Pôle écohydraulique

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

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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

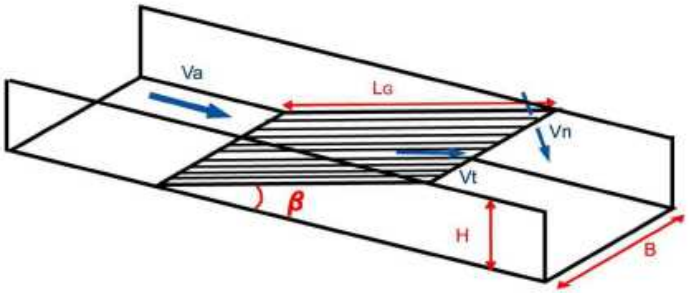
*Gomes P. & Larinier M. (2008) – *Dommages subis par les anguilles lors de leur passage au travers des turbines Kaplan*. Rapport GHAAPPE RA.08.05. 70p.

How to protect fish?

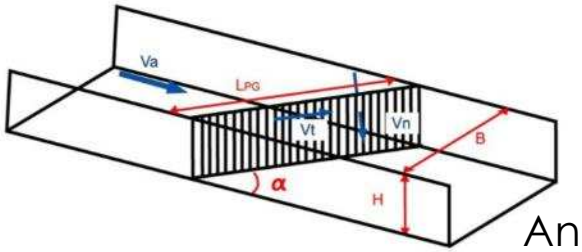
Two types of solutions currently accepted in France to protect downstream migrating fish :

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

Principle = STOP / GUIDE / TRANSFER



Inclined



Angled

Main characteristics* :

- low bar spacing (≤ 25 mm for salmon and sea trout smolts, ≤ 15-20 mm for silver eels),
- a normal velocity $Vn \leq 0.5\ m.s^{-1}$ to prevent the impingement
- a minimal inclination $\beta \leq 26°$ 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 "ichtyocompatibles" pour les petites centrales hydroélectriques.* Rapport GHAAPPE 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.

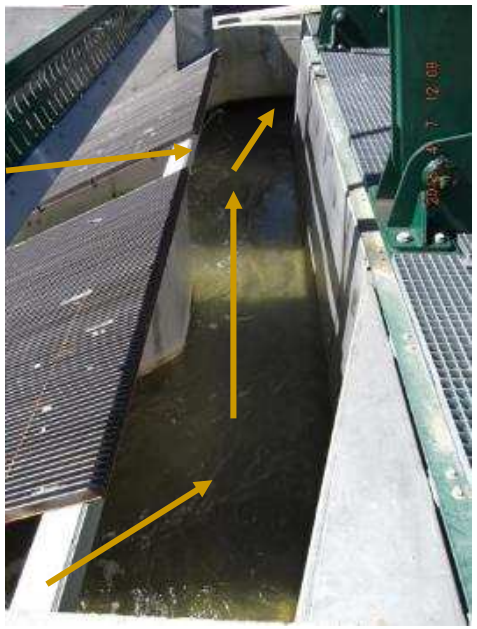
Raynal et al. 2015 : http://www.shf-lhb.org or http://dx.doi.org/10.1051/lhb/20150030

Study sites

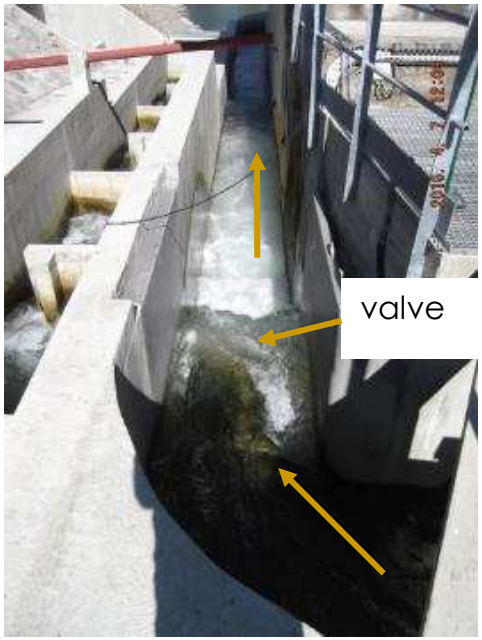
River	Gave d'Oloron	Saison		Nive
HEP name	**Auterrive**	**Gotein**	**Trois-Villes**	**Halsou**
Max intake discharge ($m^3.s^{-1}$)	10	6.6	4.5	22-30
Intake width (m)	6	6.4	4.0	20.9
Intake channel length (m)	400	780	550	925
Trashrack spacing (mm)	20	20	20	20
Total bypass discharge ($m^3.s^{-1}$)	0.50	0.38	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

