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Efficiency of fish-friendly intakes, bypasses associated with low bar-spacing trashracks, for downstream migration of Atlantic salmon smolts

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In: Fish Market 2016 : International workshop on downstream fish passage best practices and innovations at hydropower stations, 6 October 2016 - 7 October 2016 (Roermond, Netherlands)



Pôle écohydraulique



Efficiency of fish-friendly intakes, bypasses associated with low bar-spacing trashracks, for downstream migration of Atlantic salmon smolts

P. Sagnes, S. Tomanova, D. Courret, A. Alric,
E. de Oliveira, S. Tétard



ASSOCIATION DU GAVE D'OLORON POUR LA PECHE ET LA PROTECTION DU MILIEU AQUATIQUE



Société hydroélectrique
de Gotein

Syndicat Mixte de
Production d'Auterrive



Why to protect fish from entering turbines?

Important fish mortality in turbines (Gomes & Larinier 2008*)



A. Richard, ONEMA



HEP < 40kW,
without fish
passage
facilities

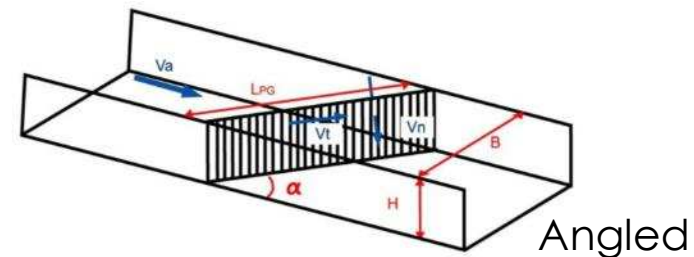
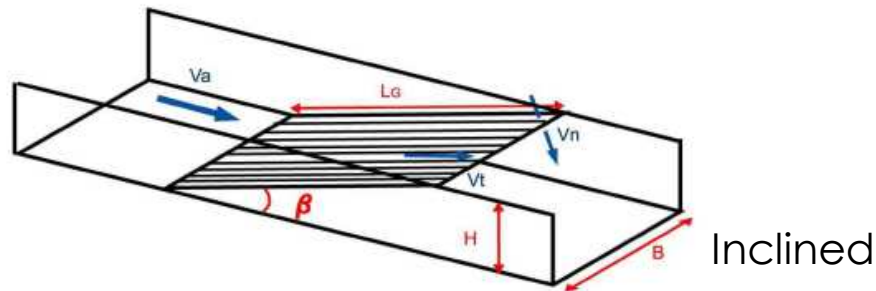
*Gomes P. & Larinier M. (2008) – *Domages subis par les anguilles lors de leur passage au travers des turbines Kaplan*. Rapport GHAPPE RA.08.05. 70p.

How to protect fish?

Two types of solutions currently accepted in France to protect downstream migrating fish :

- "fish-friendly" turbines
- trashracks associated to bypass(es),
for small to medium hydroelectric powerplants (HEP)

**Principle =
STOP / GUIDE / TRANSFER**



Main characteristics* :

- low bar spacing (≤ 25 mm for salmon and sea trout smolts, $\leq 15-20$ mm for silver eels),
- a normal velocity $V_n \leq 0.5 \text{ m.s}^{-1}$ to prevent the impingement
- a minimal inclination $\beta \leq 26^\circ$ to guide fish to the top of the rack
- several criteria for the bypass entrance's dimensions, the bypass discharge based on the intake characteristics of the HEP

* for more details, see Courret D. & Larinier M. (2008) - *Guide pour la conception de prises d'eau "ichthyocompatibles" pour les petites centrales hydroélectriques*. Rapport GHAPPE RA.08.04. 60p + annexe.

How to protect the fish?

ex. of low-sloping racks with bypass



Las Rives (construction)



Auterrive

Does it work?

Hydraulic studies (Raynal *et al.*, 2012, 2013, 2015) have confirmed satisfactory conditions for energy production (low head-loss) and for fish (good guidance, no risk for impingement).

However, the biological *efficiency in situ* remained to be tested



2015-2016 : 4 tests of the efficiency of such fish passage facilities, for Atlantic salmon smolts



Raynal S., Chatellier L., David L., Courret D. & Larinier M. (2012) - *Définition de prises d'eau ichtyocompatibles - Pertes de charge au passage des plans de grille inclinés ou orientés dans des configurations ichtyocompatibles et champs de vitesse à leur approche*. Rapport Pole RA11.02. 114p.

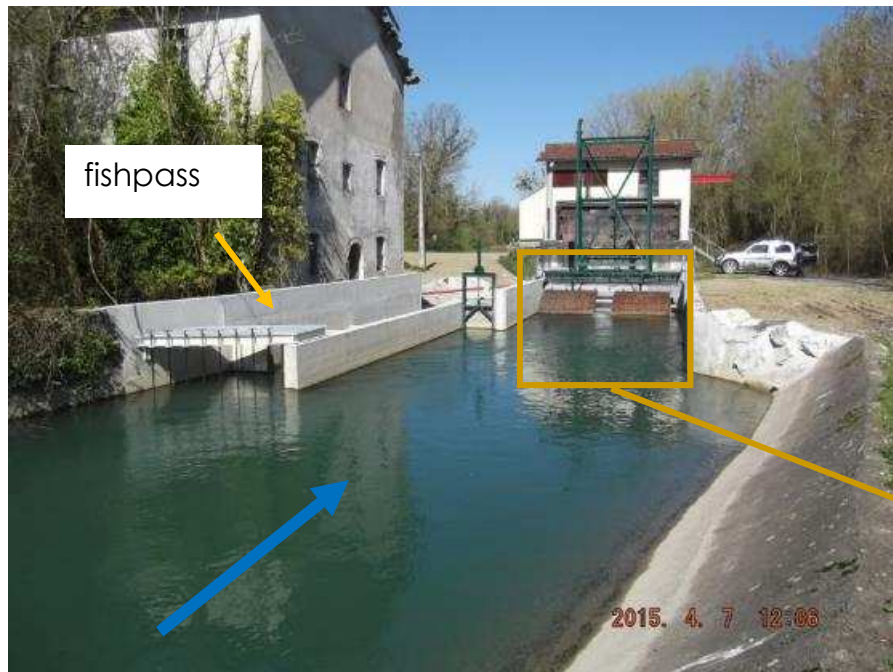
Raynal S., Chatellier L., David L., Courret D. & Larinier M. (2013) - *Définition de prises d'eau ichtyocompatibles - Etude de l'alimentation en débit et du positionnement des exutoires de dévalaison au niveau de plans de grille inclinés ou orientés dans des configurations ichtyocompatibles*. Rapport Pole RA12.02. 123p.

