SUMMARY OF THE STUDY OF YOUNG SHAD IN THE LOWER REACHES OF THE RIVERS GARONNE AND DORDOGNE

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Maître d'ouvrage Partenaires :

CONTENTS

I – BACKGROUND AND AIMS OF THE STUDY

I.1 – The Life + Shad project

A Franco-German Life project to reintroduce the Allis shad into the Rhine by restocking with strains from the Garonne and Dordogne rivers was undertaken jointly between 2008 and 2010 by teams of German and French researchers and technicians (the French team came from Irstea and Migado).

Further to this initial Life project on shad, a second project (Life+Shad 2011-2015) was submitted to the European Commission. It was accepted by the Commission on 29 September 2010 (Grant agreement number Life09 NAT/DE/000008).
In addition to continuing the reintroduction of shad into the Rhine, the second project includes a French component focusing on the conditions of migration, spawning and capture of shad in the Garonne and Dordogne rivers. It includes the following three actions:
- Action A1: Updating of knowledge about shad passes,
- Action A2: Study of the free circulation of shad in the lower reaches of the Garonne and Dordogne,
- Action E4: Study of young shad in the lower reaches of the Rivers Garonne and Dordogne.

The Life+ Shad project began on 1 January 2011.

I.2 - Action E4: Study of young shad in the lower reaches of the Garonne and Dordogne

Sméag is the contractor for the E4 study, "Study of Young Shad in the Lower Reaches of the Rivers Garonne and Dordogne". The project consists of sampling the population of young shad (fry) before downstream migration by conducting scientific fishing. The study is being conducted on the Dordogne in partnership with Epidor, which is acting as a relay with stakeholders in Dordogne and which is also contractor for Action A2, "Study of the Free Circulation of Shad in the Lower Reaches of the Garonne and Dordogne".
Onema, Migado and EDF are also partnering Sméag for the purposes of the study:

- Epidor is more particularly involved in the part of the study being conducted on the Dordogne: by acting as a relay for Sméag in its dealings with stakeholders in Dordogne.
- Onema is providing technical assistance with the physical definition of shad fishing sites, the definition and design of fishing equipment and involvement in the scientific fishing.
- During the years of scientific fishing, EDF will be providing the data produced by two stations measuring water quality (Golfech and Mauzac).
- Migado will be sharing its knowledge of the terrain and real-time information on the spawning activity of shad in the selected sites.

2011 was taken up with the building and testing of fishing equipment. Fry were then studied using several types of fishing between 2012 and 2014 on the Garonne and Dordogne. This report summarises the results and the conclusions of the study. It also includes, in its annexes, the results of the analysis of otoliths from shad fished in 2014.

II – SUMMARY OF THE STUDY OF YOUNG SHAD IN THE LOWER REACHES OF THE GARONNE AND DORDOGNE IN 2012, 2013 AND 2014 (sub-contracting report – – JL Bellariva)

II.1 – THE MAIN ISSUE

This study was undertaken as part of the Life project aimed at reintroducing the Allis shad (*Alosa alosa,* L.) to the estuaries of the Gironde and Rhine. One aspect of the action was the monitoring of fry in the lower reaches of the Garonne and the Dordogne.

The aim of the study, which lasted for three years (2012-2014), was to understand the function of the spawning sites, try and introduce an indicator of spawning success and better understand the fry stage of the shad life cycle.

Over the three years of the study, four sites were monitored viz. Saint-Sixte and Couthures-sur-Garonne on the Garonne and the spawning sites of Prigonrieux (in 2012) and Mouleydier (in 2013 and 2014) on the Dordogne. The various techniques used during the three years of monitoring were as follows:

- Push net fishing;
- Driftnet fishing;
- Fishing with a landing net (2012 only);
- Fishing with a sweep net (2014 only).

Although actual dates varied from year to year, the work was conducted between the month of June and early September, once a week on each site, as often as possible.

Based on the fry caught in 2014, a more specific study was conducted on the otoliths of the fish, mainly to determine their age.

This report displays the results obtained during the various sampling periods and, based on the conclusions obtained, attempts to establish new directions of work to improve knowledge of this part of the life cycle of this species of fish.

II.2 – EQUIPMENT AND METHODS

II.2.1. Choice of sites

II.2.1.1. The Garonne

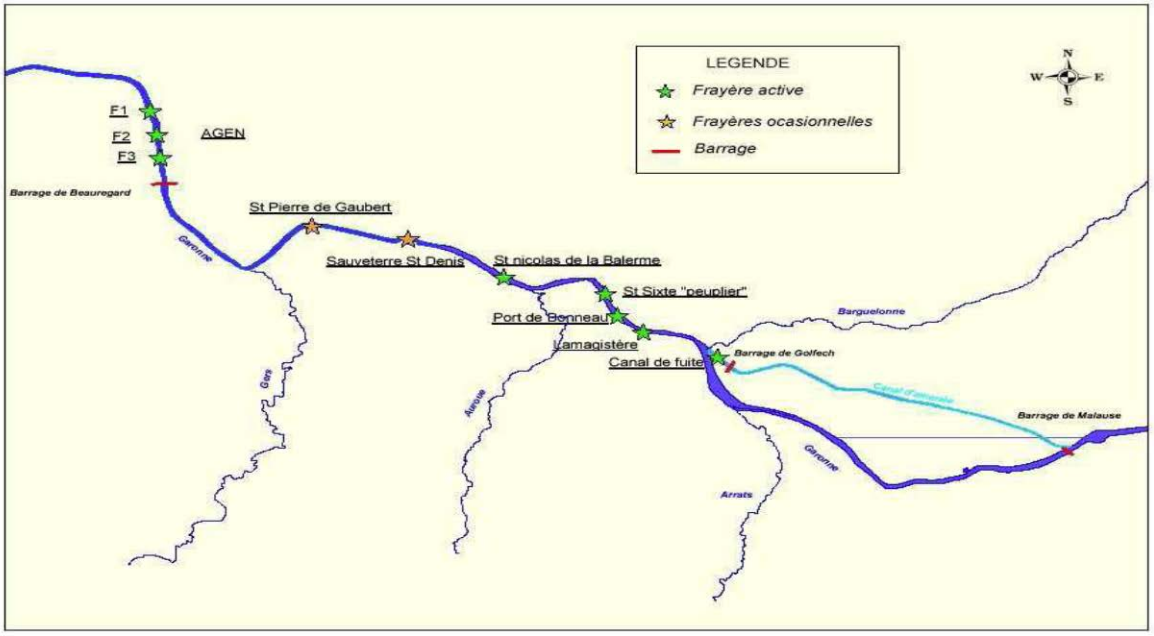
During its spawning migration, the Allis shad swims up the River Garonne to a point upstream from Toulouse. A certain number of spawning grounds were observed along the course of the river, some more active than others depending on the year and the size of the migratory population.

