Webinar series “Restoring river continuity : methods and open challenges”

Monitoring and evaluating fish connectivity : novel methods and experiences

This webinar series was supported by the European Commission through LIFE NGO funding

Yann Abdallah – 22/01/2018

“ Habitat fragmentation has been recognized for 30 years as one of the five major factors of biodiversity loss, along with pollution, overexploitation of natural resources, invasive species and climate change ”

Why are fish moving ?

Fish are constantly moving to accomplish their various **vital functions**

Ensure their survival
(predators, competitors, environmental constraints)

To reproduce
(sustainability of species)

Eat
(growth, sexual maturity)

Move needs change during life history **(larva, fry, juvenile, adult)**

Why are fish moving ?

Variability of move needs at **varying time scales**

During the same **day**

During an **annual** cycle of life

Variability of move needs at scales of **varying distances**

A few centimeters

Thousand kilometers

Why are fish moving ?

And variability in **3 dimensions**

Longitudinally
(upstream/downstream)

Vertically
(case of lakes and large rivers)

Laterally
(main channel to tributaries or hydraulic annexes)

Why are fish moving ?

We identify **active moves** that require **energy consumption**

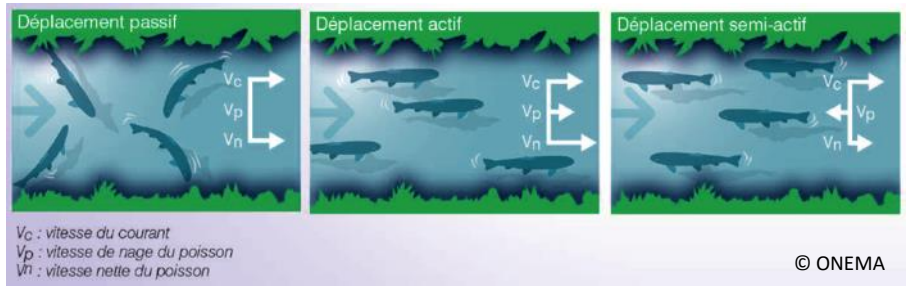
and **passive moves** that consist of **transport by the moving environment**

Major categories of movement in fish

Why are fish moving ?

PASSIVE MOVES : transport, drift, dispersion

Forced transport downstream of part of the population (floods)

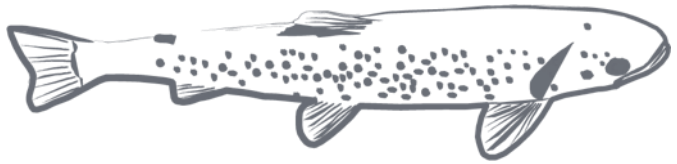


Passive moves(by drift) between the **spawning / emergence zone** and the first **growth habitats** (larvae, fry)

Why are fish moving ?

ACTIVE MOVES

Periodic movements (daily)



Very different **physical habitats**

Why are fish moving ?

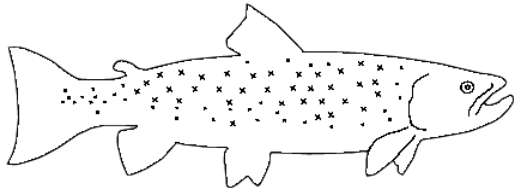
ACTIVE MOVES

Ontogenetic movements

Larva

Fry

Juvenile



Adult

Evolution of nutritional needs, dietary behavior and ecological / physiological / biological requirements during life

Habitat changes

Relation “height of water column / size of fish” in the same species

Why are fish moving ?

ACTIVE MOVES

Migrations

“Movements between two functional habitats occurring regularly during the life of the individual and affecting a large part of the population.” **Northcote, 1979**

Synchronous and **seasonal** movements

Distances

Single reproductive migration for semeleparous

Double trajectories for iteroparous

Gregarious mass movements

Why talk about fish continuity problems?

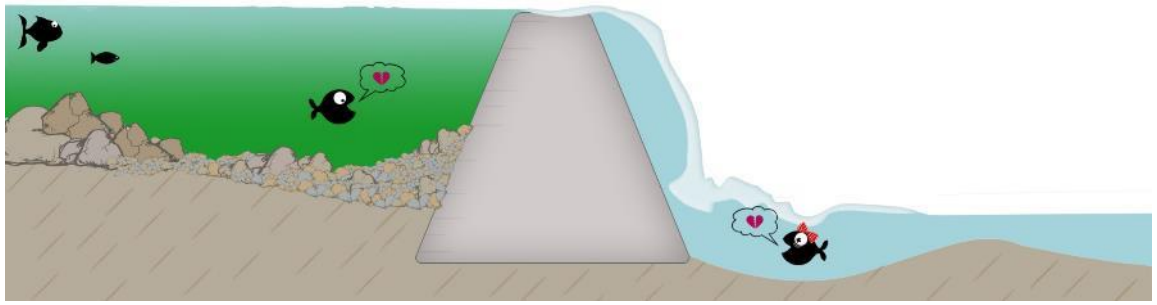
A picture is better than a long speech, so…

about **70 000 dams** identified in France

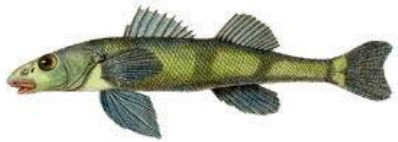
Thousands of kilometers of **recalibrated** rivers

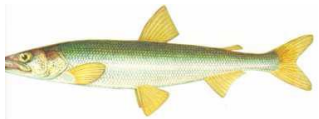
Why talk about fish continuity problems?

And the result is…



many **vulnerable species** even in **danger of extinction**





Solutions ?

Dam removal

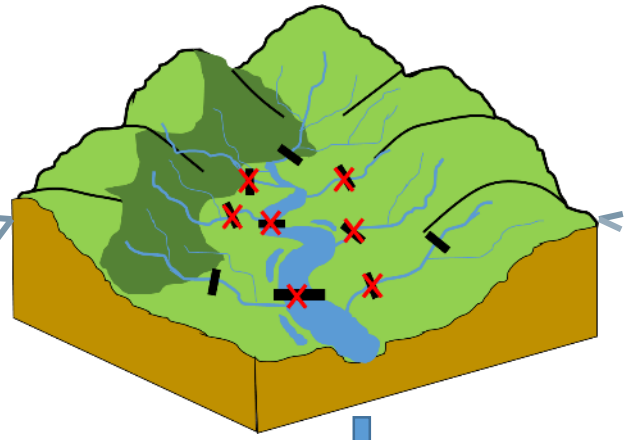
Fish passages

In all cases, these interventions require the **acquisition of knowledge**, whether before, at the **diagnostic stage**, or after, at the **evaluation stage**

Why evaluate fish connectivity ?

Check the level of achievement objectives

Advancing « art » thanks to background



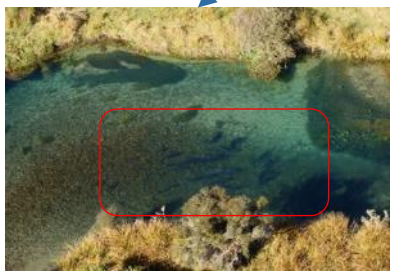
Inform and sensitize local actors, elected officials and public

Generate objective knowledge to guide policy and decision-making

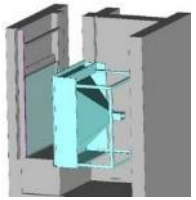
Needs of concrete elements measurable *in situ*

What tools to evaluate fish connectivity ?

Fisheries



Observations



Underwater video-counting systems

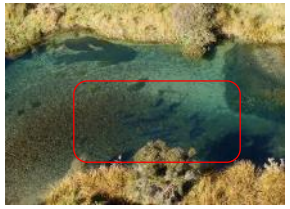
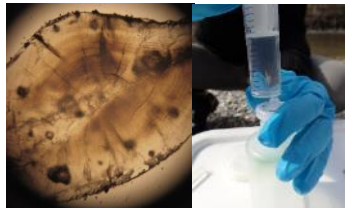
Active telemetry
Radio/Acoustic

Genetic markers

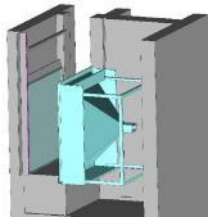
Trapping

Passive telemetry
RFID

What tools to evaluate fish connectivity ?





Spatial scale

type of project

Technical skills

Type of dam

Time scale

Species
Biological stage

Budget

Type of environnement

Stage of the project

Which tool for which information ?

What tools to evaluate fish connectivity ?

Some good truths to remember ;-)

« The greater the migratory determinism, the more the dam is impassable and the easier it is to highlight the biological gains »

↕

… in some cases, the gains are difficult to highlight

Importance of having **robust initial assessment**

Choose the **right spatial scale** *: watershed, subbasin, river, dam*

Choose the **right biological scale** : *species, population, stock, individual*

Favor **multi-year** approach to smooth **defragmentation effects**, **natural variations of populations** and **hydroclimatic extremes**

What tools to evaluate fish connectivity ?

VIDEO-COUNTING SYSTEMS

Lateral underground viewing room

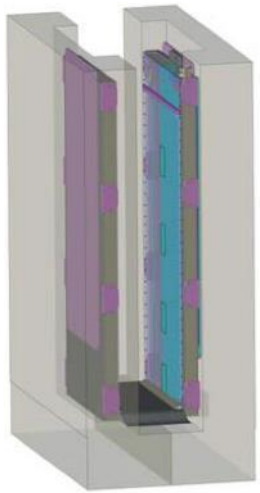
Qualitative or quantitative approach
Reliability proven by 20 years of use
Optimal solution to study migration needs for many species
Good communication / sensibilisation tool

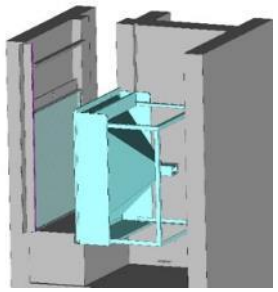
Principal tool limit = turbidity
Hydraulic constraints + civil engeneering
Maintenance (windows, backlighting)
Cost of installation
Cost of the counting
Tool with little evolution over time
Reserved for strong issues and big fishways

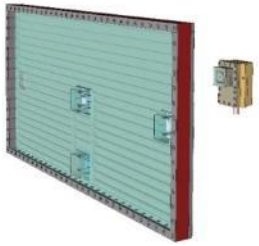
What tools to evaluate fish connectivity ?

VIDEO-COUNTING SYSTEMS

Removable systems



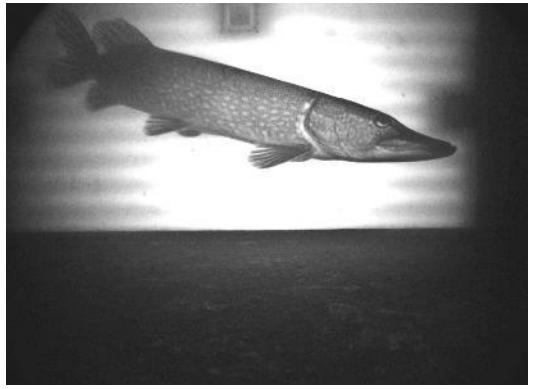


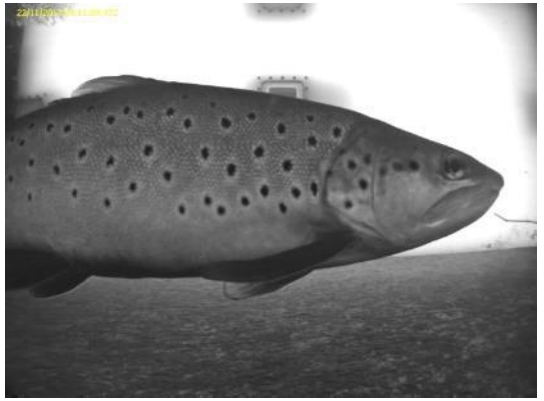


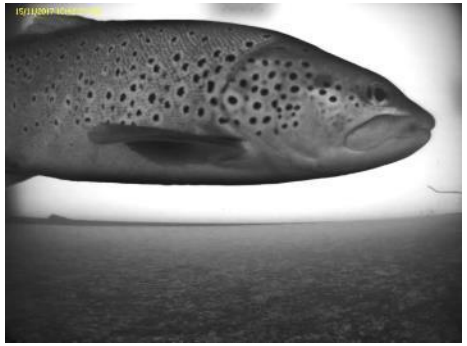
What tools to evaluate fish connectivity ?

