

# Investigating the Behavior of Atlantic Salmon smolts (*Salmo salar* L.) upstream migration barriers: Factors influencing migration route selection.

SALMON PROGRAM IN WALLONIA  
Research conducted by the University of Liège



UGERAA : Management of Aquatic  
Ressources and Aquaculture Unit



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Séverine RENARDY & Michaël OVIDIO

Funded by



Service public  
de **Wallonie**

# SALMON PROGRAM AND ITS INTERACTIONS



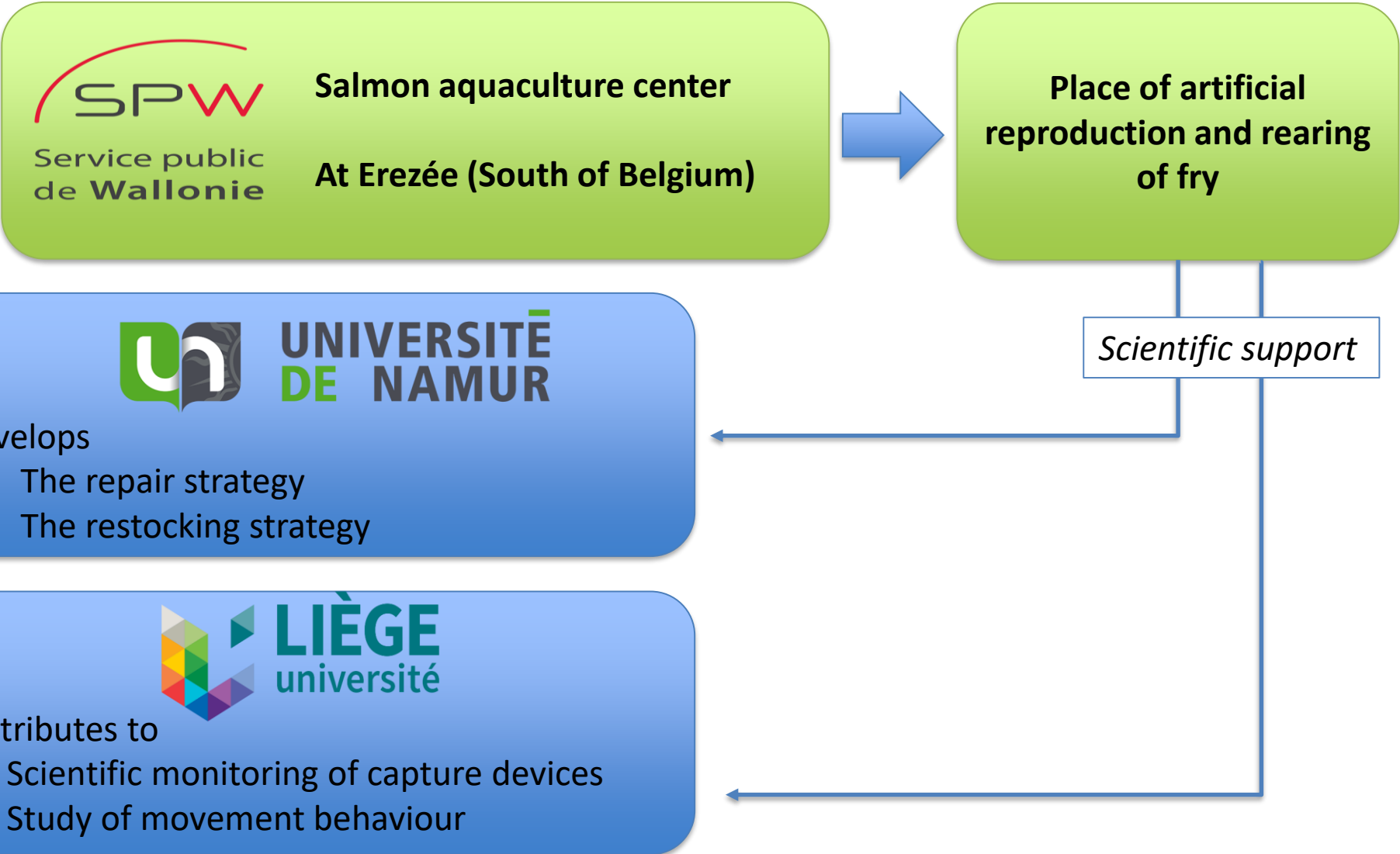
**Salmon aquaculture center  
At Erezée (South of Belgium)**



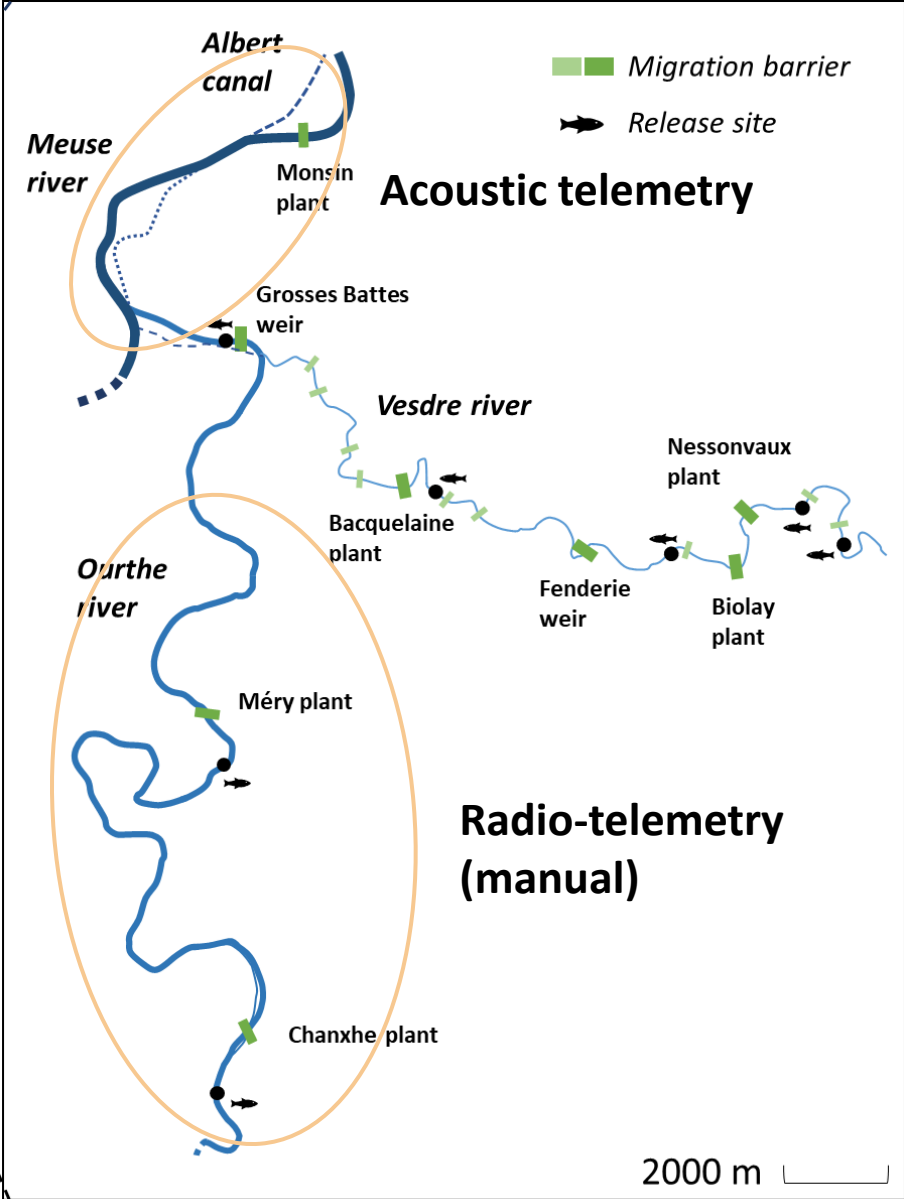
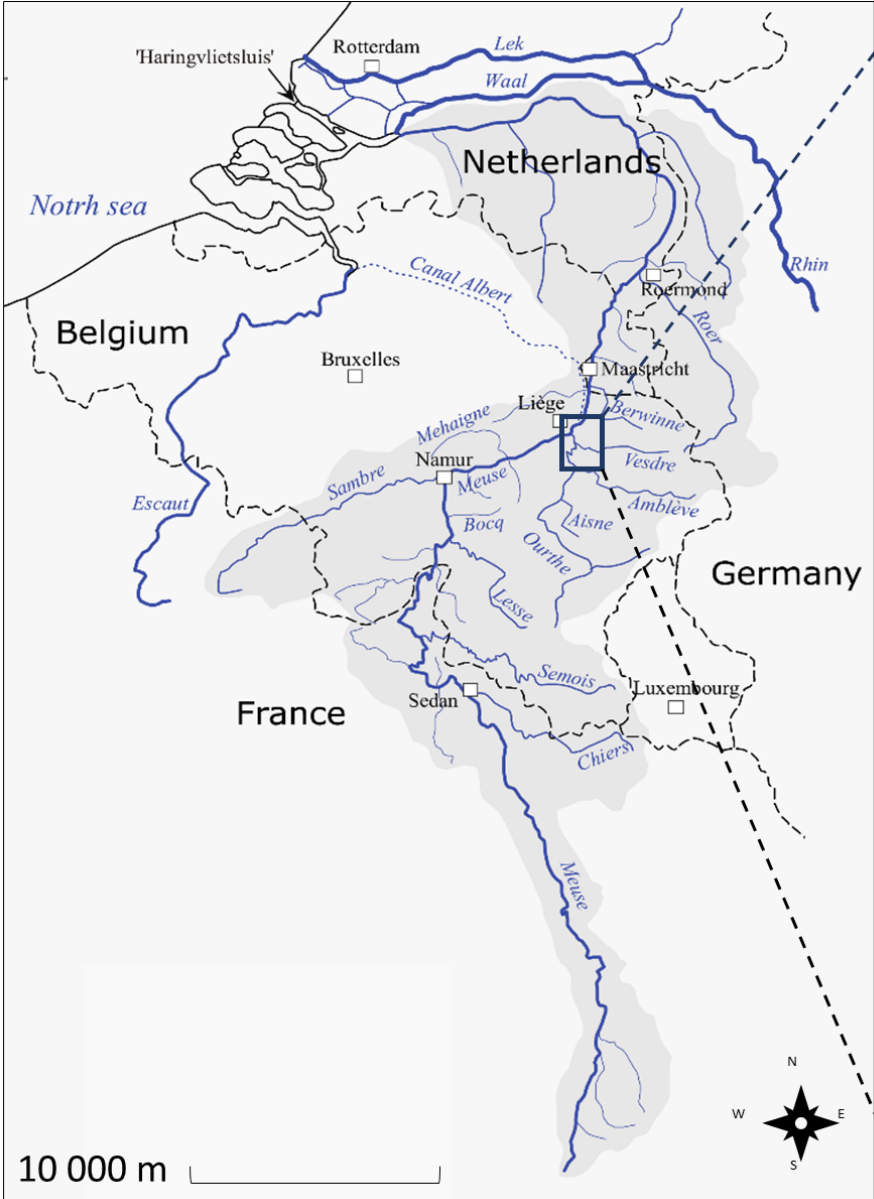
**Place of artificial  
reproduction and rearing  
of fry**



# SALMON PROGRAM AND ITS INTERACTIONS

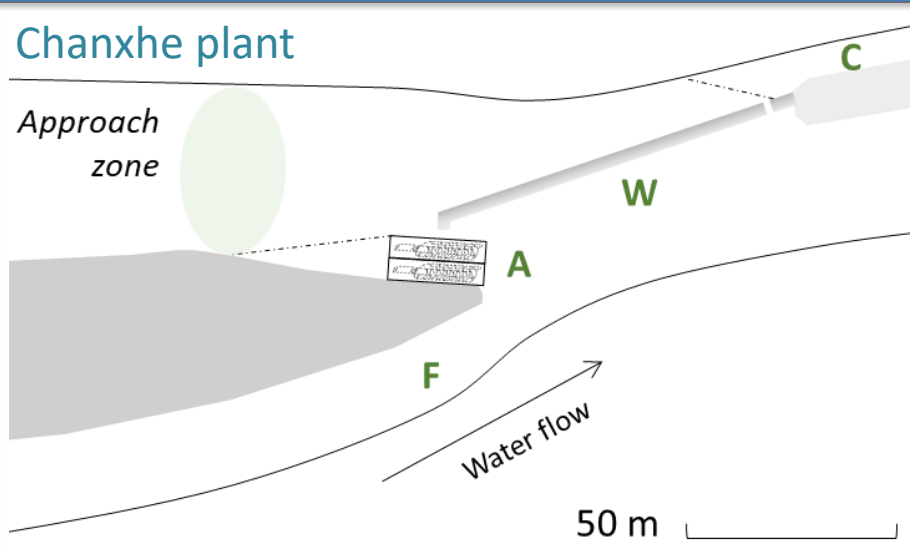
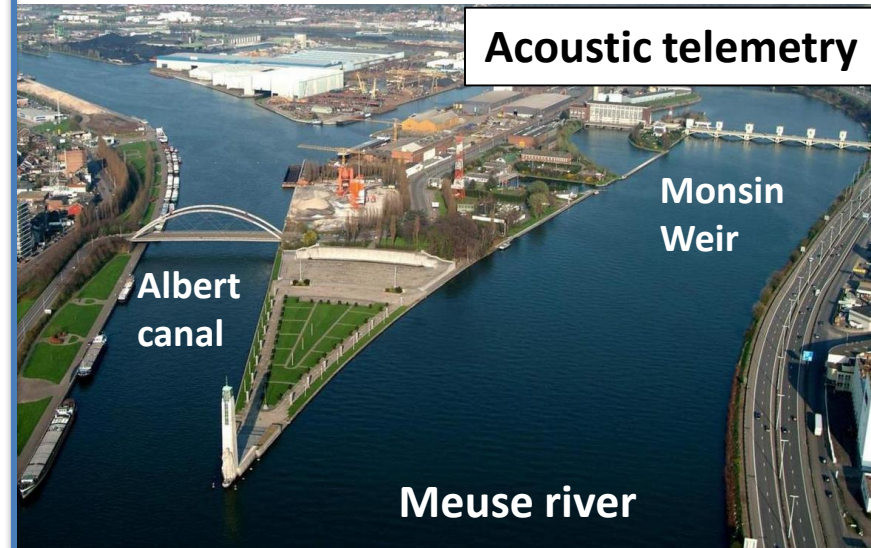
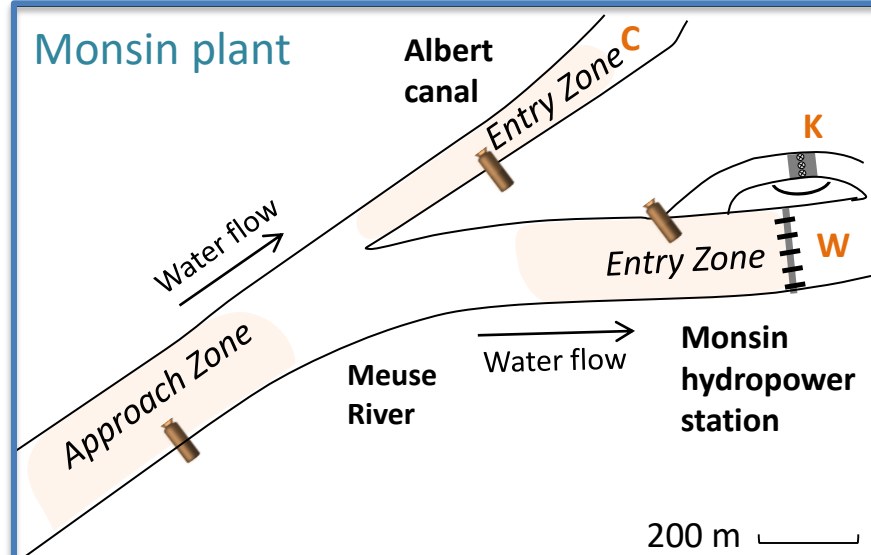
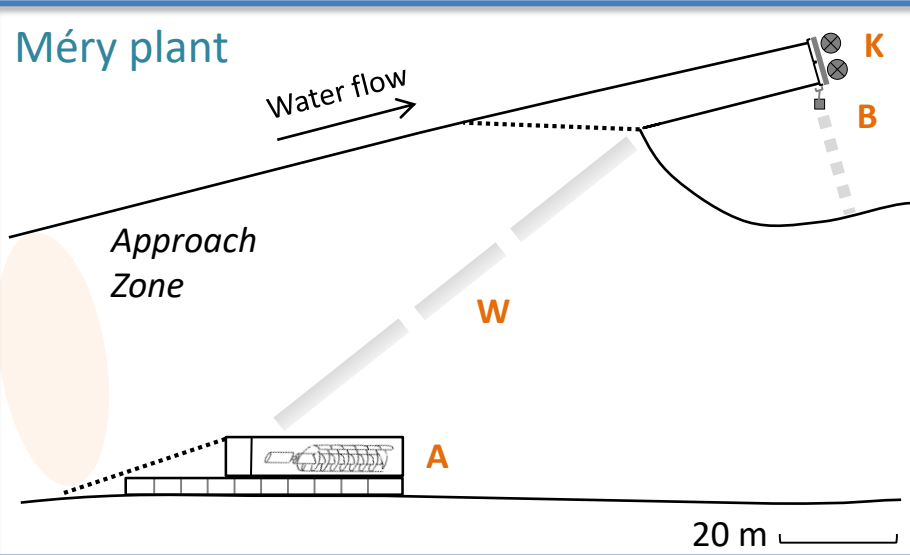


