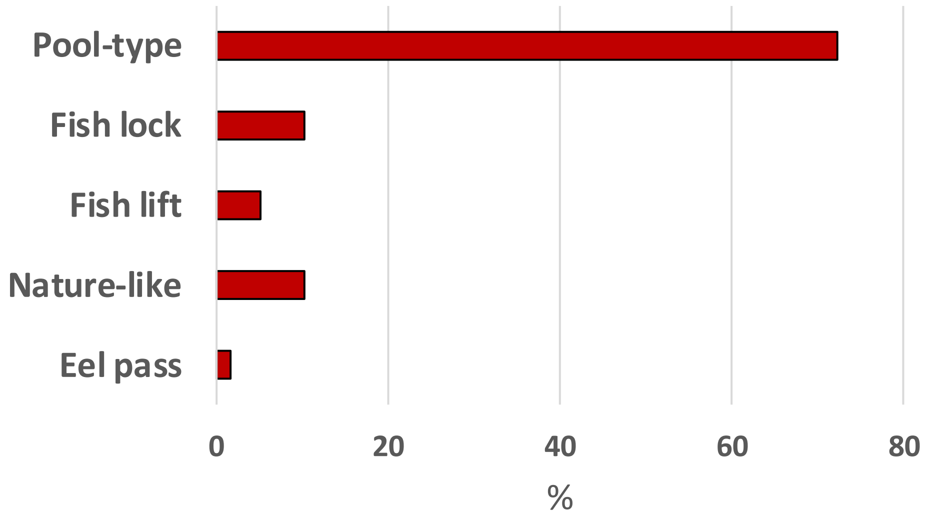
Small offset blocks

Natural “rock garden”

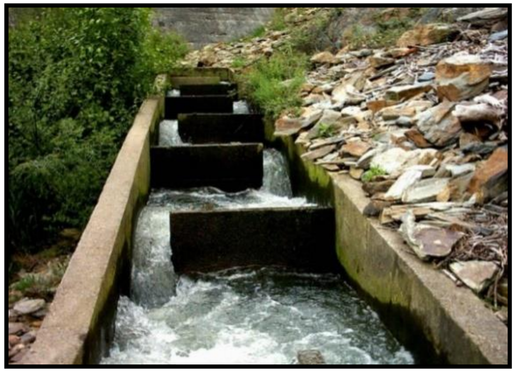
Large straight blocks

Small straight blocks

DEVELOPMENT OF EFFECTIVE FISHWAYS



- Pool-type fishways represent more than 70% of the fishways in Portugal



- Fishways mostly designed according to criteria developed in northern European rivers
- Specific fish assemblages, primarily dominated by potamodromous and small resident cyprinid fishes

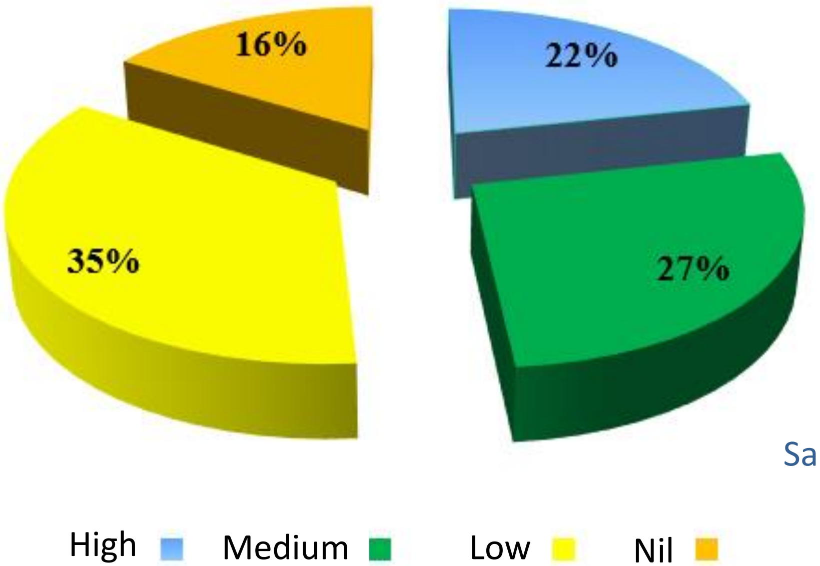
Santos *et al.* (2012)