Downstream from the Golfech Dam, which is the first real obstacle to fish swimming up the Garonne (since the removal of the Beauregard passage in Agen),

10 spawning grounds were observed on the Garonne and 1 on the River Lot. From downstream to upstream, they were:

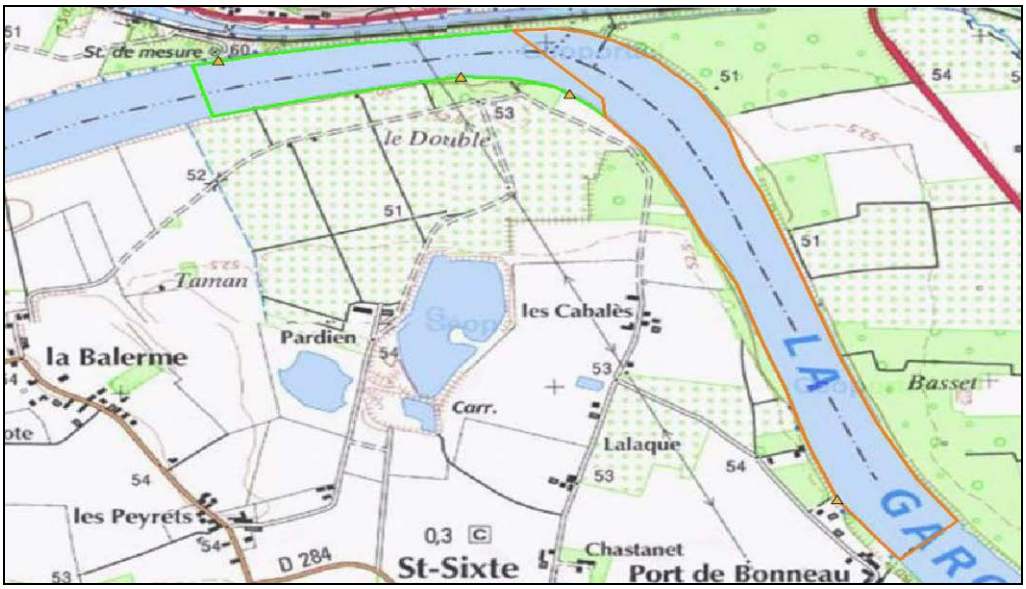
- Aiguillon sur le Lot;
- Agen downstream from the Beauregard Dam where there were 3 considered to be active;
- Saint-Pierre de Gaubert, considered as being in occasional use;
- Sauveterre Saint-Denis, considered as being in occasional use;
- Saint-Nicolas de la Balerme, considered as active;
- Saint-Sixte, considered as active;
- Port de Bonneau, considered as active;
- Lamagistère, considered as active;
- Tailrace of the hydroelectric power plant at Golfech, considered as active.

Map 1 indicates the locations of these spawning grounds.



Map 1: Location of shad spawning grounds downstream from the Golfech Dam (Source: MIGADO)

The spawning ground selected for the project was the one in Saint-Sixte. It is located downstream from those in Port de Bonneau and Lamagistère. The fishing stand was positioned immediately downstream from the spawning ground. It was easier to conduct the experiment on this site because of its morpho-dynamic configuration, with acceptable flow rates and depths that allowed for samples across almost the entire zone. Map 2 shows the respective positions of the spawning ground in St Sixte (in orange) and the fishing zone (green).



Map 2: Spawning ground and sampling site (Source: SMEAG).

In 2013, spawning numbers suffered a significant downturn, especially in the upper reaches of the Garonne. Observation revealed that spawning was more significant on the Lot and it was therefore decided to add to the list of sites previously monitored on the stretch of the Garonne downstream from the confluence of the Garonne and Lot in the Couthures-sur-Garonne area. Map 3 shows the sampling zone from 2013 onwards, stretching downstream from Sainte Bazeilles to upstream from Marmande.

