



## BEHAVIORAL STUDY OF SALMON RUNS AT A VLH PLANT

Losse hydroelectric site on the Vézère  
River Monitoring Summary 2011 – 2012

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## **Background and Objectives**

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Hydroelectric facilities can be problematic for the downstream migration of migratory fish (salmon and eel in particular) causing direct mortality. Among the many solutions tested in the world, the only one that currently has sufficient guarantees of efficiency consists of limiting the fish from going through the turbines by installing fine screening grids in associated passages. More recently, efforts in research and development have been made to develop so-called "fish-friendly" equipment that causes little or no impact.

The VLH turbine (for Very Low Head) belongs to this category. It was developed by MJ2 Technologies to work at low head elevations (1.5 m to about 4.5 m). This turbine is characterized by a large diameter rotor (3 to 5 m) and low rotational speeds (varying around 30 to 40 rev/min).

However, given the flow velocities in the turbine are around a few meters per second (1.85 m/s in the case of the test site), it could attract fish with strong swimming abilities, like adult salmon, who could attempt to enter the turbine and might get hit by the blades (mechanical impacts).

About thirty sites located mainly in France and Europe are currently equipped with VLH turbines. The Losse site (2010) was the first site to be equipped with these turbines on a river that is an important river for Atlantic Salmon. It was therefore necessary to understand the potential impacts of turbines on fish migrating upstream.

This paper summarizes the key results obtained by monitoring salmon by radio telemetry from April 2011 to December 2012. The main objective was to study the behavior of upstream migrating fish at the site, particularly at the VLH, in order to measure how much the fish is attracted to this type of turbine, the attempts made to clear the turbine and any associated impacts (injury, death).

## Site Description

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The Losse hydroelectric site is located on the Vézère River, just downstream of the town of Terrasson-Lavilledieu in the Dordogne (South West of France), 66 km upstream from its confluence with the Dordogne river.

The stream flow at the turbine rotor-shaft height is around  $52 \text{ m}^3/\text{s}$ .

The structure consists of fixed height weir, an intake canal of about 200 m in length located on the left bank and a hydroelectric plant with two VLH turbines without a tailrace (Fig. 1).

The bypassed portion of the Vézère river is approximately 300 m long with an ecological flow of about  $1.3 \text{ m}^3/\text{s}$ . The weir is equipped with a fish passage located on the right bank.

The two VLH turbines can operate in a flow range of between 3 and  $18 \text{ m}^3/\text{s}$ . In compliance with the Departmental regulation, the flow must not exceed  $14 \text{ m}^3/\text{s}$  per unit, and the net power must not exceed 480 kW.