- Most of them (>50%) not hydraulically adequate for target species

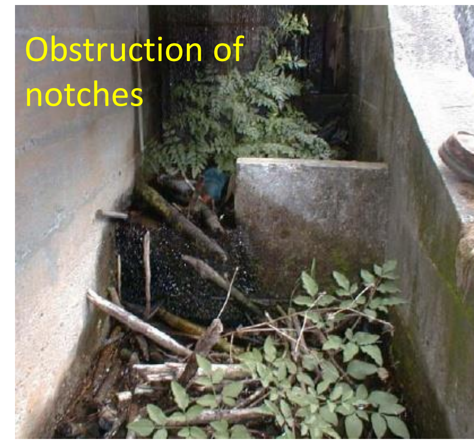


Weaker swimmers
Migratory patterns less known
Species afford legislative protection under EWFD

Effectiveness of PT pool-type fish passes according to hydraulic criteria

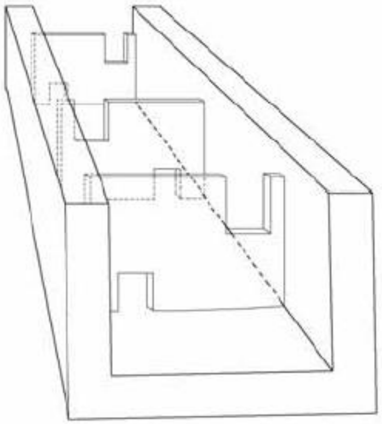


Santos *et al.*, 2012

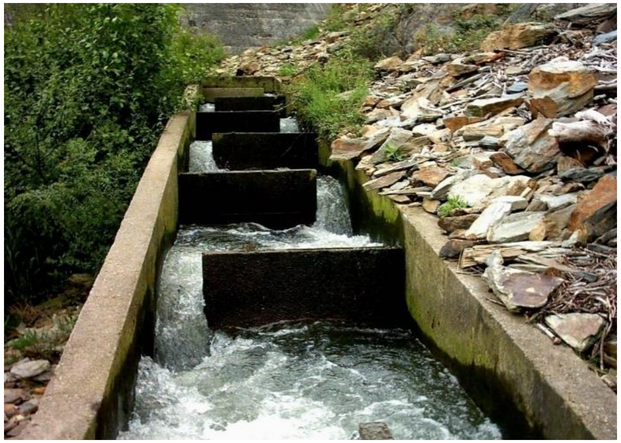


Santos *et al.* (2012). *Ecological engineering* 48: 38-50

1. Does the flow regime of fishways matter?



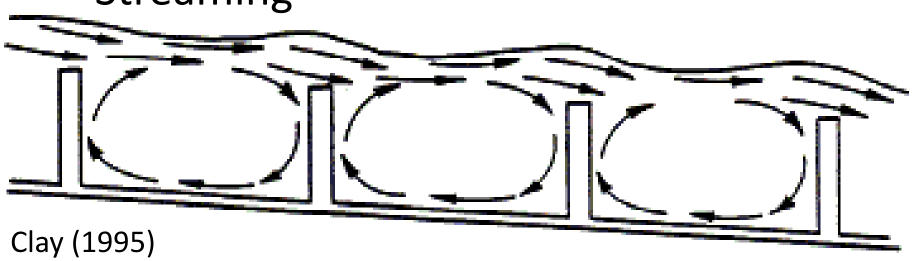
Pool-and-weir fishway



- Flow regimes

Plunging

Streaming

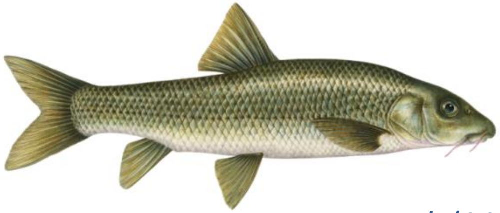


Clay (1995)