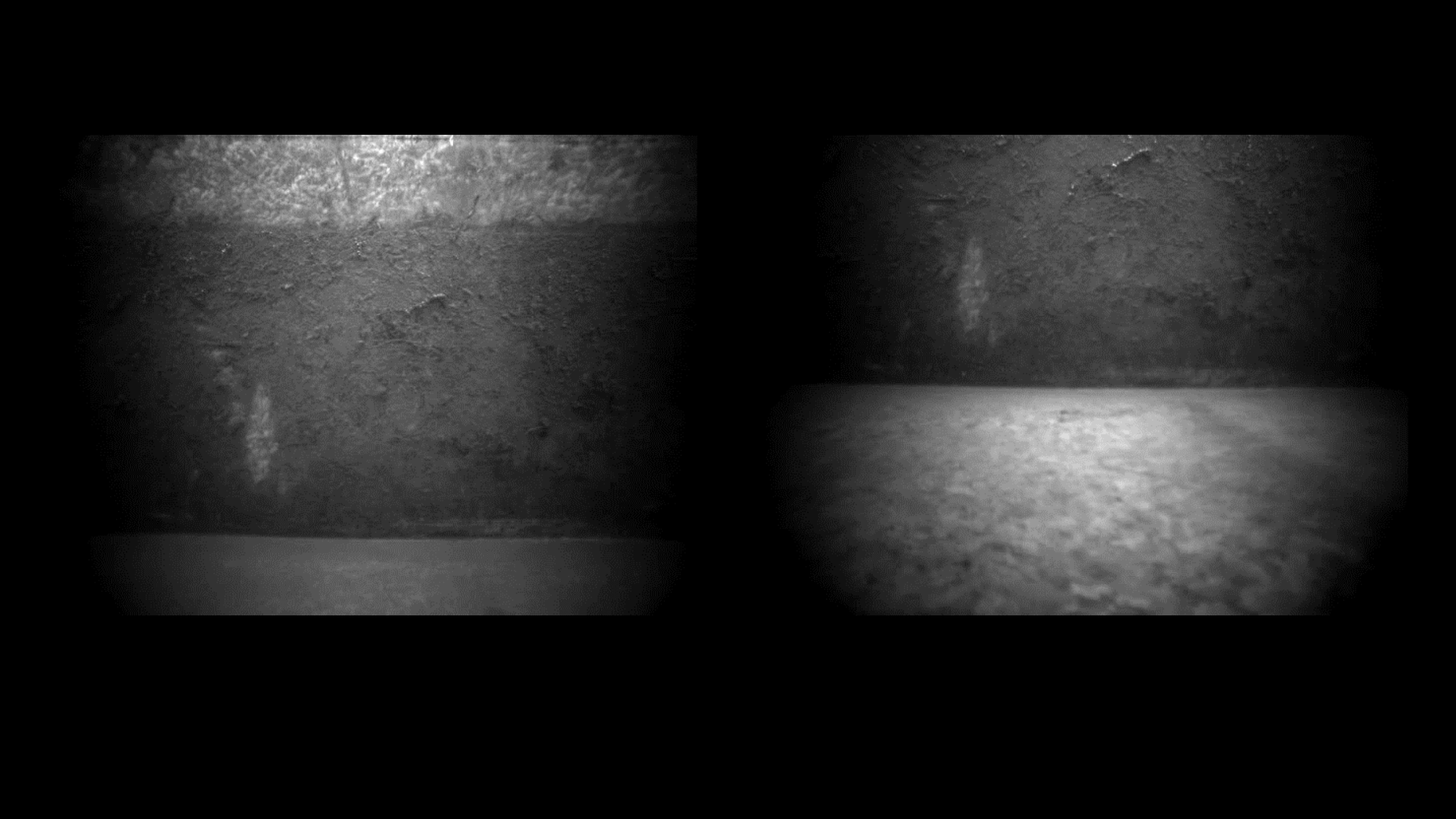
VIDEO-COUNTING SYSTEMS

Removable systems









What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

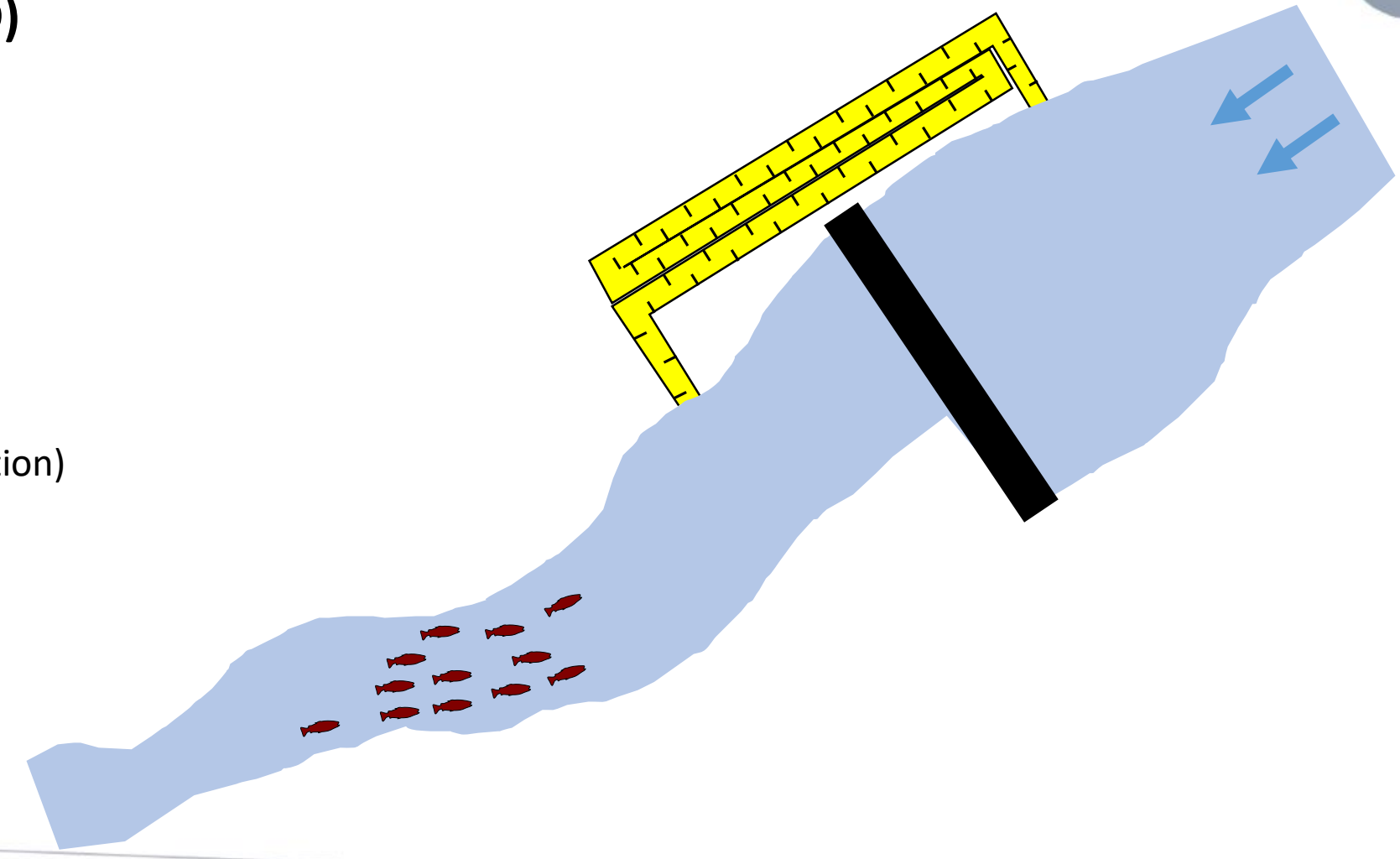
A robust tool for controlling the efficiency of fish passages

Efficiency = Number of individuals of a species that manage to cross the fishway versus the number of individuals who "try" to cross it (Bunt *et al.*, 2012)

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

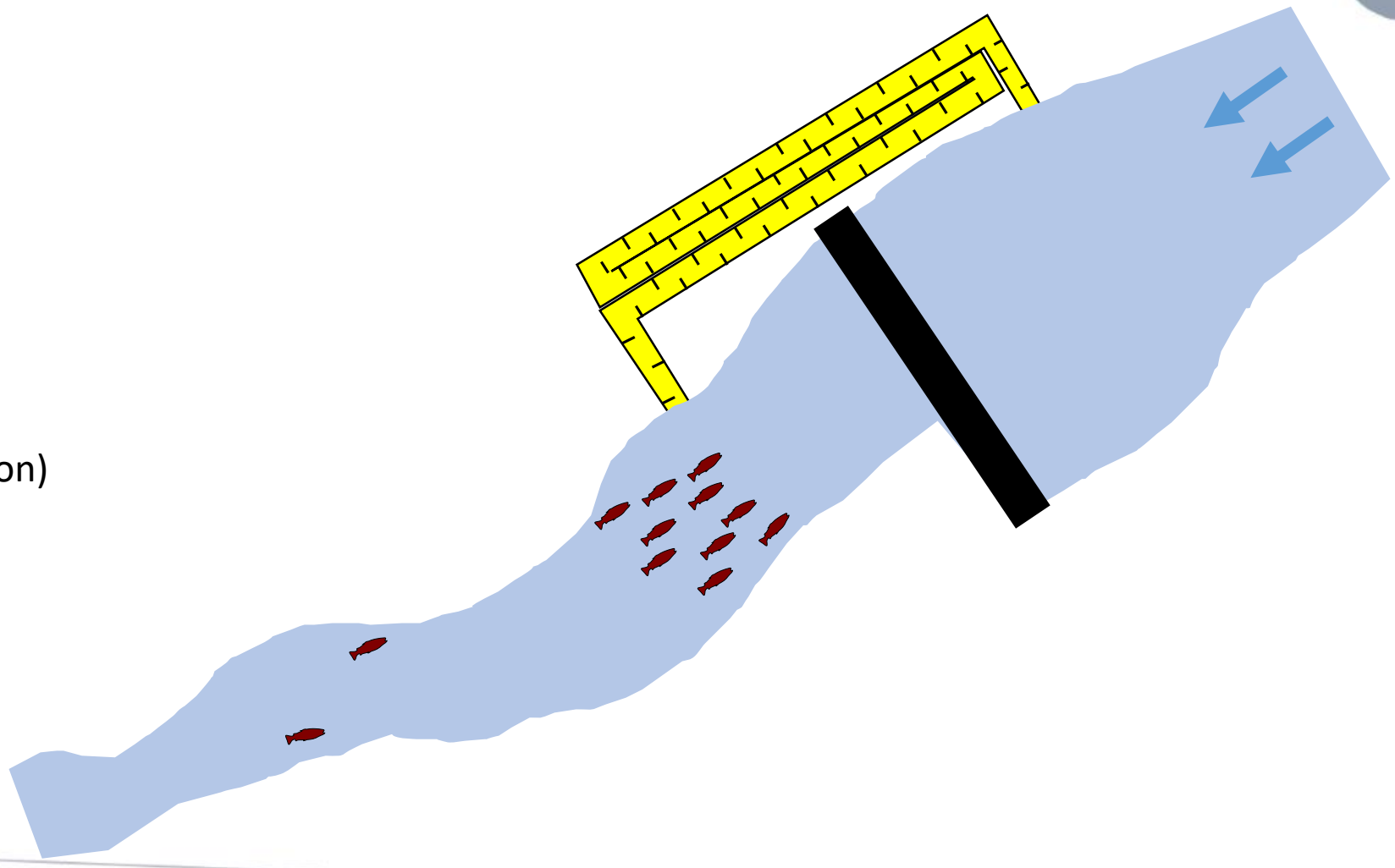
Exemple:
n = 12 fish (theoretical population)



What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

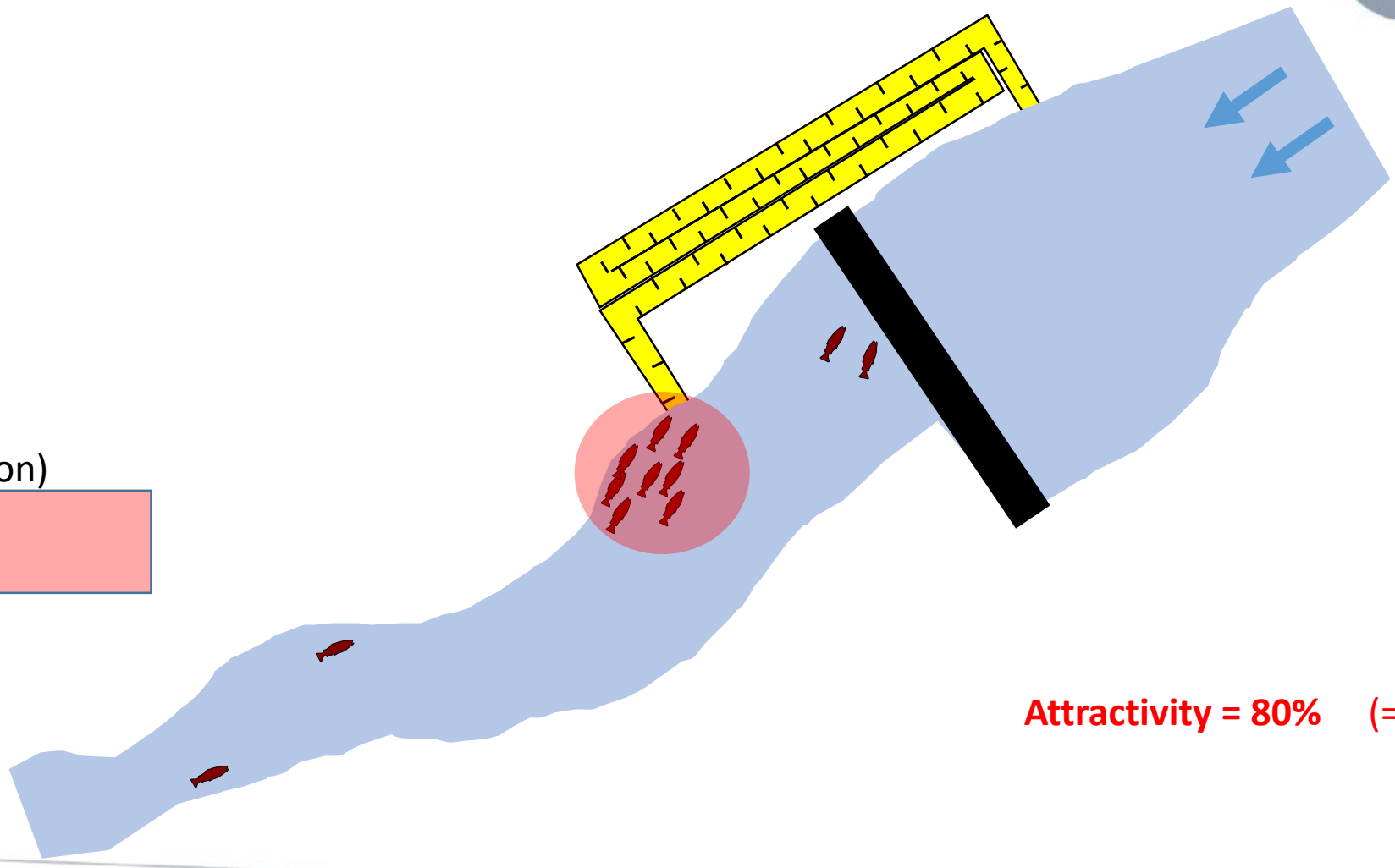
Exemple:
n = 12 fish (theoretical population)
n = 10 fish moving upstream



What tools to evaluate fish connectivity ?

Exemple:
n = 12 fish (theoretical population)

n = 10 fish moving upstream
n = 8 fish find the entrance

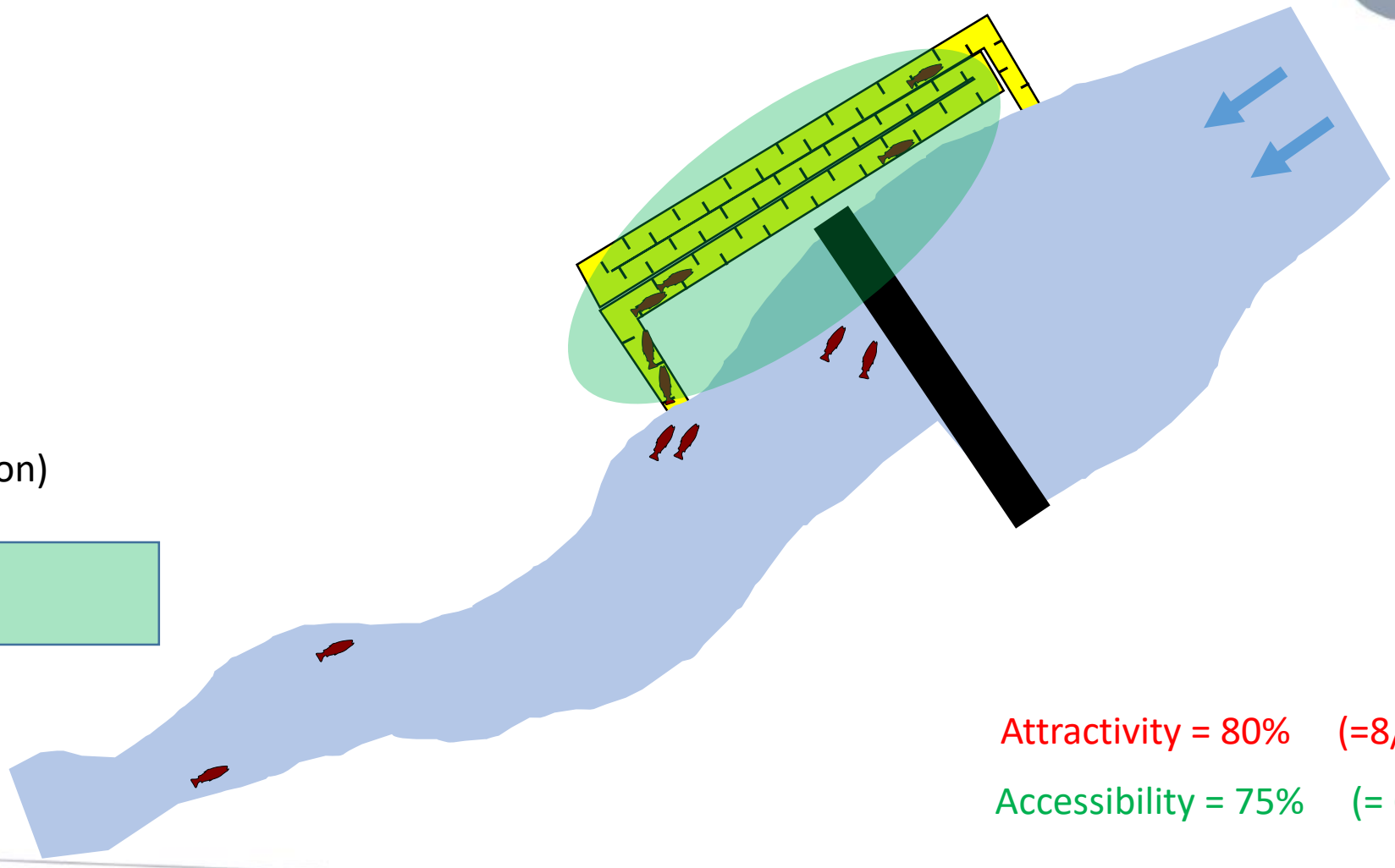


Attractivity = 80% (=8/10)

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

Exemple:
n = 12 fish (theoretical population)
n = 10 fish moving upstream
n = 8 fish find the entrance
n = 6 fish enter