# STUDIED HYDROPOWER PLANTS



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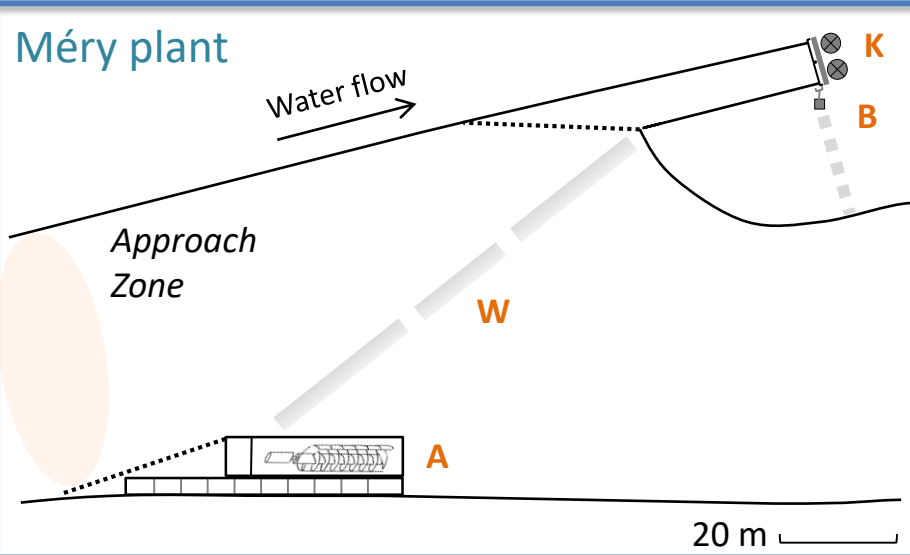
A : Archimedes screw – K : Kaplan turbine – W : Weir – B : Bypass – C : Canal – F : Fishway



# STUDIED HYDROPOWER PLANTS

A : Archimedes screw – K : Kaplan turbine – W : Weir – B : Bypass – C : Canal – F : Fishway

**Méry plant**



Water flow

Approach Zone


A

W

B

K

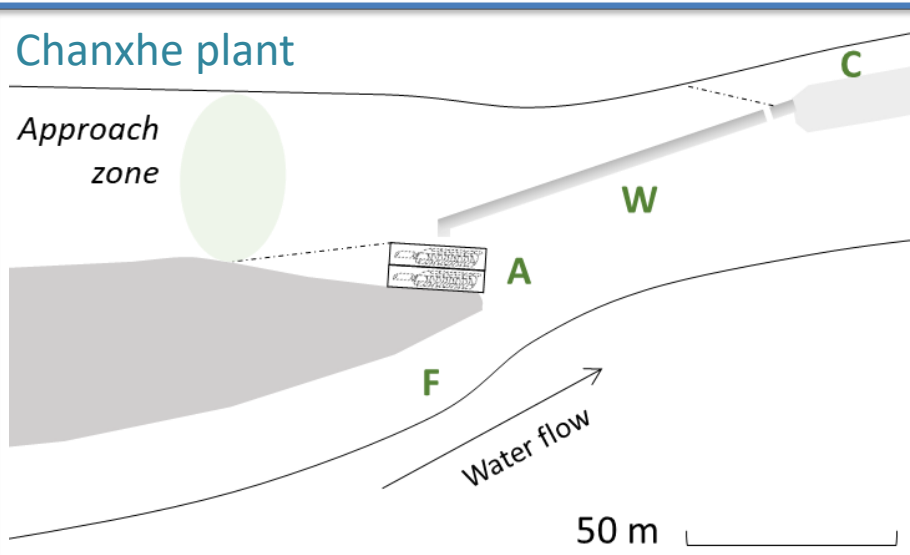
20 m



Radio-telemetry (manual)

Ourthe river

**Chanxhe plant**



Approach zone

F


A

W

C

Water flow

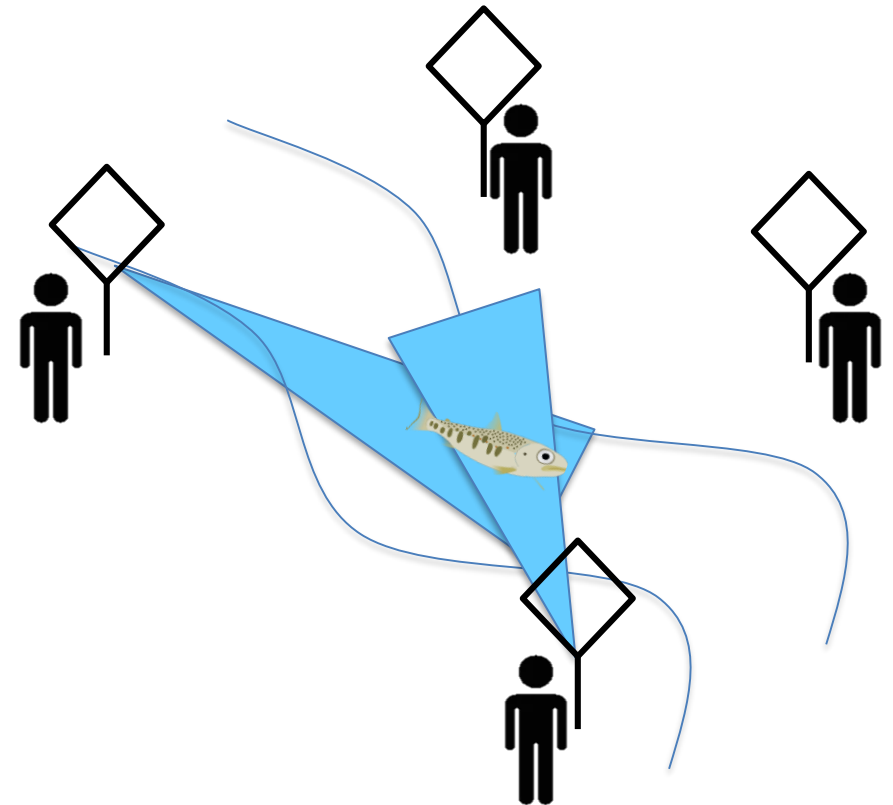
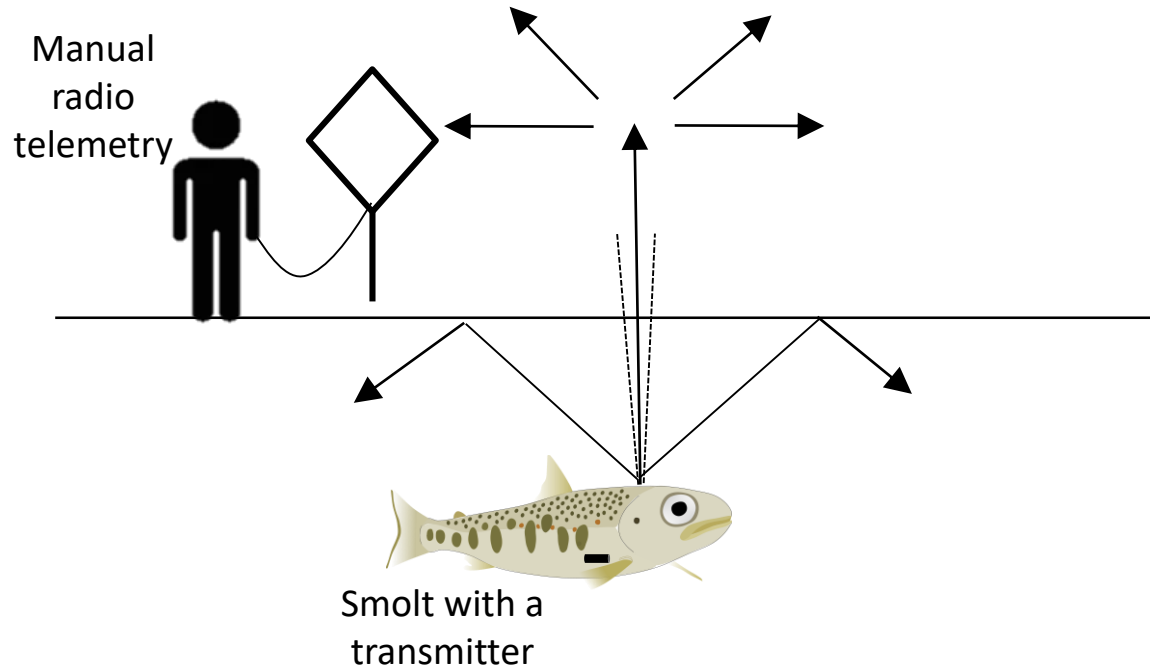
50 m



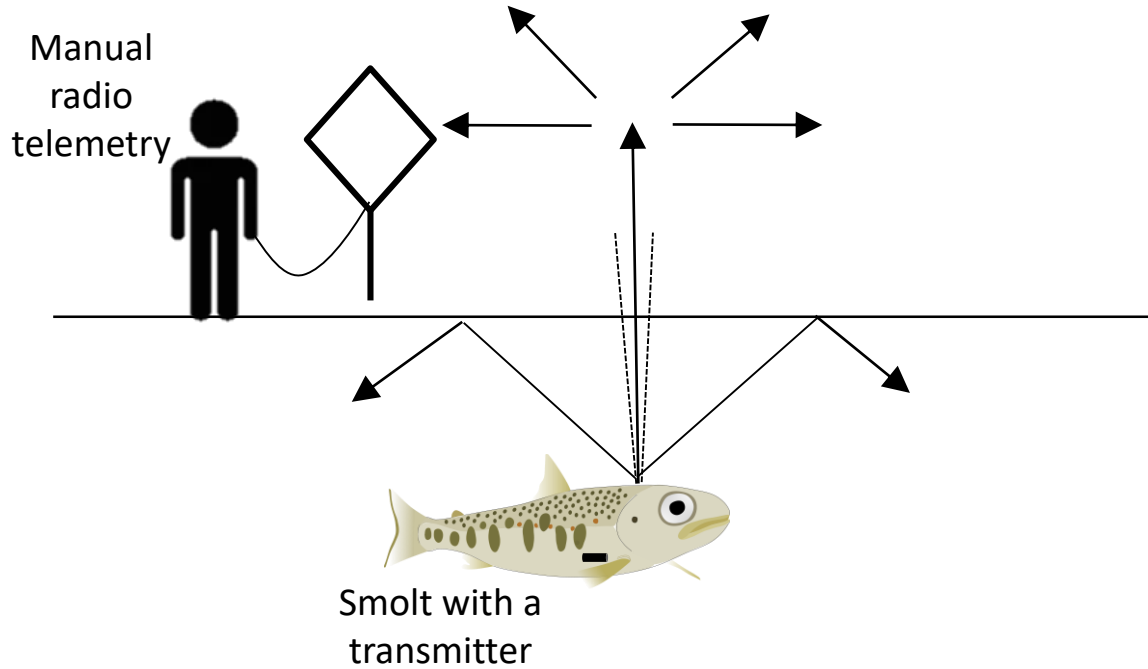
Radio-telemetry (manual)