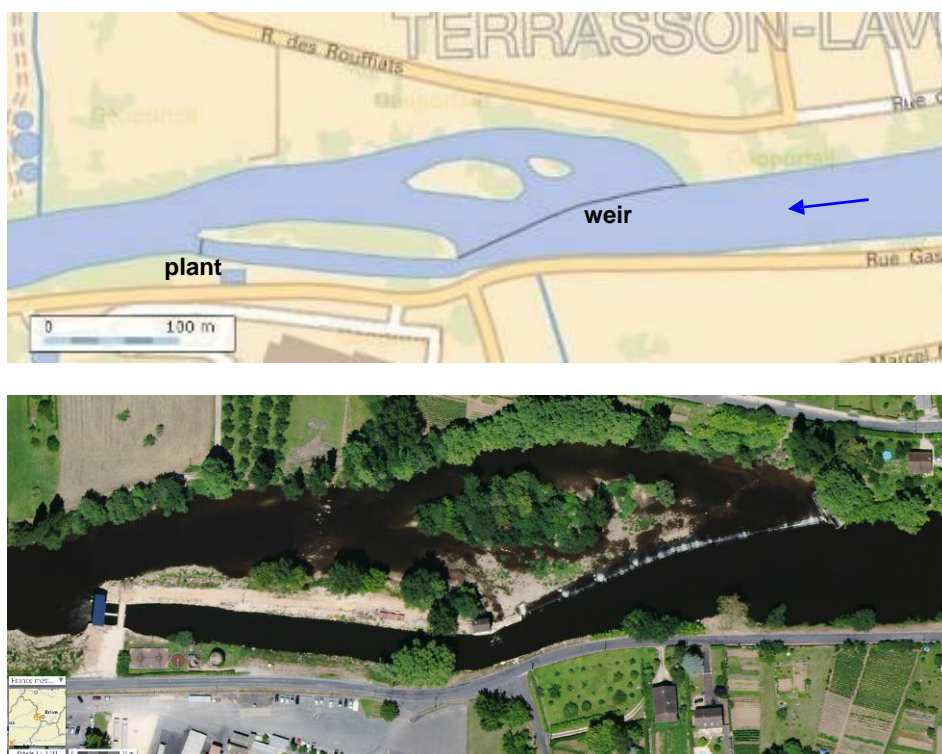


Fig. 1: Map and aerial photo of the Losse hydroelectric site (©IGN)

## Environmental Conditions and Plant Operation during Study

The 2011 phase of the study was characterized by very low flow conditions with a few small flow spikes that did not exceed 60% of the plant capacity. Only one unit was therefore used for most of the time. Plant operation was stopped between June 20 and 25 until July 10. Water temperatures rose early, reaching 20 °C by May 10 (Fig. 2).

In 2012, flows in the Vézère River were higher in the spring, with flooding close to the bi-annual flood period near the end of April (exceeding plant capacity by more than 5 times). From May to July, flows were more moderate with two main flow spikes (approximately 2 times plant capacity). The plant operated with both units until July 20 and then with one unit until August 10. After that low flow conditions necessitated a shutdown, interspersed with two short periods of operation. Temperatures were near or just below normal (lower than 16 °C before May 28).