Raynal *et al.* 2015 : <http://www.shf-lhb.org> or <http://dx.doi.org/10.1051/lhb/20150030>

Study sites

River	Gave d'Oloron	Saison		Nive
HEP name	Auterrive	Gotein	Trois-Villes	Halsou
Max intake discharge (m ³ .s ⁻¹)	10	6.6	4.5	22-30
Intake width (m)	6	6.4	4.0	20.9
Intake channel length (m)	400	780	550	925
Trashrack spacing (mm)	20	20	20	20
Total bypass discharge (m ³ .s ⁻¹)	0.50	0.38	0.20	1-1.5
Total bypass discharge (%)	5	5.7	4.4	4.5-5
Nb of bypasses	2	2	1	1
Bypasses width (m)	0.7 + 0.5	0.8 + 0.8	1	1.38
Bypasses width (%)	20	25	25	7.3
Collecting channel (fish & other items going downstream)	dual	dual	dual	separate

Study site : Auterrive

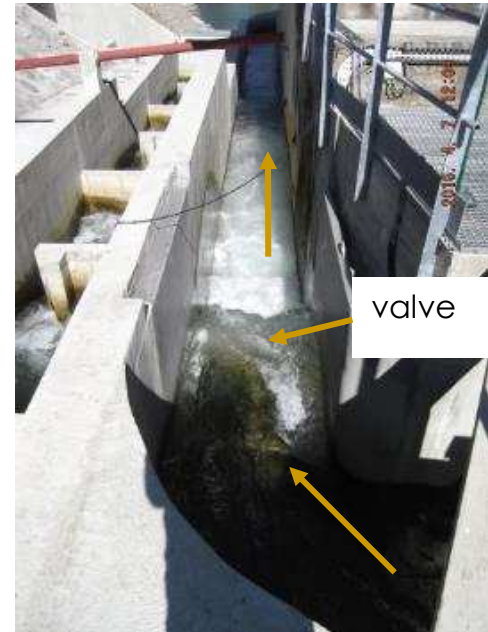


→ fish passage

collecting bypass channel

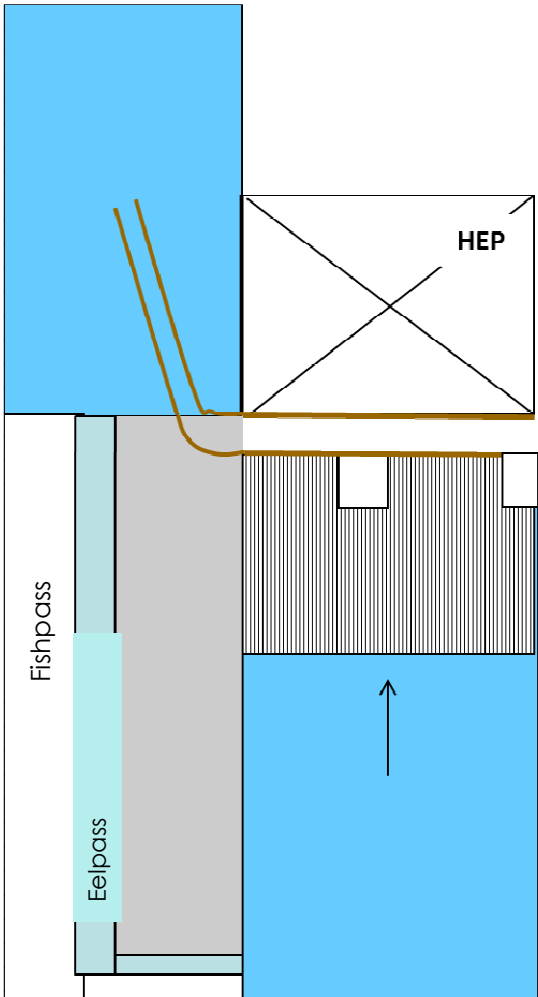


transfer bypass channel + exit

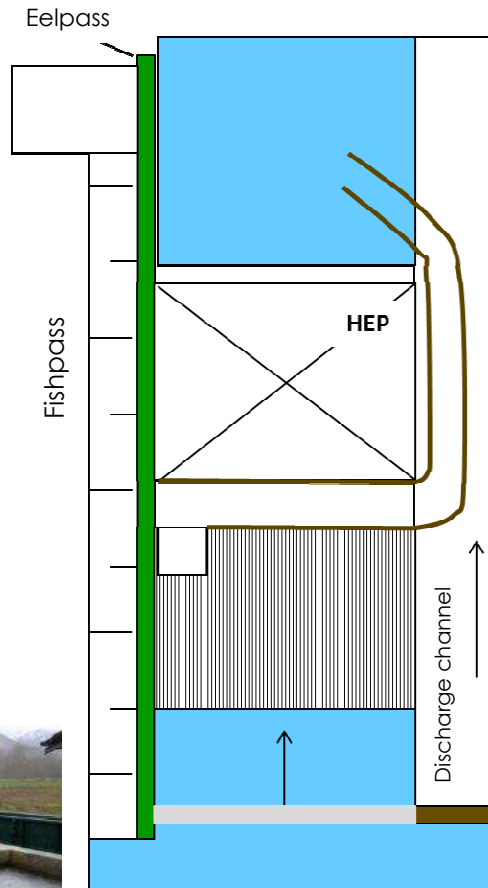


low-sloping racks with 2 bypass entrances

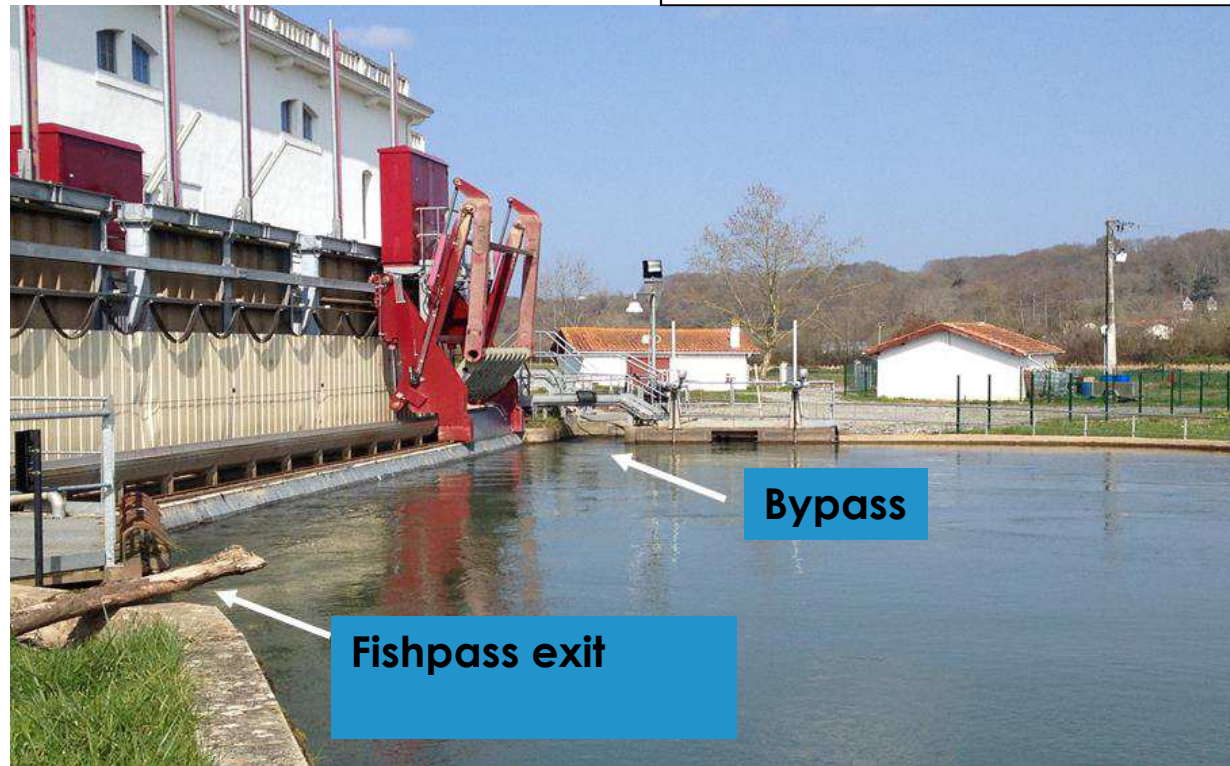
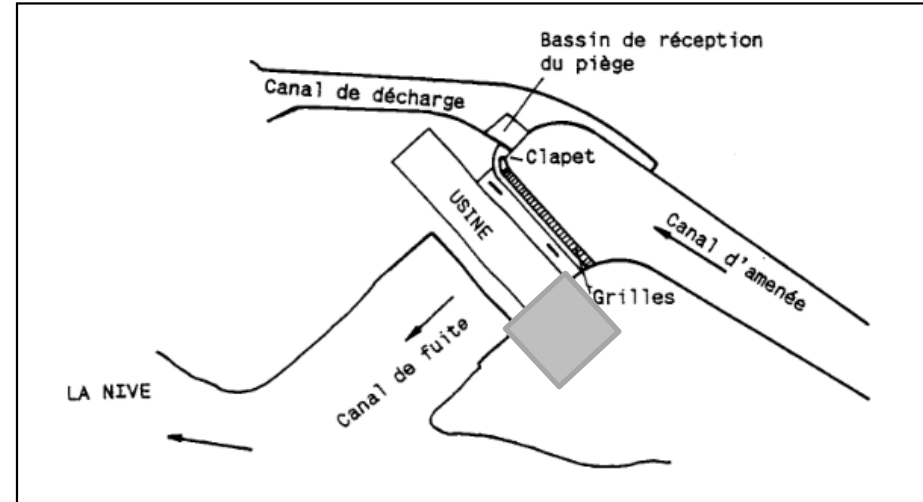
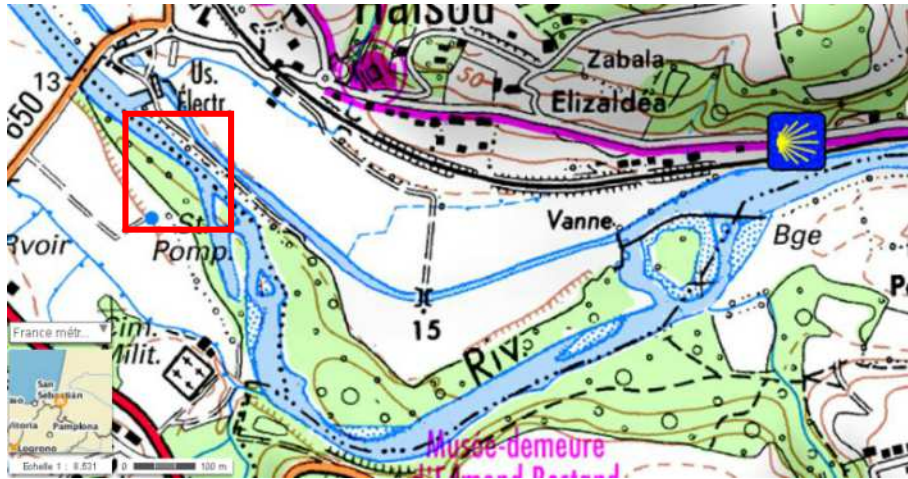
Study site : Gotein