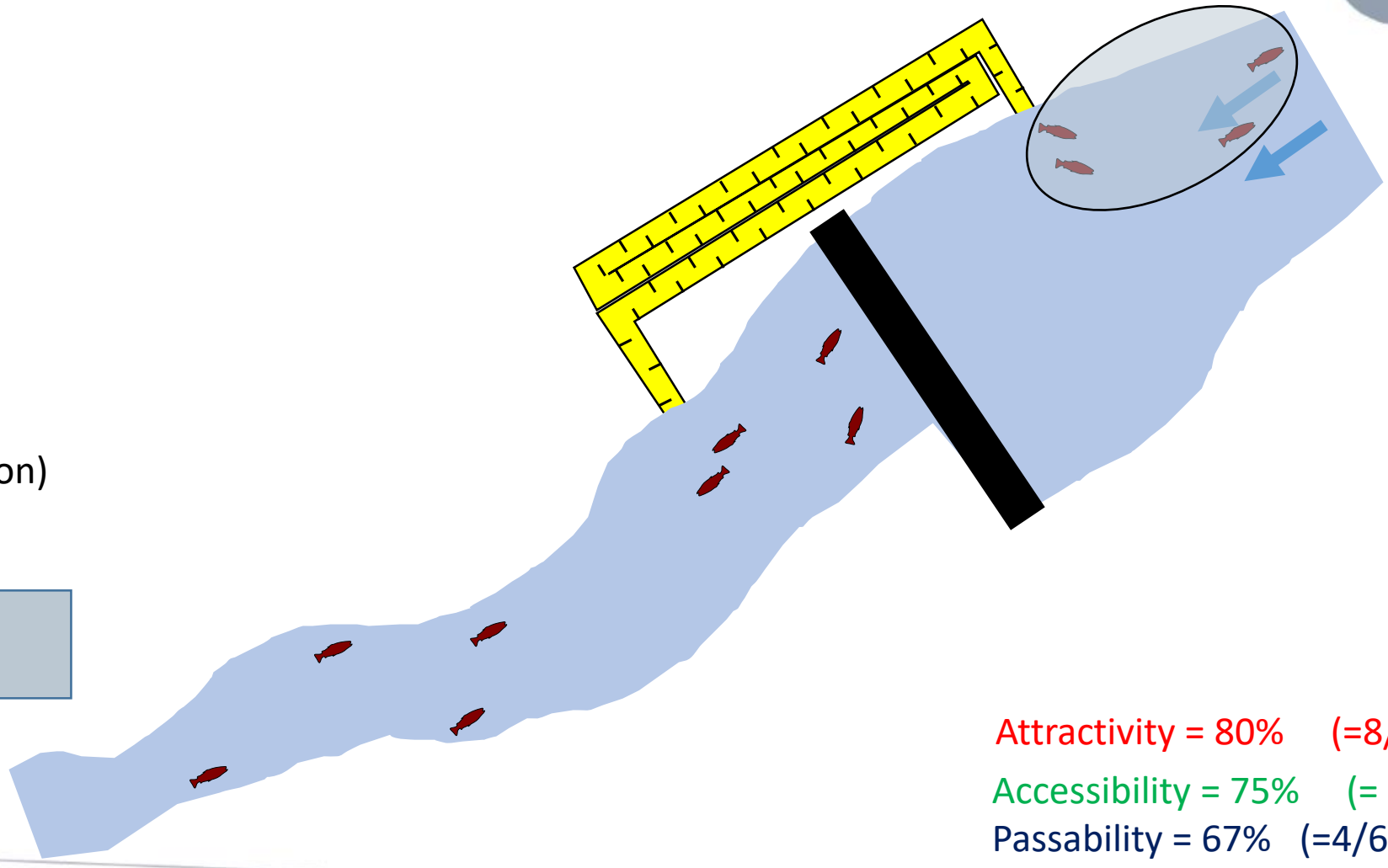
Attractivity = 80% (=8/10)

Accessibility = 75% (= 6/8)

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

Exemple:
n = 12 fish (theoretical population)
n = 10 fish moving upstream
n = 8 fish find the entrance
n = 6 fish enter
n = 4 fish come out !

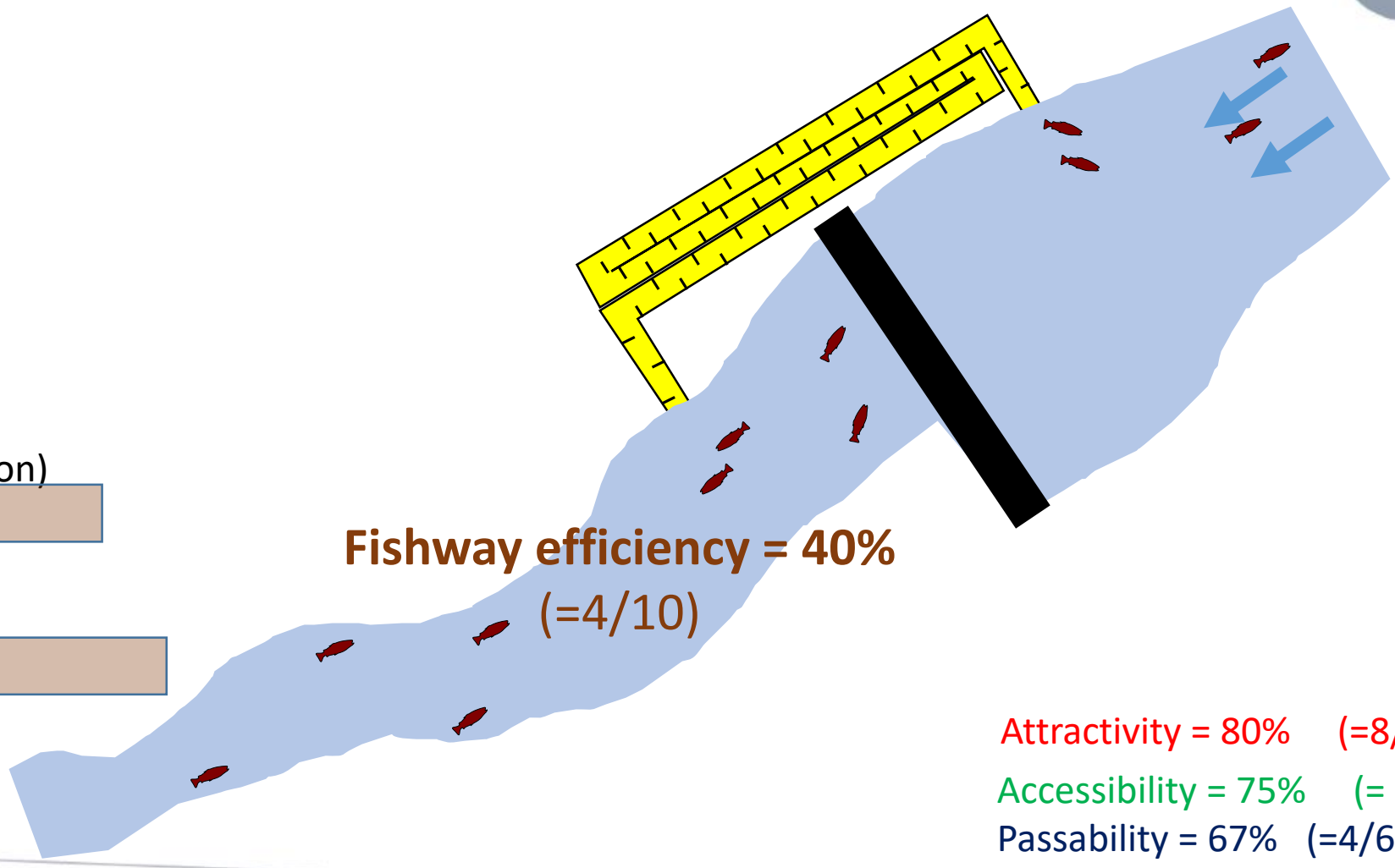


Attractivity = 80% (=8/10)
Accessibility = 75% (= 6/8)
Passability = 67% (=4/6)

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

Exemple:
n = 12 fish (theoretical population)
n = 10 fish moving upstream
n = 8 fish find the entrance
n = 6 fish enter
n = 4 fish come out !



Fishway efficiency = 40%
(=4/10)

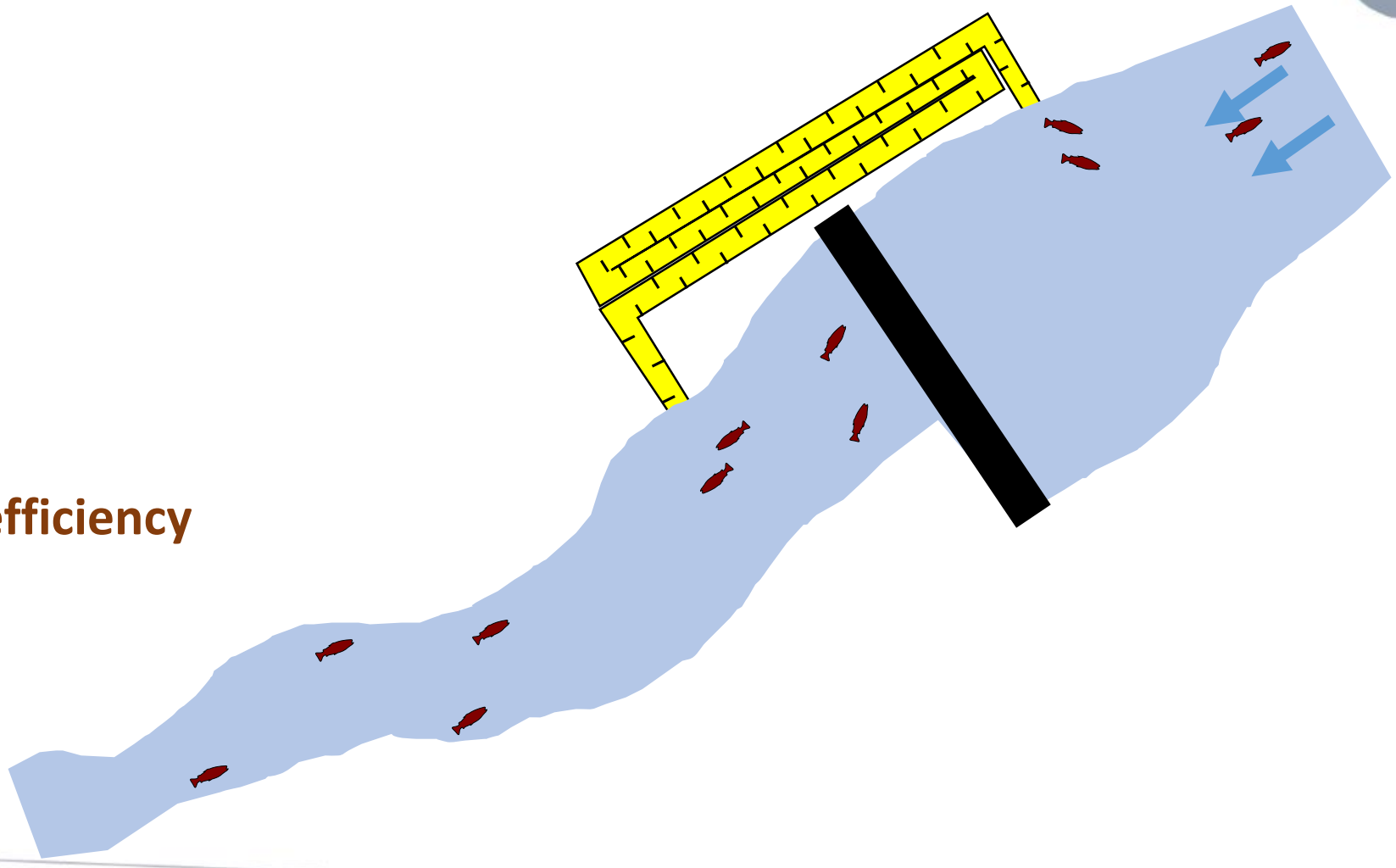
Attractivity = 80% (=8/10)
Accessibility = 75% (= 6/8)
Passability = 67% (=4/6)

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

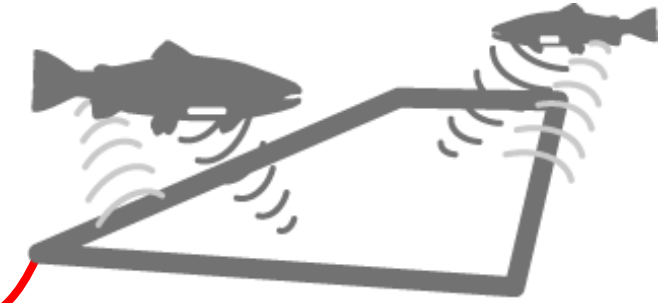
Attractivity
Accessibility
Passability

Fishway efficiency



What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)



Passive mark (responds to an **electromagnetic** field)

- transponder lifetime = life time of the fish!
- weakly invasive = allows to mark fish of 5 cm
- a transponder = an alphanumeric code
- very accessible cost = between 2 and 3 € / transponder
- simple and rapid tagging (internal in peritoneal cavity)

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

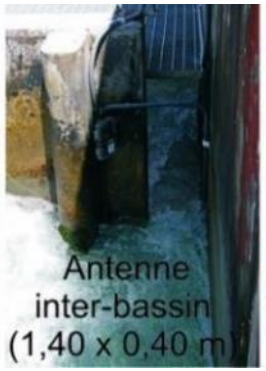
Diffusion of the electromagnetic field from fixed or portable (copper) antennas. High possibilities of adaptation to the sites

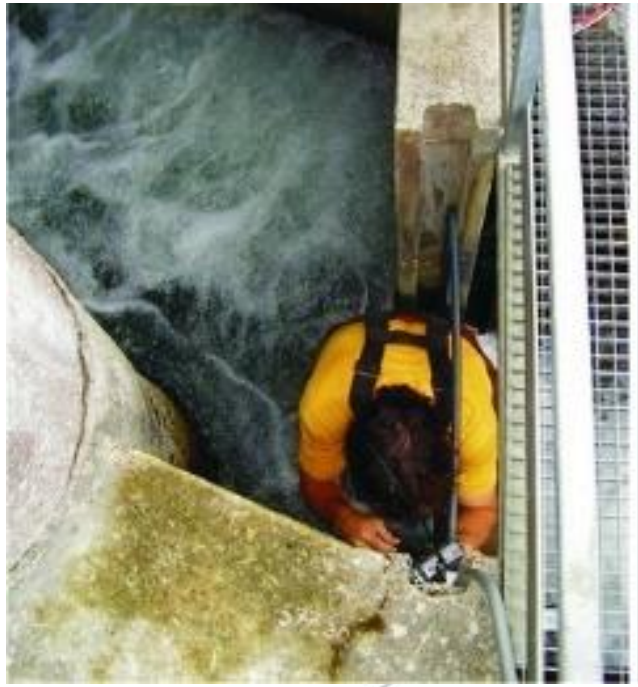
Variable detection distances (10 cm to 1 m) depending on:

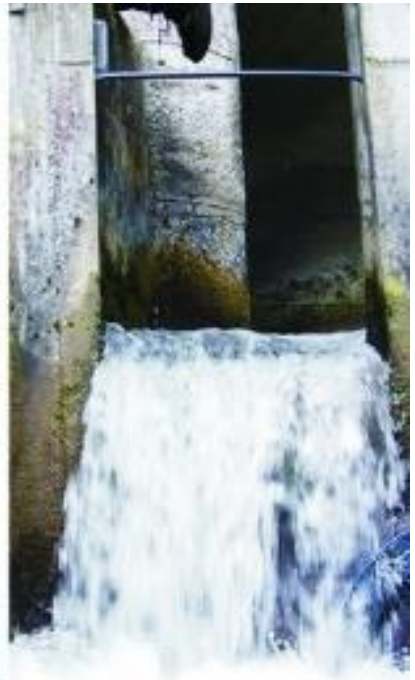
- transponder size
- antennas (thickness, laying technique)
- environment (conductivity)

Data recorded *in situ* but possibility of remote transfer (GSM modem)