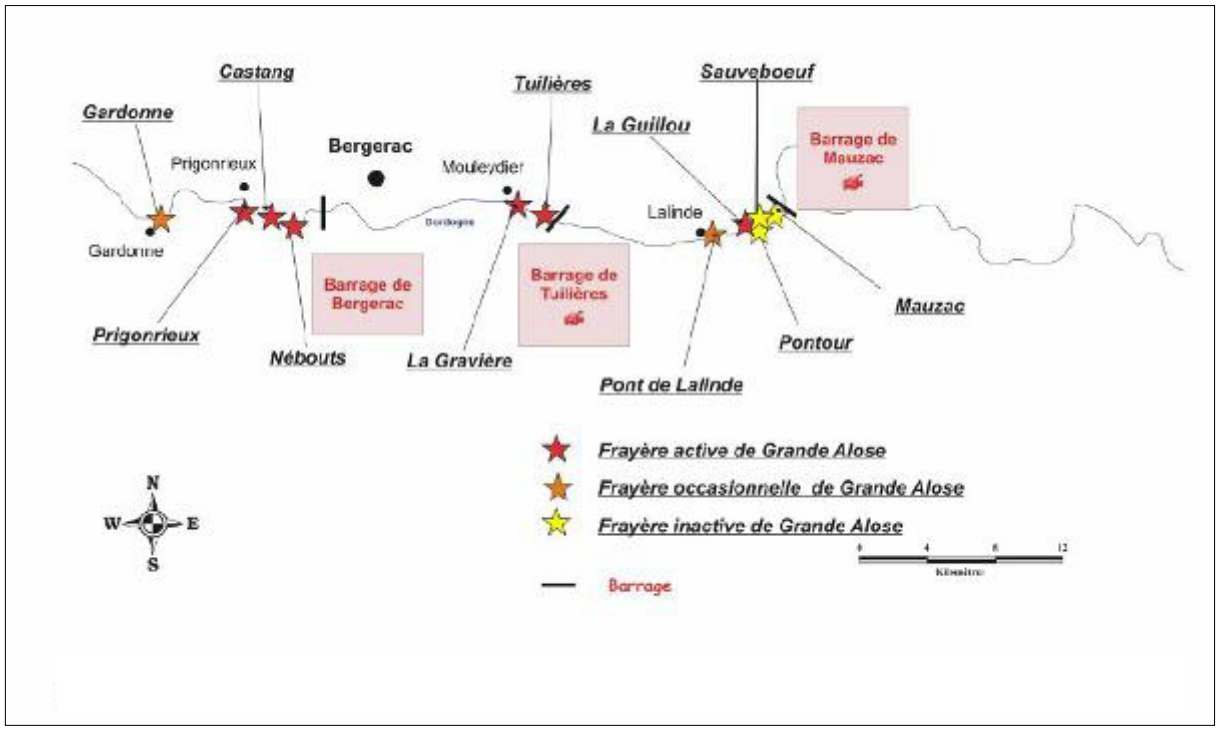
Map 3: Sampling zone around Couthures-sur-Garonne

II.2.1.2. The Dordogne

On the Dordogne, the Allis shad swims upstream to Mauzac during the migration that accompanies spawning. Downstream from this dam, there are 11 spawning grounds, some active and others in occasional use or now inactive. From downstream to upstream they are:

- Gardonne, occasional spawning ground (downstream from Bergerac);
- Prigonrieux, active spawning ground (downstream from Bergerac);
- Castang, active spawning ground (downstream from Bergerac);
- Nebouts, active spawning ground (downstream from Bergerac);
- La Gravière, active spawning ground (downstream from Tuillières);
- Tuillières, active spawning ground (downstream from Tuillières);
- Pont de Lalinde, occasional spawning ground (downstream from Mauzac);
- La Guillou, active spawning ground (downstream from Mauzac);
- Pontour, inactive spawning ground (downstream from Mauzac);
- Sauveboeuf, inactive spawning ground (downstream from Mauzac);
- Mauzac, inactive spawning ground (downstream from Mauzac).

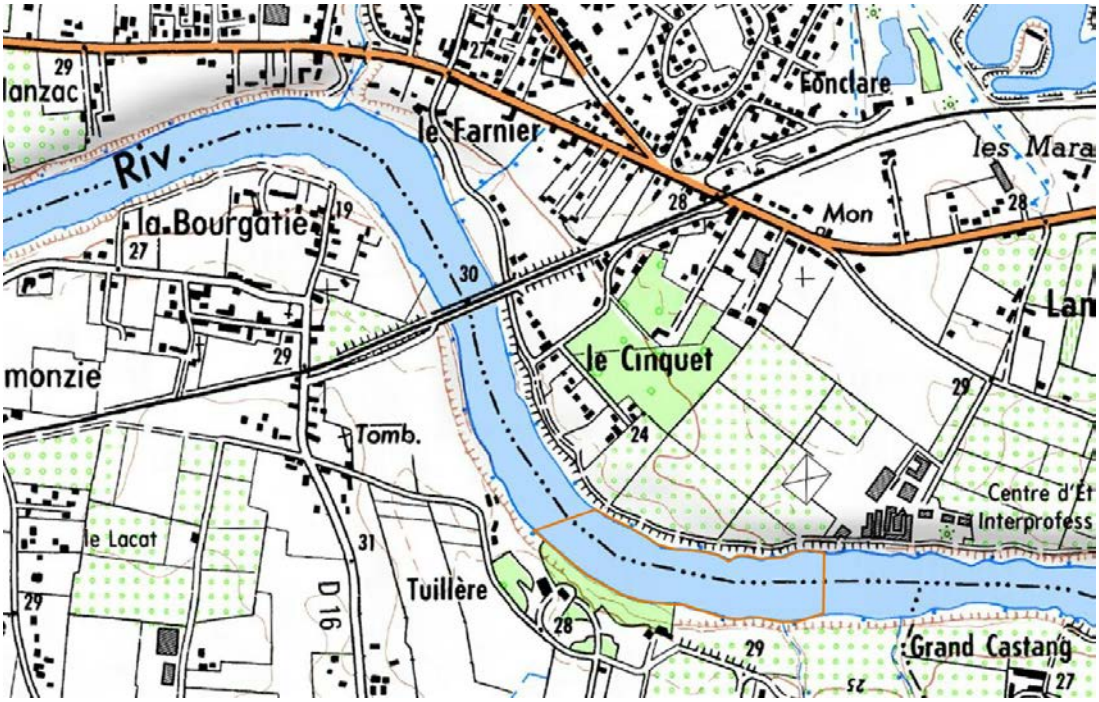
Map 4 shows the location of these spawning grounds along the course of the River Dordogne.