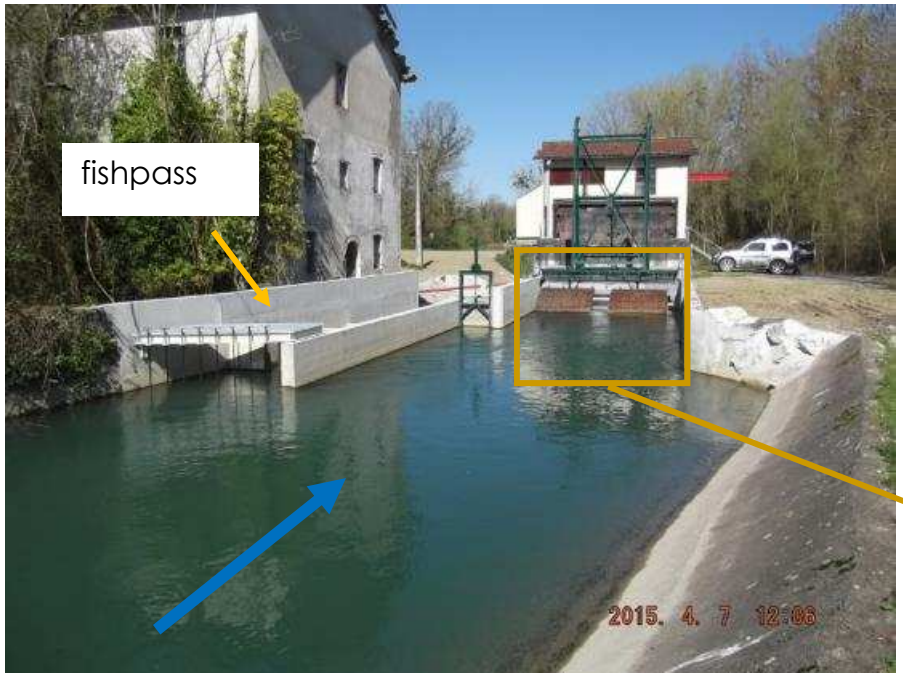
Study site : Auterrive

collecting bypass channel



transfer bypass channel + exit

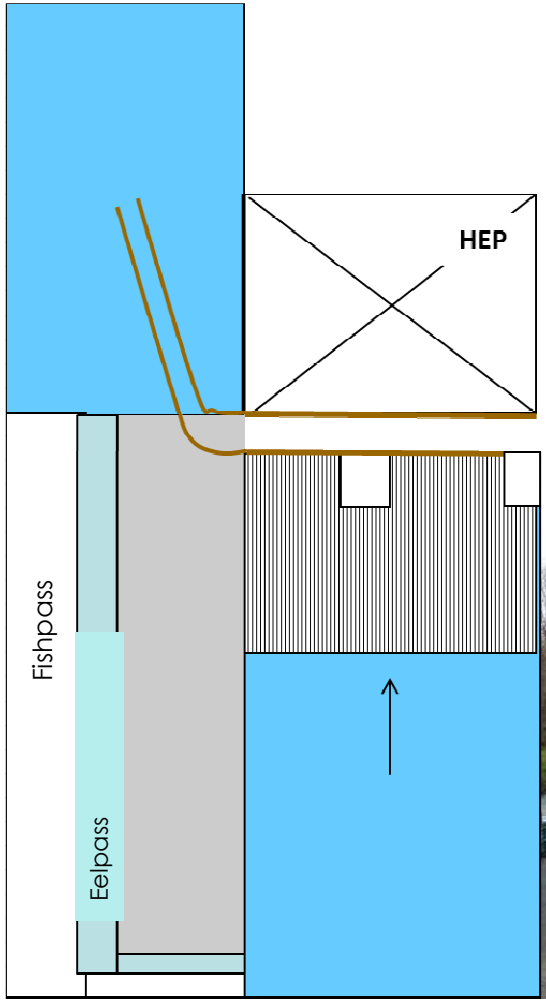




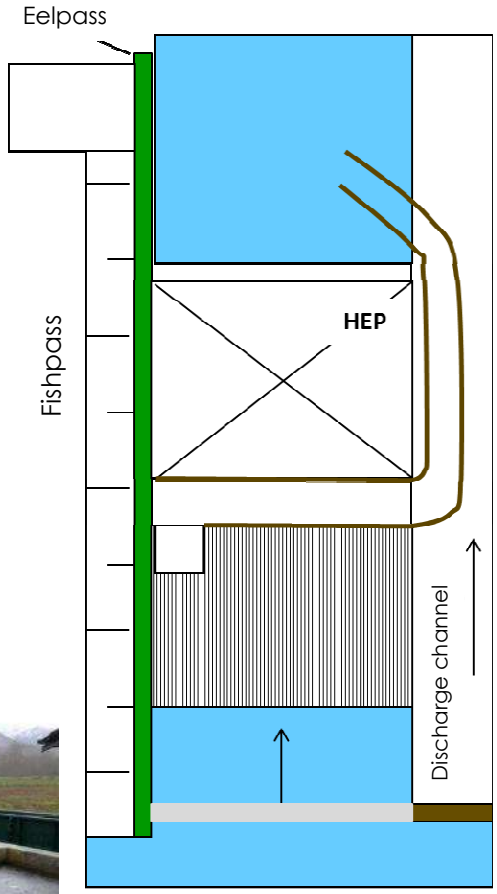
low-sloping racks with 2 bypass entrances