Antenna design within fish passages



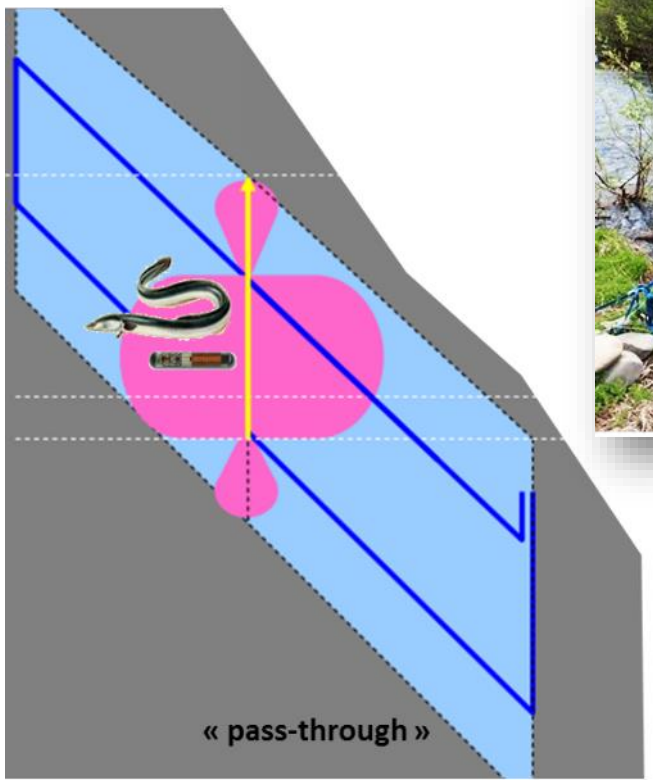




What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

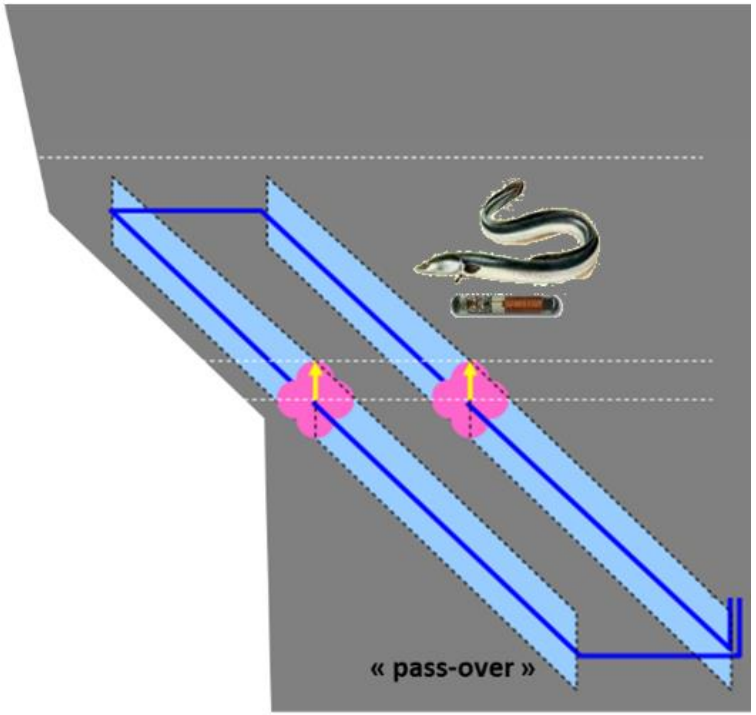
Antenna design for rivers



What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

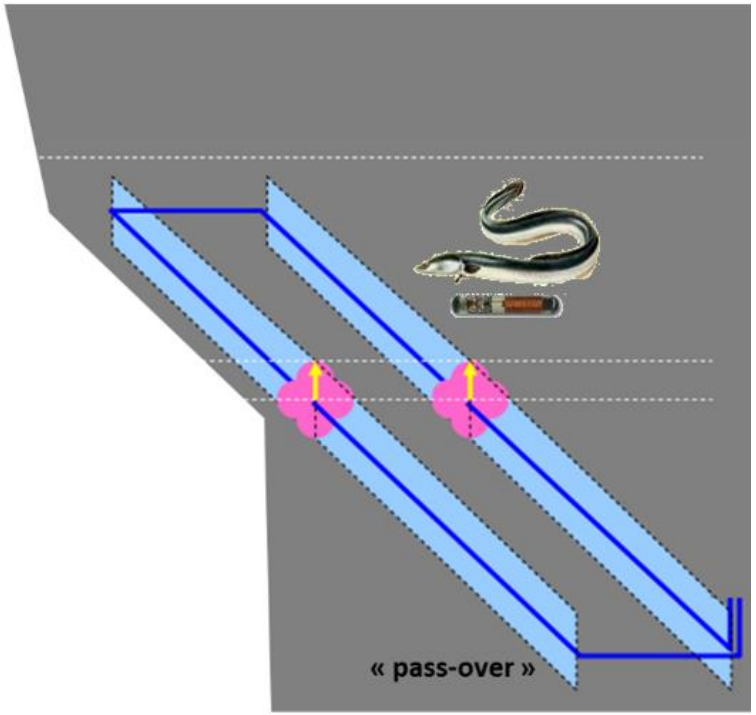
Antenna design for rivers



What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

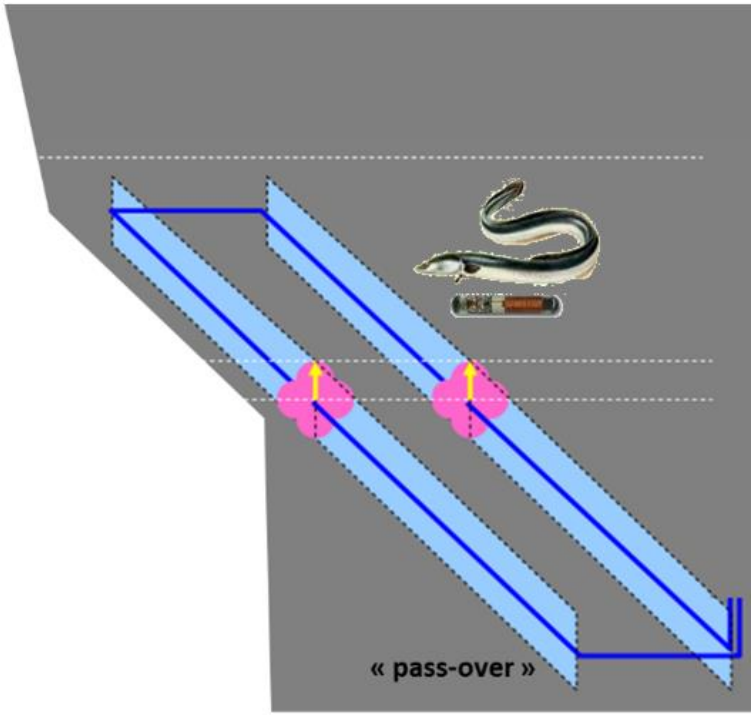
Antenna design for rivers



What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

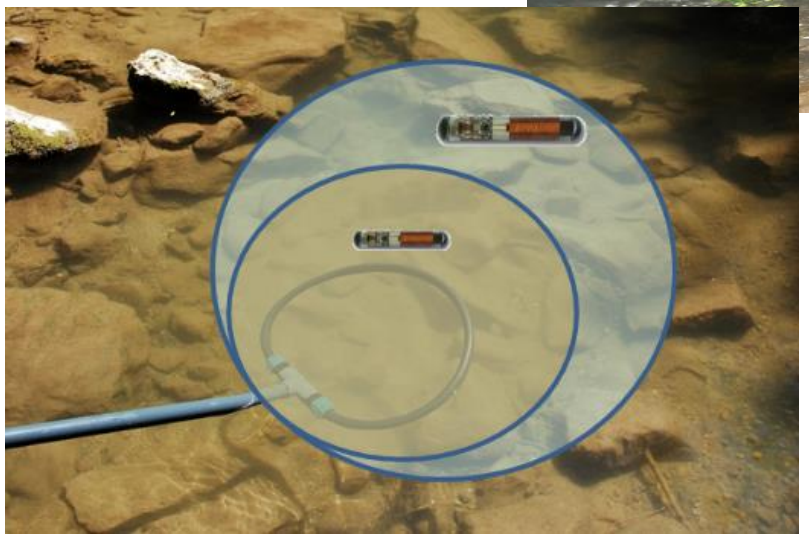
Antenna design for rivers



What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

Mobile antenna



What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

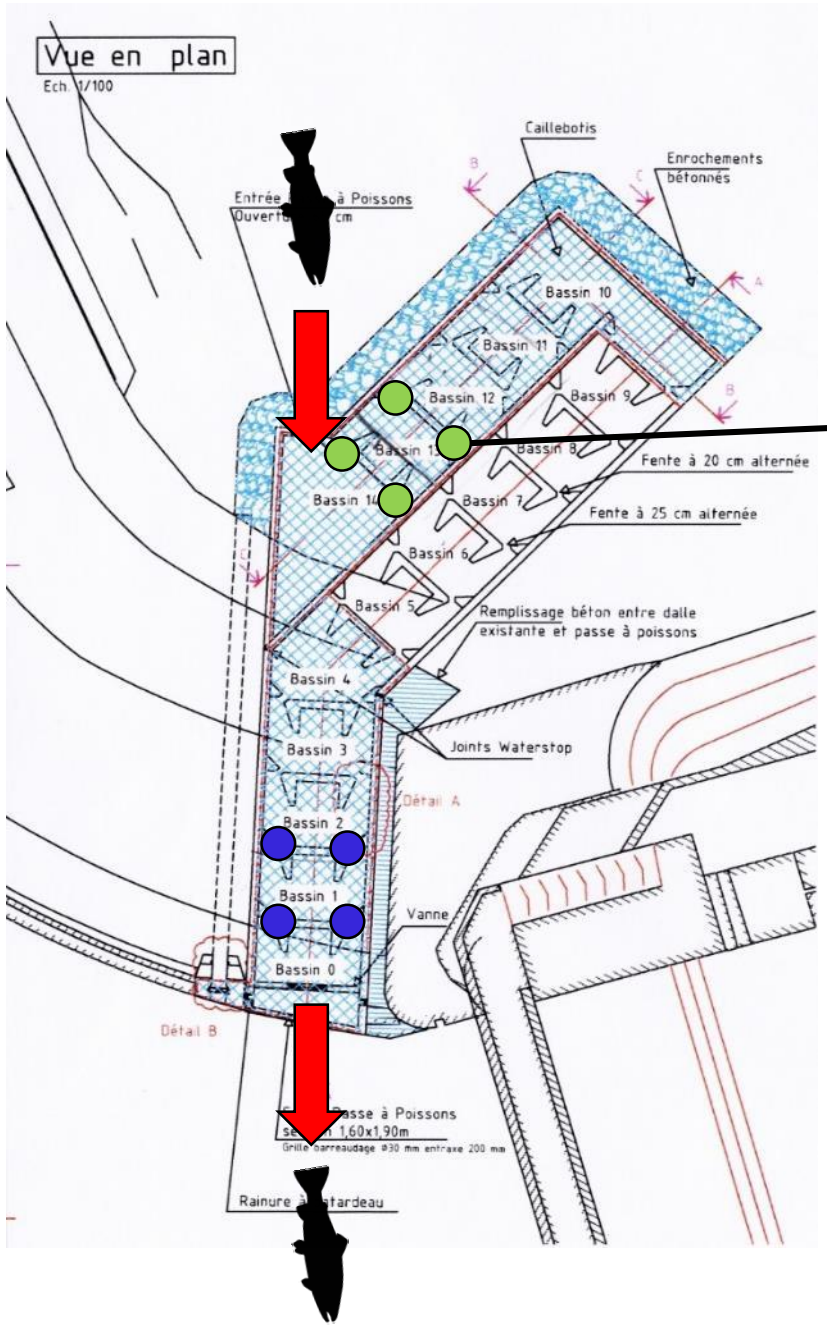
Mobile antenna

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

Evaluation of the passability of the "Saut du Moine" fishpass on the Drac river (Isère basin)

Pools fishpass (15 pools)
4 slots / pool (2 upstream / 2 downstream)
Species : trout, sculpin, barbel



RFID system with 8 antenna :

- 4 antenna at fishpass entrance
- 4 antenna at fishpass exit

1 « marker tag » (test tag) per antenna

Fine reading of behaviors

Evaluation of the probabilities of non-detection

A lot of data generated !

What tools to evaluate fish connectivity ?

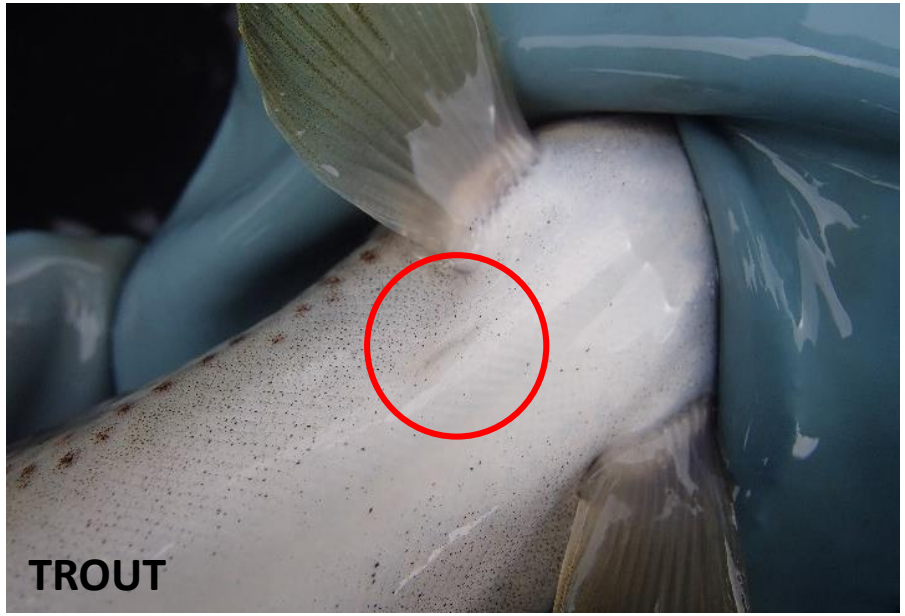
PASSIVE TELEMETRY (RFID)

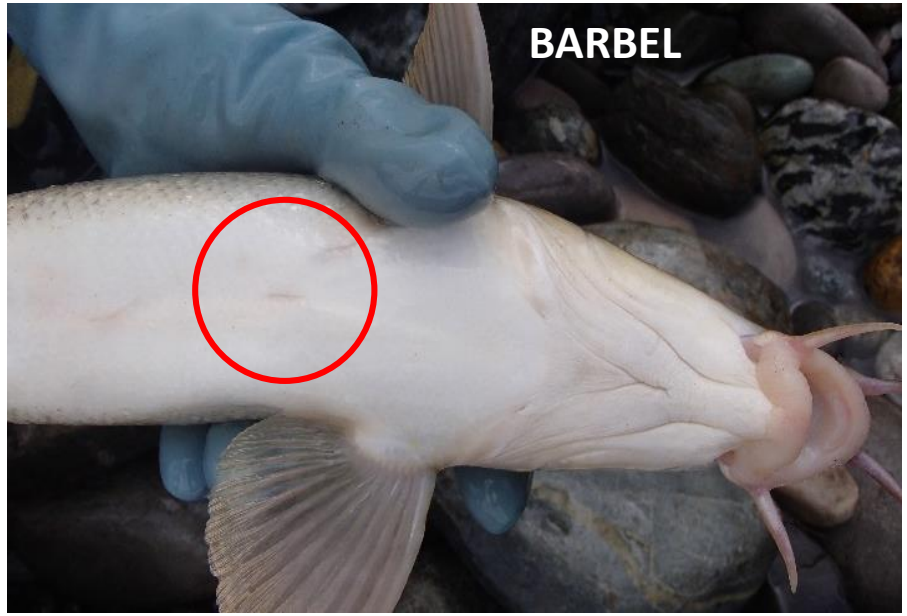
Evaluation of the passability of the “Saut du Moine” fishpass on the Drac river (Isère basin)

FISH TAGGING – *5 electric fishing*

12 and 23 mm

HEALING





What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

Evaluation of the passability of the "Saut du Moine" fishpass on the Drac river (Isère basin)