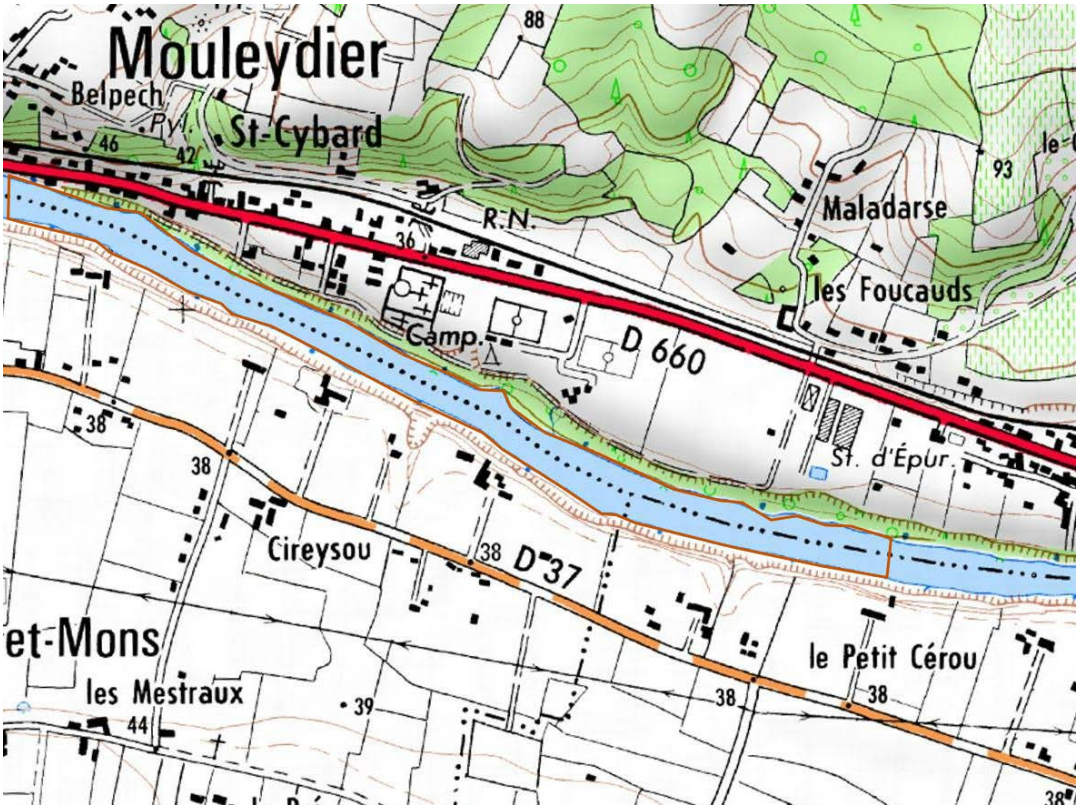
Map 4: Location of shad spawning grounds downstream from the Mauzac Dam (Source: MIGADO)

In 2012, the spawning ground in Prigonrieux was selected as the sampling site on the Dordogne. Located downstream from all the listed breeding grounds on the Dordogne except the one in Gardonne, it was the second such area used during the spawning run (Map 5). In 2013, hydraulic conditions in spring modified the run on the Dordogne. Spawning occurred later in the season and was more significant

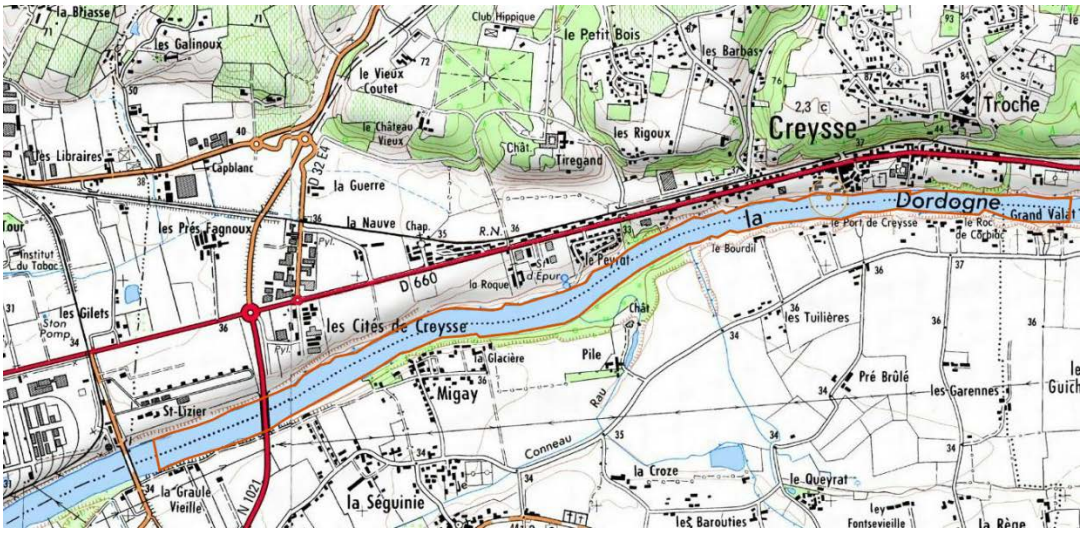
at La Gravière, just downstream from Tuillières. It had been observed, in 2012, that this spawning ground was more active. However, the professional fishermen with whom we had worked in 2012 had retired and it was decided, with another professional, to conduct sampling in this spawning ground and further downstream in Creysse in 2013 and 2014 (Maps 6 and 7).