Study site : Trois-Villes

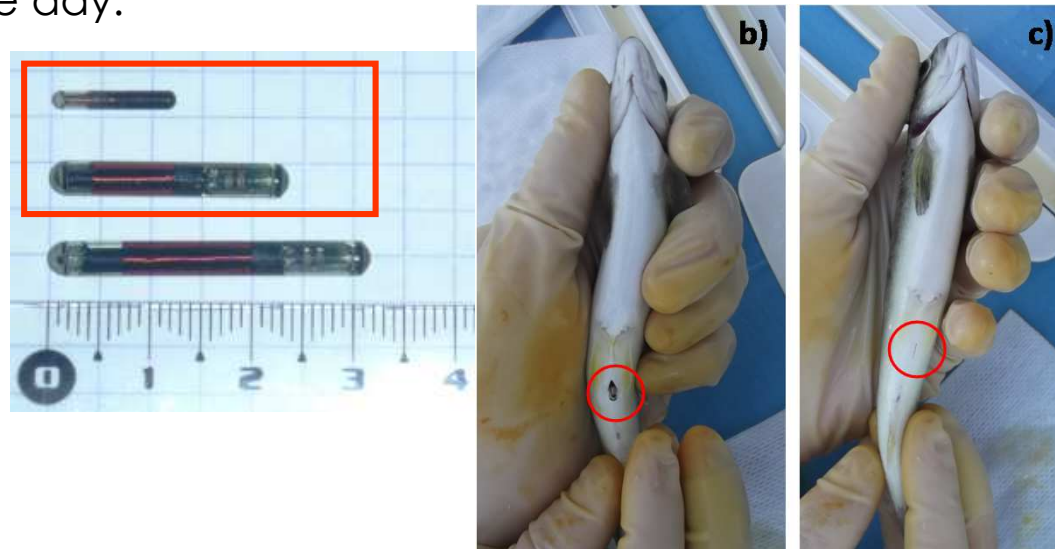


Study site : Halsou



Methodology

- PIT-tag & RFID antennae
- Hatchery fish (MIGADO association) were PIT-tagged and released in 5-6 groups in the intake channel, about 100 meters upstream of the HEP, at different periods of the day.



- Fish passages were monitored with RFID antennae

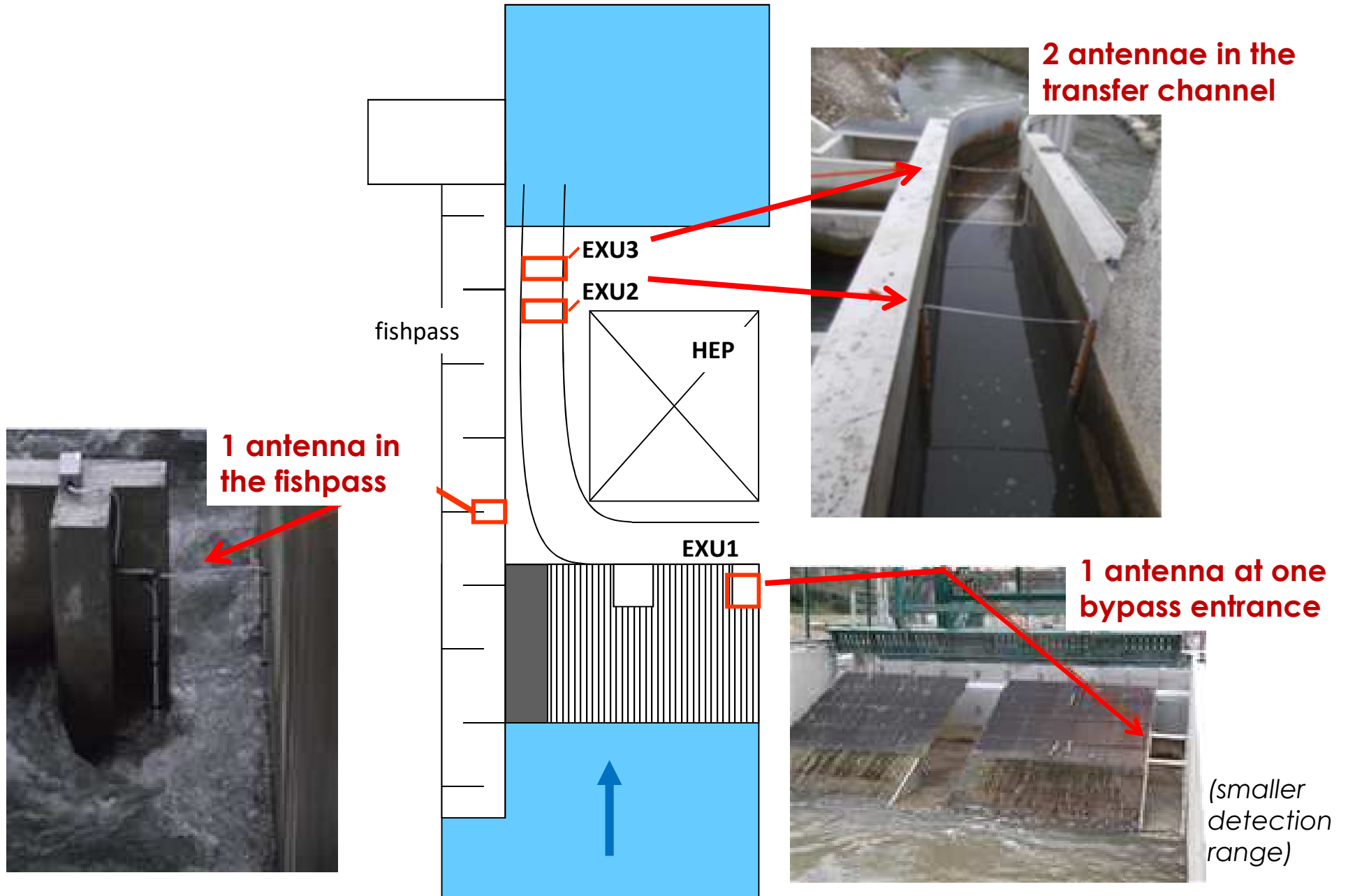
Main hypothesis :