fish passage

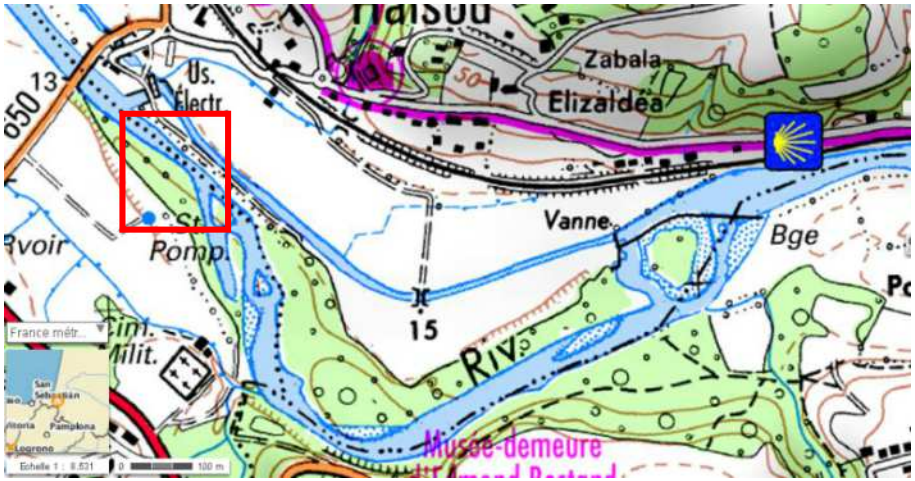
Study site : Gotein

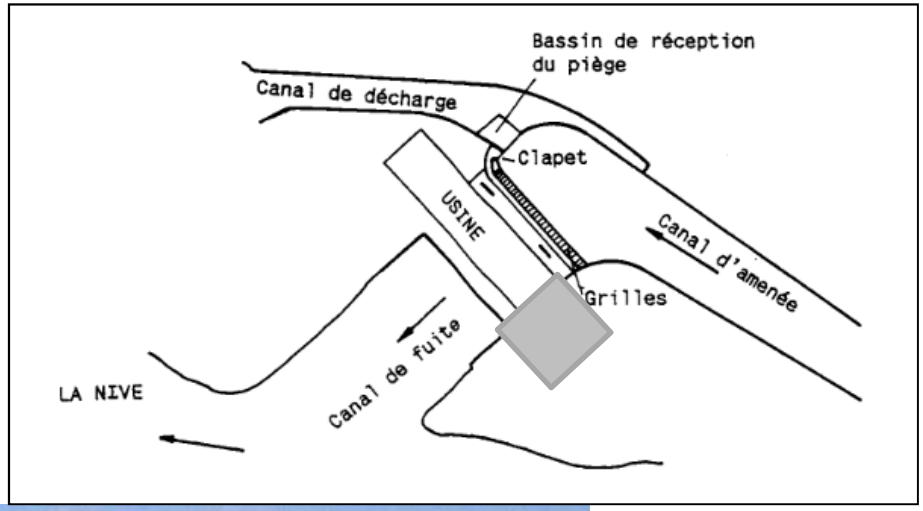