Map 5: Sampling zone in Prigonrieux in 2012



Map 6: Sampling zone in Mouleydier (2013 and 2014)



Map 7: Sampling zone in Creysse (2014)

II.2.2. Sampling

The protocol initially drafted by SMEAG and Onema included three types of sampling:

- push net fishing using boats;
- night-time sampling, with fishing lights and a landnet from a fixed stand, to catch small fish (<30 mm);
- driftnet fishing, for larger fish (> 50 mm).

On both rivers, each sampling operation was conducted jointly with professional fishermen, Mr. Gautier on the Garonne and Mr. Queyreau (in 2012) and Mr. Delmarès (in 2013 and 2014) on the Dordogne. They made their boats available to us, with the equipment used for the various types of sampling (apart from push nets). They also provided knowledge of sampling sites and the behaviour patterns of the target species.

The three types of sampling were designed to cover the entire range of sizes of fry, since the length of the fish changes over the course of the season. The idea was to begin by catching fry growing on the chosen site then catching fry migrating downstream (actively or passively).

Given the acknowledged difficulties of catching fry using the techniques selected initially, a test was conducted using a beach sweep net in 2014. This type of sampling had the advantage of catching a large range of sizes and, more importantly, was an active form of fishing in as much as all the fish present within the sampling zone were caught and could not, apparently, escape from the pouch formed by the net. The technique was tested on the Garonne (in Couthures sur Garonne and Saint-Sixte) and on the Dordogne (in Mouleydier).

Sampling was conducted once a week on the Garonne and Dordogne, beginning approximately one month after the observed peak laying period, and continued for eight weeks.

II.2.2.1. Push nets

The general principle of this method is to push nets mounted on metal frames positioned on each side of the boat over a given distance.

A pouch consisting of a net with 10 mm mesh at the front and 4 mm at the back is mounted on a metal frame 1 m wide and 0.5 m high. The pouch can be opened at the end of the net to make it easier to recover the fish caught. Each frame is topped with a handle so that it can be moved along the boat. The frames are attached by a system of ropes so that they are stable when pushed and are easy to bring back into the boat at the end of sampling to check the catch. In theory, the system allows the frames to be placed in any position along the sides of the boat. Photo 1 illustrates the device. After hydraulic measurements were taken with the devices in 2012, it was decided to place them as far forward as possible on the boat. The boat progressed relatively quickly (5 to 8 km/h, measured on the GPS).

Photo 1: Frame and nets (Source: SMEAG).

Once the devices have been positioned, the net is pushed along the entire length of the selected sampling site (Figure 1). The number of runs depends on the width of river suitable for sampling purposes but is generally limited to 3 or 4. Twice as many runs may be effected if necessary.

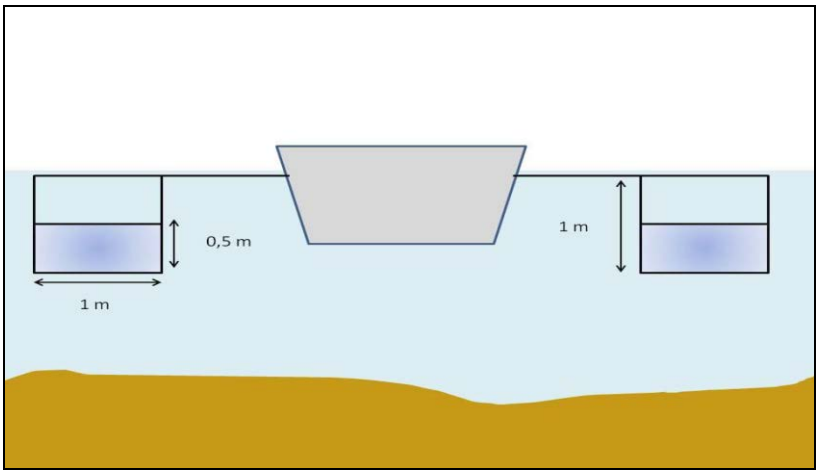


Figure 1: Illustration of the push net technique (Source: SMEAG).

After each run with push nets, the devices are hoisted back on board and the nets are emptied into buckets, taking care to separate the catch from each net on each side of the boat. An operator is responsible for identifying the fish caught. Fish other than fry are thrown back. Any fry caught are measured then quick frozen to allow for subsequent additional measurements (otoliths, stomach contents etc.).

With each net run, a certain number of parameters are noted. A propeller flowmeter is mounted in the centre of the frame to calculate the flow filtered during sampling.

The simultaneous use of an echosounder linked to a GPS indicates the boat's position on the river when the run is effected (trace). The trace allows researchers to repeat the sampling operations over time in a fairly constant manner. The GPS

also notes the boat's speed and adjusts it from one run to the next if necessary, to improve fishing efficiency.