- all individuals swim downstream
- undetected fish passed through the turbine



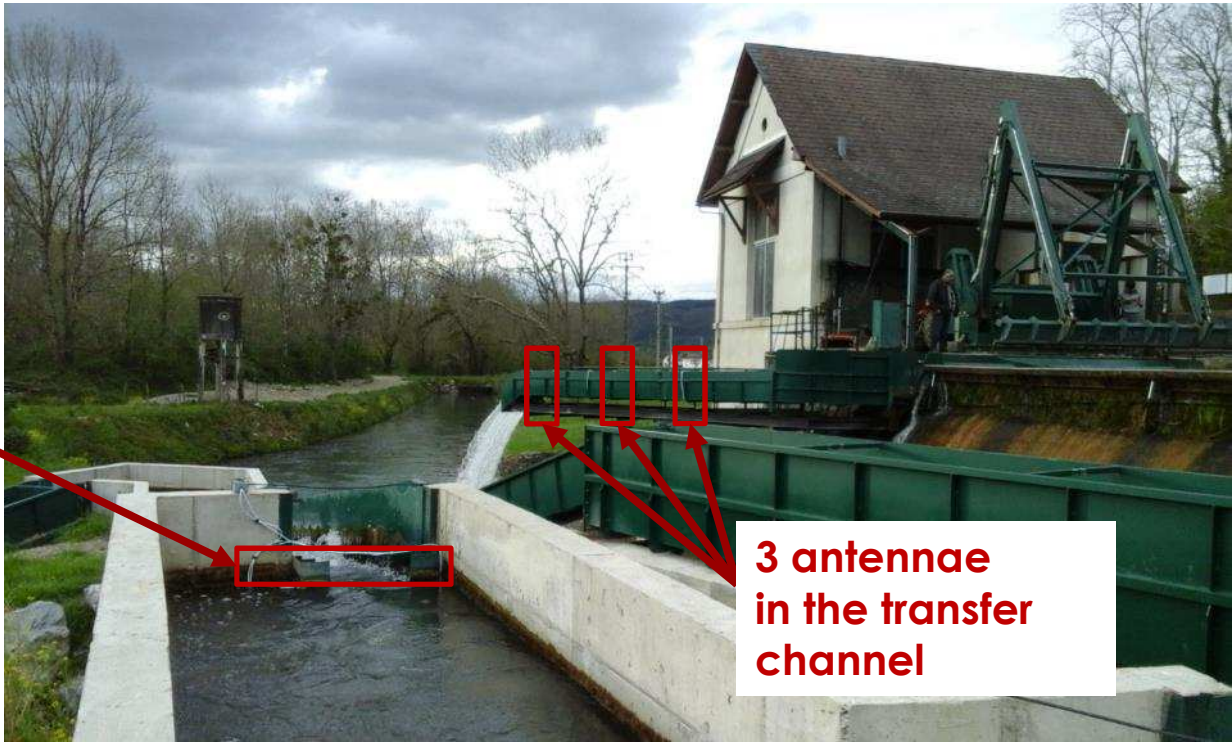
Evaluation of **minimal** efficiency

Methodology (Auterrive)



Methodology (Gotein)