Ourthe river

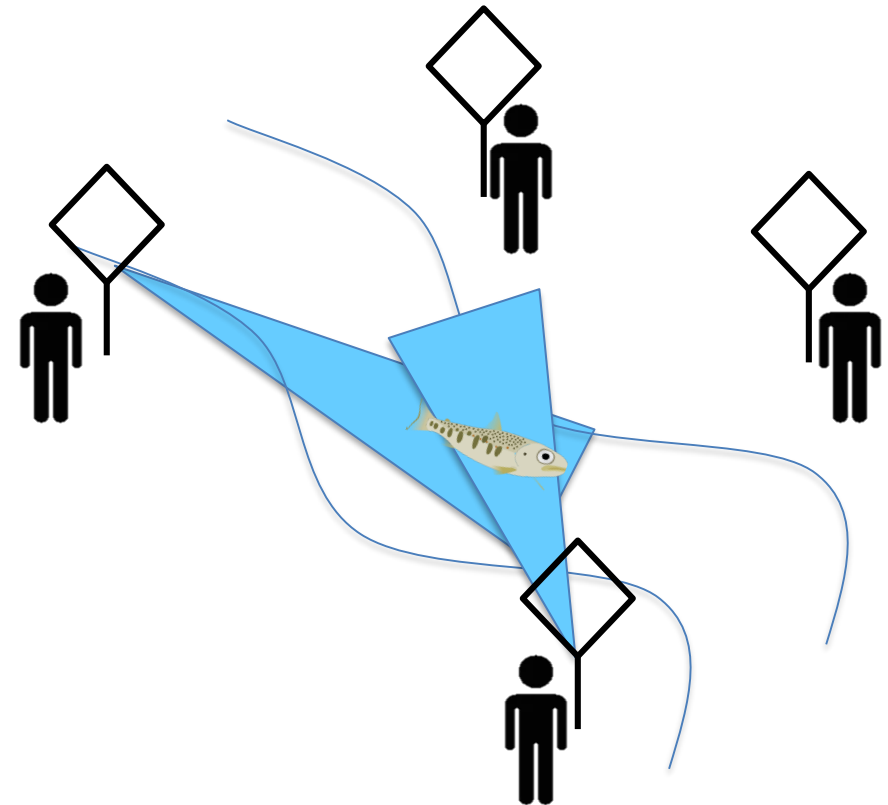
# STUDIED METHODS



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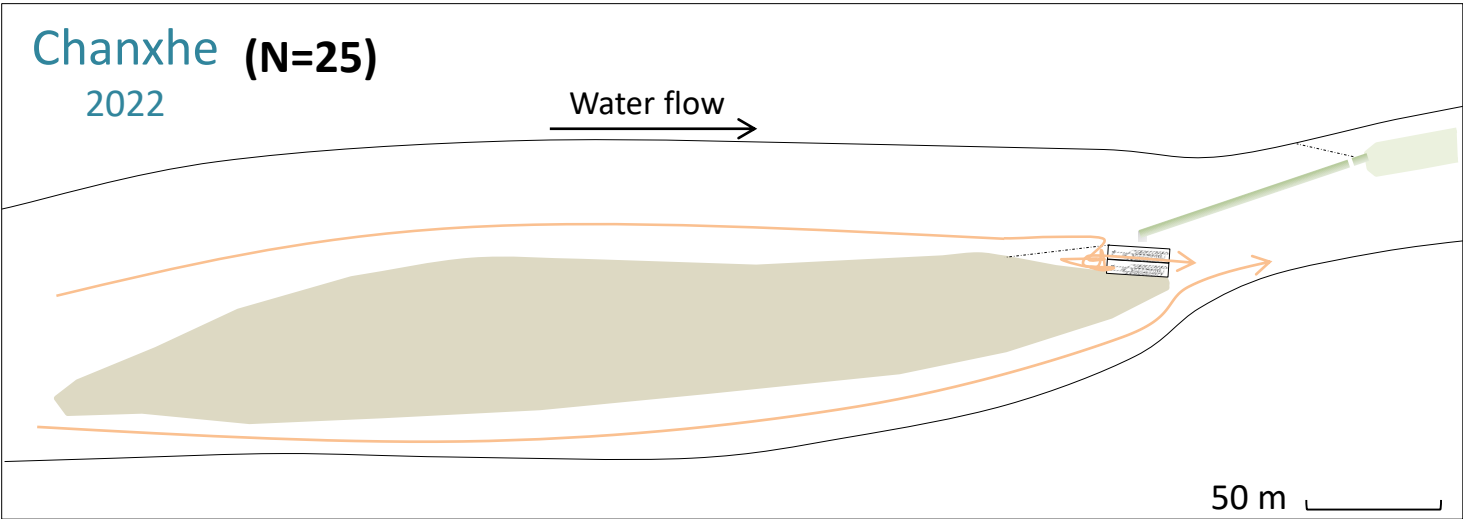
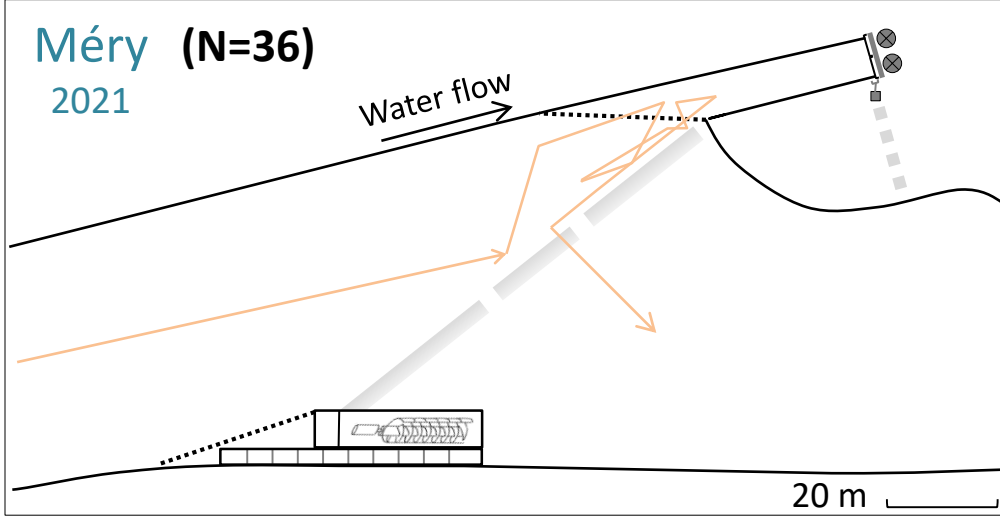
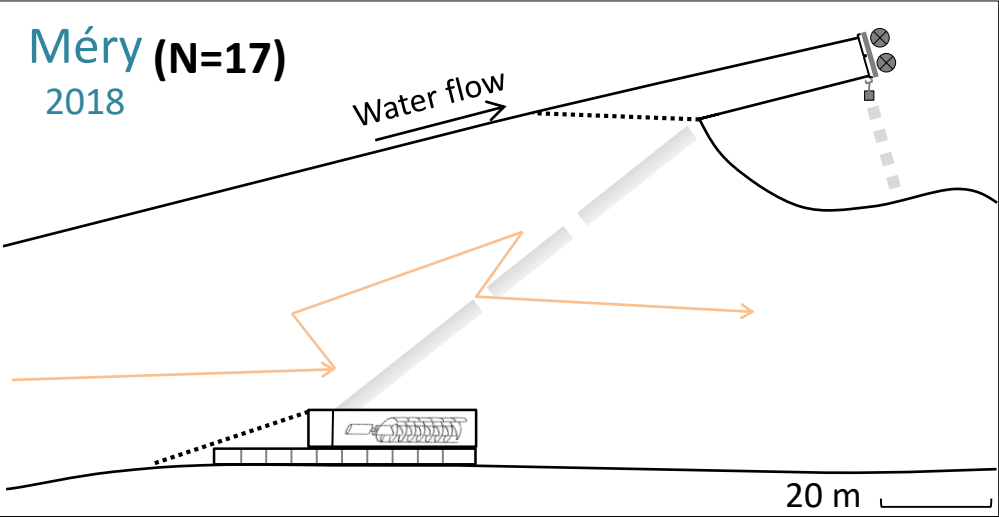


Méry (Ourthe) : n=17 (2018)  
Méry (Ourthe) : n=36 (2021)  
Chanxe (Ourthe) : n=25 (2022)  
Total n= 78 (day of release between 4 p.m. and 3 a.m.)



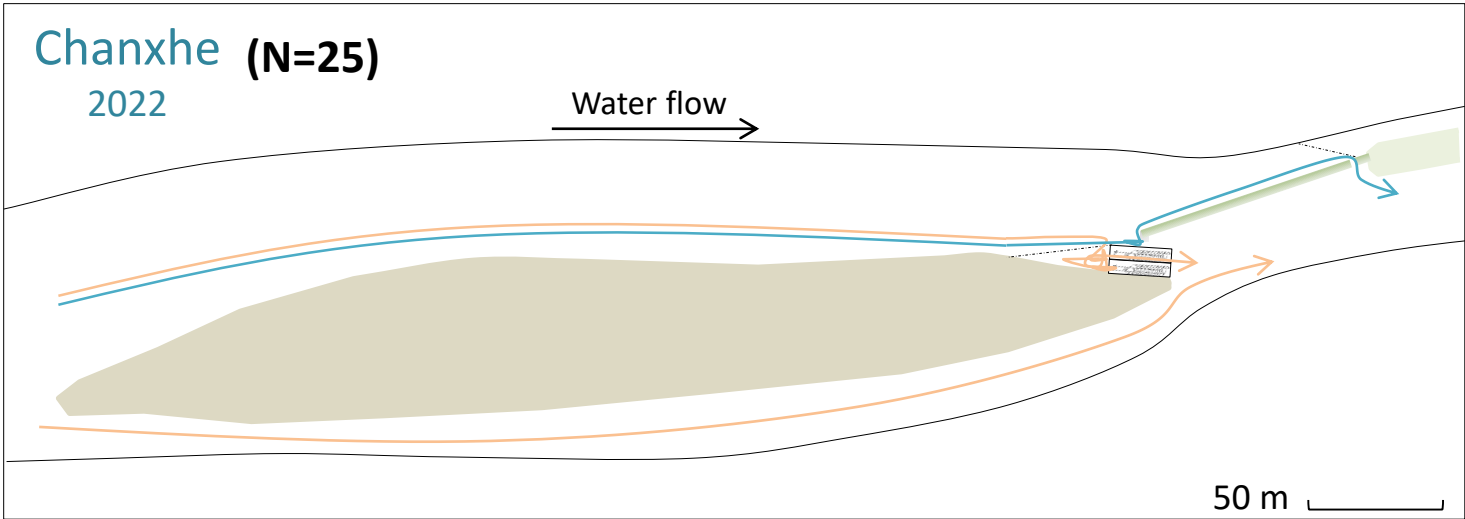
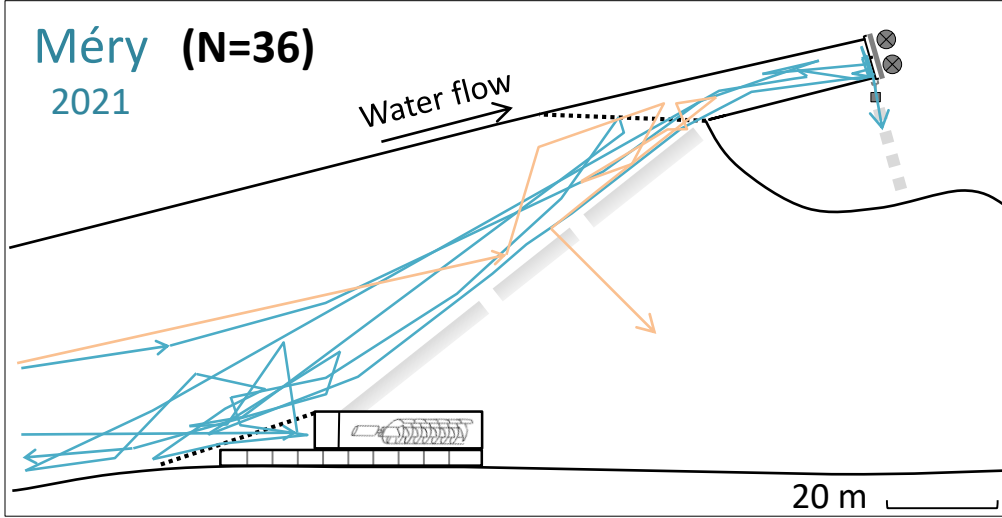
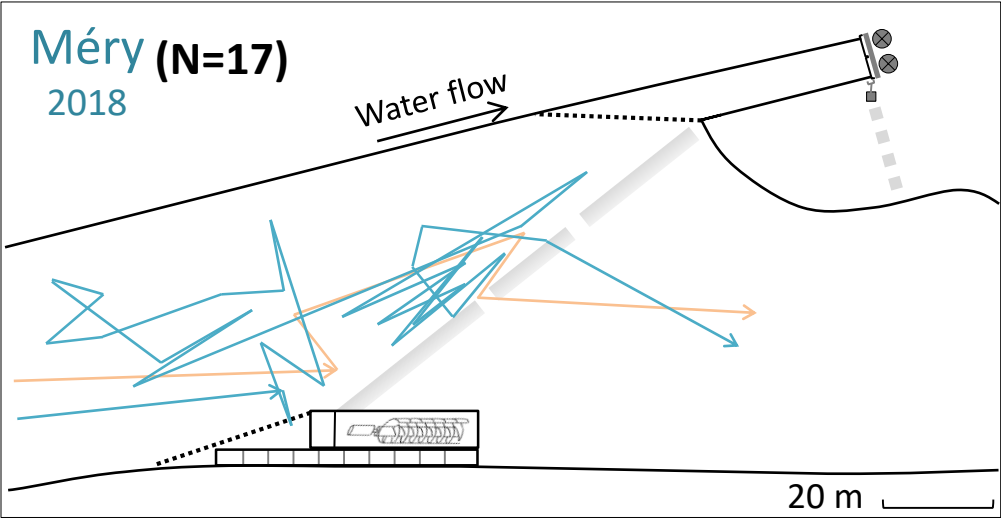


## Great diversity of smolt research behaviour

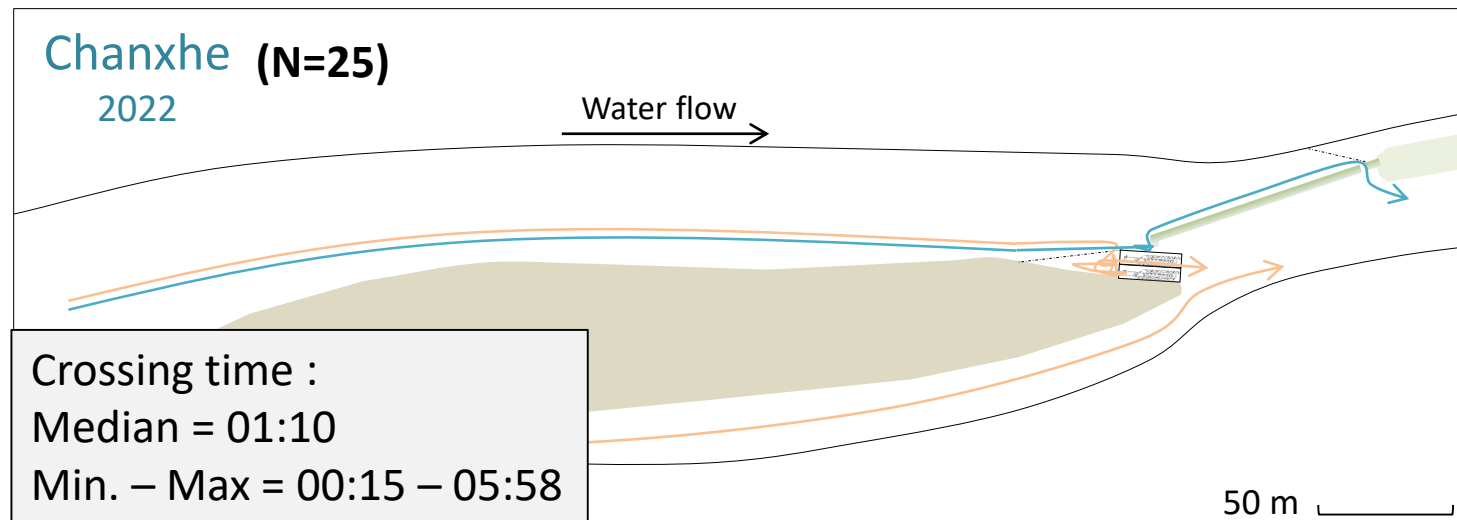
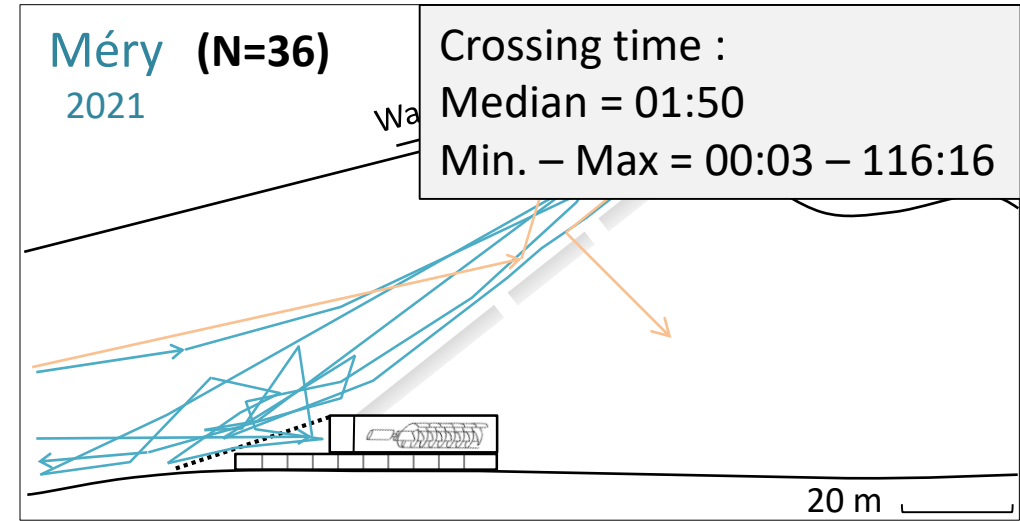
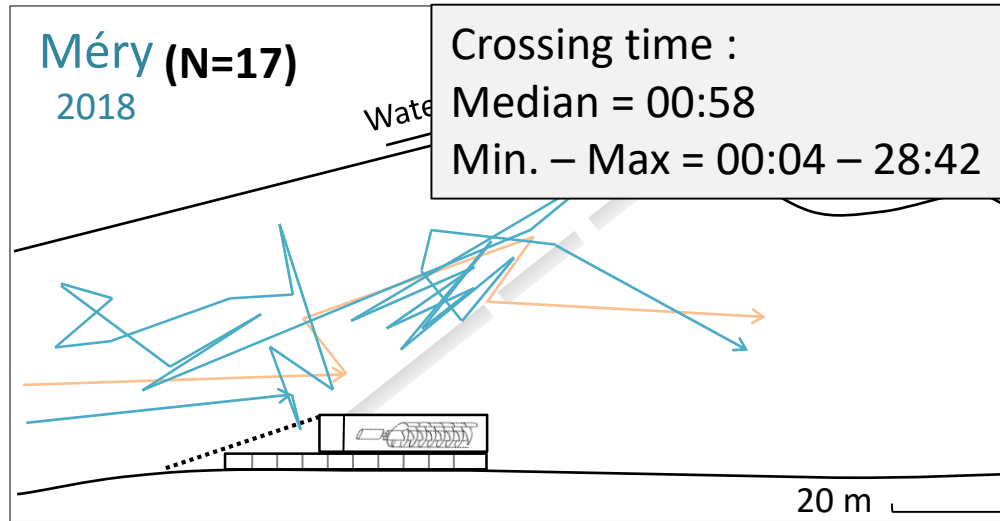