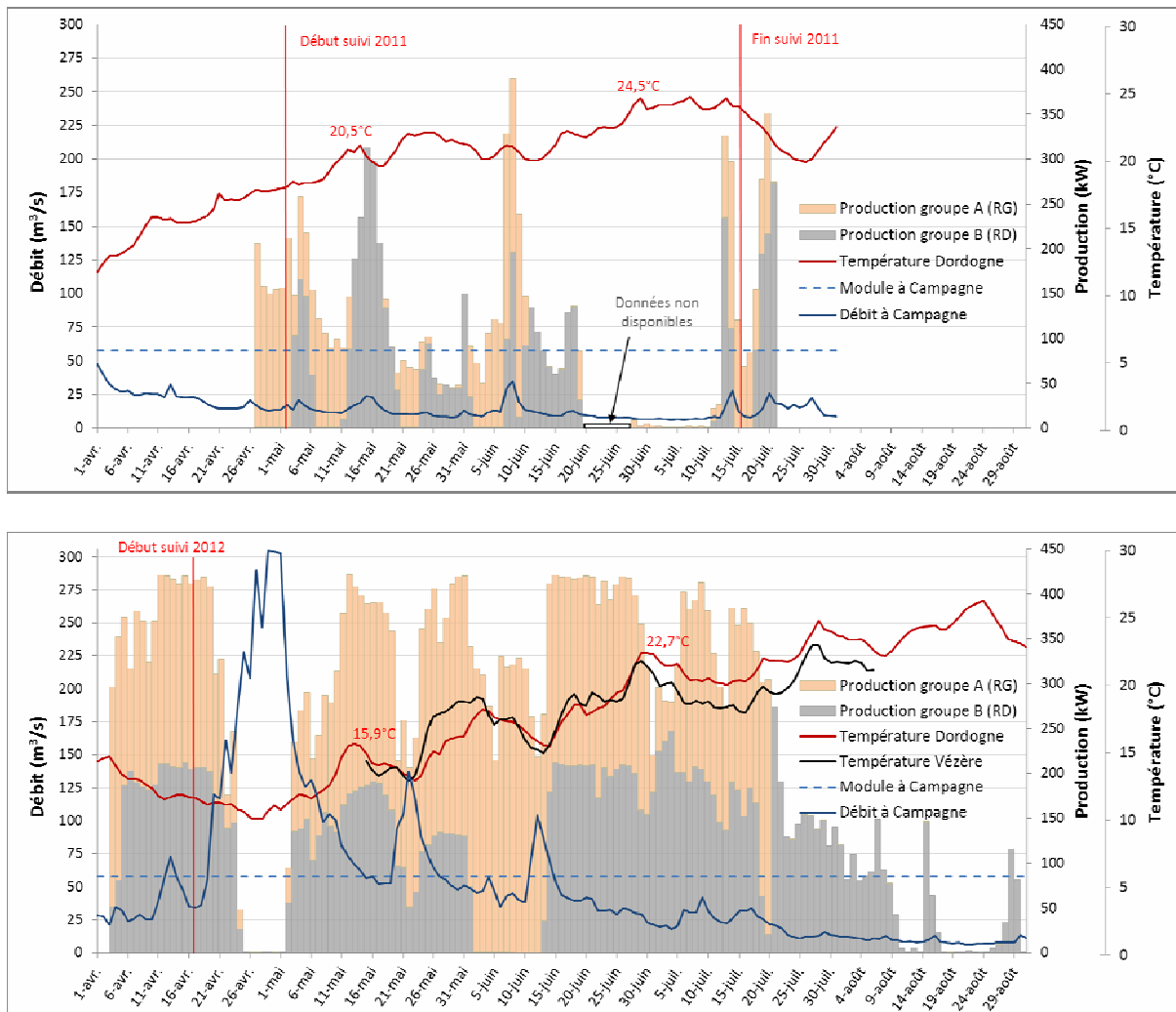


Fig. 2 : Hydrology, temperature and plant production in 2011 (top) and 2012 (bottom) (Vézère hydrology in Campagne: DREAL, Dordogne temperature at Tuilières: MIGADO, Vézère temperature at Losse: EPIDOR, Losse plant production: MILON EURL)

## Tagging and monitoring of salmon

Between April 2011 and July 2012, 19 salmon were captured at the Tuilières fish passage on the Dordogne River. They were tagged with radio transmitters (ATS brand, model F1840, unencoded) by intra-esophageal insertion and then transported and released on the Vézère about 3 km downstream of the Losse site.

The salmon were manually tracked on a very regular basis. At the Losse site, 6 tag recorders (ATS R2100 and D5041 DCC) connected to air or submerged antennas were installed as to cover 5 delineated detection zones, in order to monitor fish behavior at the site (Fig. 3).

Out of 19 tagged salmon, 13 managed to reach the Losse site (6 in 2011 and 7 in 2012). Only six individuals reached the weir and only 5 passed through the fish passage. This low passage rate (approximately 40%) is mainly due to the fact that the fish is not attracted to the bypassed channel when its flow is the minimum flow.

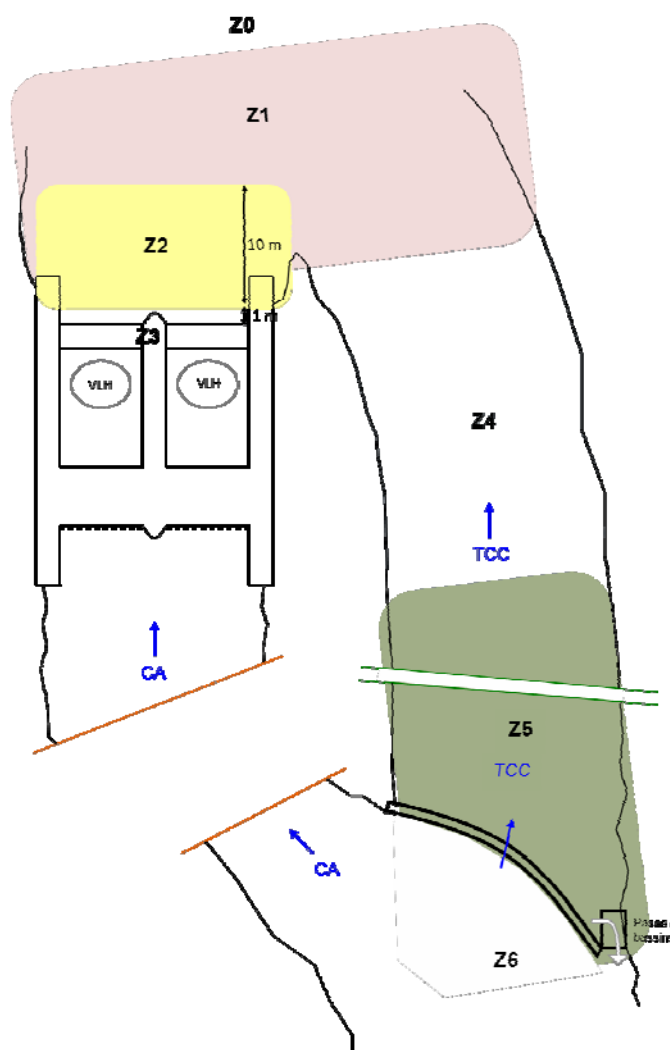
The salmon were tracked quite well over the entire site studied and the fixed location recorders provided data consistent with the available knowledge on the typical behavior of this species at these type of structures.