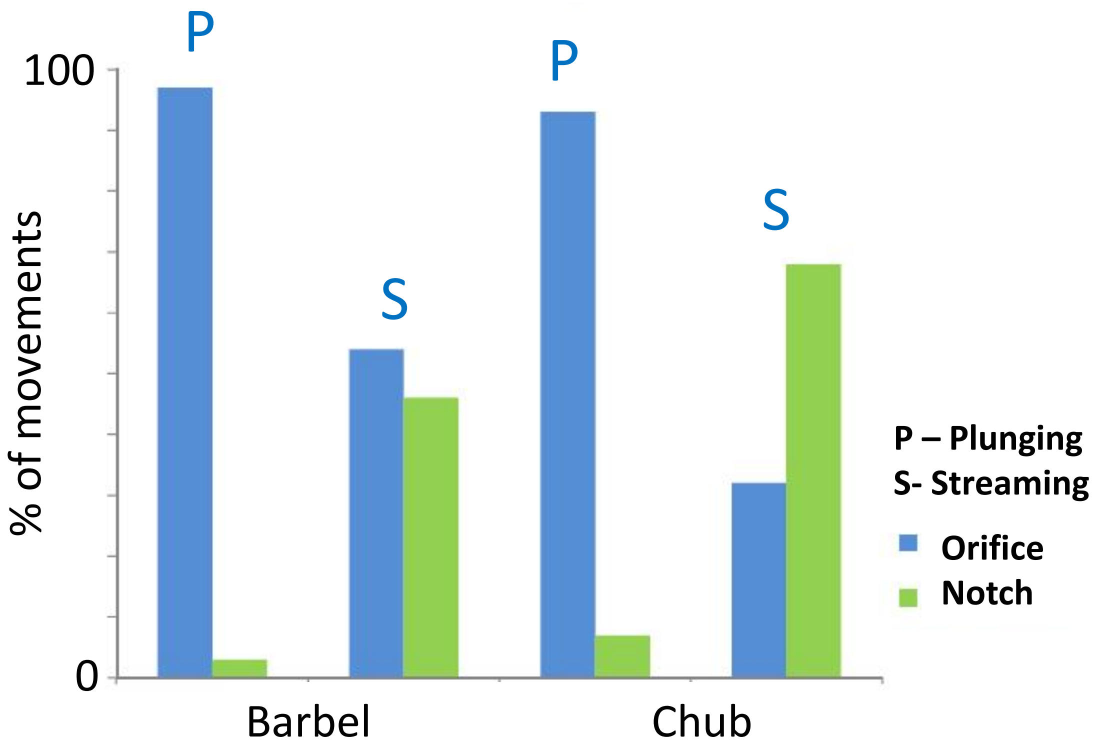
- Species

Chub
Small-size
Resident
Water column

Barbel
Medium-size
Potamodromous
Benthic



Branco *et al.* (2013)



Barbel

80% ↑ Streaming
98.6% Notch ↑ Streaming
76.2% Success Streaming

Chub

67.9% ↑ Streaming
95.1% Notch ↑ Streaming
78.3% Success Streaming

- Plunging flow regime limits the access of fish to the surface notch – effectively reducing the area available for crosswall negotiation

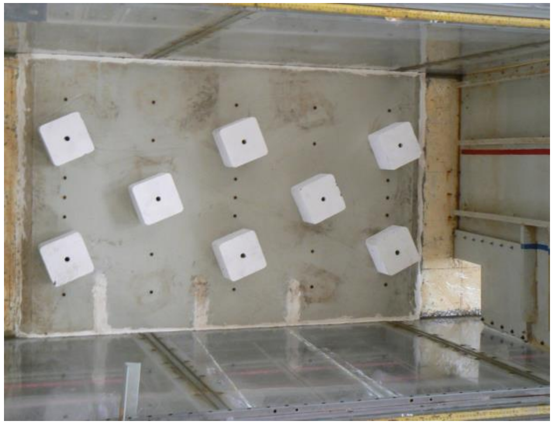
- Streaming flow regime proved to be more effective on aiding fish upstream movements for both species – contributing to a more holistic fishway

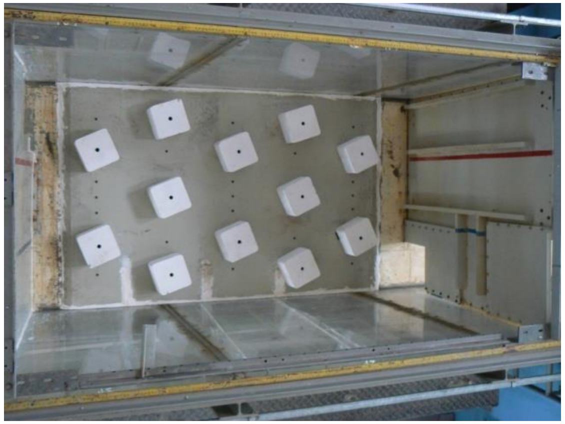
Branco *et al.* (2013). PLoS ONE 8(5): e65089

2. Can boulder placement improve fishway negotiation?

Boulder density

Santos *et al.* (2014)