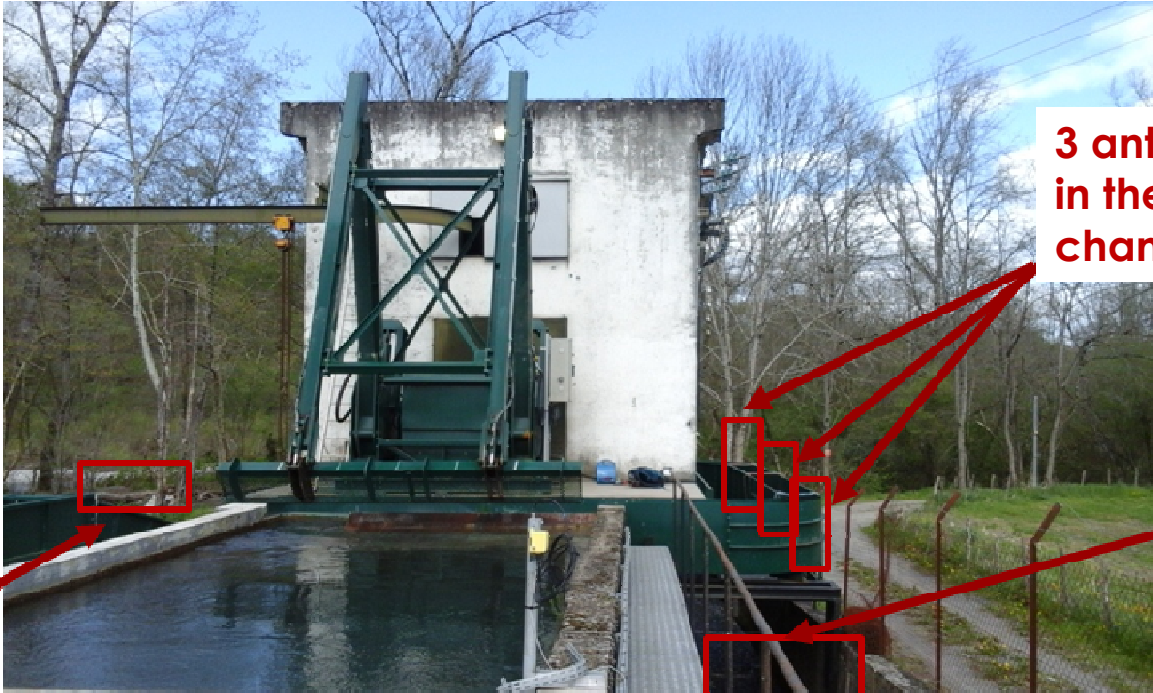
1 antenna in the fishpass



3 antennae in the transfer channel



Methodology (Trois-Villes)



**3 antennae
in the transfer
channel**

**1 antenna in
the discharge
channel**

**1 antenna in
the fishpass**



Methodology (Halsou)



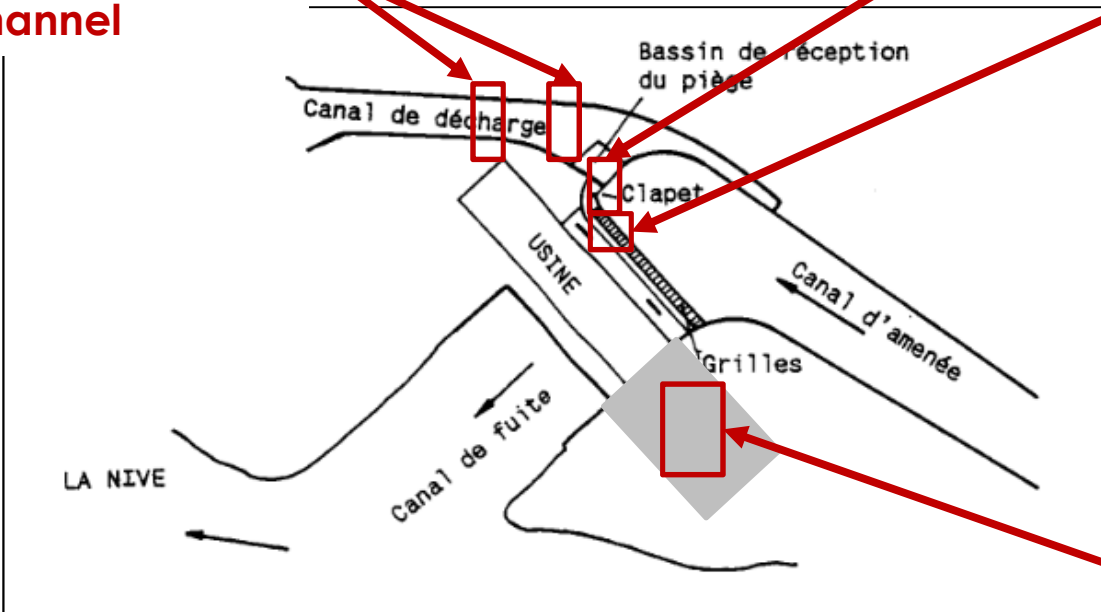
2 antennae in the discharge channel



1 antenna at the bypass entrance



1 antenna in the collecting channel



1 antenna in the fishpass

Results

HEP	Auterrive					Gotein					
Fish group	AUT1	AUT2	AUT3	AUT4	AUT5	GOT1	GOT2	GOT3	GOT4	GOT5	GOT6
Nb of fish released	37	59	47	49	47	50	50	50	50	50	52
Release time (h:min)	20:20	14:48	21:21	23:28	10:25	19:45	22:40	00:40	18:37	22:38	00:17
% passage in bypass	89.2	84.7	76.6	75.5	85.1	100	76	78	88	72	71.2
% passage in fishpass	2.7	3.4	6.4	0	6.4	0	2	2	2	0	5.8
% pass. in discharge channel	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
% safe (minimum)	91.9	88.1	83	75.5	85.1	100	78	80	90	72	76.9
Mean % safe (weighted)	84.5					82.8					
Min passage time (h:min:s)	00:07:47					00:02:45					
Med passage time (h:min:s)	00:22:24					00:19:21					
Q75	01:51:50										
Max passage time (h:min:s)	54:18:34					187:33:03					

HEP	Trois-Ville						Halsou					
Fish group	TRV1	TRV2	TRV3	TRV4	TRV5	TRV6	HAL1	HAL2	HAL3	HAL4	HAL5	HAL6
Nb of fish released	50	50	50	50	50	50	50	50	50	50	66	72
Release time (h:min)	18:28	22:20	00:12	18:07	22:07	23:34	18:00	21:00	23:00	18:00	22:00	23:00
% passage in bypass	74	48	50	76	66	52	72	86	86	90	79	94
% passage in fishpass	2	0	2	0	0	0	0	0	0	0	0	0
% pass. in discharge channel	16	40	42	20	32	34	NA	NA	NA	NA	NA	NA
% safe (minimum)	92	88	94	96	98	86	72	86	86	90	79	94
Mean % safe (weighted)	92.3						87					
Min passage time (h:min:s)	00:04:25						00:00:09					
Med passage time (h:min:s)	00:52:34						00:21:30					
Q75							02:30:00					
Max passage time (h:min:s)	40:58:11						82.5 days					