FISH TAGGING – *5 electric fishing*

634 fish tagged
Mostly **trout** and **barbel**
24% of fish tagged **< 10 cm**

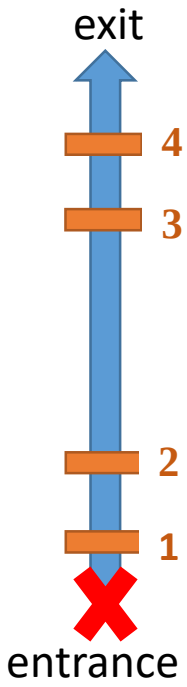
Tagging date	BAF	BLN	CHA	CHE	TRF	Total général
14/05/2014	5	20	24	15	36	100
24/06/2014	10	2	21	3	25	61
29/09/2014	22	21	10	5	52	110
30/04/2015	19	9	29		65	122
03/08/2015	53	7	8	8	165	241
Total général	**109**	**59**	**92**	**31**	**343**	**634**
	17%	**9%**	**14%**	**6%**	**54%**	

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

RESULTS – *Fish tagged behavior patterns*

Evaluated from group of 2 antenna
Each group of 2 antenna = 1 passibility level

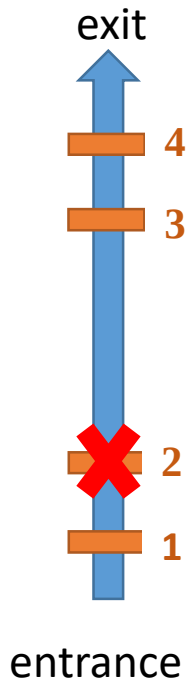


Group	Criterion	Potential behavior pattern	Trout	Barbel
Group 1 :	Fish tagged but never detected in the fish pass	- Non migrant - Dead - Did not find the fishpass entrance	76%	56%

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

RESULTS – *Fish tagged behavior patterns*

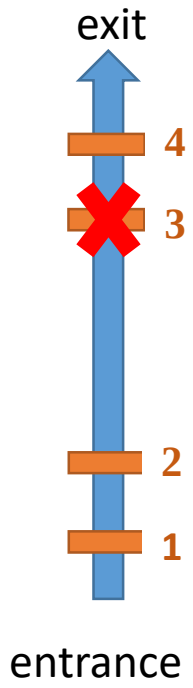


Group	Criterion	Potential behavior pattern	Trout	Barbel
Group 1 :	Fish tagged but never detected in the fish pass	- Non migrant - Dead - Did not find the fishpass entrance	76%	56%
Group 2 :	Fish detected in the fishpass, without exceeding level n°2	- Non migrant (exploratory movements just before the entrance)	4%	5%

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

RESULTS – *Fish tagged behavior patterns*



Group	Criterion	Potential behavior pattern	Trout	Barbel
Group 1 :	Fish tagged but never detected in the fish pass	- Non migrant - Dead - Did not find the fishpass entrance	76%	56%
Group 2 :	Fish detected in the fishpass, without exceeding level n°2	- Non migrant (exploratory movements just before the entrance)	4%	5%
Group 3 :	Fish detected in the fishpass, without exceeding level n°3	- Non migrant (exploratory movements just before the entrance) - Migrant having failed to cross the fishpass	4%	5%

What tools to evaluate fish connectivity ?

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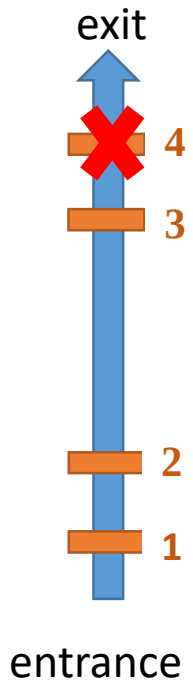

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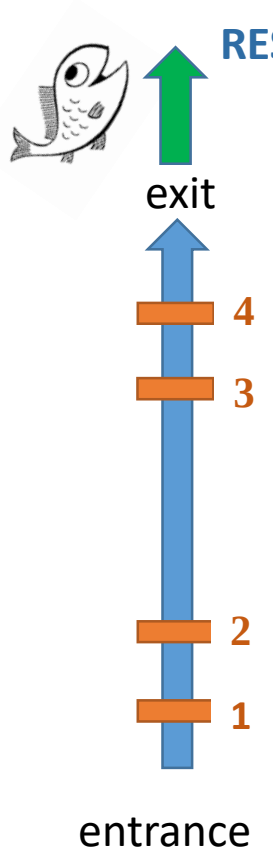
Group 4 :	Fish detected at level 4 but stayed in the fishpass	- fish stuck upstream for behavioral or physical reasons (jams), - Non migrant remaining in the fishpass	0.3%	2%

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)



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Groupe 5 :	**fish having crossed the fishpass one or more times**	- **Migrant** - **risk of involuntary downstream for multiple crossings**	**16%**	**32%**

What tools to evaluate fish connectivity ?

PASSIVE TELEMETRY (RFID)

RESULTS – *Global reports*

Important to **tagged a lot of fish** (see diversity of behaviors)

All the tagged species were detected in the fishpass but very **variable determinism**

Barbel = 56 % non-migrant during the study

Sculpin = 98 % non-migrant during the study

Significant **passability** of fish **entering** the fishpass

Trout = 80% **Barbel** = 83% **Vairone** = 40%

Very short **crossing times** (70% in less than 1 hour)

All size classes represented (+ small = 90 mm trout)

What tools to evaluate fish connectivity ?

GENETIC MARKERS

Characterize the genetic structuring of populations on a microgeographic scale

Evaluate gene flow between populations, in relation to the presence of dams

It is therefore a well adapted tool for:

- Identify **isolated / connected** populations
- Monitor the **effect of restoration actions** on population fragmentation
- Determine the **biological gains** of actions
- Evaluate these gains over the **long term**

What tools to evaluate fish connectivity ?

GENETIC MARKERS

Characterize the genetic structuring of populations on a microgeographic scale

Evaluate gene flow between populations, in relation to the presence of dams

Applies primarily to a **watershed** or **sub-basin scale**

Allows to evaluate several dams **simultaneously**

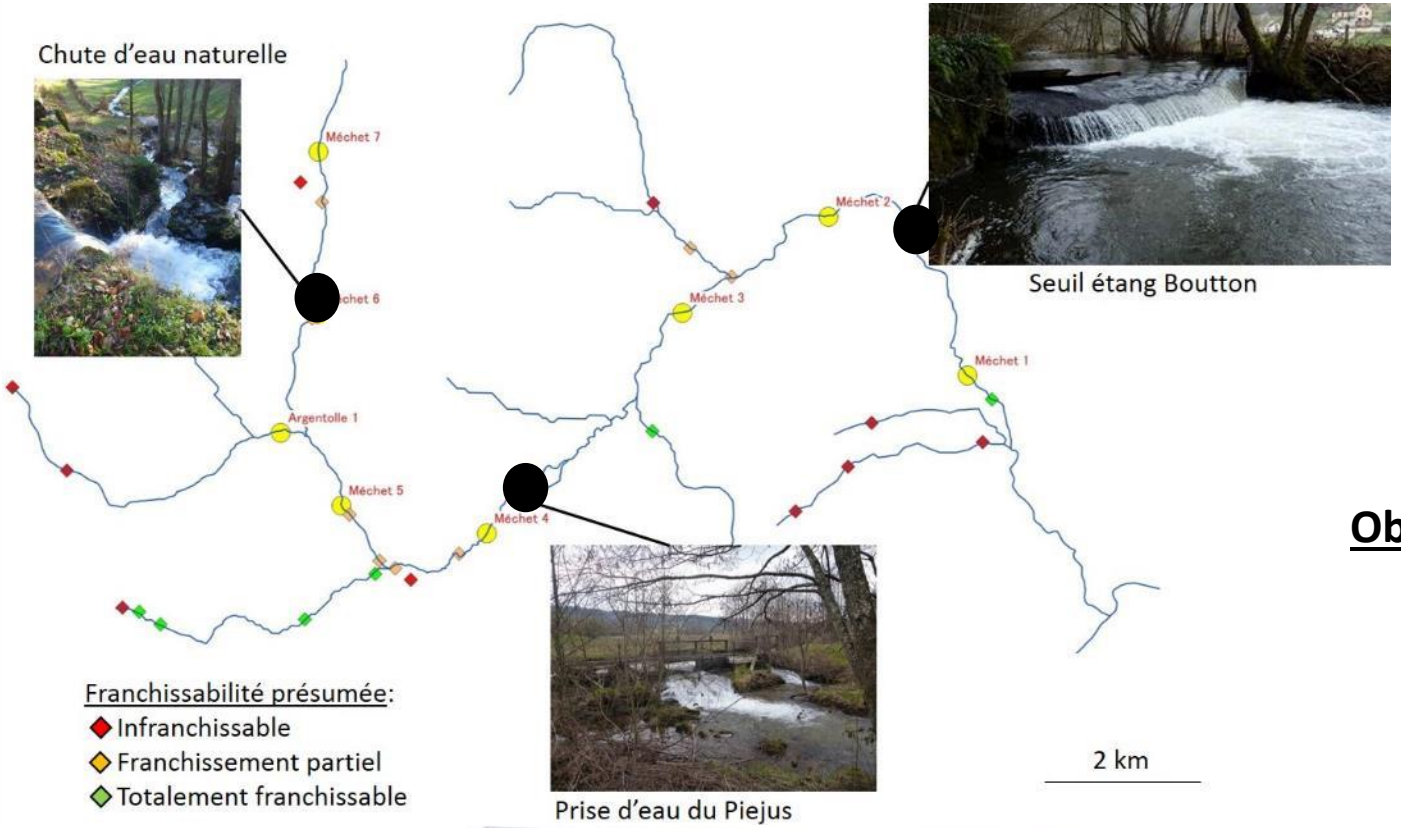
Requires **field investigations** to collect **biological material**

Costs related to genetic analyzes + limited interpretations

What tools to evaluate fish connectivity ?

GENETIC MARKERS

Evaluation of the real effects of the fragmentation of the environment by dams on the genetic functioning of the brown trout populations of Méchet river (Saône-et-Loire)



Context :

Project of defragmentation on the whole river (*cf. EU Water Framework Directive*)

2 dams particullary impacting

1 natural obstacle upstream

Objectifs :

Measure the impact of dams on gene flow

Make an initial assessment before actions

What tools to evaluate fish connectivity ?

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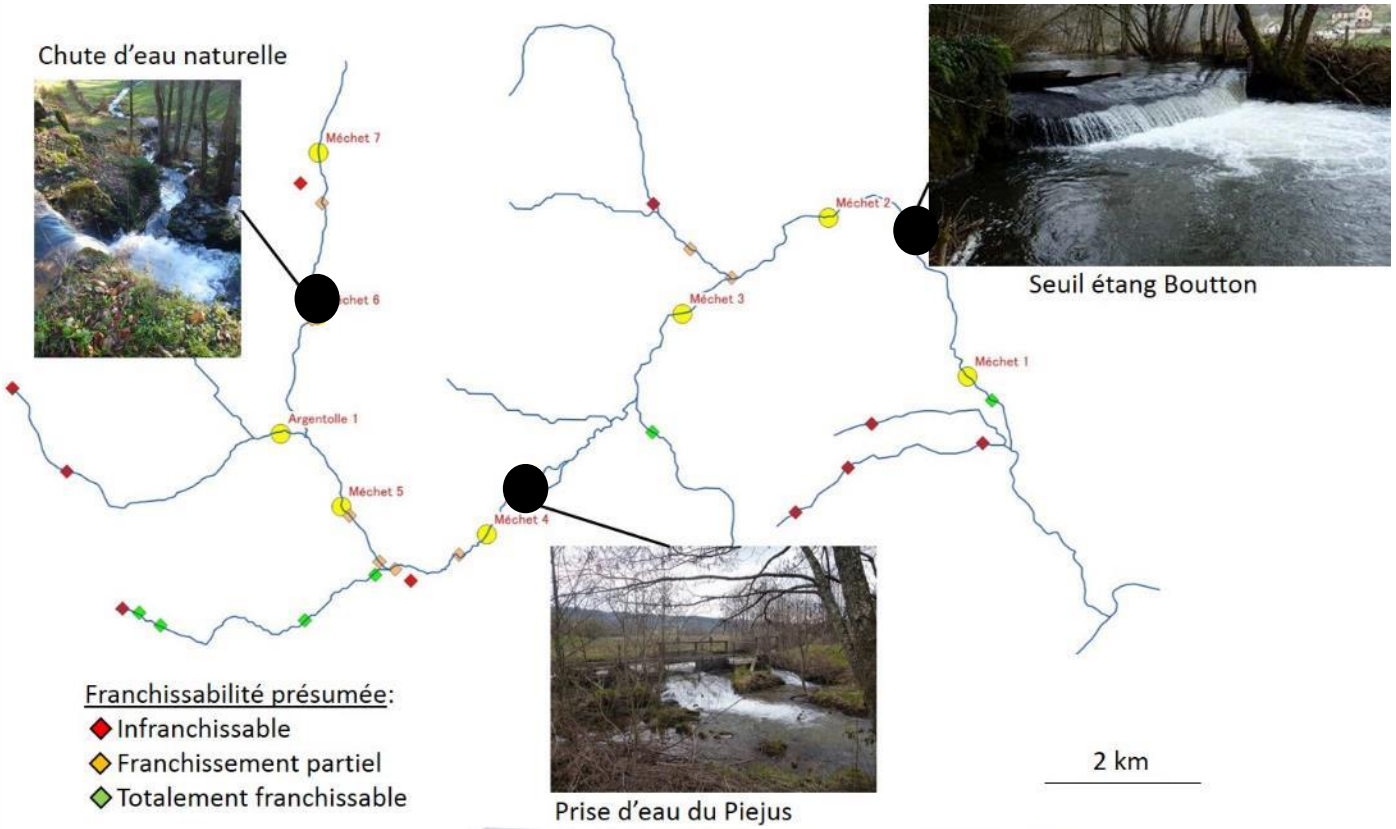

Methodology :

River Méchet divided into **7 sections**
+ 1 tributary section (Argentolle)

22 to 51 trouts sampled per station

Genotyping of each individual at the level of
14 microsatellites

What tools to evaluate fish connectivity ?

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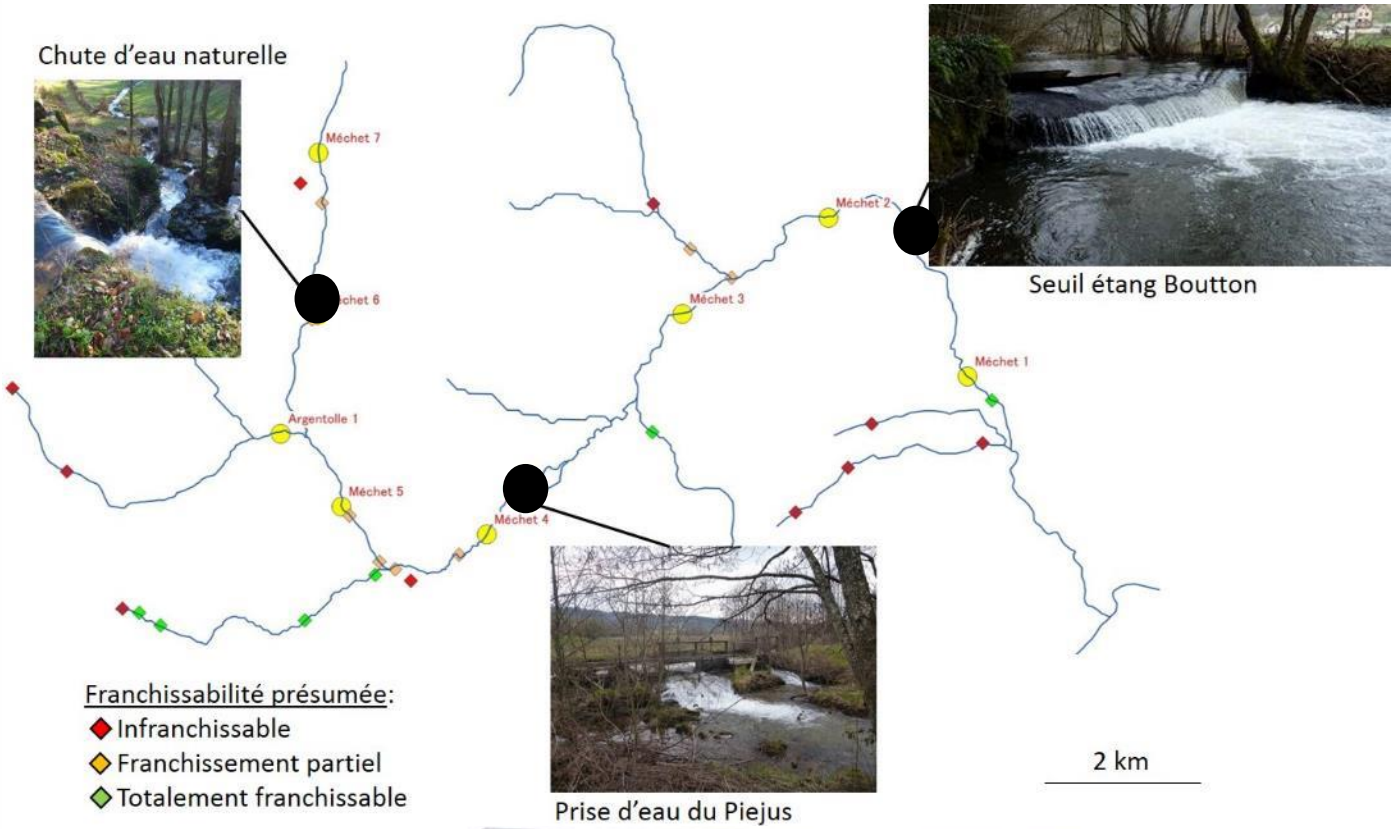

Methodology :

River Méchet divided into **7 sections**
+ 1 tributary section (Argentolle)

22 to 51 trouts sampled per station

Genotyping of each individual at the level of **14 microsatellites**

Genetic diversity within **each** station

Differentiation / genetic structure between stations

What tools to evaluate fish connectivity ?