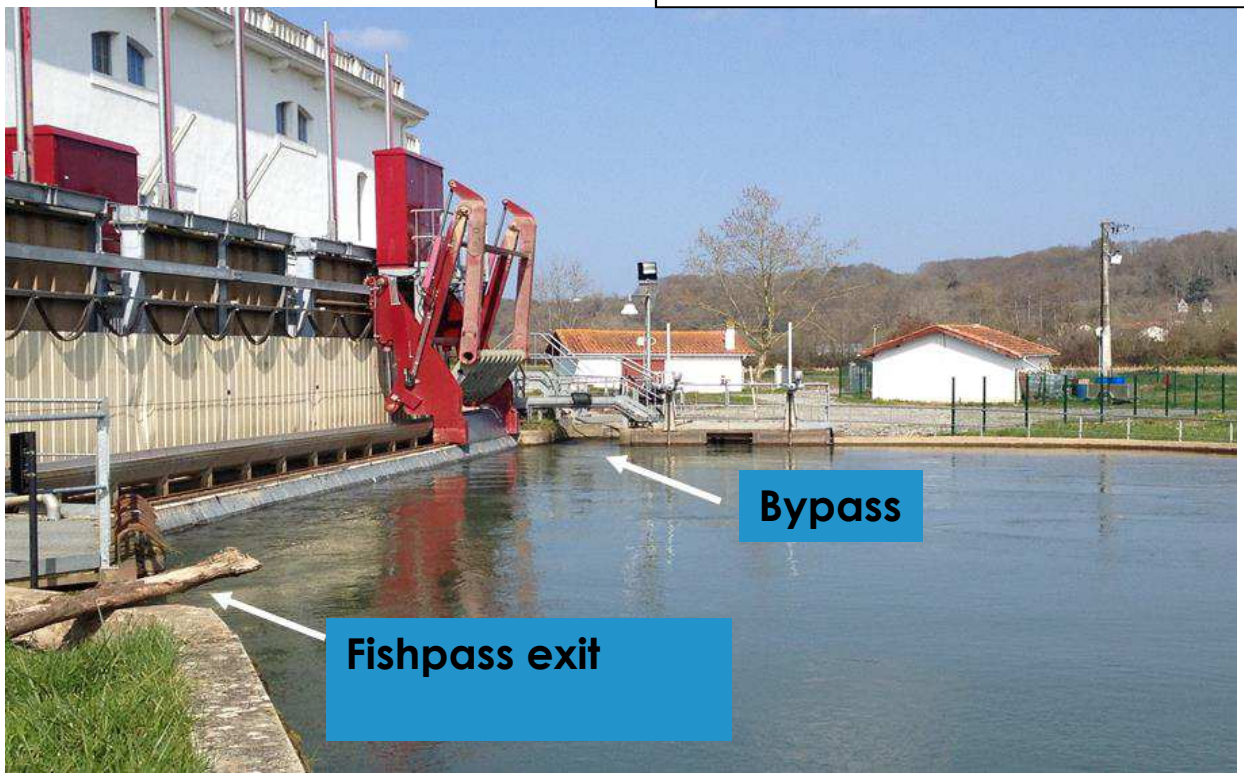
Study site : Trois-Villes



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.