Results: minimal proportions of successfully migrating fishes

HEP	Auterrive					Gotein					
Fish group	AUT1	AUT2	AUT3	AUT4	AUT5	GOT1	GOT2	GOT3	GOT4	GOT5	GOT6
Nb of fish released	37	59	47	49	47	50	50	50	50	50	52
Release time (h:min)	00:00	11:40	01:01	00:00	10:05	10:45	00:40	00:40	10:07	00:00	00:17

A majority of released fish successfully went downstream (>82%)

% safe (minimum)	91.9	88.1	85	75.9	85.1	100	78	80	90	72	70.9
Mean % safe (weighted)	84.5					82.8					
Min passage time (h:min:s)			00:07:47					00:02:45			
Med passage time (h:min:s)			00:22:24					00:19:21			
Q75			01:51:50								
Max passage time (h:min:s)			54:18:34					187:33:03			

HEP	Trois-Ville						Halsou					
Fish group	TRV1	TRV2	TRV3	TRV4	TRV5	TRV6	HAL1	HAL2	HAL3	HAL4	HAL5	HAL6
Nb of fish released	50	50	50	50	50	50	50	50	50	50	66	72
Release time (h:min)	18:28	22:20	00:12	18:07	22:07	23:34	18:00	21:00	23:00	18:00	22:00	23:00
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% passage in fishpass	2	0	2	0	0	0	0	0	0	0	0	0
% pass. in discharge channel	16	40	42	20	32	34	NA	NA	NA	NA	NA	NA
% safe (minimum)	92	88	94	96	98	86	72	86	86	90	79	94
Mean % safe (weighted)	92.3						87					
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Med passage time (h:min:s)			00:52:34						00:21:30			
Q75									02:30:00			
Max passage time (h:min:s)			40:58:11						82.5 days			

Results: minimal proportions of successfully migrating fishes

HEP	Auterrive					Gotein					
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% passage in fishpass	2.7	3.4	6.4	0	6.4	0	2	2	2	0	5.8
% pass. in discharge channel	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

A majority of fish successfully went downstream through bypasses

Some of them use fishpasses

HEP	Trois-Ville						Halsou					
Fish group	TRV1	TRV2	TRV3	TRV4	TRV5	TRV6	HAL1	HAL2	HAL3	HAL4	HAL5	HAL6
Nb of fish released	50	50	50	50	50	50	50	50	50	50	66	72
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% passage in bypass	74	48	50	76	66	52	72	86	86	90	79	94
% passage in fishpass	2	0	2	0	0	0	0	0	0	0	0	0
% pass. in discharge channel	16	40	42	20	32	34	NA	NA	NA	NA	NA	NA
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Q75							02:30:00					
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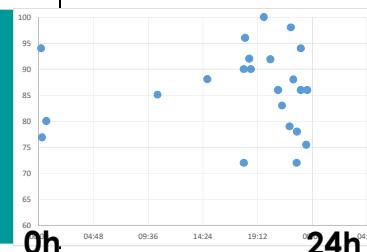
Results: minimal proportions of successfully migrating fishes

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% passage in fishpass	2.7	3.4	6.4	0	6.4	0	2	2	2	0	5.8
% pass. in discharge channel	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
% safe (minimum)	91.9	88.1	83	75.5	85.1	100	78	80	90	72	76.9

No relationship between passage success and the releasing time of the day

100%

60%



HEP	Trois-Ville						Halsou					
Fish group	TRV1	TRV2	TRV3	TRV4	TRV5	TRV6	HAL1	HAL2	HAL3	HAL4	HAL5	HAL6
Nb of fish released	50	50	50	50	50	50	50	50	50	50	66	72
Release time (h:min)	18:28	22:20	00:12	18:07	22:07	23:34	18:00	21:00	23:00	18:00	22:00	23:00
% passage in bypass	74	48	50	76	66	52	72	86	86	90	79	94
% passage in fishpass	2	0	2	0	0	0	0	0	0	0	0	0
% pass. in discharge channel	16	40	42	20	32	34	NA	NA	NA	NA	NA	NA
% safe (minimum)	92	88	94	96	98	86	72	86	86	90	79	94
Mean % safe (weighted)	92.3						87					
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Med passage time (h:min:s)	00:52:34						00:21:30					
Q75							02:30:00					
Max passage time (h:min:s)	40:58:11						82.5 days					

Results: passage duration

(= time between fish release and the last detection in the bypass)

HEP	Auterrive					Gotein					
Fish group	AUT1	AUT2	AUT3	AUT4	AUT5	GOT1	GOT2	GOT3	GOT4	GOT5	GOT6

Great individual variability in passage time

50% of individuals pass in about 20 minutes (50 minutes for "Trois-Villes")

Min passage time (h:min:s)	00:07:47	00:02:45
Med passage time (h:min:s)	00:22:24	00:19:21
Q75	01:51:50	01:07:39
Max passage time (h:min:s)	54:18:34	7.8 days