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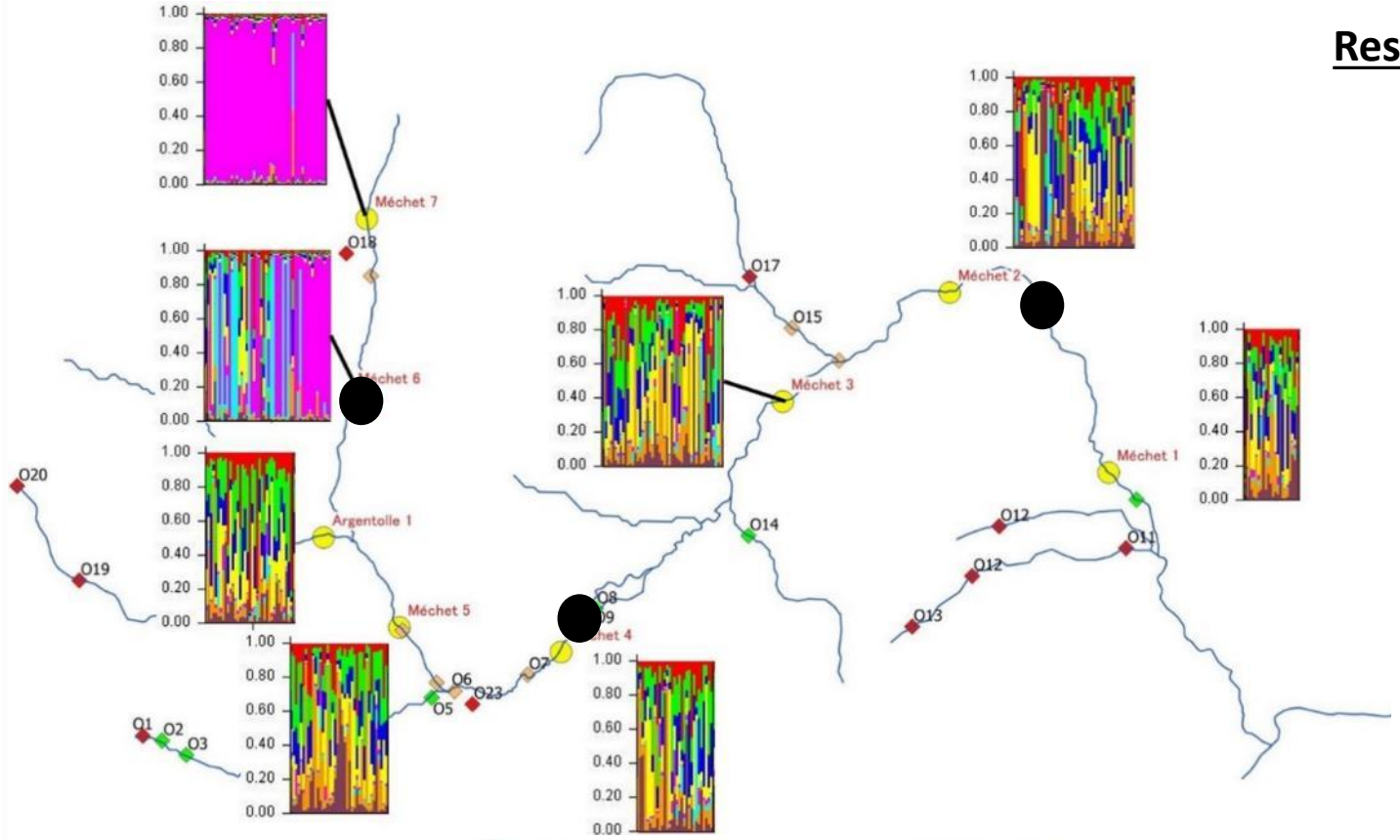

Results :

Homogenous distribution of genotypes within of the 6 most downstream stations

Brutal change to the right of the **natural fall**

What tools to evaluate fish connectivity ?

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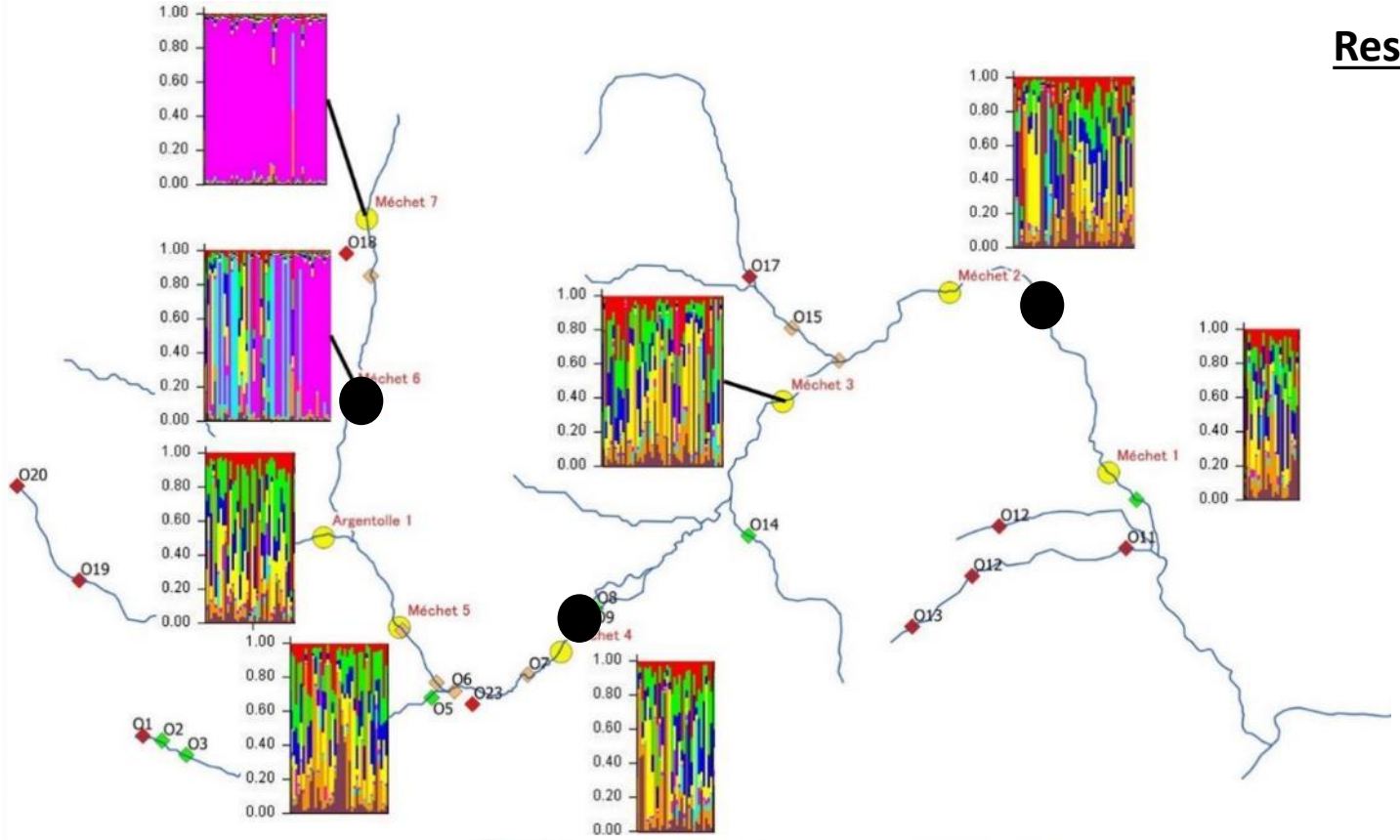

Results :

Highly isolated population **upstream** (no gene flow downstream)

Intermediate population (Méchet 6) with **influences from both the isolated upstream population and the downstream** population

What tools to evaluate fish connectivity ?

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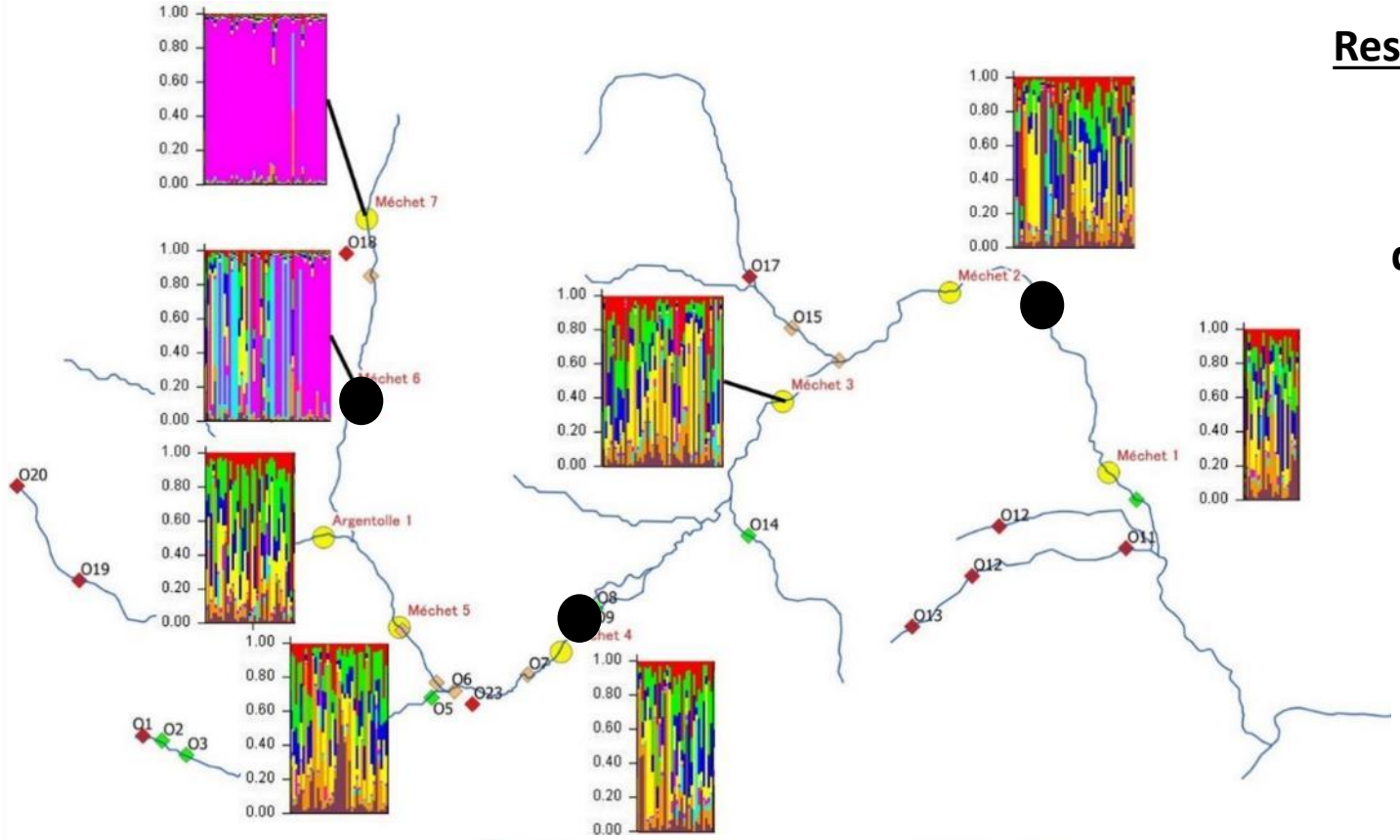


Results :

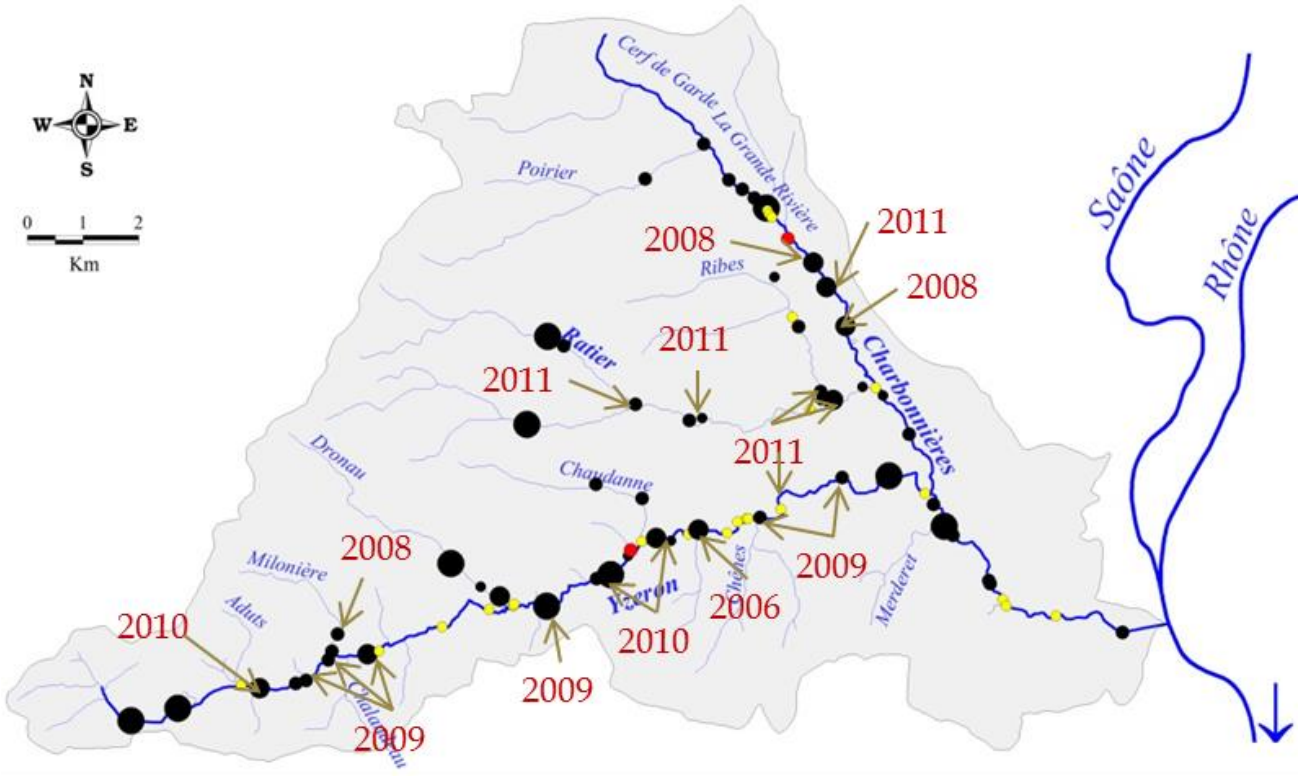
No genetic structuring due to the presence of the **dams**. Existence of **significant gene flow** between the stations.