# RESULTS – SMOLT BEHAVIOUR

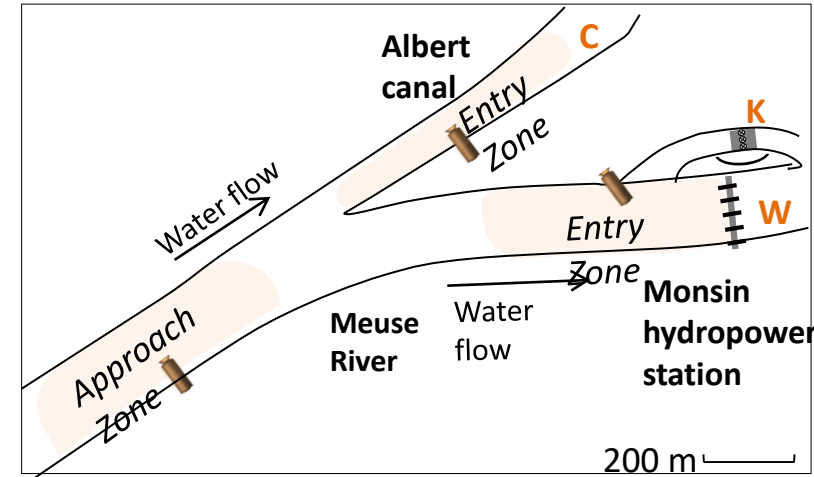
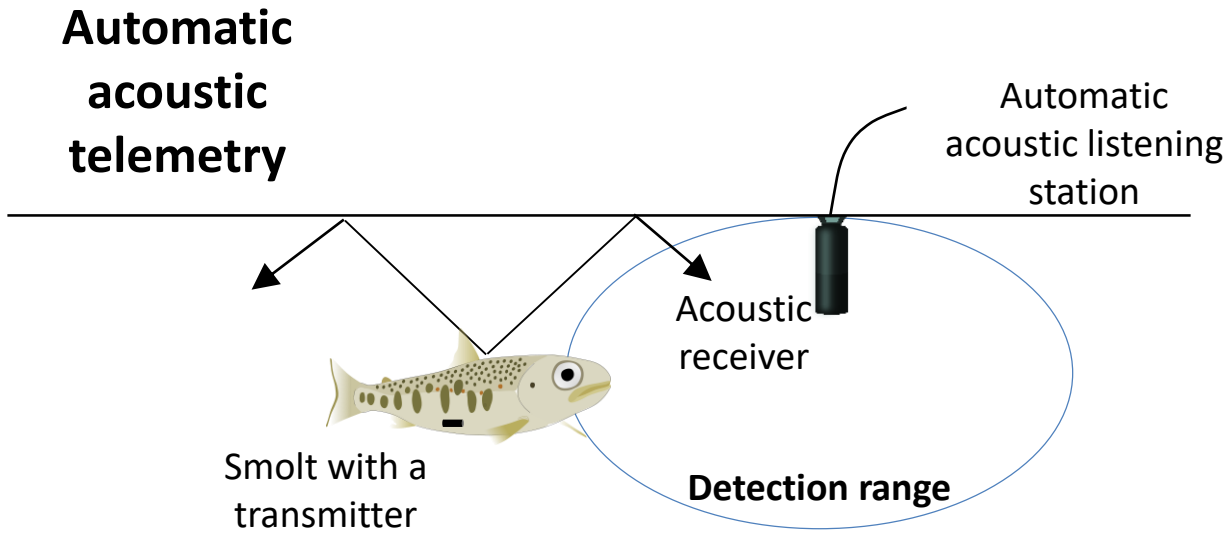
Great diversity of smolt research behaviour



## Great diversity of smolt research behaviour

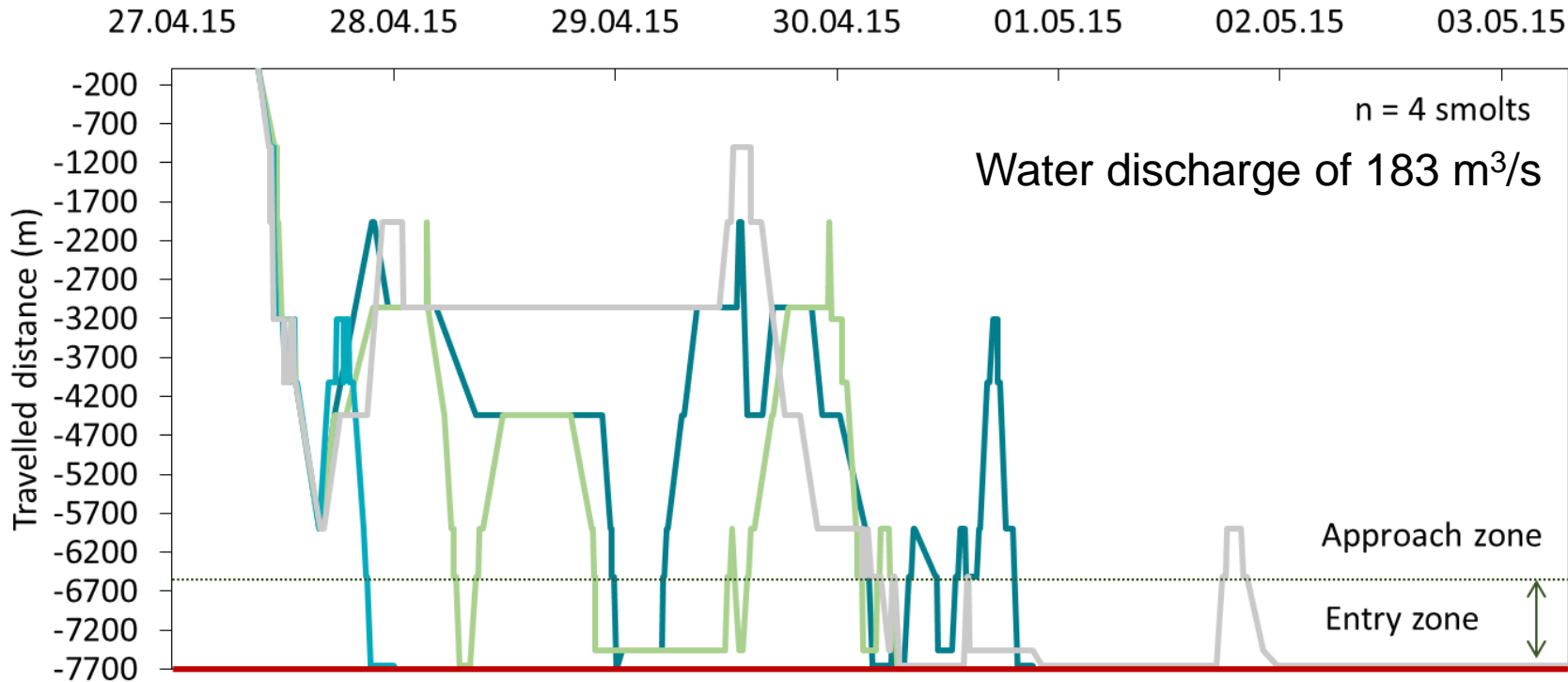


# RESULTS – SMOLT BEHAVIOUR

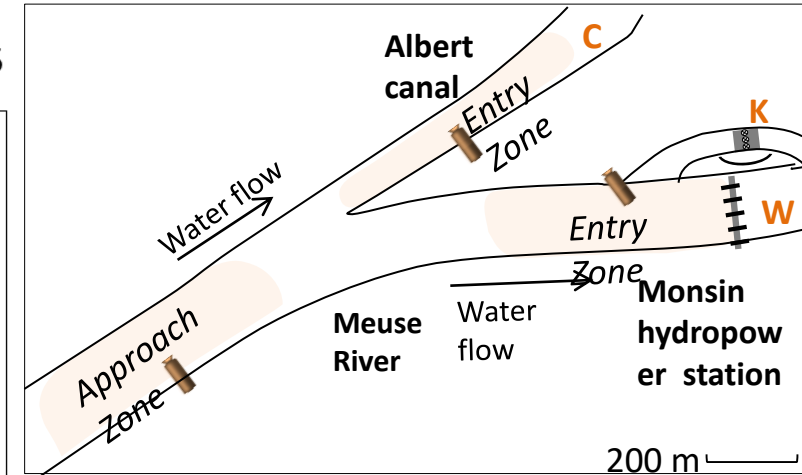


# RESULTS – SMOLT BEHAVIOUR

Great diversity of smolt research behaviour

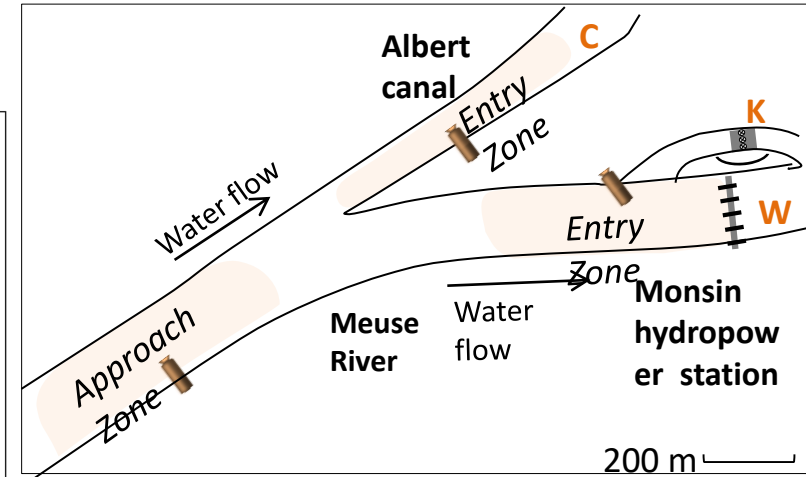
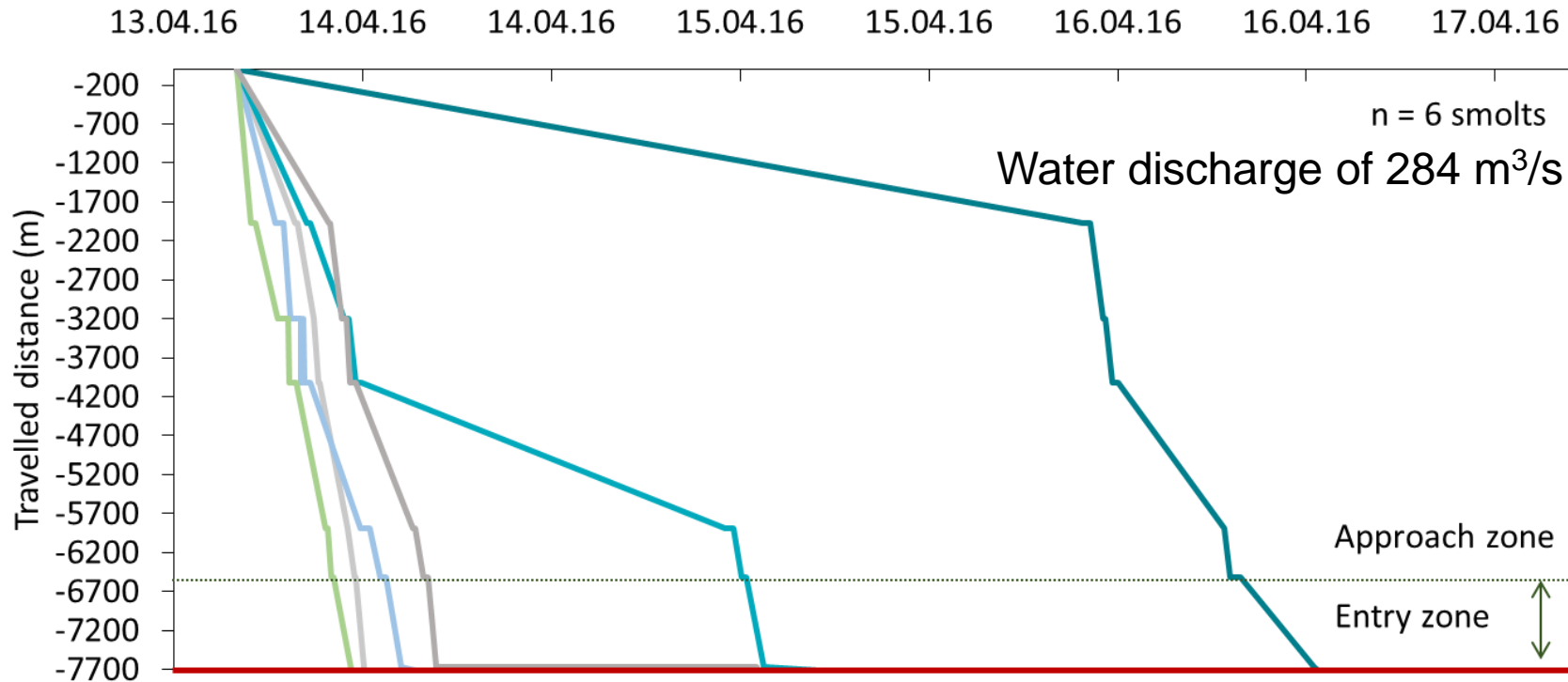


Meuse – Monsin - 3 years (2014/2016) – n=72



# RESULTS – SMOLT BEHAVIOUR

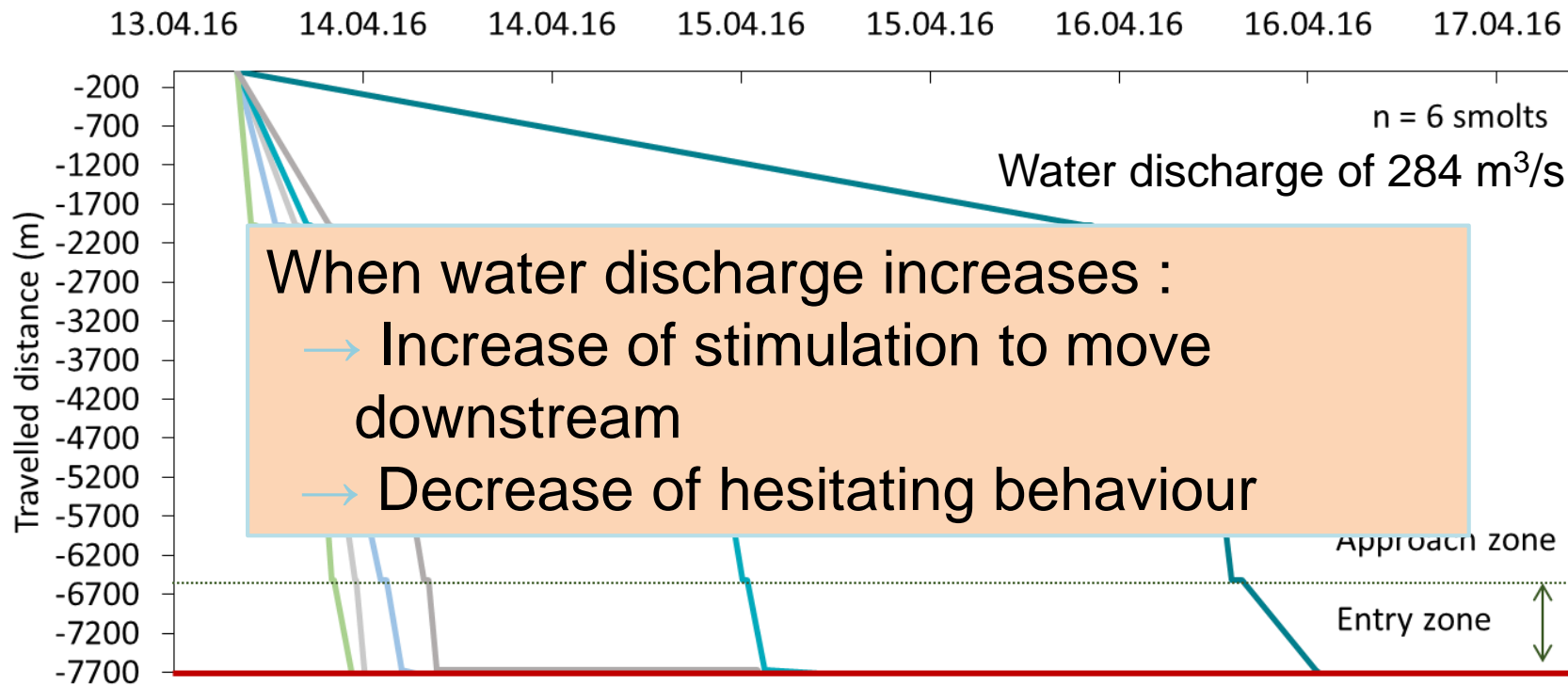
Great diversity of smolt research behaviour