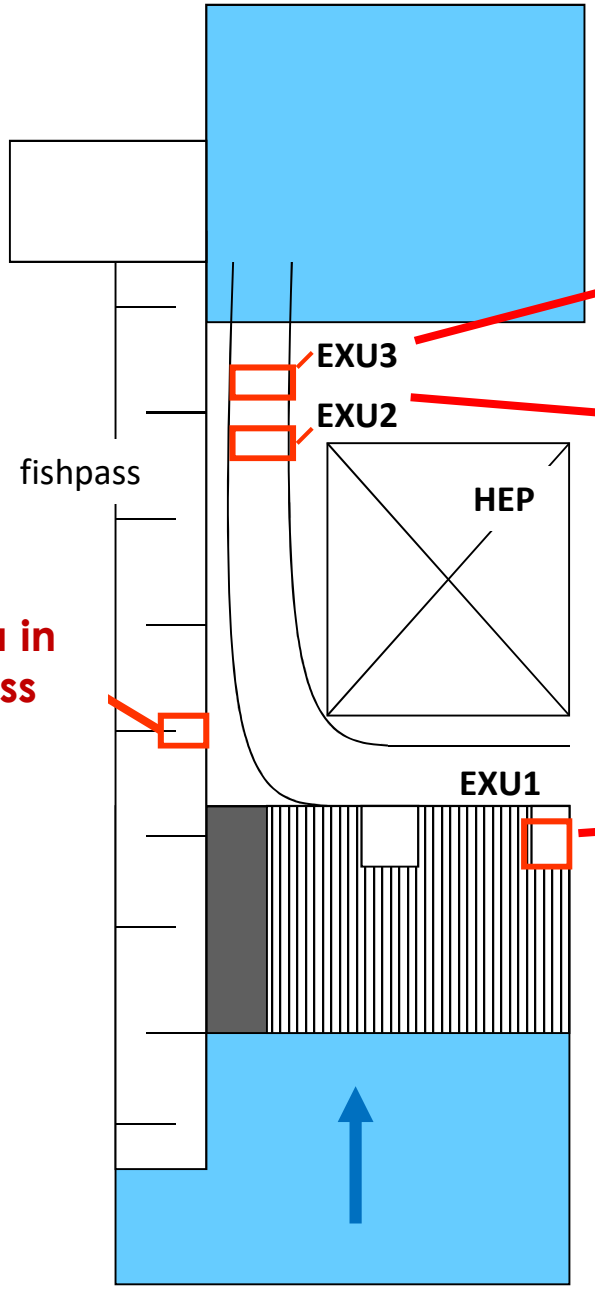
- Fish passages were monitored with RFID antennae

Main hypothesis :

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

→ Evaluation of **minimal** efficiency

Methodology (Auterrive)