It should be noted that, although the GPS indicates the boat's speed compared to the bank, the flowmeter on the frame of the fishing device gives the speed in terms of device inputs. This is the result of current speed and the speed of the boat. The corresponding echosounder gives an instant reading of water temperature during sampling and indicates any changes in depth along the trace.

Photo 2 shows an example of the traces recorded during runs with push nets.

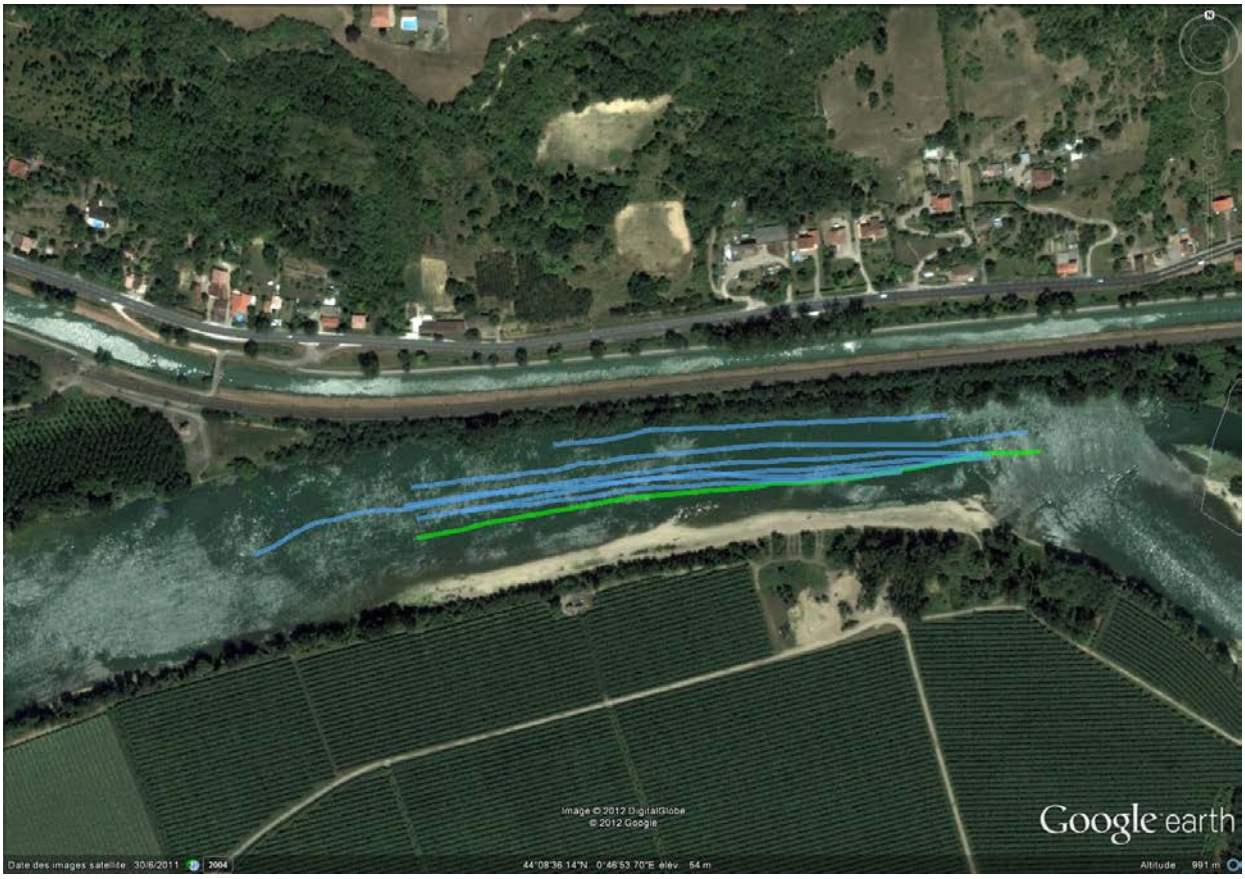


Photo 2: Traces recorded by the GPS during push net runs (blue: runs from downstream to upstream; green: runs from upstream to downstream)

II.2.2.2. Landing net

At the beginning of the sampling season when the fry tend still to be relatively small, push net fishing was conducted in addition to fishing with fine-mesh landing nets from a fishing stand and with fishing lights. Fishing was done from the riverbanks, among rocks or in areas of current not usually accessible with push nets. The nets were extended two or three times and the fish caught identified. If they were not shad, they were thrown back. When fry were caught, the procedure was the same as for shad caught using push nets. Photo 3 illustrates this technique, which was used only in 2012 because it proved to be fairly inefficient and, more importantly, difficult to implement with the strong flow rates observed at the beginning of the season in 2013 and 2014.

Photo 3: Fishing with a landing net (Source: SMEAG).

II.2.2.3. Driftnet fishing

Driftnet fishing was undertaken in addition to push net fishing, but at the end of the sampling period when the target fish had grown bigger so that they could be caught using this method. The nets used were approximately 25 metres in length with 9.5 to 10 millimetre mesh. The boat was allowed to drift with the current, dragging the net over a given distance. The net was then brought back on board. The fish were untangled from the mesh and identified. Length categories were estimated. The fish were then thrown back if they were not shad. If fry was caught, the procedure was the same as above. Photo 4 shows the technique used.

Photo 4: Driftnet fishing (Source:SMEAG).

It is worth noting that this is the technique used by professional fishermen, partners in the study, to catch bleak throughout the fishing season. The sampling period was therefore longer using this technique (usually from April to October instead of the end of June to the beginning of September for the study period). Because of this, fry were also caught accidentally, outside the actual study, providing some interesting, additional information.