Need to **complete the evaluation** with complementary approaches (habitats, **thermie**, ...)

What tools to evaluate fish connectivity ?

GENETIC MARKERS

Use of genetic markers to study the influence of obstacles and their equipment / removal on the movements of trouts population of Yzeron river (Rhône)



Contexte :

A **multi-year** intervention program (2008-2014) on **many dams**

Need to evaluate the **effectiveness of actions** but difficulty to work **dam by dam**

Possibility of achieving an **initial assessment** on certain sectors. **Before / after approach**

What tools to evaluate fish connectivity ?

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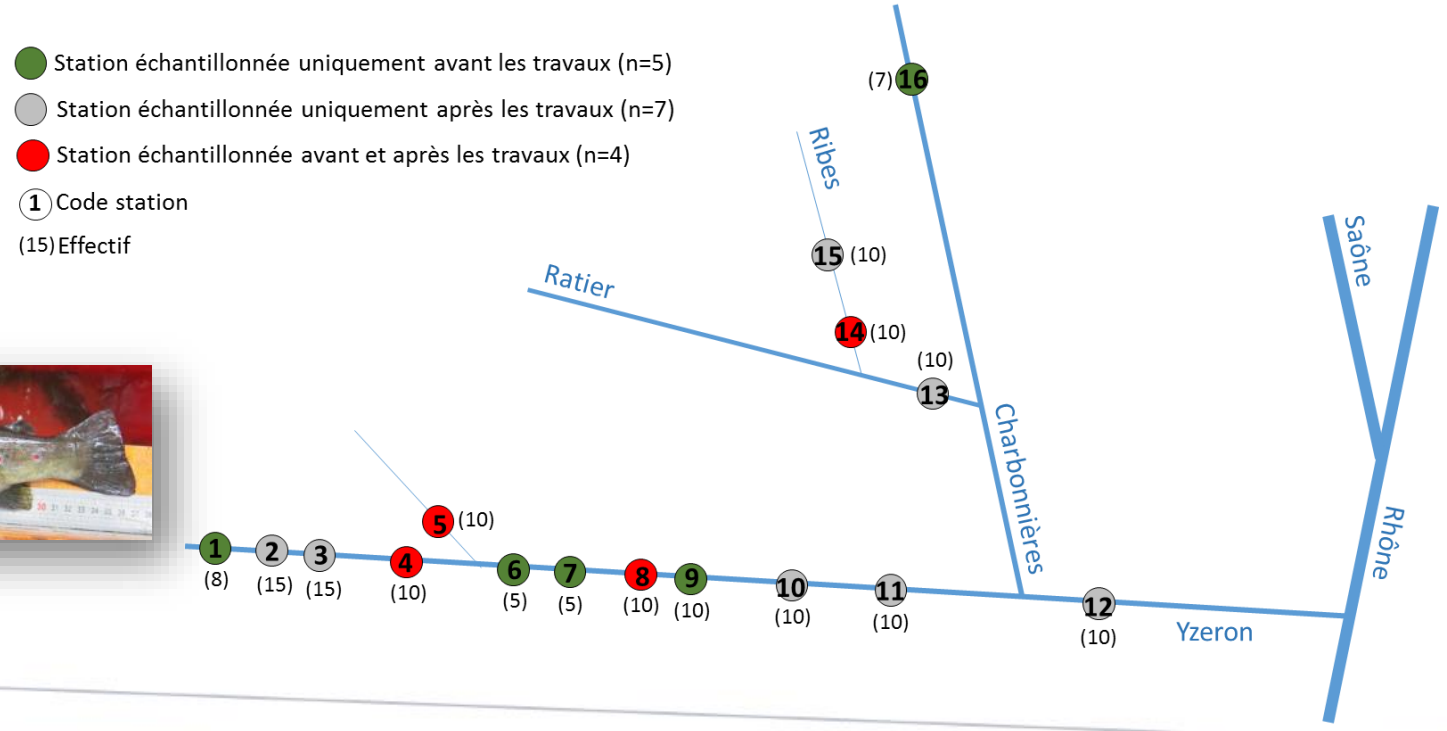


What tools to evaluate fish connectivity ?

GENETIC MARKERS

Use of genetic markers to study the influence of obstacles and their equipment / removal on the movements of trouts population of Yzeron river (Rhône)

Bassin de l'Yzeron
Vivre avec nos rivières

69 FÉDÉRATION DÉPARTEMENTALE PÊCHE

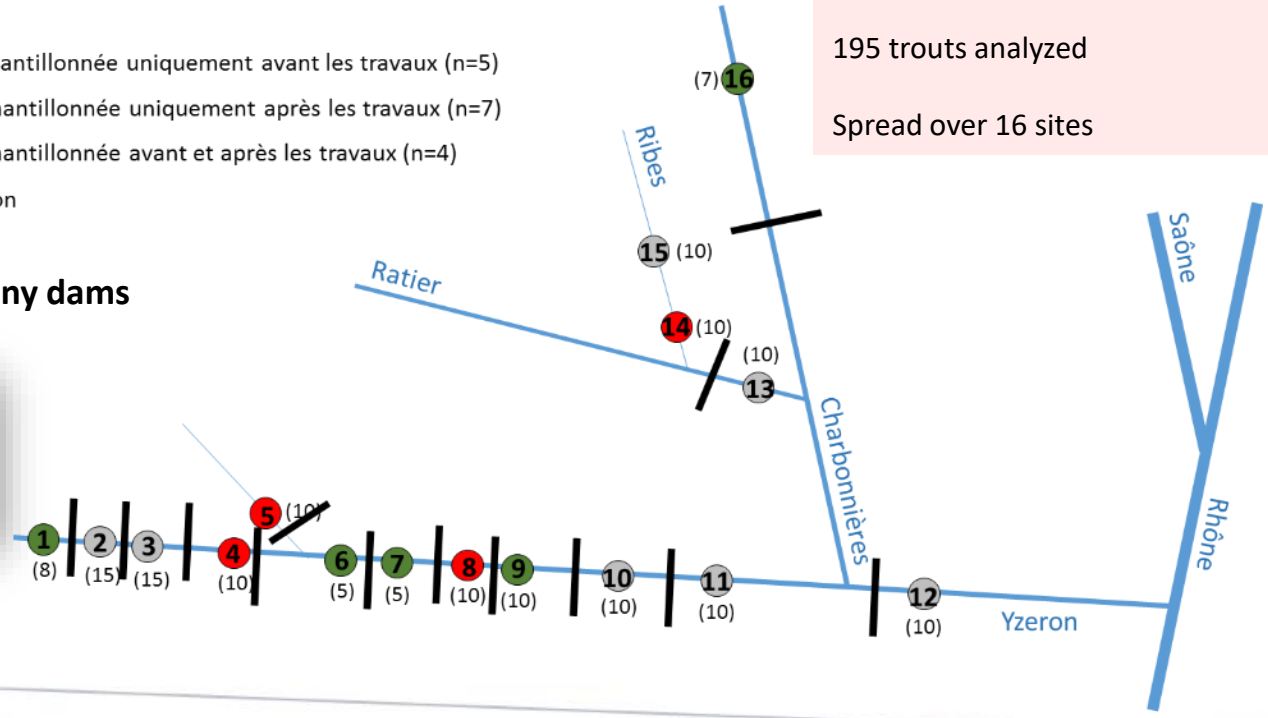
Methodology :

- Station échantillonnée uniquement avant les travaux (n=5)
- Station échantillonnée uniquement après les travaux (n=7)
- Station échantillonnée avant et après les travaux (n=4)
- (1) Code station
- (15) Effectif
- Many dams

Analysis: 14 microsatellite markers

195 trouts analyzed

Spread over 16 sites



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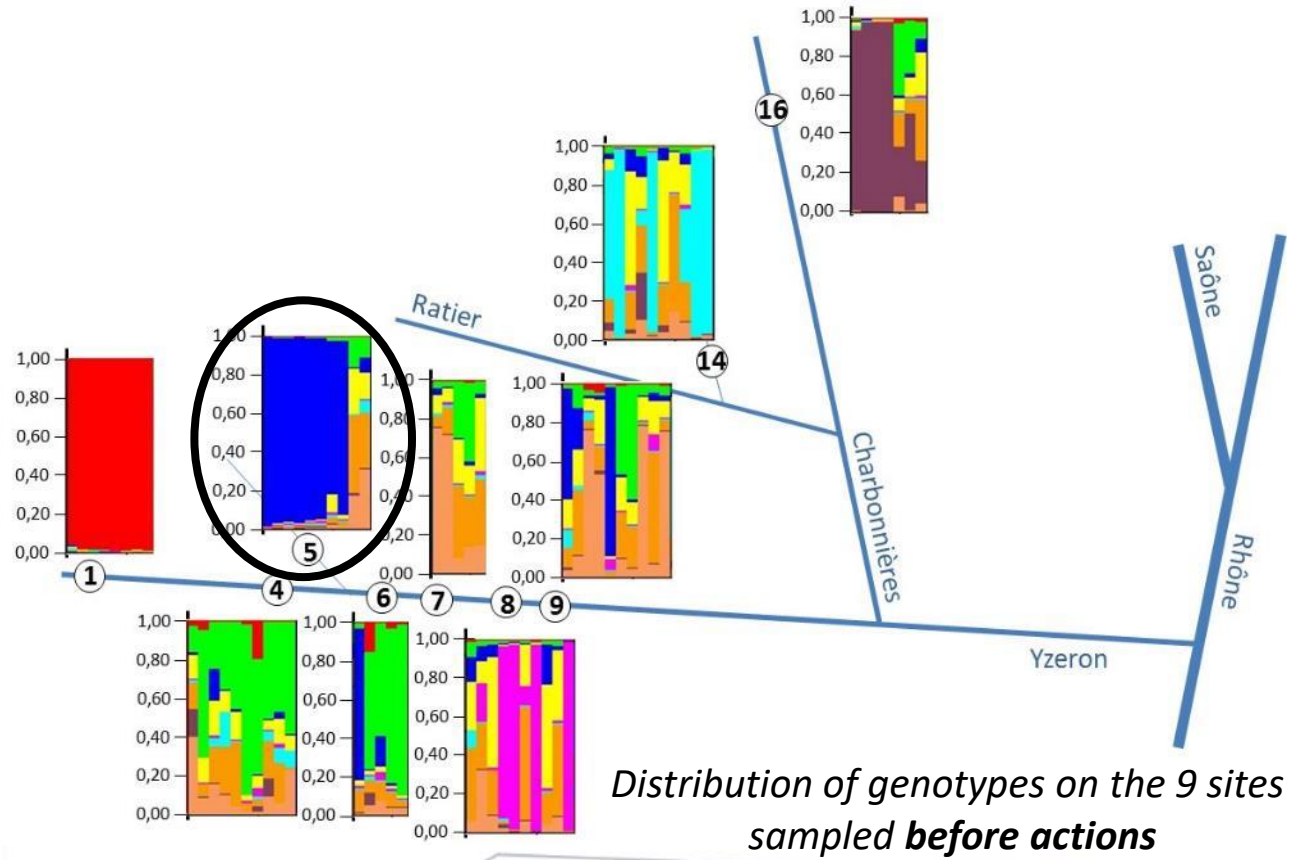

*Distribution of genotypes on the 9 sites sampled **before actions***

Results :

Site 1 = poorly diversified population. Characteristic of a **founder effect** and / or **geographical isolation**. No exchange or gene additions to pop. downstream

Site 5 = also suffers from **geographic isolation** with low gene flow from **downstream**

What tools to evaluate fish connectivity ?

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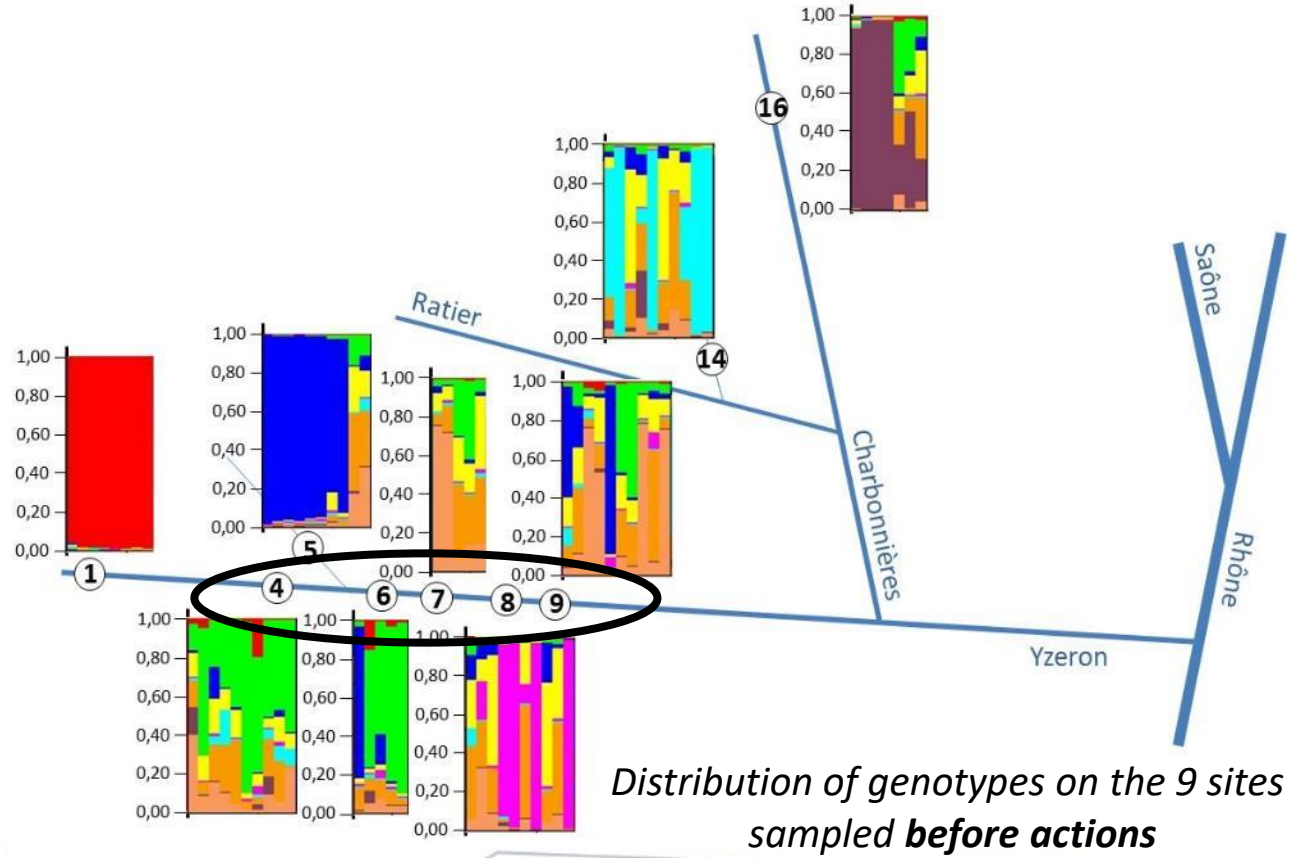

*Distribution of genotypes on the 9 sites sampled **before actions***

Results :

Sites 14 and 16 = tendency to **isolation**. No movement of trouts from these stations to others located **on the main river**

Sites 4 to 9 (8) = maintenance of **genetic diversity** by **downstream migration**

What tools to evaluate fish connectivity ?