% success

High discharge* **(62.7 L/s)**

* $P < 0.05$

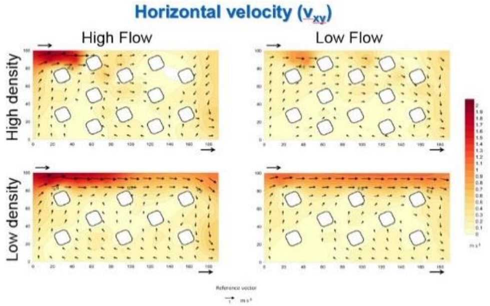
High density (5.3 ± 4.2 min.)* **50%**

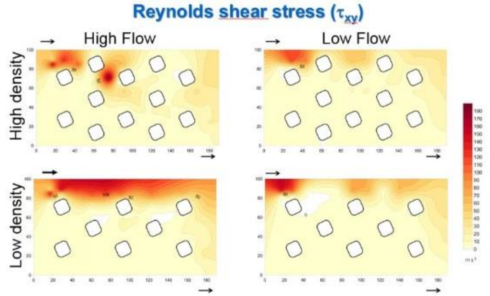
Low density (12.1± 6.5 min.) **50%**

Low discharge (38.5 L/s)

High density (5.3 ± 4.2 min.)* 20%

Low density (12.1± 6.5 min.) 30%

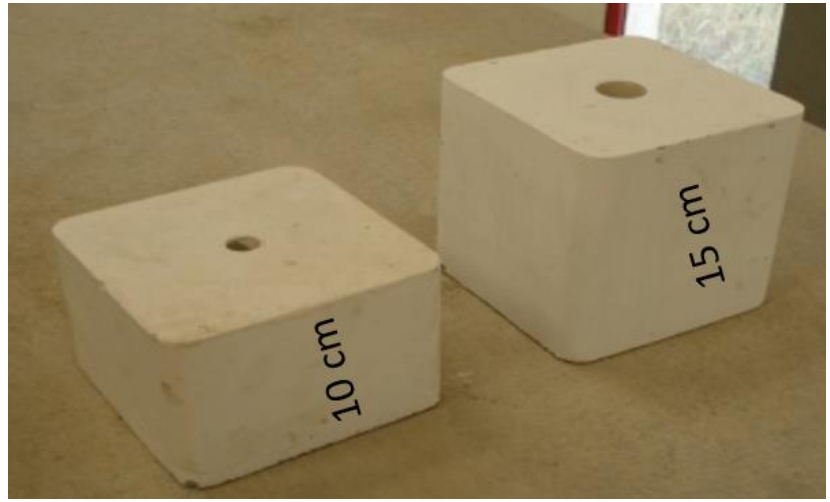




Santos *et al.* (2014). *Ecological engineering 73*: 335-344

Boulder height

Santos *et al.* (2013)



% success

High discharge

(62.7 L/s)

Low boulders (5.3 ± 4.2 min.) **55%**

Higher transit times

7.1 ± 5.8 min

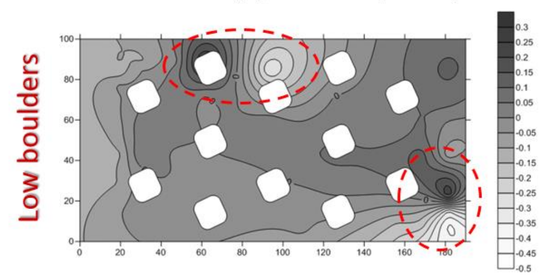
High boulders (12.1± 6.5 min.) **60%**

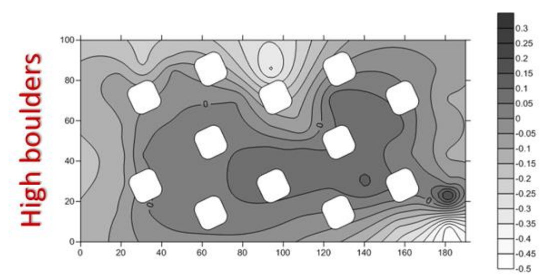
Lower transit times*

2.6 ± 1.6 min

* *P* < 0.05

Water velocity **(vertical component)**





Santos *et al.* (2013). *Journal of Applied Ichthyology 29*: 425-430

- Boulders placed at the bottom of pool-type fishways act as drivers for fish movements

- Successful negotiation found to be discharge-related…but higher densities combined with increased discharge, reduced transit time