2 antennae in the transfer channel

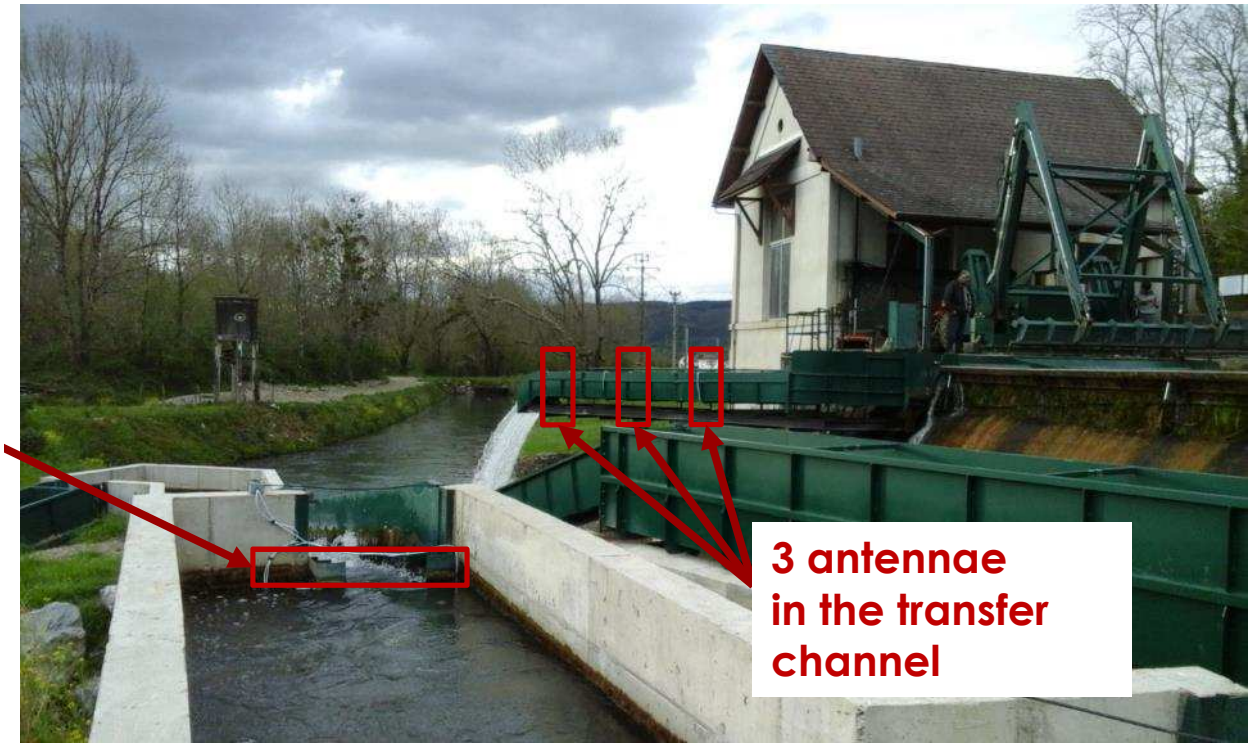
1 antenna in the fishpass

1 antenna at one bypass entrance

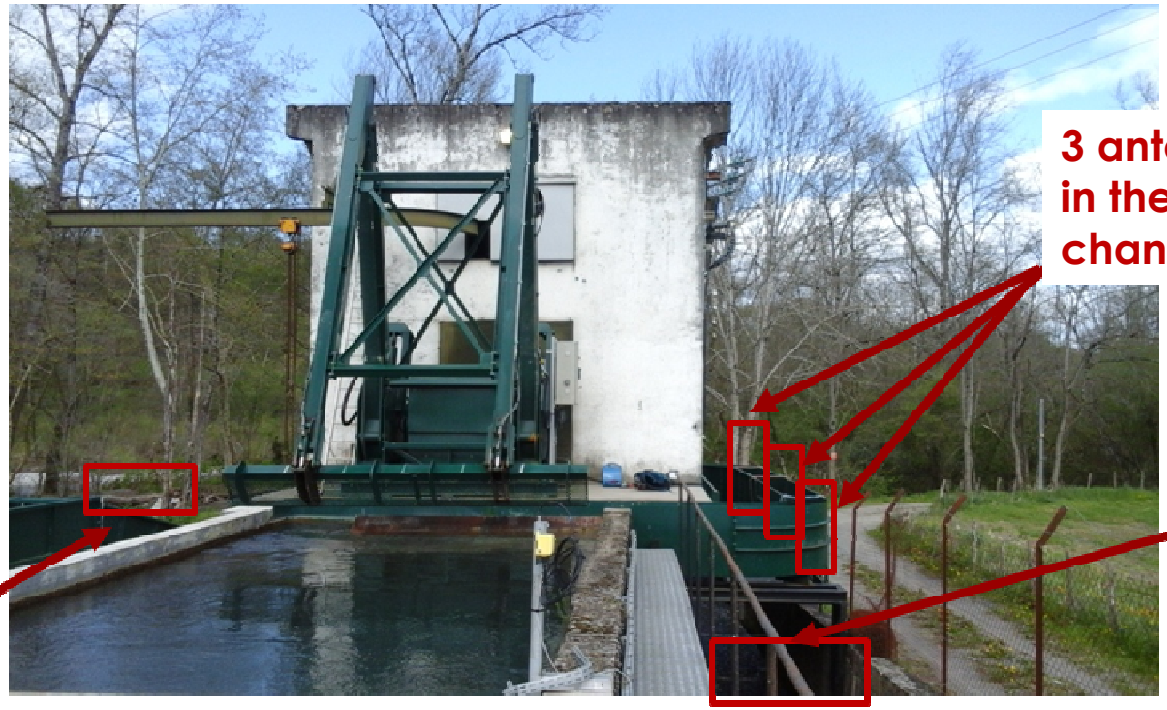
(smaller detection range)