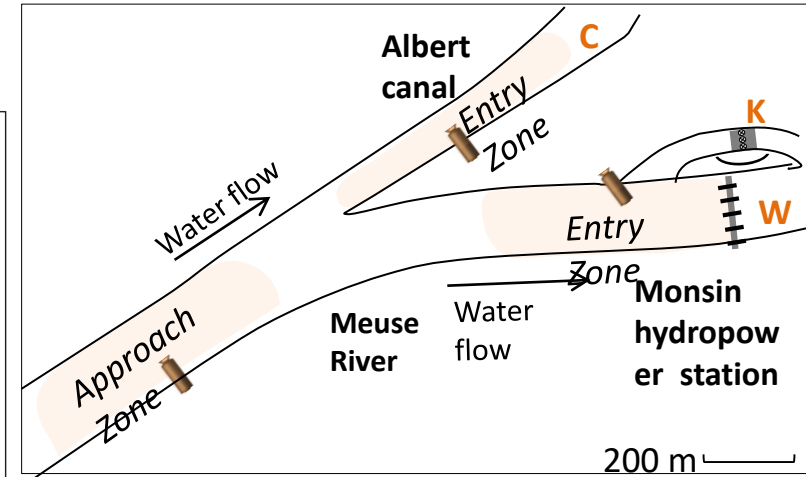
Meuse – Monsin - 3 years (2014/2016) – n=72

# RESULTS – SMOLT BEHAVIOUR

Great diversity of smolt research behaviour

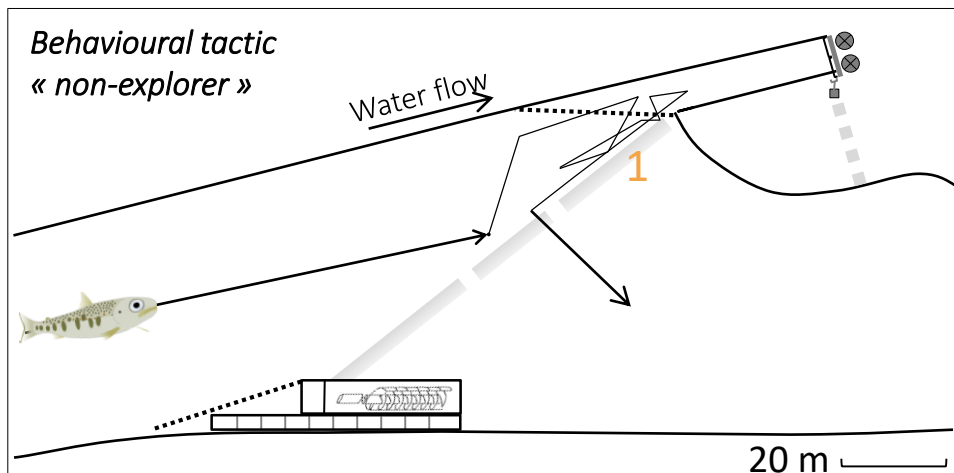
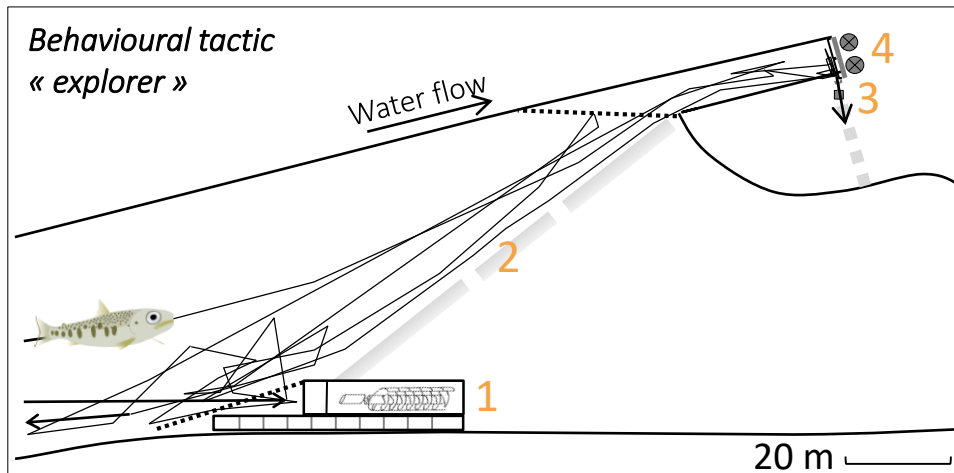


Meuse – Monsin - 3 years (2014/2016) – n=72



## 1) Explorer vs. Non-explorer

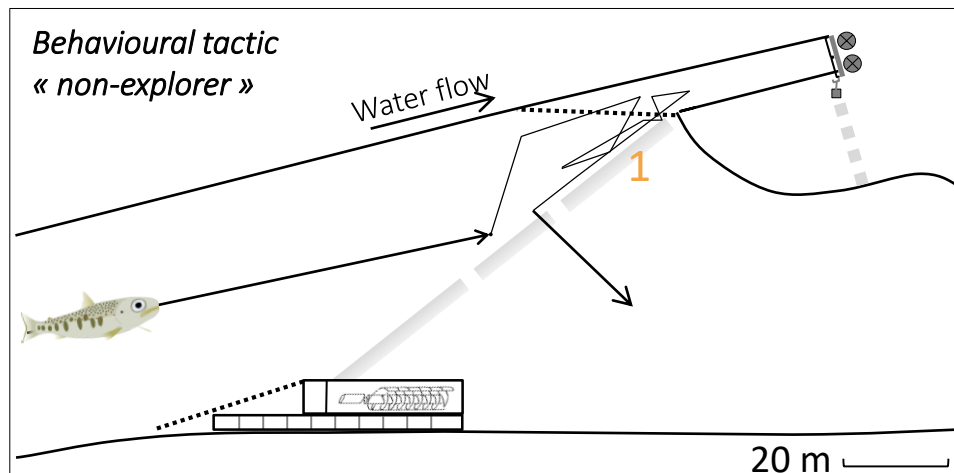
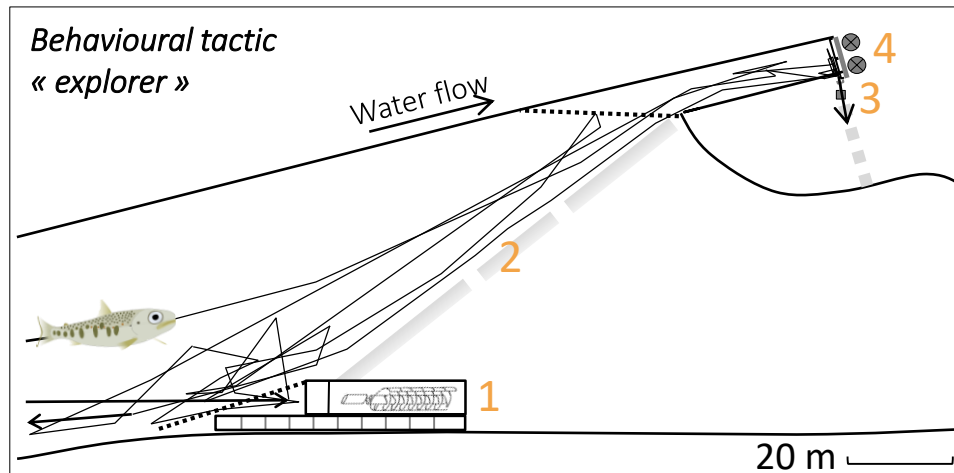
**Explorer** : « a smolt who approaches more than one migration route »





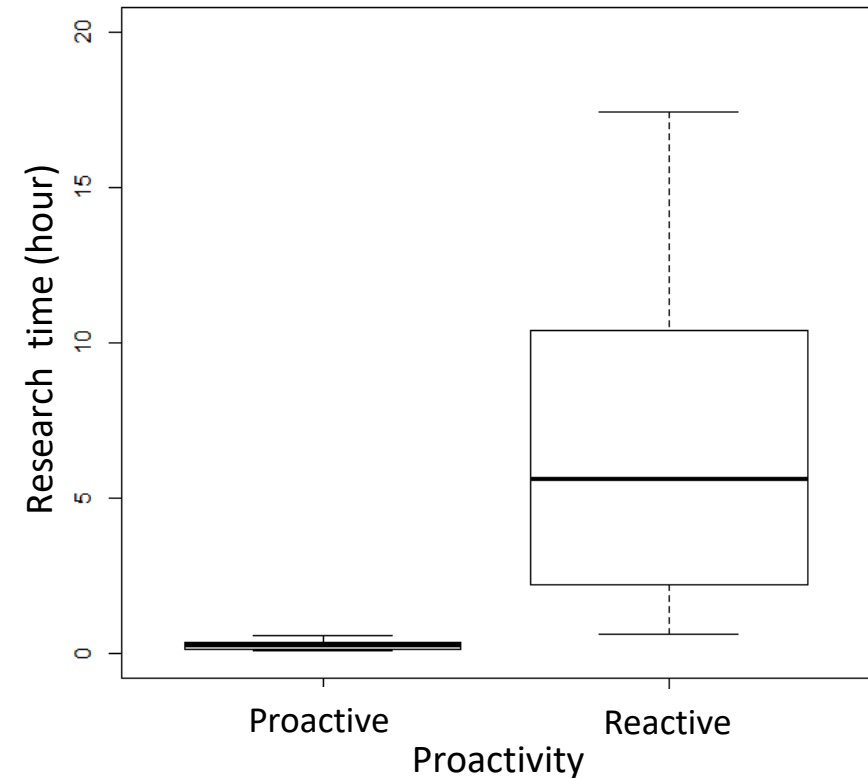
## 1) Explorer vs. Non-explorer

**Explorer** : « a smolt who approaches more than one migration route »



## 2) Proactive vs. reactive

**Proactive** : « a smolt who crosses the migration barrier in less than the first quartile of the range »

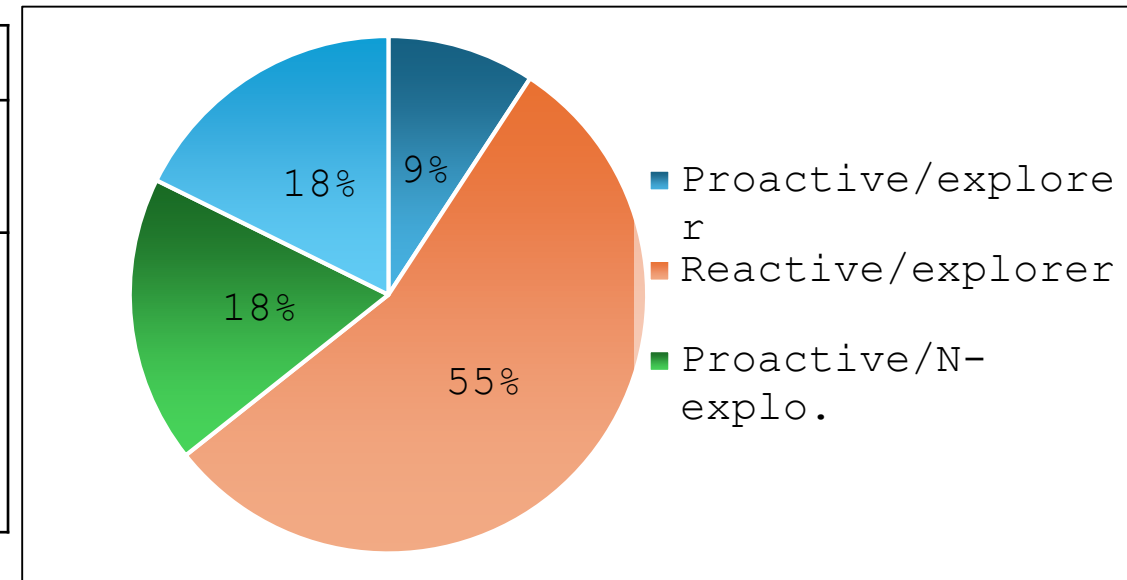


## Four smolt behavioural tactics were defined based on smolt research behaviour

**Explorer** : « a smolt who approaches more than one migration route »

**Proactive** : « a smolt who crosses the migration barrier in less than the first quartile of the range »

Migration barriers	Behavioural tactics (%)			
	Proactive explorer	Reactive explorer	Proactive non-explorer	Reactive non-explorer
Méry (1)	7	60	20	13
Méry (2)	9	75	16	0
Chanxhe	19	31	13	38
Monsin	2	55	23	20



## Four smolt behavioural tactics were defined based on smolt research behaviour

**Explorer** : « *a smolt who approaches more than one migration route* »

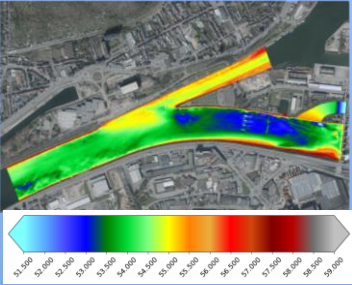
**Proactive** : « *a smolt who crosses the migration barrier in less than the first quartile of the range* »

### Key points to remember ...

- **Great diversity of behavioural responses** expressed by smolts when facing migration barriers in rivers.
- Identification of **four behavioural tactics**.
- Main expression of the "**reactive explorer**" behavioural tactic, suggesting the low attractiveness of alternative migration routes.