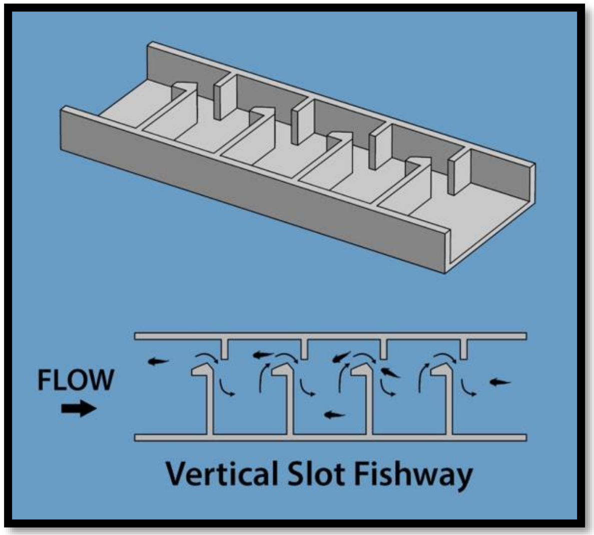
- Higher boulders (lower relative depth of flow) potentiate high spatial hydraulic heterogeneity reducing fish transit times

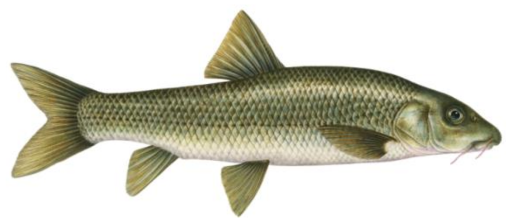
- Boulder placement facilitates fish movements while turning the fishway more nature-friendly

Santos *et al.* (2013). *Journal of Applied Ichthyology 29*: 425-430

Santos *et al.* (2014). *Ecological engineering 73*: 335-344

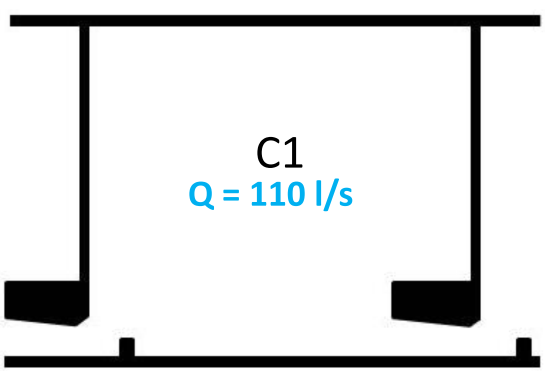
3. Passage performance of cyprinid species with different ecological traits in vertical slot fishways (VSF) with distinct slot configurations



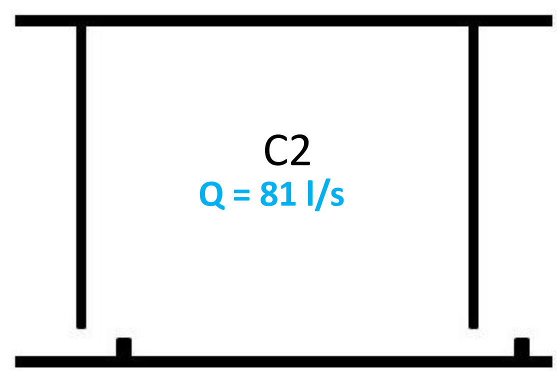


Barbel
Medium-size
Potamodromous
Benthic

Chub
Small-size
Resident
Water column

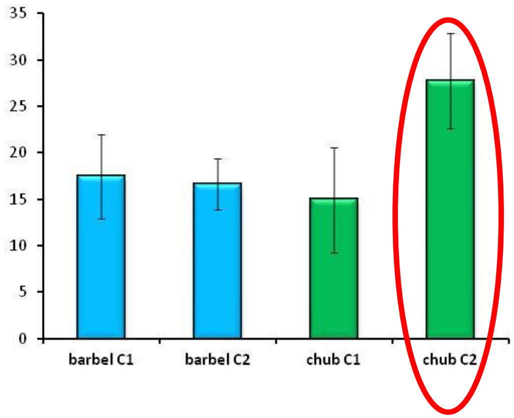


Slope = 8.5 %
hm = 0.8 m
ΔH = 0.16 m
b = 0.1 m



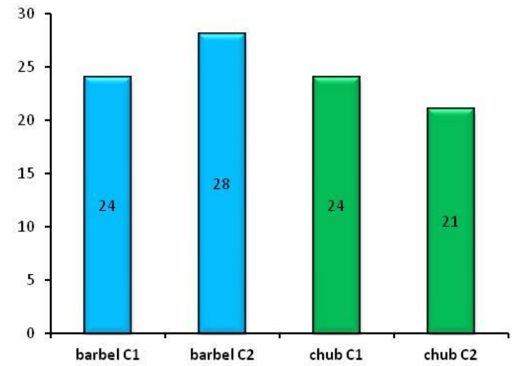
Romão *et al.* (2017)