Methodology (Gotein)

1 antenna in the fishpass



Methodology (Trois-Villes)

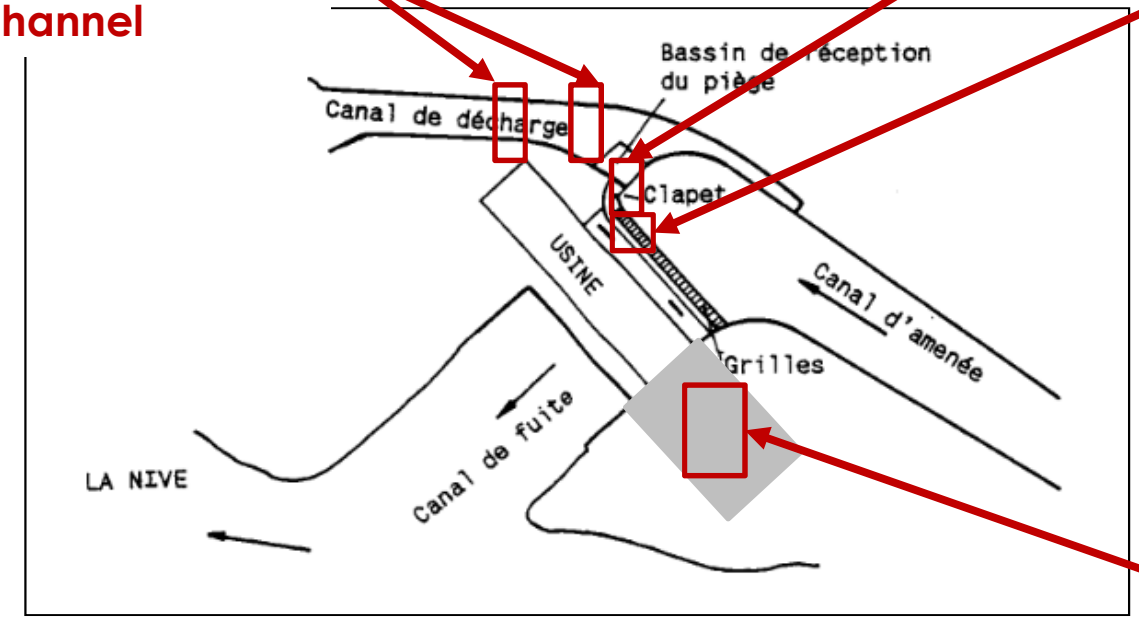


Methodology (Halsou)

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

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

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Fish group	AUT1	AUT2	AUT3	AUT4	AUT5	GOT1	GOT2	GOT3	GOT4	GOT5	GOT6
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HEP	Trois-Ville						Halsou					
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Nb of fish released	50	50	50	50	50	50	50	50	50	50	66	72
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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

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
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
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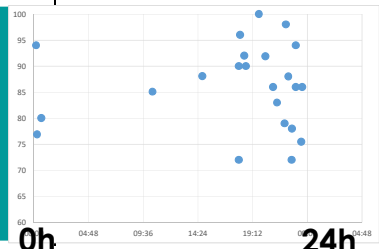
% pass. in discharge channel	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
% safe (minimum)	**91.9**	**88.1**	**83**	**75.5**	**85.1**	**100**	**78**	**80**	**90**	**72**	**76.9**

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



HEP	Trois-Ville						Halsou					
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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: passage duration

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

Great individual variability in passage time

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

HEP	Auterrive					Gotein					
Fish group	AUT1	AUT2	AUT3	AUT4	AUT5	GOT1	GOT2	GOT3	GOT4	GOT5	GOT6
Min passage time (h:min:s)	**00:07:47**					**00:02:45**					
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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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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