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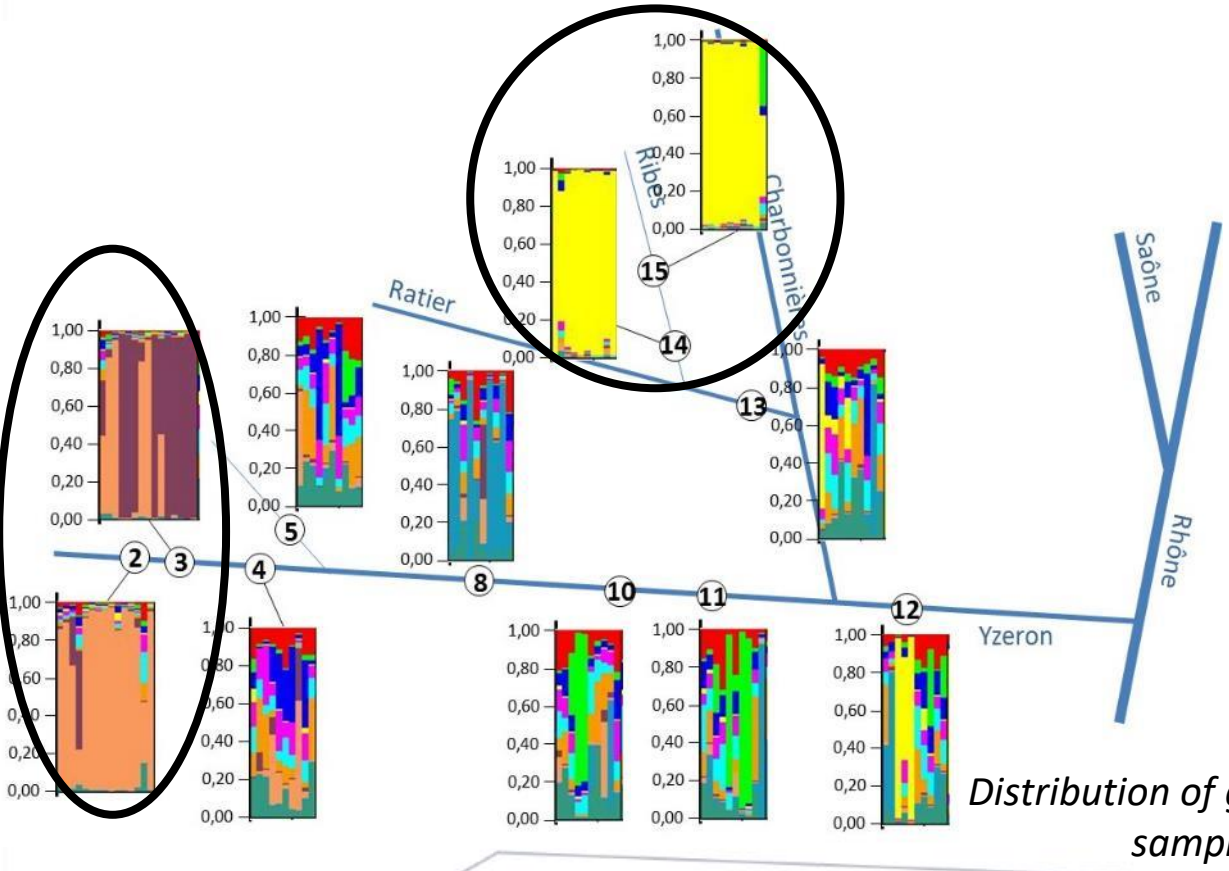

*Distribution of genotypes on the **11 sites** sampled **after actions***

Results :

Movements of trouts took place between the various **dams equiped or erased**

Most significant result on the **Yzeron axis** (site 8) and a **small tributary** (site 5)

Several sites still show **signs of isolation** (sites 2, 3, 14 and 15)

What tools to evaluate fish connectivity ?

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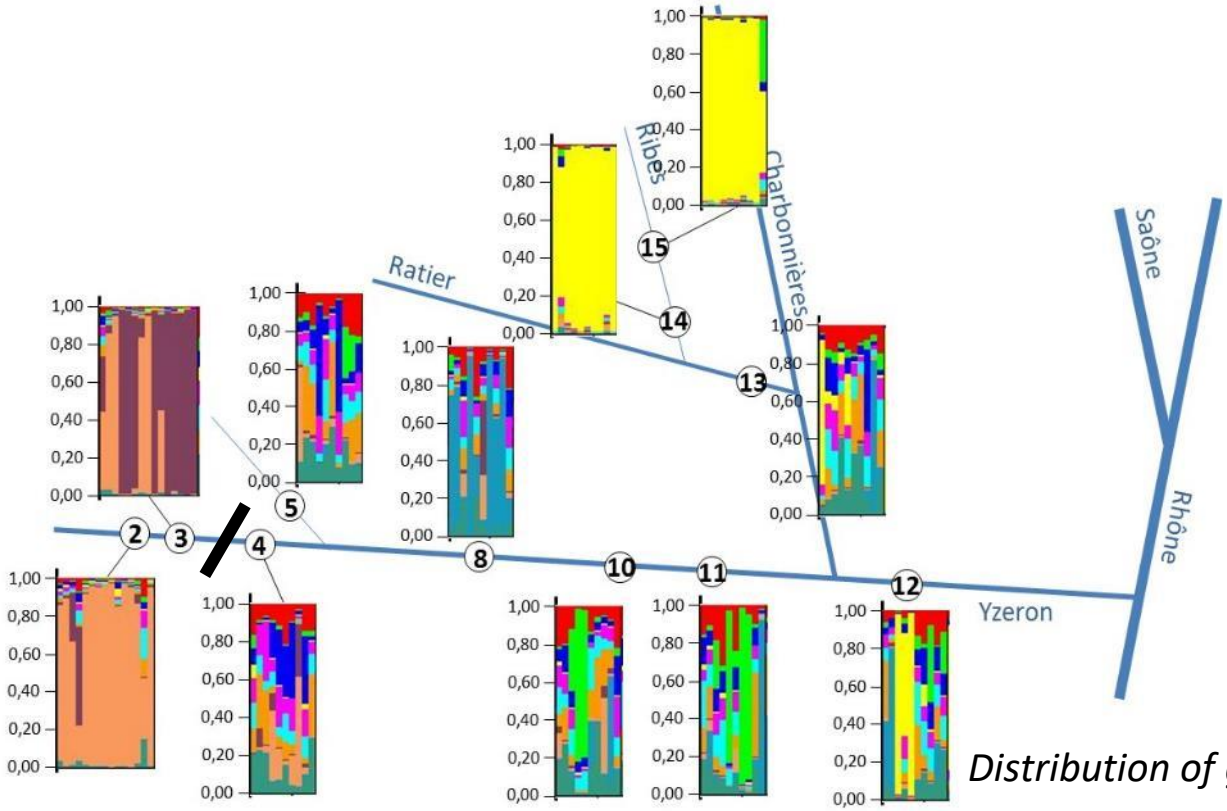

*Distribution of genotypes on the **11 sites** sampled **after actions***

Results :

Several sites still show **signs of isolation**
Special case (sites 2 and 3) = unrestored fish continuity despite construction of a **fishway**

Efficiency ???

What tools to evaluate fish connectivity ?

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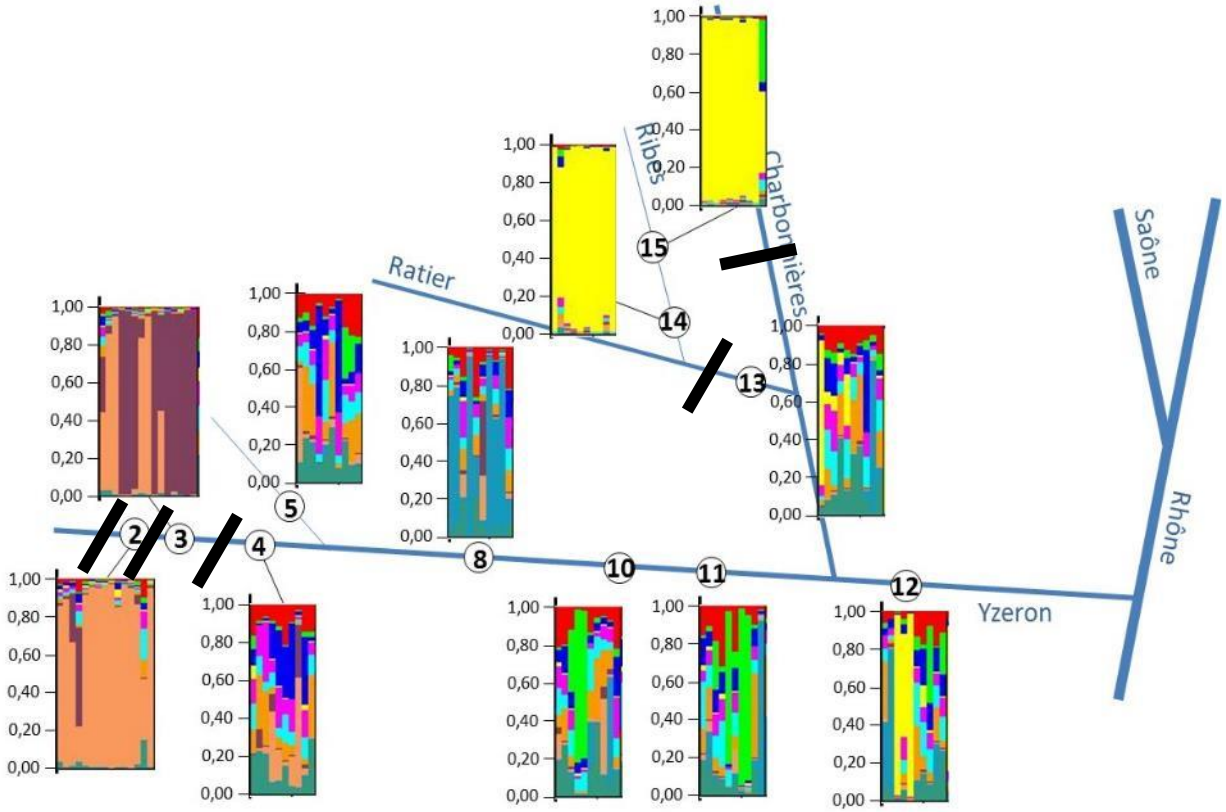
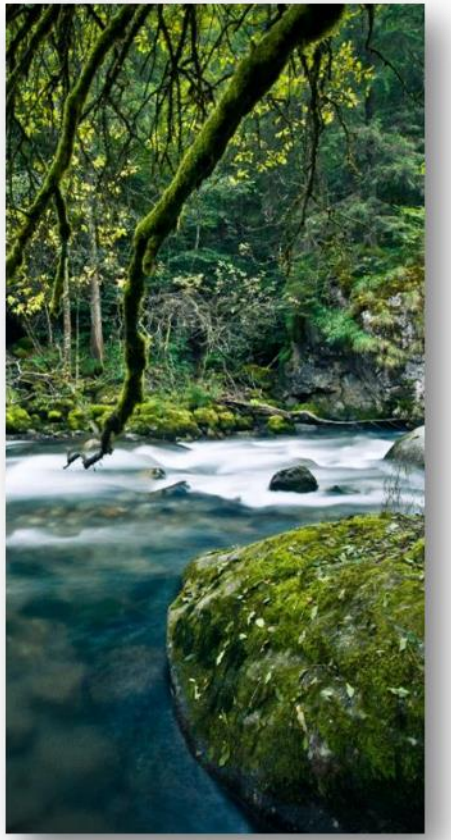


Identification of **still isolated** populations

Allows you to target the dams to be **treated first**

A conclusion test ?

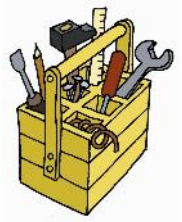


fish connectivity is important for **all species** of fish, but needs are expressed at different **scales of time and space**

Programming and performing **effective actions** therefore require **knowledge** based on **robust data**

Any action aimed at restoring fish continuity should **ideally include** a **diagnostic** prior to intervention and an ***ex post* evaluation**

wide range of tools at our disposal



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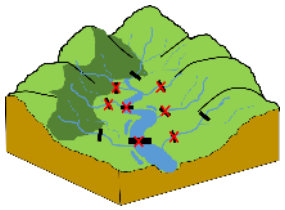
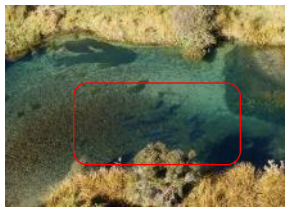
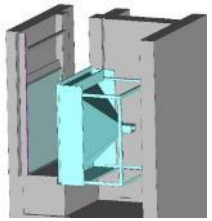


Many knowledge to acquire ⟺ **Many tools**

Which tool for which information ?



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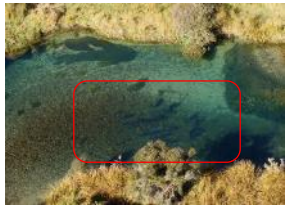
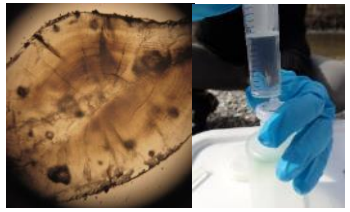
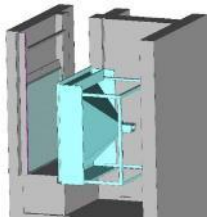
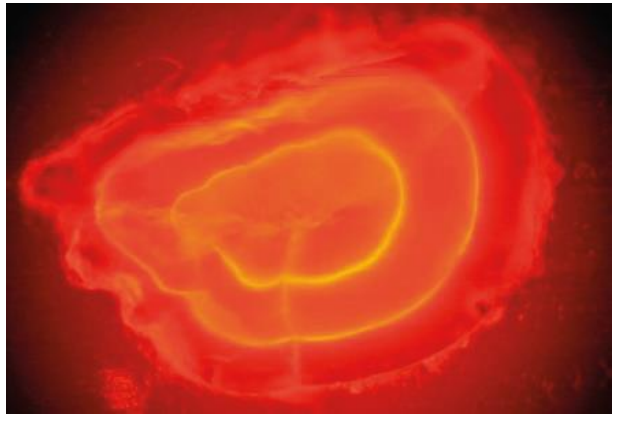



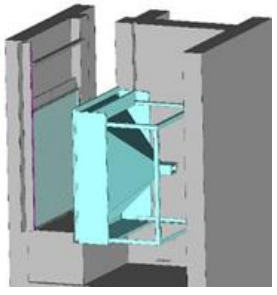


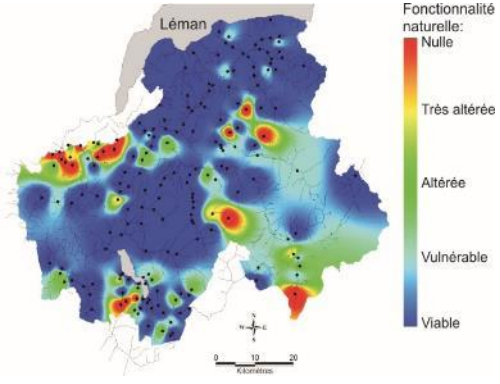


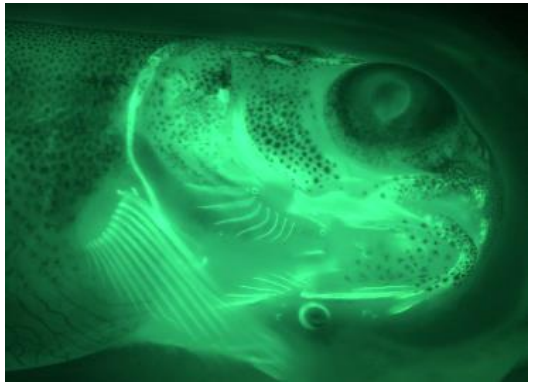
	Migration flows	Efficiency / Passability	Gene flow
Tools	**Trapping** **Video-counting**	**Passive telemetry** **Active telemetry**	**Genetic tools (DNA microsatellites, SNPs)**
Advantages	All species, all stages (low selictivity) Relation with data monitoring	Search for passageways(RFID) Individuals trajectories (radio/acoustic)	Down/upstream comparison Comparison with natural sites Viabilty, Fonctionnality of pop. Watershed vision
Disadvantages	No idea of real fishway efficiency Time consuming (automatisation ?) Limited to the dam scale	Tagging (number ?) Cost of tags (radio/acoustic) Selectivity (size, species) Animal welfare laws	Development of specific marker sets (cost) Technicity

Thank you for your attention









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