Mean entry efficiency (%)



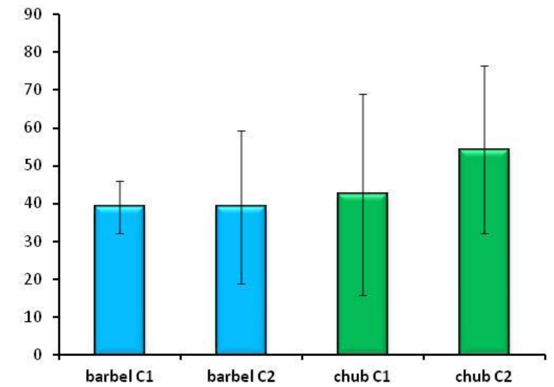
$P < 0.05$

Number of successes



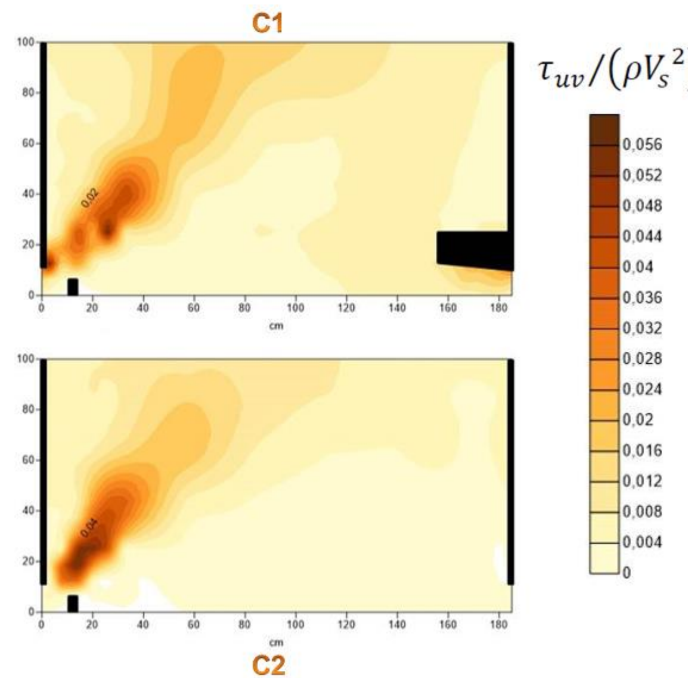
$P > 0.05$

Mean transit time (min)



$P > 0.05$

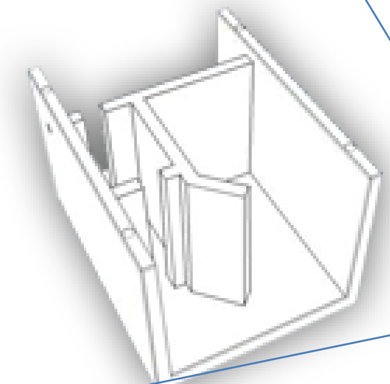
- C2 requires lower discharge (26%) to operate for the same mean water depth
- C2 is a more cost-effective VSF design than C1
- C2 lower velocities favoured a higher number of movements of the chub
- **C2 may be a better option for rheophilic stream-dwelling cyprinids in Mediterranean regions**