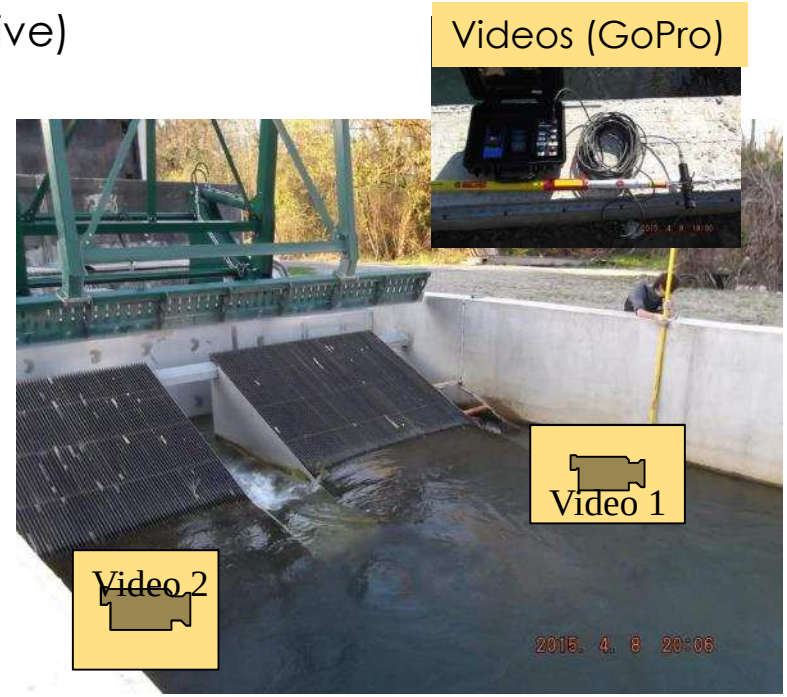
The efficiency of the HEP low-sloping rack is satisfactory (more than 82%)

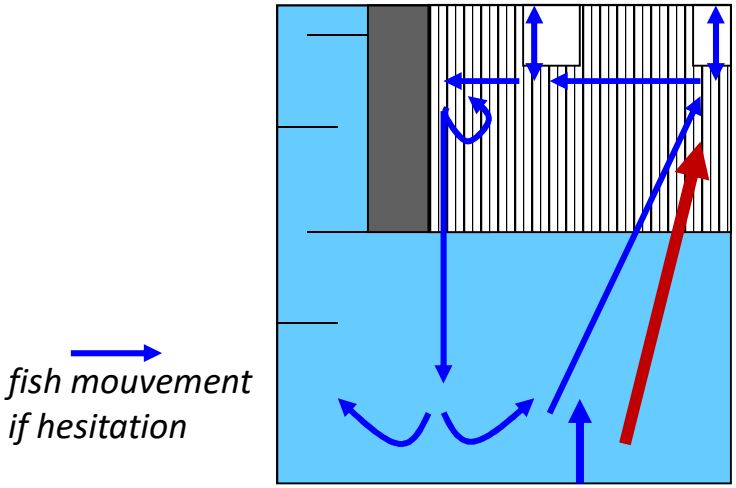
But…
fish hesitations were observed
(e.g. repeated detections for 39/72 fish at Auterrive)

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

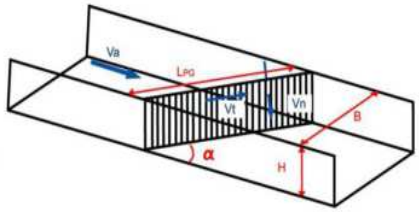
Our study confirms the recommendation of low-sloping racks (*), which is the main solution implemented in France for small HEPs.

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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ONEMA
Office national de l'eau et des milieux aquatiques

INP

IMFT

Pôle écohydraulique

eDF

Syndicat Mixte de Production d'Auterrive

ECOGEA

MIGADO
Migrateurs Garonne Dordogne

CAM ENERGIE

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

INSTITUT P'

Société hydroélectrique de Gotein