II.2.2.4. Sweep net

The principle behind this method is the use of a specific net some 50 metres long, with a drop of approximately 1.5 metres and 10 millimetre mesh. As far as possible, the selected area should not include any obstacles such as tree roots, branches or rocks, to avoid snagging and/or tearing the net, making it difficult to handle. We left from a fixed point on the river bank and the boat unrolled the net as it moved out into midstream then as it returned to the bank a short distance downstream. This meant that all the fish in that zone were caught in the pouch formed by the manœuvre. The sweep net was brought back on board and the fish were identified. Photo 5 illustrates this operation. When the sweep net is pulled, the mesh tends to stretch and retract, introducing a slight measure of selection in the fish caught using this method and allowing us to sample a wide range of different sizes.

Photo 5: Fishing with a sweep net (Source: Bellariva)

II.3 – SUMMARY OF RESULTS IN 2012, 2013 and 2014

II.3.1. The Garonne

II.3.1.1. Push nets

On the Garonne, sampling dates were as follows:

- in 2012, 26 June to 7 August;
- in 2013, 9 July to 3 September;
- in 2014, 1 July to 19 August.

For each sampling year, Table 1 summarises the environmental conditions (flow rate and water temperature), the total number of fish caught and the number of fry in the samples obtained with push nets.

	Sample	1	2	3	4	5	6	7	8	9	Total
2012	Flow (m^3 /s)	144	170	127	76	67	73	184	-	-	
	Temperature (°C)	25	23.7	23	22.8	26	27	28	-	-	
	Nb fish	22	400	100	200	150	350	350	-	-	**1572**
	Nb fry	0	0	0	0	0	0	2	-	-	**2**
	Volume filtered (m^3)	4616	3522	2880	2508	3742	3838	2454	-	-	**23560**
	Nb fish/m^3	0.005	0.114	0.034	0.080	0.040	0.091	0.143	-	-	**0.552**
2013	Flow (m^3 /s)	351	289	240	235	123	139	120	104	80	
	Temperature (°C)	21.3	23.7	23.8	24.2	25.6	24.1	24.3	23	22.8	
	Nb fish	38	30	75	70	35	130	210	560	175	**1323**
	Nb fry	0	0	0	0	0	0	0	0	0	**0**
	Volume filtered (m^3)	4079	4315	4263	3203	1975	2228	2147	3464	2107	**27781**
	Nb fish/m^3	0.001	0.001	0.017	0.022	0.018	0.058	0.098	0.162	0.083	**0.460**
2014	Flow (m^3 /s)	294	444	255	209	164	158	-	-	-	
	Temperature (°C)	19.9	20.2	20.3	23.1	22.8	21.6	-	-	-	
	Nb fish	133	275	75	235	230	165	-	-	-	**1113**
	Nb fry	0	0	0	0	0	0	-	-	-	**0**
	Volume filtered (m^3)	4721	2551	3422	3580	2424	1310	-	-	-	**18008**
	Nb fish/m^3	0.028	0.1058	0.022	0.066	0.095	0.126	-	-	-	**0.445**

Table 1: Summary of results obtained with push nets 2012 - 2014

Over the three years of the study, we conducted a total of 22 push net runs, catching approximately 4,000 fish including only 2 fry. This gives a very unfavourable ratio of number of fish caught to number of fry, even though shad was the target species. Generally speaking, it is noticeable that only a very small number of fish can be sampled per cubic metre filtered using this method (less

than, or equal to, 0.5). The likelihood of catching fry is further reduced by the significant drop in spawning figures for shad over the past few years.

It should also be noted that, during the push net runs, most of the fish caught were young carp, hence the very high number of fish caught.

II.3.1.2. Driftnets

On the Garonne, sampling dates were as follows (for the purposes of this project):

- in 2012, 24 July to 7 August;
- in 2013, 15 July to 3 September (sampling conducted on the sites in Saint-Sixte and Couthures-sur-Garonne);
- in 2014, 1 July to 19 August (sampling conducted on the sites in Saint-Sixte and Couthures-sur-Garonne).

For each year of sampling, Table 2 summarises the environmental conditions (flow rate and water temperature), the total number of fish caught and the number of fry caught with the driftnets. To allow a comparison between the data obtained using this method and the data obtained using push nets, we calculated the volume fished, based on the length of the net run, with a net drop of 1 metre and a mean length of 30 metres.

	Sample	1	2	3	4	5	6	7	Total
2012	Flow (m^3 /s)	67	73	184	-	-	-	-	
	Temperature (°C)	26	27	28	-	-	-	-	
	Nb fish	100	100	150	-		-	-	**350**
	Nb fry	0	0	2	-	-	-	-	**2**
	Volume fished (m^3)	3600	11100	10500	-	-	--	-	**25200**
	Nb fish/m^3	0.03	0.01	0.015	-	-	-	-	**0.055**
2013	Flow (m^3 /s)	289	235	123	139	120	104	80	
	Temperature (°C)	23.7	24.2	25.6	24.1	24.3	23	22.8	
	Nb fish	0	100	40	100	100	60	200	**600**
	Nb fry	0	0	0	0	0	0	0	**0**
	Volume fished (m^3)	13500	21600	21000	15000	22500	20100	24600	**138300**
	Nb fish/m^3	0	0.004	0.002	0.007	0.004	0.003	0.008	**0.028**
2014	Flow (m^3 /s)	294	444	255	209	164	158	-	
	Temperature (°C)	19.9	20.2	20.3	23.1	22.8	21.6	-	
	Nb fish	140	2	100	150	200	80	-	**670**
	Nb fry	0	0	0	0	0	0	-	**0**
	Volume fished (m^3)	22500	52500	22500	39900	22500	24900	-	**739200**
	Nb fish/m^3	0.006	0	0.004	0.004	0.009	0.003	-	**0.026**

Table 2: Summary of results obtained with driftnets in 2012, 2013 and 2014 in Saint Sixte.