Romão *et al.* (2017). *Ecological Engineering* 105: 180-188

4. Comparing the effectiveness of a VSF with a Multi-slot fishway (MSF)

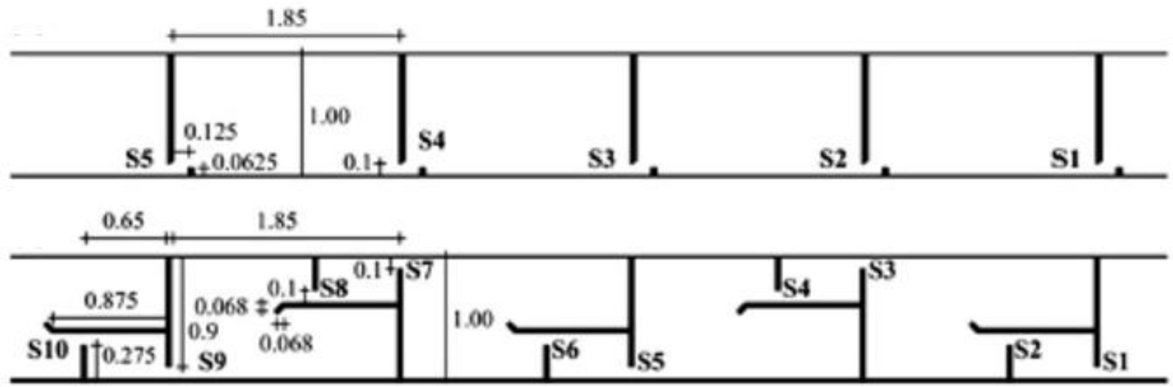
Enature® fishpass



Tauber and Mader, 2010

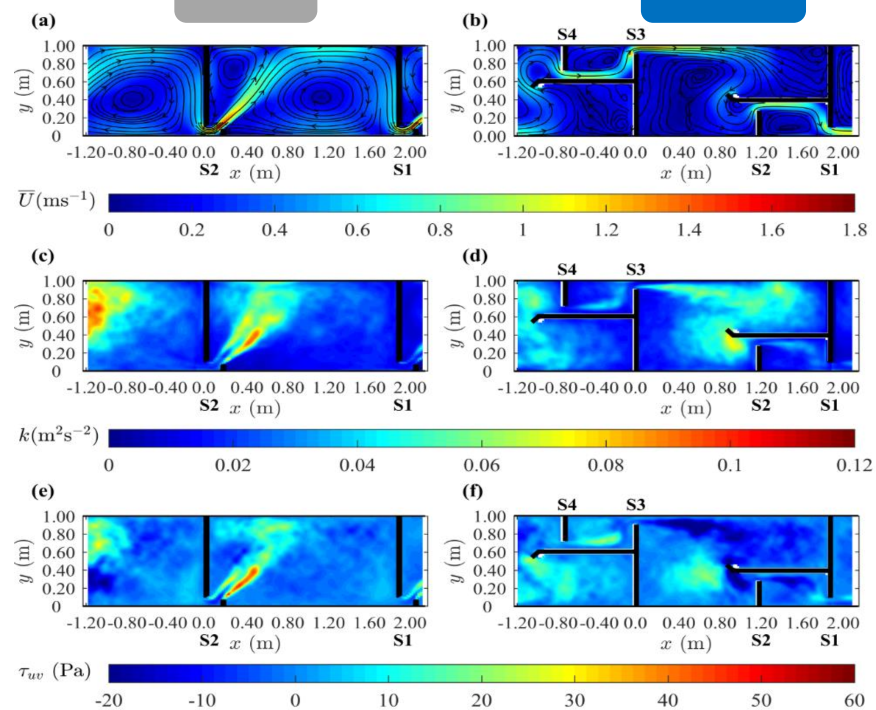
VSF
Q = 81 l/s

MSF
Q = 56 l/s



VSF

MSF

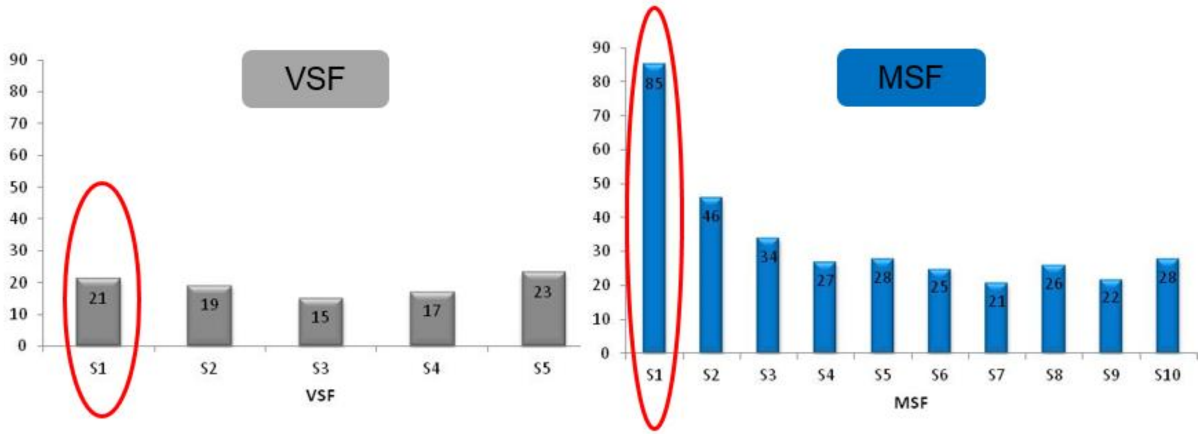


VSF

MSF

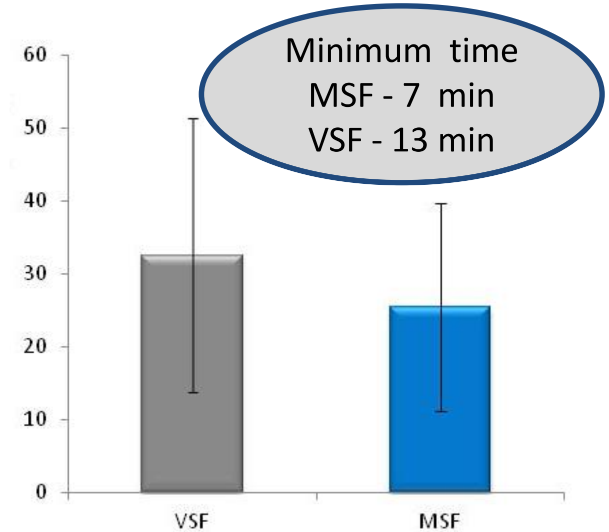
Romão *et al.* (2018); Quaresma *et al.* (2018)

Number of Upstream Movements

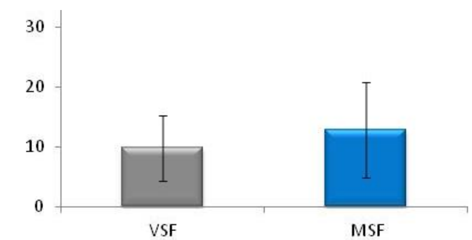


- Significant differences in slot 1 negotiation
- No differences in the number of successes

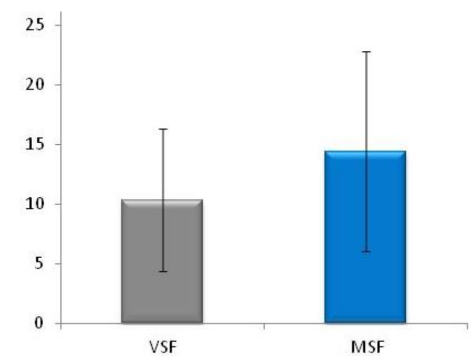
Mean transit time (min)



Mean entrance time (min)



Mean entry efficiency (%)



- ➢ Equivalent performance in VSF and MSF
- ➢ The MSF presents lower velocities and turbulence magnitudes compared to a VSF
- ➢ **The MSF is more cost-effective solution to restore connectivity (Q < 30%)**
- ➢ The entrance conditions should be improved in the MSF

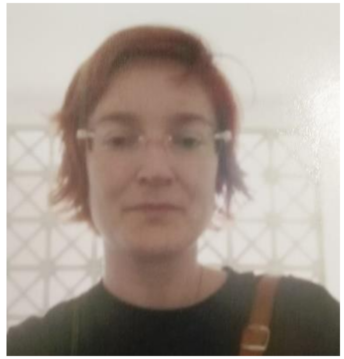
Romão *et al.* (2018). *Hydrobiologia* 816: 153-163
Quaresma *et al.* (2018). *Ecological Engineering* 122: 197-206

FUTURE RESEARCH SHOULD ADDRESS:

- ☐ Better understand the fine-scale relationships between turbulent environments, sensory function, biomechanics, and individual/schooling behaviour to improve attraction, entry and multispecies passage;
- ☐ Assess the effects of multiple instream obstacles on fish behaviour and migration;
- ☐ Improve and develop downstream migration solutions, particular at hydropower plants;
- ☐ Address sublethal costs of fish passage (i.e. multiple passage attempts, passage delay, fallbacks, chronicle stress from non-passage);
- ☐ Develop selective fish passage: allowing native species migration while blocking exotic species invasion;
- ☐ Develop methods to apply multicriteria decision in connectivity restoration planning at the catchment scale.

Research team:


Paulo Branco
(CEF, ISA)


Susana Amaral
(CEF, ISA)


Filipe Romão
(CERIS, IST)


Ana Quaresma
(CERIS, IST)


Teresa Viseu
(LNEC)


António Pinheiro
(CERIS, IST)

Teresa Ferreira
(CEF, ISA)

cef Centro de Estudos Florestais

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Thank you! Questions?

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sustainability

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Keywords:
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water

IMPACT FACTOR 2.069

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Co-Chair
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TERESA FERREIRA
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HERMAN WANNINGEN
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SC representative
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Member
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ULisboa

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Member
Principal Researcher, ISA,
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Member
Assistant Professor, Évora
University

TERESA VISEU
Member
Head of Water Resources and
Hydraulic Structures Division,
LNEC