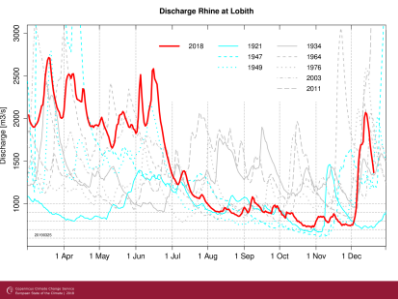
# RESULTS – SMOLT BEHAVIOUR VS. HYDRODYNAMIC MODELLING

Bathymetry



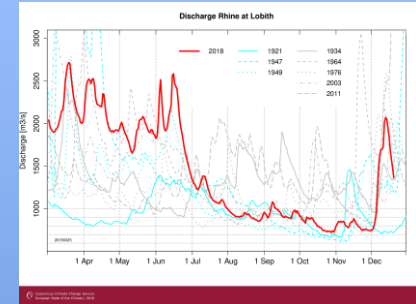
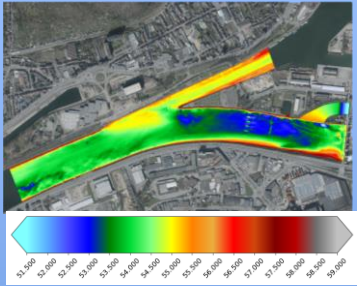
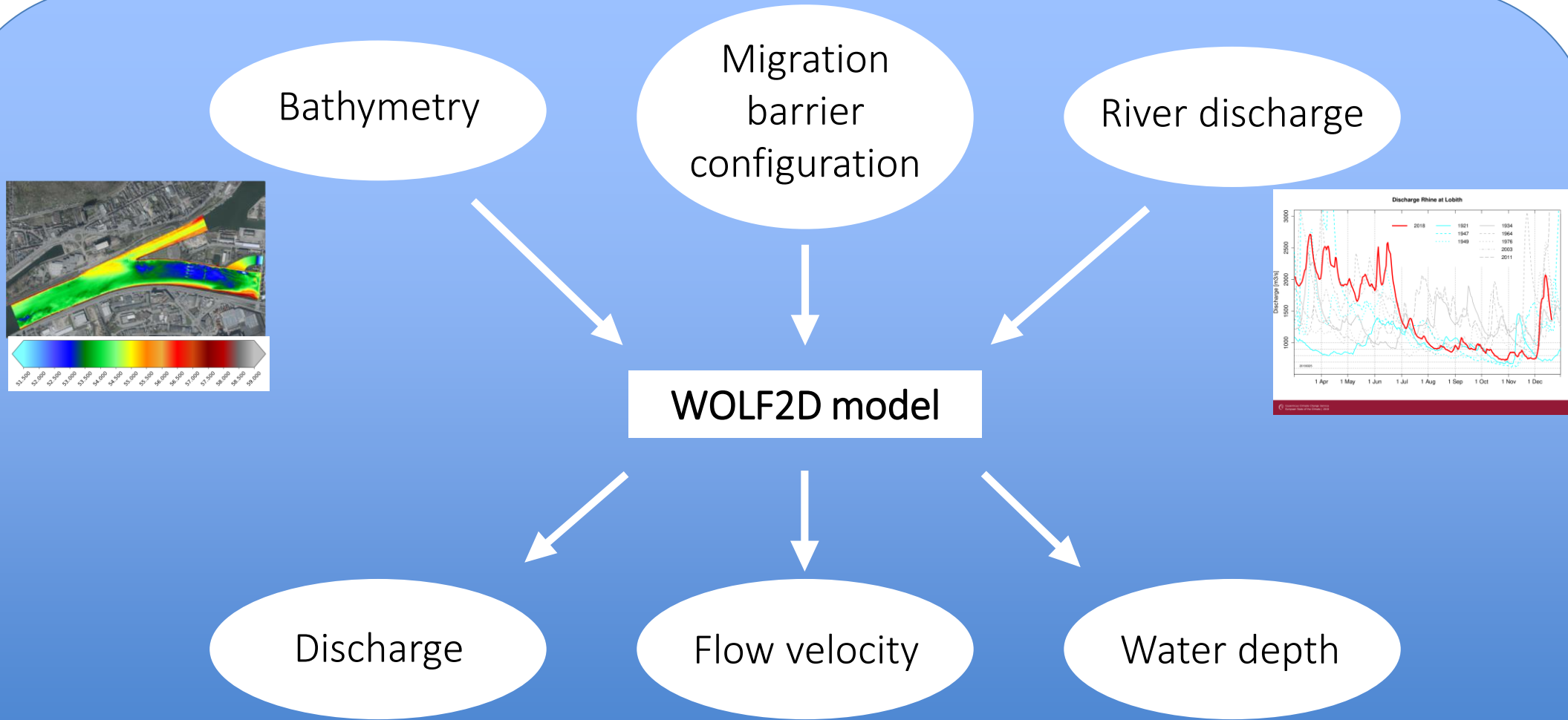
Migration barrier configuration

River discharge



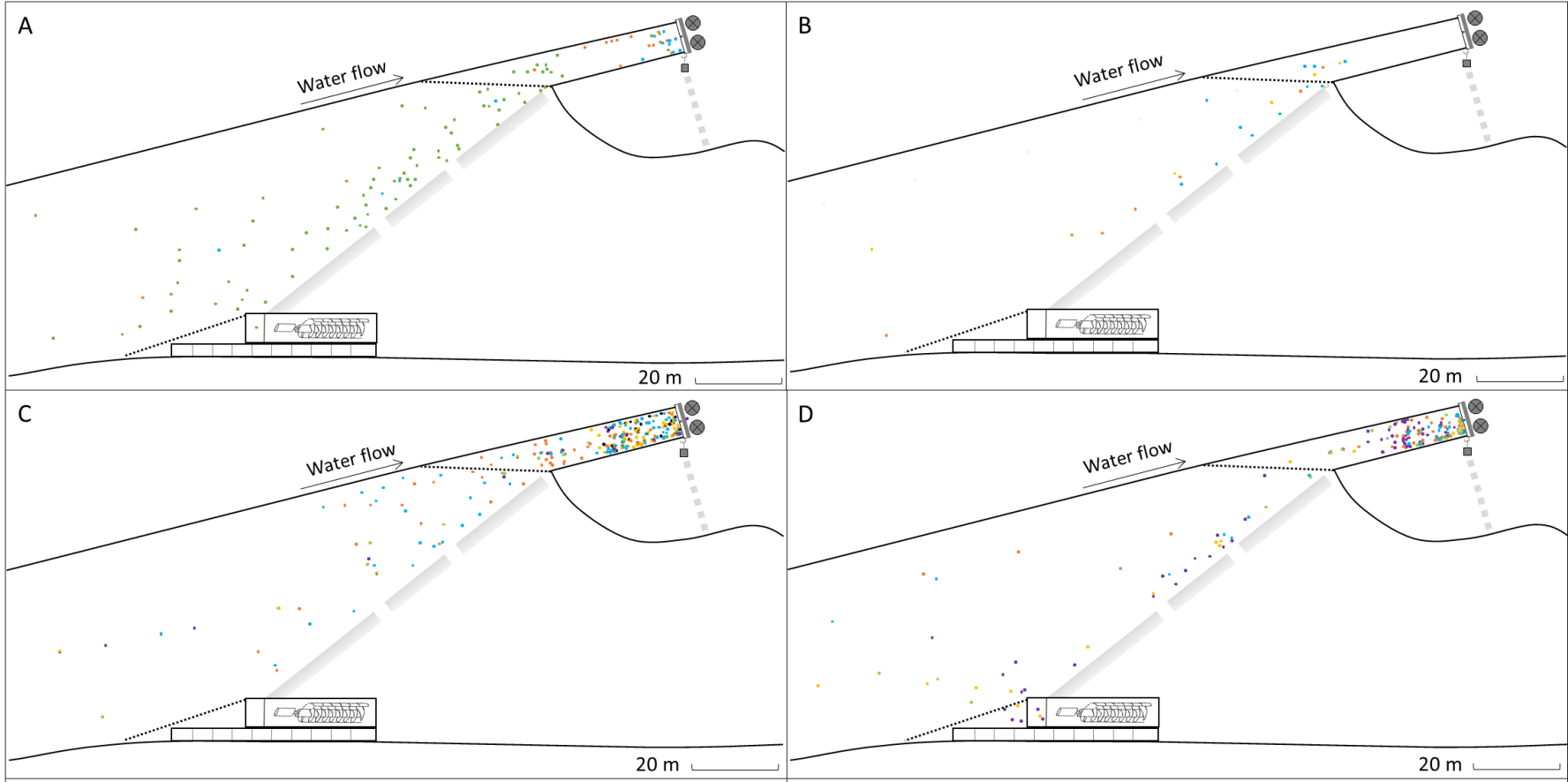
WOLF2D model

# RESULTS – SMOLT BEHAVIOUR VS. HYDRODYNAMIC MODELLING

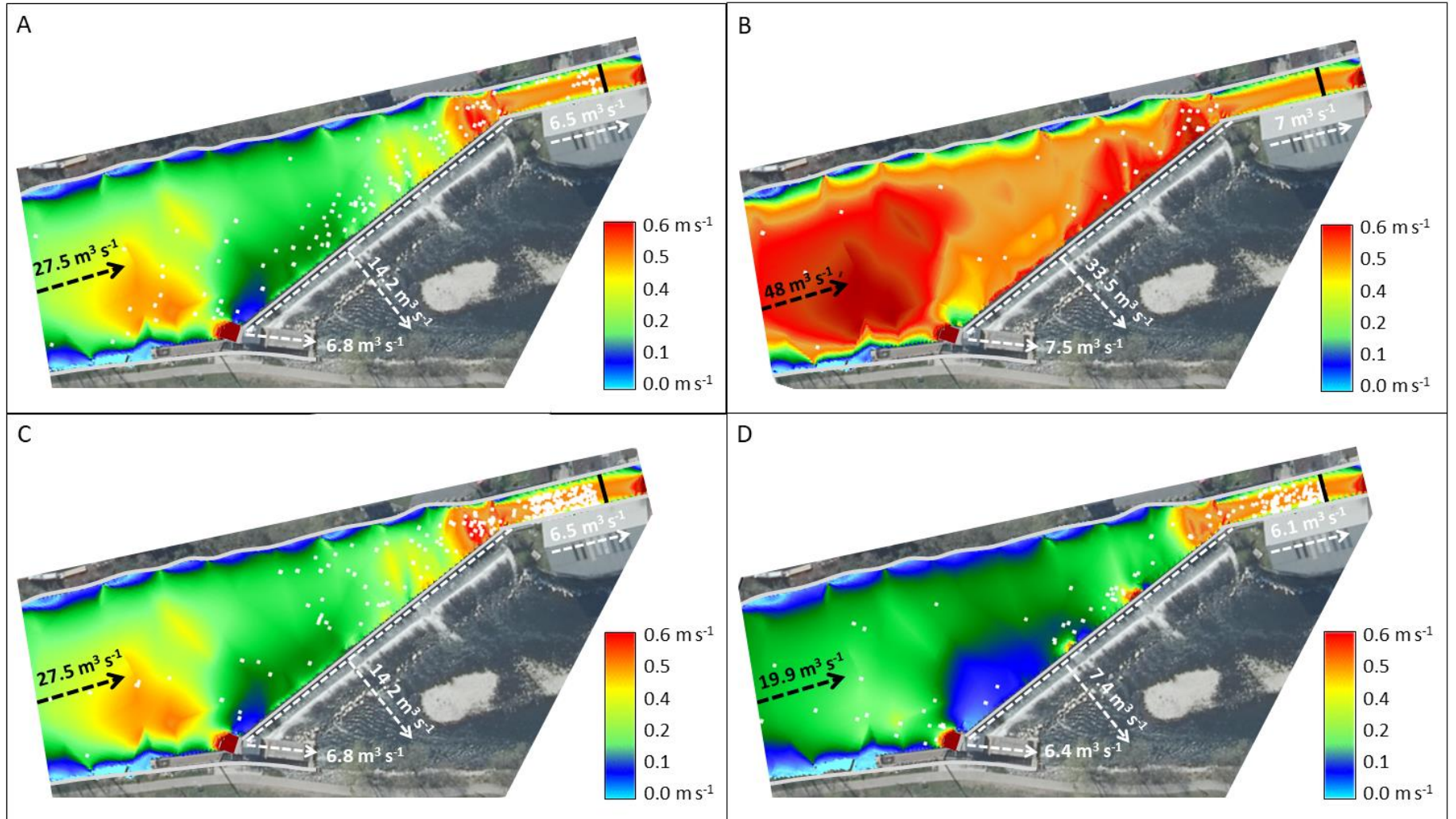


*1 m horizontal resolution and 0.15 m vertical accuracy*

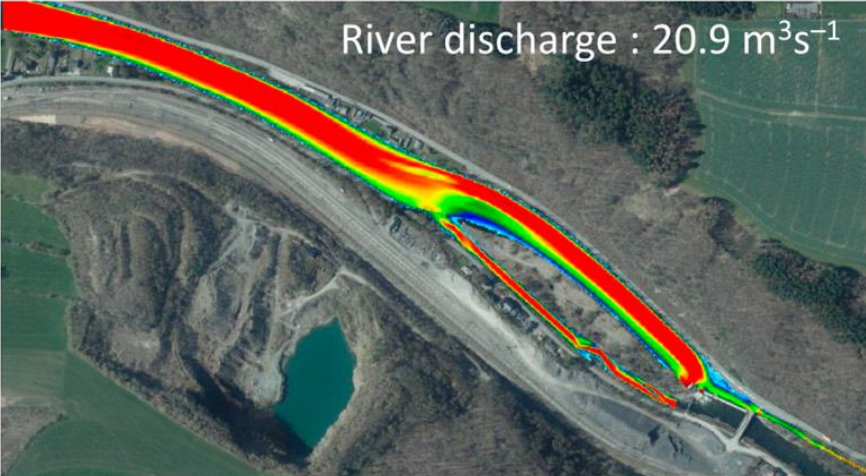
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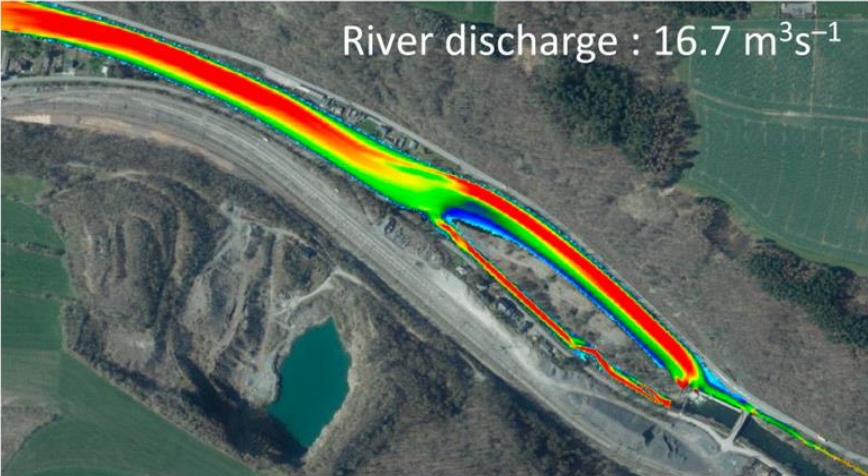
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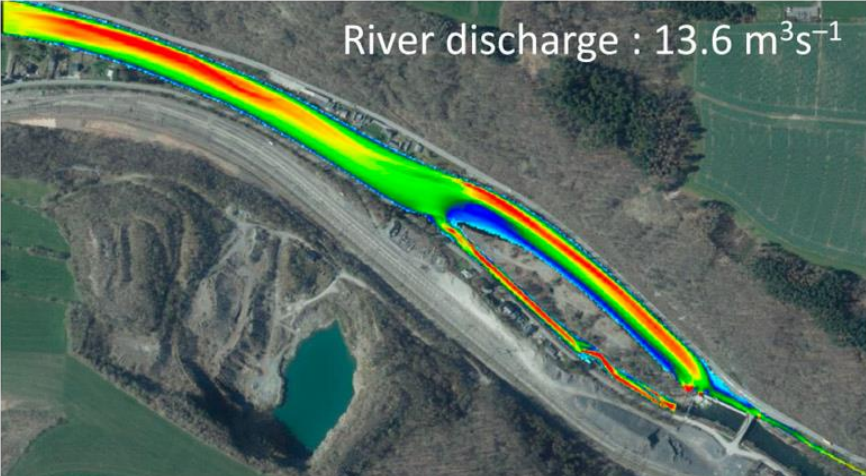
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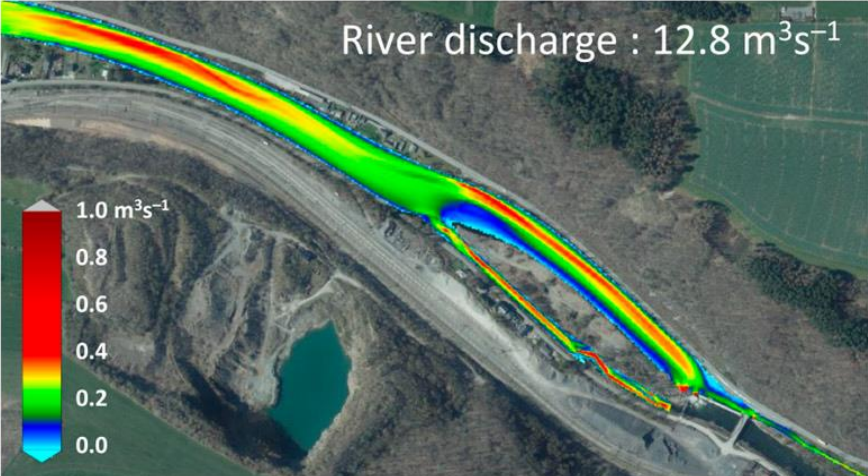
(a)