Due to the water turbidity, the difficult bank access and no indication of mortality from the transmitters in 2011, no dead salmon were found. Four transmitters were later found, but only about a month after the fish died. The cause of death could therefore not be identified for any of the salmon.

Table 1: Tagging times and numbers

Year	Release date	Number	Total
2011	28-Apr	2	9
	03-May	5	
	10-May	1	
	11-May	1	
2012	17-Apr	1	10
	18-Apr	1	
	19-Apr	1	
	25-Apr	1	
	16-May	2	
	12-Jun	2	
	21-Jun	1	
	18-Jul	1	
			19 salmon tagged

Fig. 3: Site zoning



## **Fish Behavior at the Plant**

Out of the 13 salmon that swam to the site, 3 stayed at a distance and did not try to pass it. The other 10 individuals (5 in 2011 and 5 in 2012) first actively explored the site.

Tracked fish spent significantly more time on the site in 2011 than in 2012 (1,623 hours versus 116). This is due to the site configuration and different hydrological conditions. In 2011 there were low flows in the bypass channel, which the fish find uninviting and therefore tended to remain downstream of the plant. In 2012, when flows were high, the salmon were quickly attracted to the bypass channel with its higher flows, and quickly swam towards the weir.

The accumulated time fish spend downstream of the plant (excluding the bypass channel) is 1,583 hours (average of 122 h, 0.7 h for the 1<sup>st</sup> quartile, median of 13 h, and 54 h for the 3<sup>rd</sup> quartile).

Ten fish actively explored to within 10 m of the turbine outlets (Zone 2). They got close to the area a total of 286 times, for a cumulative time of 178 hours, which is an average of 11% of the time spend downstream of the plant (Zones 1, 2 and 3). It should be noted that similar results were obtained during two years of follow-up monitoring (11% of the time in 2011 and 17% of the time in 2012). There is however significant individual variability (varying between 2% and 67% of time spent by individuals). The average time duration of each foray in Zone 2 is 37 minutes (1<sup>st</sup> quartile 4 min, median 13 min, 3<sup>rd</sup> quartile 28 min).

Only 3 salmon came very close to the operating VLH turbines (Zone 3). They made at least 15 approaches lasting no more than a few seconds each time. These forays occurred at very different flow conditions and operation of the plant:

- Vézère flow 11 m<sup>3</sup>/s, Turbine A stopped and Turbine B in operation,
- Vézère flow 31 m<sup>3</sup>/s, Turbines A and B in operation,
- Vézère flow of 120 m<sup>3</sup>/s, Turbines A and B in operation.

Of these three fish, two eventually passed the site using the fish passage located at the weir. They therefore have not suffered any damage when they came close to the VLH. The third salmon did not pass the site. After its foray near the VLH, it continued to swim around the site for about 6 hours until sunset. It then followed the typical evening downstream behavior observed in salmon. The fish did not return to the site and died within the following 17 days, it was not possible to determine the exact date with certainty. Its body was not found and the cause of death could therefore not be determined. Given the high water temperatures (around 24 °C) and rising at this time, it is possible, and presumed most likely, that the fish succumbed to environmental conditions typically adverse for the species.

## Fish Behavior at the Plant

Tab. 2: Summary of operation

		<b>2011</b>		<b>2012</b>		<b>TOTAL</b>
	marked	9		10		<b>19</b>
came to Z1	came to the site	6		7		<b>13</b>
came to Z2	came downstream of turbines	5		5		<b>10</b>
came to Z3	came within immediate area of turbines	0		3		<b>3</b>
	came closest to the VLH without passing it	0		1		<b>1</b>
<hr/>						
	Total at the site (hours)	1623		116		<b>1739</b>
in Z1+Z2+Z3	at the plant (h)	1537		46		<b>1583</b>
in Z2	downstream of the VLH (h)	171	11%	7,6	17%	<b>178</b> 11%
in Z3	immediately downstream of the VLH while in operation(min)	0		6,6		<b>6,6</b>
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	came to the weir	2		4		<b>6</b>
	passed through	2		3		<b>5</b>

Detailed results (durations and number of forays in different zones) are available in the annex.