HEP	Trois-Ville						Halsou					
Fish group	TRV1	TRV2	TRV3	TRV4	TRV5	TRV6	HAL1	HAL2	HAL3	HAL4	HAL5	HAL6
Nb of fish released	50	50	50	50	50	50	50	50	50	50	66	72
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% passage in bypass	74	48	50	76	66	52	72	86	86	90	79	94
% passage in fishpass	2	0	2	0	0	0	0	0	0	0	0	0
% pass. in discharge channel	16	40	42	20	32	34	NA	NA	NA	NA	NA	NA
% safe (minimum)	92	88	94	96	98	86	72	86	86	90	79	94
Mean % safe (weighted)	92.3						87					
Min passage time (h:min:s)	00:04:25						00:00:09					
Med passage time (h:min:s)	00:52:34						00:21:30					
Q75	03:08:12 (bypass)						02:30:00					
Max passage time (h:min:s)	40:58:11						82.5 days					

Results: passage duration

(= time between fish release and the last detection in the bypass)

Passage duration was significantly higher when fish were released in the morning

Auterrive : duration of passage (h:min:s)

	Number of individuals	Time of release	Min.	1Quartile	Median	3Quartile	Max.
group 1	33	evening	0:11:03	0:14:59	0:18:47	0:23:12	0:58:55
group 2	50	afternoon	0:07:47	0:13:53	0:18:29	0:31:51	46:13:00
group 3	36	night	0:12:49	0:15:05	0:20:04	0:39:47	5:46:54
group 4	37	night	0:11:50	0:15:33	0:21:36	0:54:26	47:00:00
group 5	37	morning	0:12:43	2:28:12	3:17:00	6:37:06	54:18:34
all groups	193		0:07:47	0:15:33	0:22:24	1:51:50	54:18:34

Discussion - Conclusion

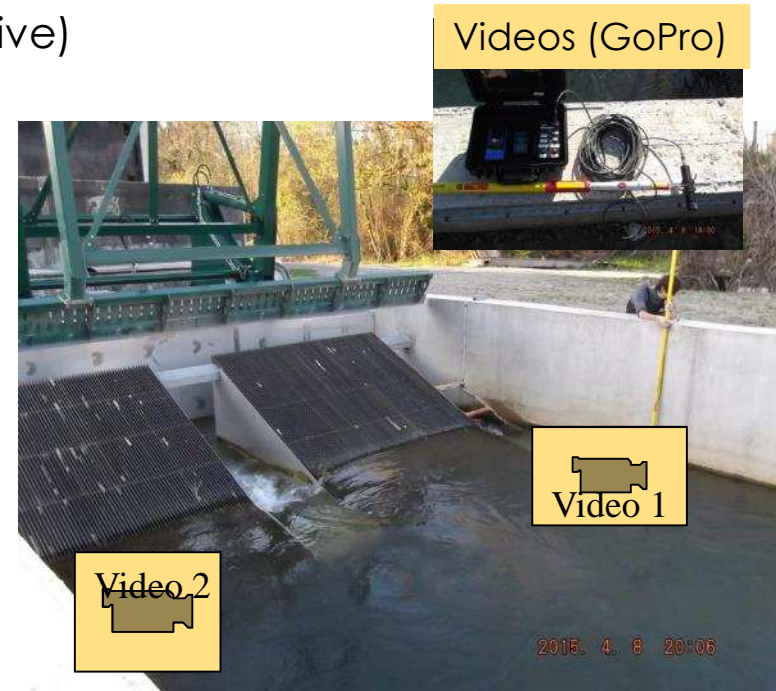
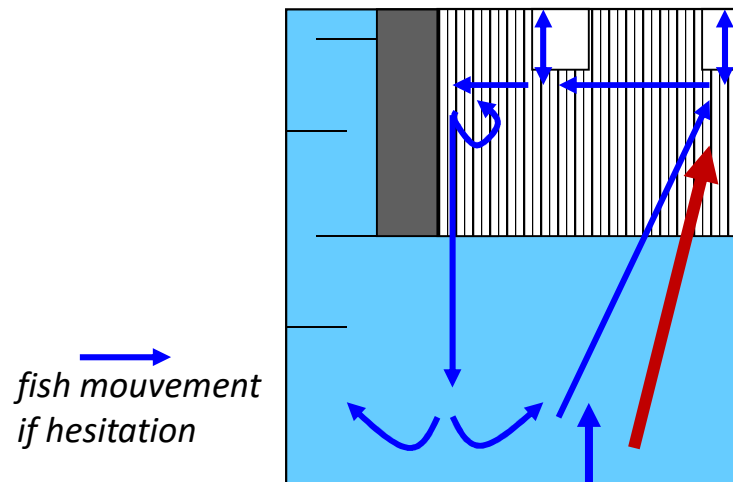
The efficiency of the HEP low-sloping rack is satisfactory (more than 82%)

But...

fish hesitations were observed
(e.g. repeated detections for 39/72 fish at Auterrive)

As possible explanations:

- velocity acceleration and higher turbulences near the bypass entrance
- recirculation zone at the top of the rack along the left bank (without bypass entrance)



→ Particular attention should be paid to the position of the bypass entrances in order to fully adapt it to the site-specific flow pattern

Perspectives

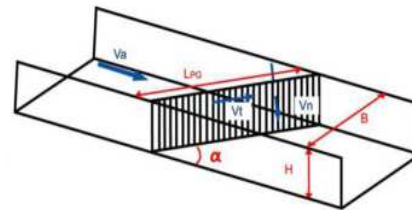
Our study confirms the recommendation of low-sloping racks (*), which is the main solution implemented in France for small HEPs.

Need of additional studies

↳ on bigger HEPs



↳ different types of rack configurations



↳ other migratory fish species
(e.g. silver eels)



→ our projects 2016 + 2017!

* Courret D., Larinier M. (2008) - *Guide pour la conception de prises d'eau "ichtyocompatibles" pour les petites centrales hydroélectriques*. Rapport GHAAPPE RA.08.04. 60p + annexe.

Many thanks for your attention

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Pôle écohydraulique