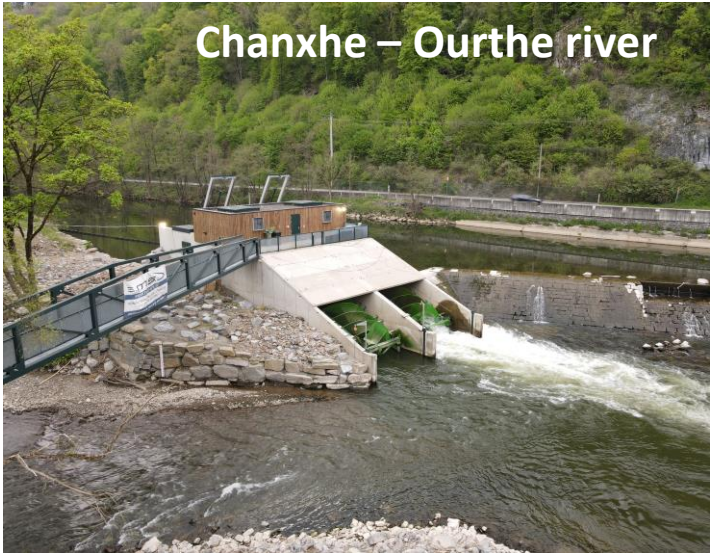
(b)



(c)

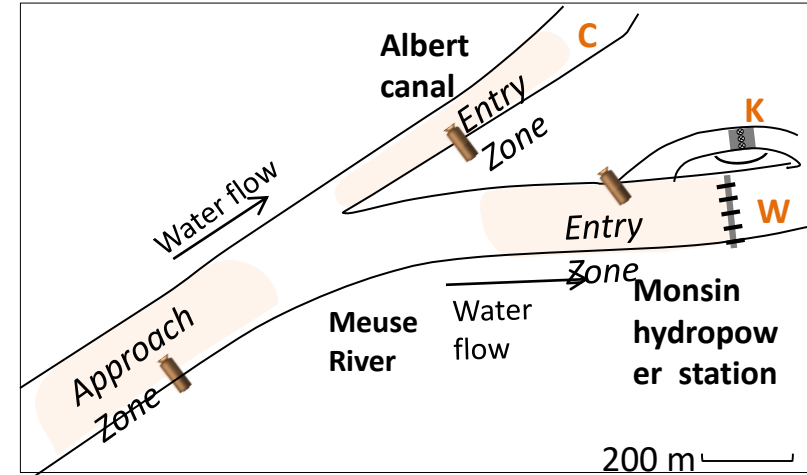
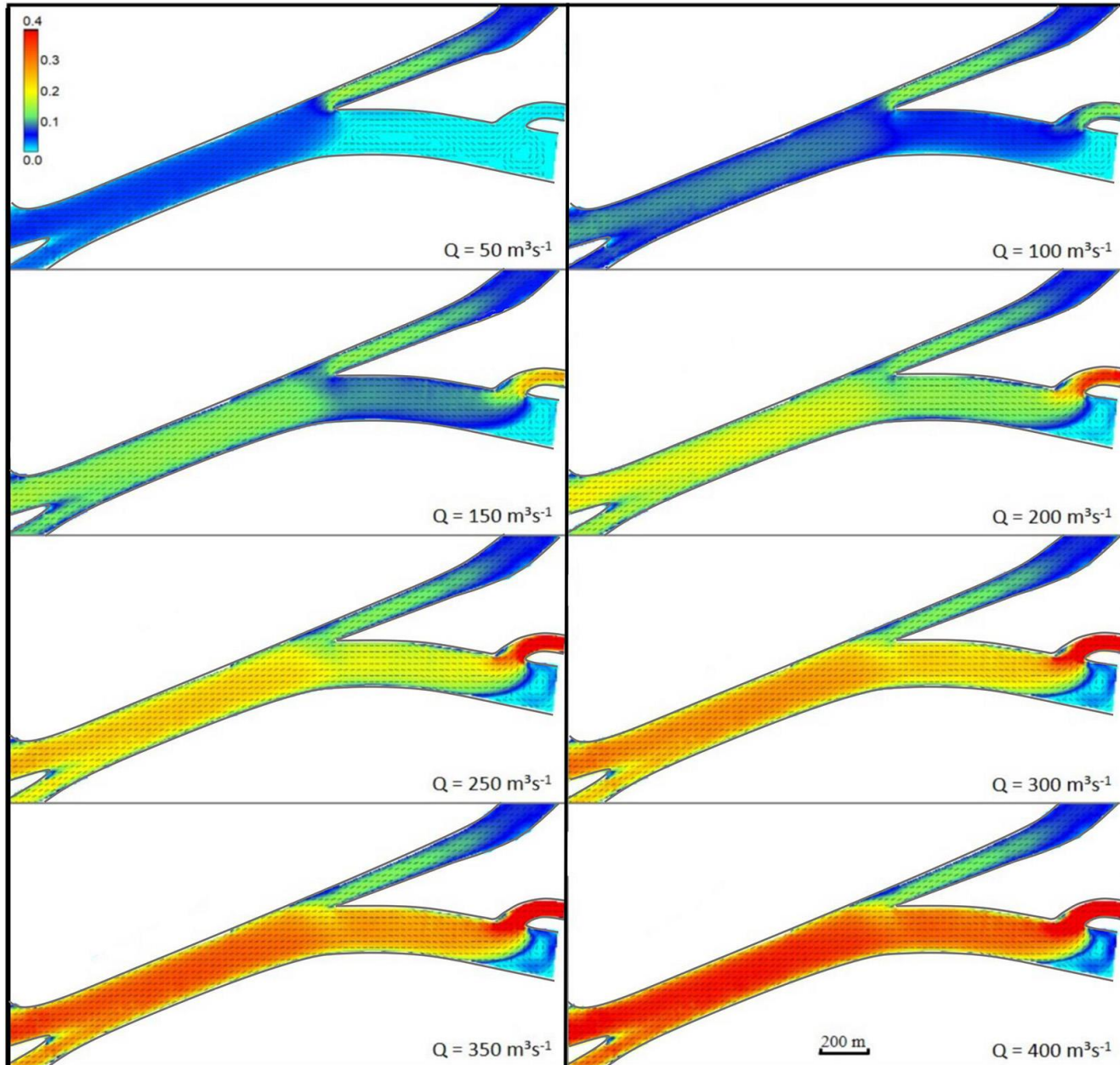


(d)

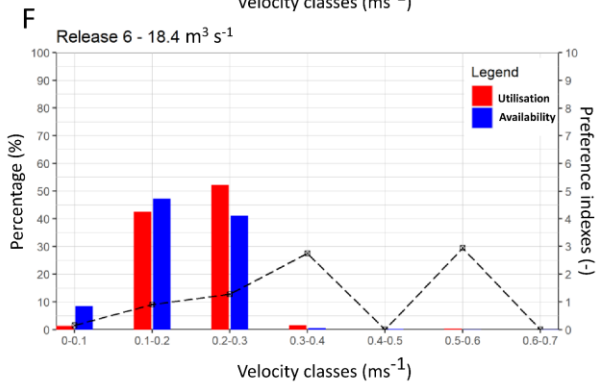
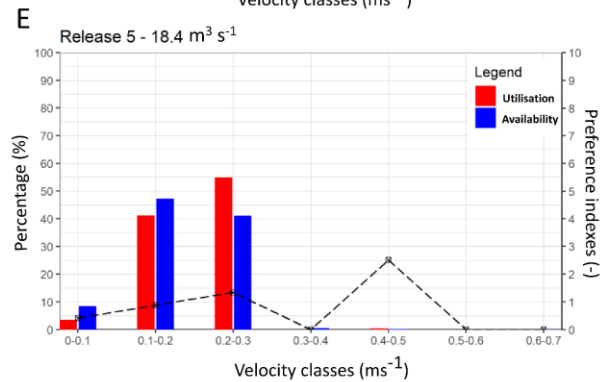
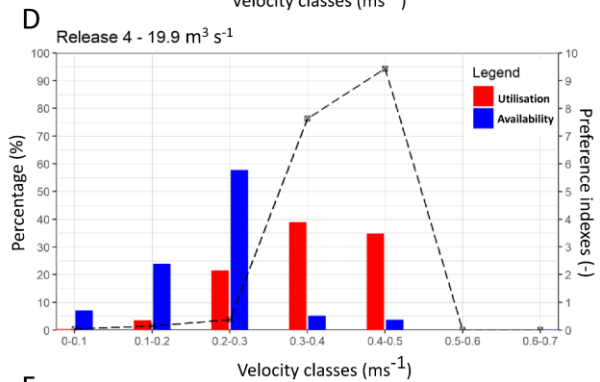
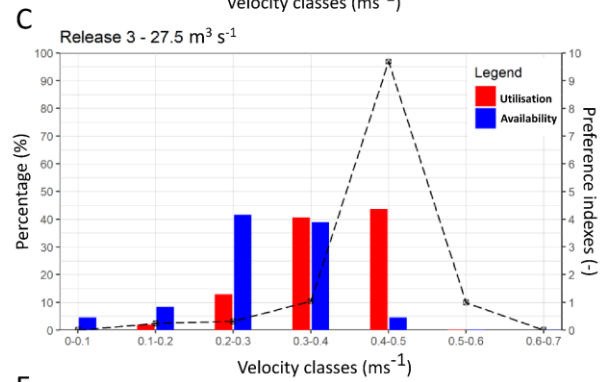
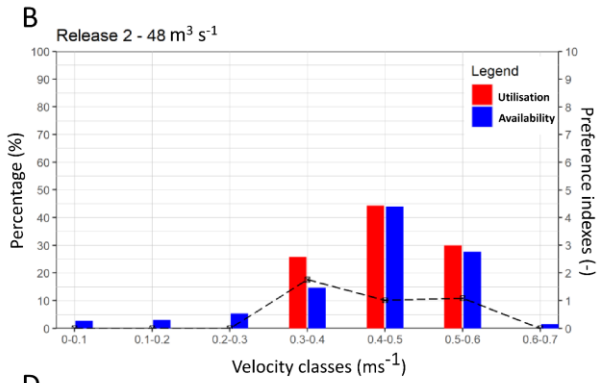
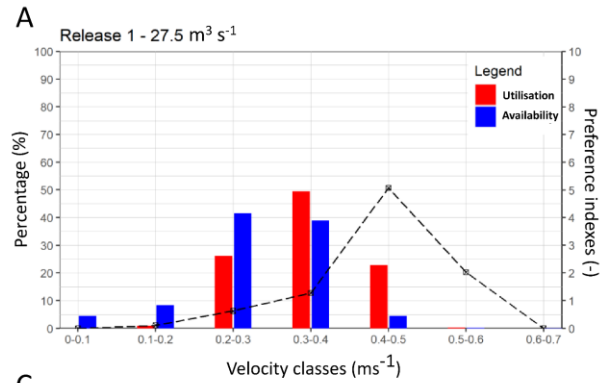




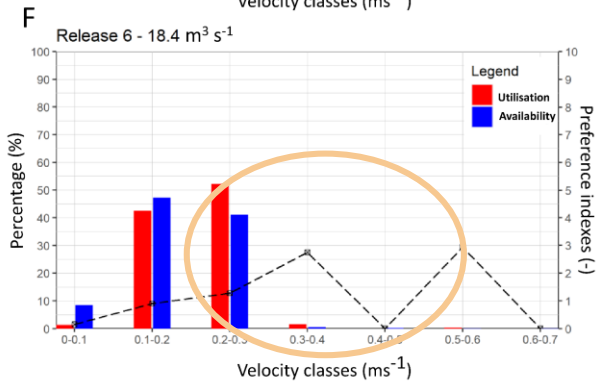
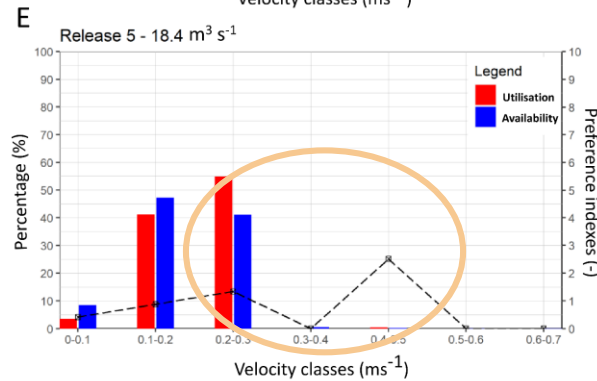
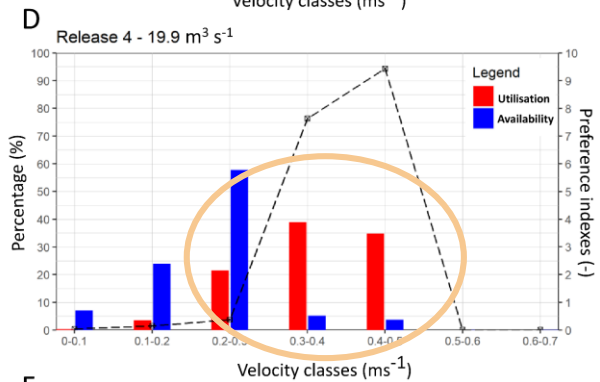
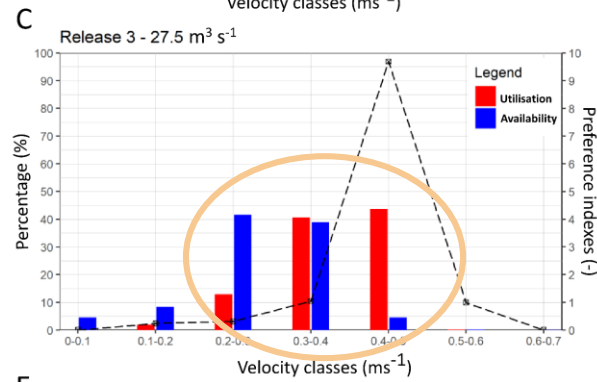
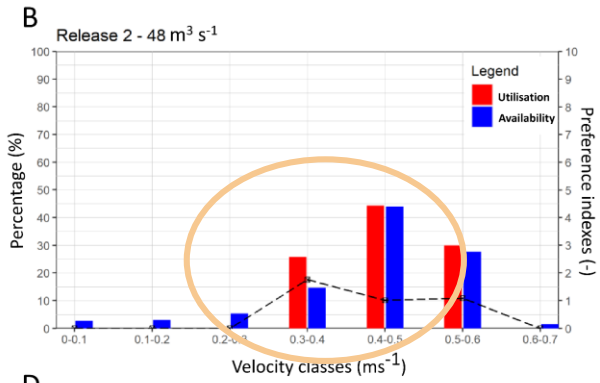
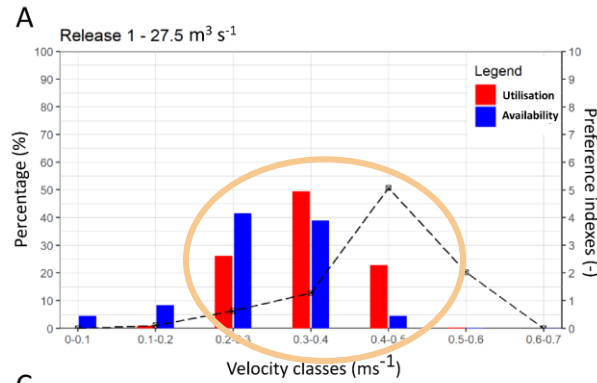
# RESULTS – SMOLT BEHAVIOUR VS. HYDRODYNAMIC MODELLING