## **CONCLUSION**

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The study was conducted over a two year period observing the behavior of salmon runs downstream of a hydroelectric power plant equipped with VLH turbines under varying hydrological conditions and turbine operations. Fish behavior in the two years of monitoring was generally comparable.

The fish is strongly attracted to the area immediately downstream of the turbines (within 10 m): they entered the area 286 times for a total time of 178 hours. The durations of forays into this area is however relatively short (average of 37 minutes and median 13 minutes).

Out of the 10 fish that came downstream of the turbines, 3 fish came right up to the VLH while in operation. The forays were however very short (lasting only a few seconds).

Two of the 3 salmon were able to subsequently pass the site, indicating that they did not suffer injury during their forays in very close proximity to the turbines. The third fish did not pass the structure and died downstream of the plant. The cause of death could not be determined with certainty. However, it seems most likely that in light of its behavior, it succumbed to adverse environmental conditions (water temperature in particular). In any case, nothing points to the fact it might have been hit by the VHL blades.

Thus, in the context of two experiments conducted in 2011 and 2012 at the Losse site, it appears that no fish attempted to swim upstream through the VLH turbines and that there was no evidence of blade hits or impacts.

Further information could potentially be obtained by conducting other experiments that one, increase the number of fish used and two, study the behavior of fish at sites with different configurations (e.g. no bypass stretch, the presence of a tailrace ...).



## Annex

### Detailed results of the monitoring of salmon at Losse in 2011-2012

	Salmon (transmitter)	Release date	Duration between release and arriving at site	Duration blocked <sup>(1)</sup> (h)	Duration at site (h)	Duration in Z1 (h)	Duration in Z2 (h)	Duration in Z3 (min)	Duration at plant Z1+Z2+Z3 (h)	Duration in Z4 (h)	Duration in Z5 (h)	Inc site <sup>(2)</sup>	Inc Z2	Inc Z3	Inc Z5	Passed upstream
<b>2011</b>	49 571	28-Apr	93 h	159	54	41	12.9		54	0.3	16	17	17			No
	49751	03-May	10 h	35	30	9	4		13	0.5		3	24			Yes
	49 941	03-May	16 h	1989	1110	929	138.3	0.37 <sup>(3)</sup>	1067	43	18	147	167		1 <sup>(3)</sup>	No
	49 701	03-May	19 h	895	84	54	8.6		62	3.9		20	16		1	Yes
	49 761	03-May	54 h	1483	332	320	6.9		327	4.9		82	27			No
	49 641	10-May	81 h	15	13	13			13			3				
<b>2012</b>	49 392	17-Apr	5 h	45	45	0.6	0.1		0.7	14.5	30	1	3		4	Yes
	49 421	18-Apr	1 h	50	0.9	0.2	0.02	0.37	0.2	0.7	? <sup>(4)</sup>	3	1	1	≥1 <sup>(4)</sup>	Yes
	49 144	19-Apr	3 h	6.2	6.2	0.02	0.03		0.05	0.5	5.7	1	1		3	No
	49 441	16-May	14 h	4.7	1	1			1			4				No
	49 271	16-May	77 j.	65	40	34,8	5.4	2	40.2	0.03		4	19	5		No
	49 411	12-Jun	81 j.	4.1	0.5	0.4	2.1		0.4	0.2		2				No
	49 210	21-Jun	22 h	22	22	1.2		4.2	3.4	0.4	18	1	1	9	1	
Total				4772	1739	1404	178	6.9	1583	69	>87	288	286	16	≥11	

- (1) : The time duration between first and last arriving at site
- (2) : Number of incursions into Zone 1 (downstream of the plant) from Zone 0 (downstream of the site)
- (3) : The incursion took place while the VLH turbines were shutdown
- (4) : No confirmation from radio transmitter monitoring that this individual crossed the weir



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