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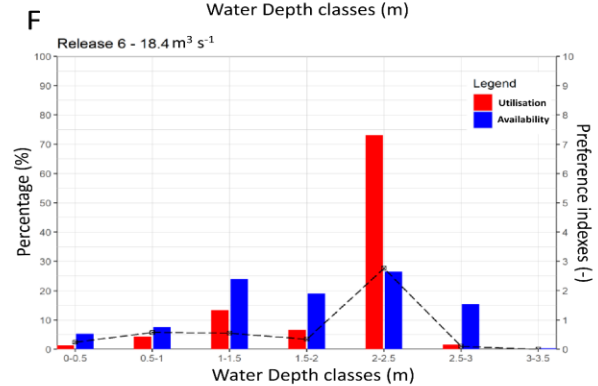
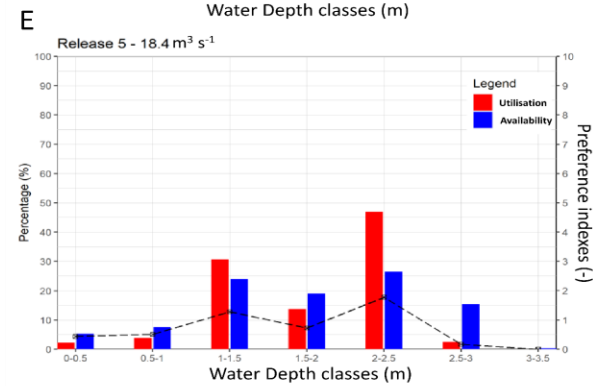
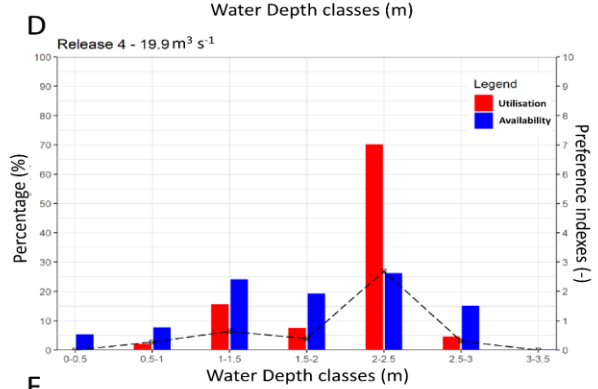
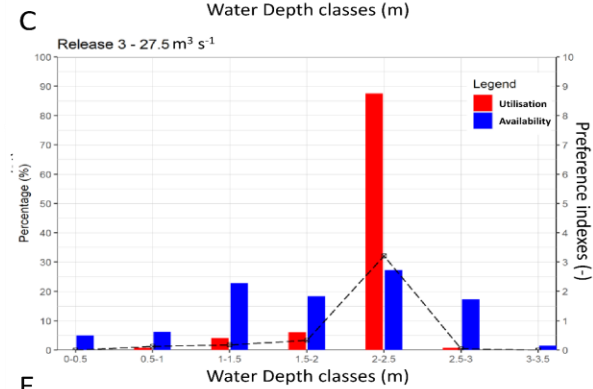
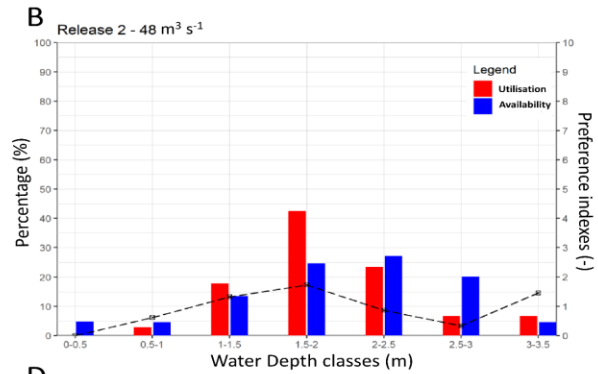
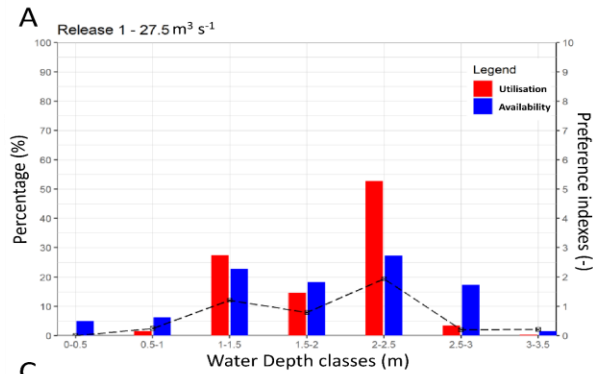
# RESULTS – SMOLT BEHAVIOUR VS. HYDRODYNAMIC MODELLING



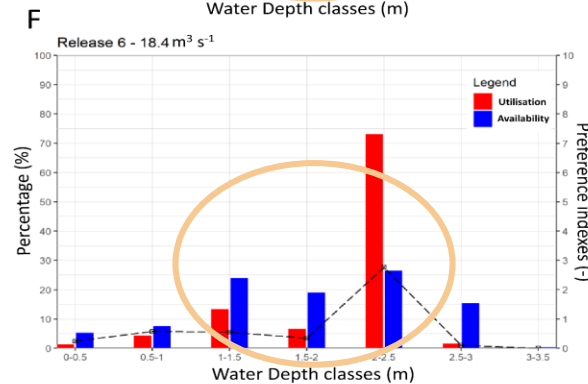
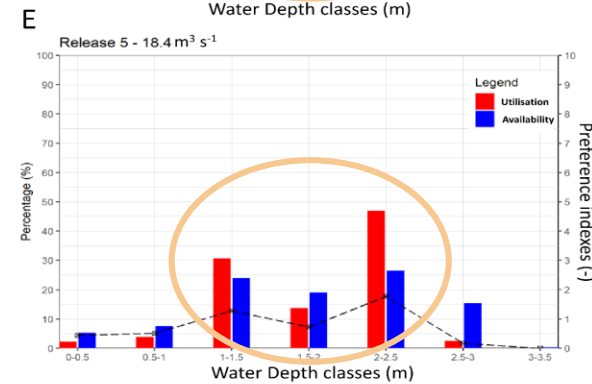
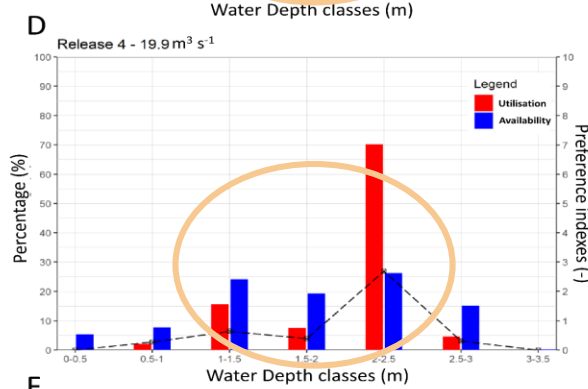
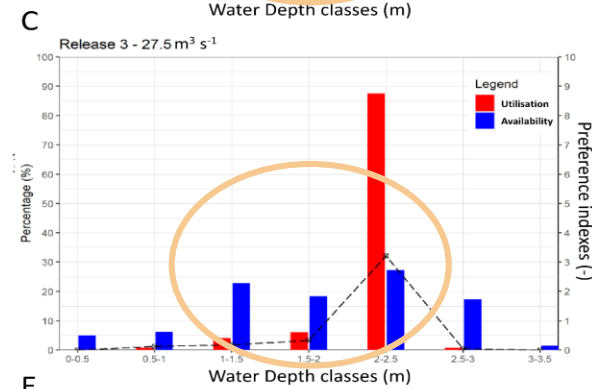
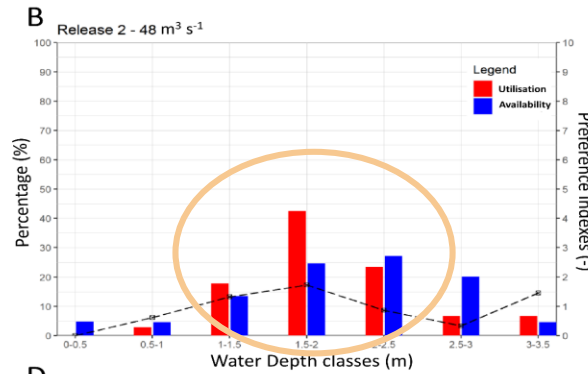
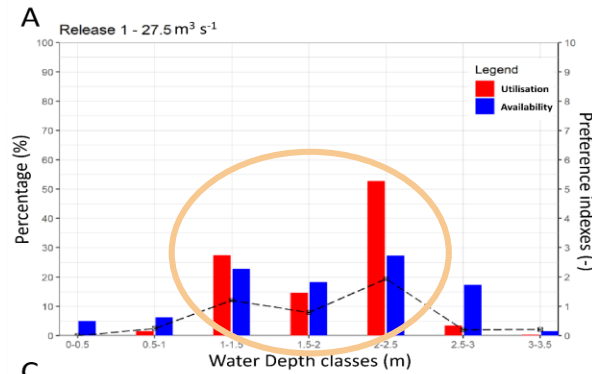
The influence of flow velocities

→ Preference for flow velocities between **0.2 and 0.6  $\text{m s}^{-1}$**

# RESULTS – SMOLT BEHAVIOUR VS. HYDRODYNAMIC MODELLING



# RESULTS – SMOLT BEHAVIOUR VS. HYDRODYNAMIC MODELLING



The influence of water depths

→ Preference for water depths **above 1 m**

→ Water depths **below than 1m** are less approached

## Key points to remember ...

### Discharge

- **Elevated discharges** promote downstream movements and crossing.
- Smolts follow the **main flow** and approach migration routes with the **highest discharge proportion**.

### Flow velocities

- Flow velocities **below than  $0.2 \text{ m s}^{-1}$**  cause smolt disorientation.
- Smolts have preferences for flow velocities **between  $0.2$  and  $0.7 \text{ m s}^{-1}$** .
- Flow velocities **above  $0.20 \text{ m s}^{-1}$**  promote downstream movements.

### Water depths

- Water depths **above  $1 \text{ m}$**  seem to be more attractive for the smolts.

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Trying to choose the less bad route: Individual migratory behaviour of Atlantic salmon smolts (*Salmo salar* L.) approaching a bifurcation between a hydropower station and a navigation canal

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Article

**Assessment of the Attractiveness and Passage Efficiency of Different Fish Passage Solutions at a Hydropower Plant by Combining Fine Scale 2D-Telemetry and Hydraulic Numerical Modelling**

Séverine Renardy<sup>1,\*</sup>, Utashi D. Ciraane<sup>2</sup>, Jean-Philippe Benitez<sup>1</sup>, Arnaud Dierckx<sup>1</sup>, Justine Gelder<sup>1</sup>, Ana T. Silva<sup>3</sup>, Pierre Archambeau<sup>2</sup>, Benjamin Dewals<sup>2</sup>, Michel Piroton<sup>2</sup>, Sébastien Erpicum<sup>2</sup> and Michaël Ovidio<sup>1</sup>

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PRIMARY RESEARCH PAPER

**Combining fine-scale telemetry and hydraulic numerical modelling to understand the behavioural tactics and the migration route choice of smolts at a complex hydropower plant**

Séverine Renardy<sup>b</sup> · Utashi D. Ciraane<sup>b</sup> · Jean-Philippe Benitez<sup>b</sup> · Arnaud Dierckx · Pierre Archambeau<sup>b</sup> · Michel Piroton<sup>b</sup> · Sébastien Erpicum<sup>b</sup> · Michaël Ovidio<sup>b</sup>

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PRIMARY RESEARCH PAPER

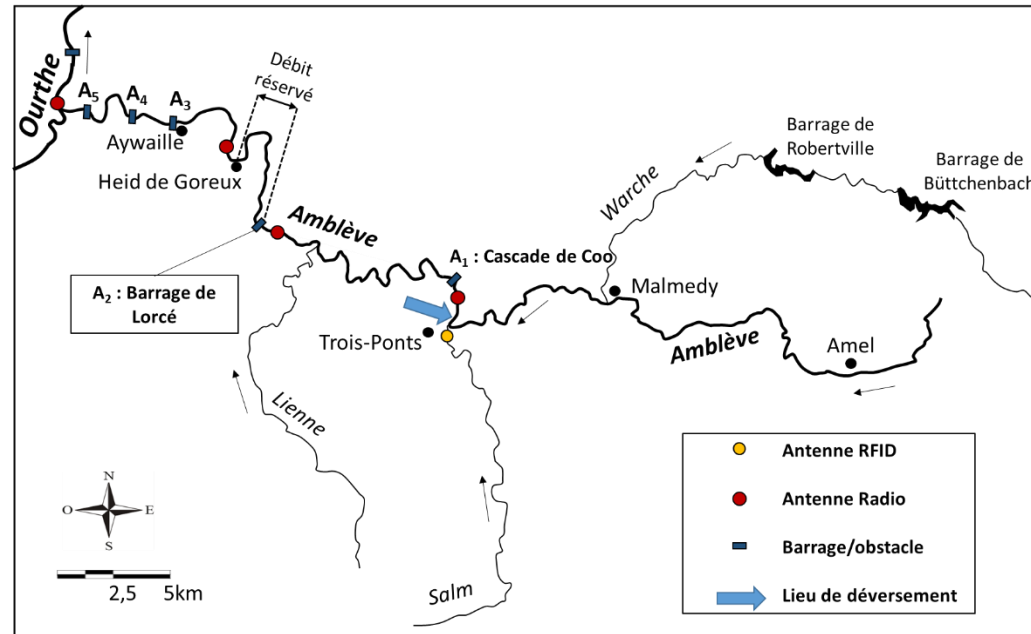
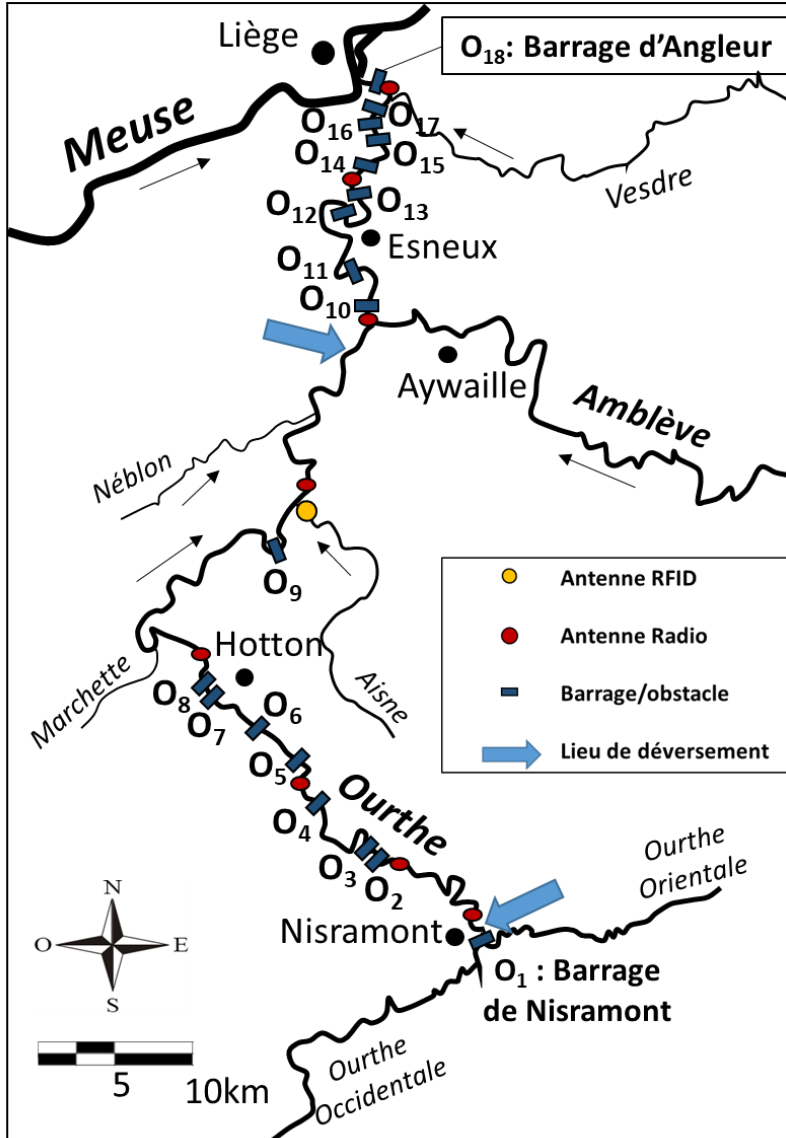
**How and where to pass? Atlantic salmon smolt's behaviour at a hydropower station offering multiple migration routes**

Séverine Renardy · Jean-Philippe Benitez · Amandine Tauzin · Arnaud Dierckx · Billy Nzau Matondo · Michaël Ovidio

# PERSPECTIVE - downstream migration along the entire stretch of the Ourthe river



FEAMPA : Downstream migration of smolt



**Radio telemetry**

**135km of river**

**2025-2026-2027**

**N= 270 individuals**  
(N=90 per year)  
(N=30 per site)

**N= 11 receivers**



Thank you for your attention