Over the three years of the study, we conducted a total of 16 driftnet runs. In all, 1,620 fish were caught, including 2 fry. Here again there is a very unfavourable ratio of number of fish caught to number of fry, even though shad was the target species. The number of fish sampled using this method was small. Moreover, we observed that the 9.5 or 10 mm mesh used selected out sizes of fish caught. Fish that were less than 6 cm in length or larger than 13 cm were not caught.

Table 3 summarises the sampling conducted with driftnets at the site in Couthures-sur-Garonne. The same calculations as the ones in Table 2 were again done to compare the various data.

	Sample	1	2	3	4	5	6	7	Total
2013	Flow (m^3 /s)	363	278	313	173	197			
	Temperature (°C)	21.7	23.2	24.6	25.6	23.9			
	Nb fish	200	160	160	185	420			**1125**
	Nb fry	0	0	6	1	1			**8**
	Volume fished (m^3)	46200	28500	31500	39300	58200			**204825**
	Nb fish/m^3	0.004	0.006	0.005	0.005	0.007			**0.27**
2014	Flow (m^3 /s)	323	316	211	224	311	312	235	
	Temperature (°C)	20.3	19.1	23.4	23	22.2	23.9	21.4	
	Nb fish	131	400	500	20	-	200	200	**1451**
	Nb fry	0	0	1	0	-	1	0	**2**
	Volume fished (m^3)	52200	85200	69300	-	-	15000	15000	**236700**
	Nb fish/m^3	0.003	0.005	0.007	-	-	0.013	0.013	**0.041**

Table 3: Summary of results obtained with driftnets in 2013 and 2014 in Couthures-sur-Garonne.

Over the two years of study on this site, 12 driftnet runs were conducted, catching a total of 1,451 fish including 10 fry. Here again, there was a very unfavourable ratio of number of fish caught to number of fry sampled, even though shad was the target species. Yet on this site we caught more fry in two years of monitoring than in three at Saint Sixte. We should therefore consider the significance of the choice of site when conducting sampling operations.

The results presented were provided by fishing runs conducted during the study period. As indicated above, professional fishermen on the Garonne use this technique to catch bleak over much of the year. Because of this, they also caught fry outside the study period and in different locations. Table 4 summarises these catches.

	Dates	Couthure-sur-Garonne	Marmande	Saint Nicolas de la Balerme	Saint-Sixte
2012	7 Aug.	-	-	3	5
	14 Aug.	-	-	10	-
	17 Aug.	-	11	-	-
	20 Aug.	-	1	-	-
	24 Aug.	2	8	-	-
	28 Aug.	-	14	-	-
2013	26 July	5	-	-	-
	29 July	6	-	-	-
	12 Aug.	1	-	-	-
2014	21 May	1	-	-	-
	30 May	1	-	-	-
	2 June	1	-	-	-
	18 June	2	-	-	-
	19 June	6	-	-	-
	21 July	1	-	-	-
	26 July	-	3	-	-
	11 Aug.	-	3	-	-
	18 Aug.	-	1	-	-

Table 4: Summary of total catches of fry for the three years of the study (in red, catches outside the period of study).

This table shows that, out of a total of 20 fry caught, 11 were netted outside the study period. Looking at the total number of fish caught, it is evident that, of the 85 fry, 57 were caught outside the study period or in other locations. This information clearly indicates that the choice of site and sampling period are both extremely important factors that must be taken into account when sampling fry.

II.3.1.3. Sweep net

On the Garonne, sampling with a beach sweep net was conducted only in 2014, on 28 July and 4, 11 and 18 August in Couthures-sur-Garonne. As we did for driftnet catches, we calculated the volume fished, based on the area sampled (as established by the GPS trace) and the mean depth of water (0.75 m) in the sample zone. Overall, the sample area was 1.5 m deep at its deepest point, corresponding

to the drop of the net, and 0 m at the water's edge. The results were entered in Table 5.

	Sample	1	2	3	4	Total
2014	Flow (m^3 /s)	209	311	163	158	
	Temperature (°C)	23.1	22.2	22.8	21.6	
	Nb fish	100	75	44	104	**323**
	Nb fry	3	0	3	1	**7**
	Volume fished (m^3)	3938	4508	3263	7050	**18759**
	Nb fish/m^3	0.03	0.02	0.01	0.01	**0.07**

Table 5: Summary of results obtained with a sweep net in 2014 in Couthures-sur-Garonne.

In 2014, which was a test year for sweep net fishing in the Couthures-sur-Garonne area, we observed that the number of fish caught per cubic metre sampled was no higher than with the other fishing methods. However, the proportion of fry samples was significantly higher, since we caught 7 fry in 4 runs whereas we caught only 2 with driftnets in 7 runs. Moreover, the sweep net allowed us to catch fry almost each time. Finally, while the mesh of driftnets is discriminatory in terms of the size of the fish that can be caught, the sweep net is much less so. Test runs with the sweep net at Saint-Sixte, on the other hand, did not catch any fry. The site itself was also quite unsuitable for the use of this method because of the many obstacles that made the net difficult to use and susceptible to damage.

II.3.1.4 Flow rates and temperatures

Figure 2 indicates the various flow rates during the sampling period throughout the three-year study.

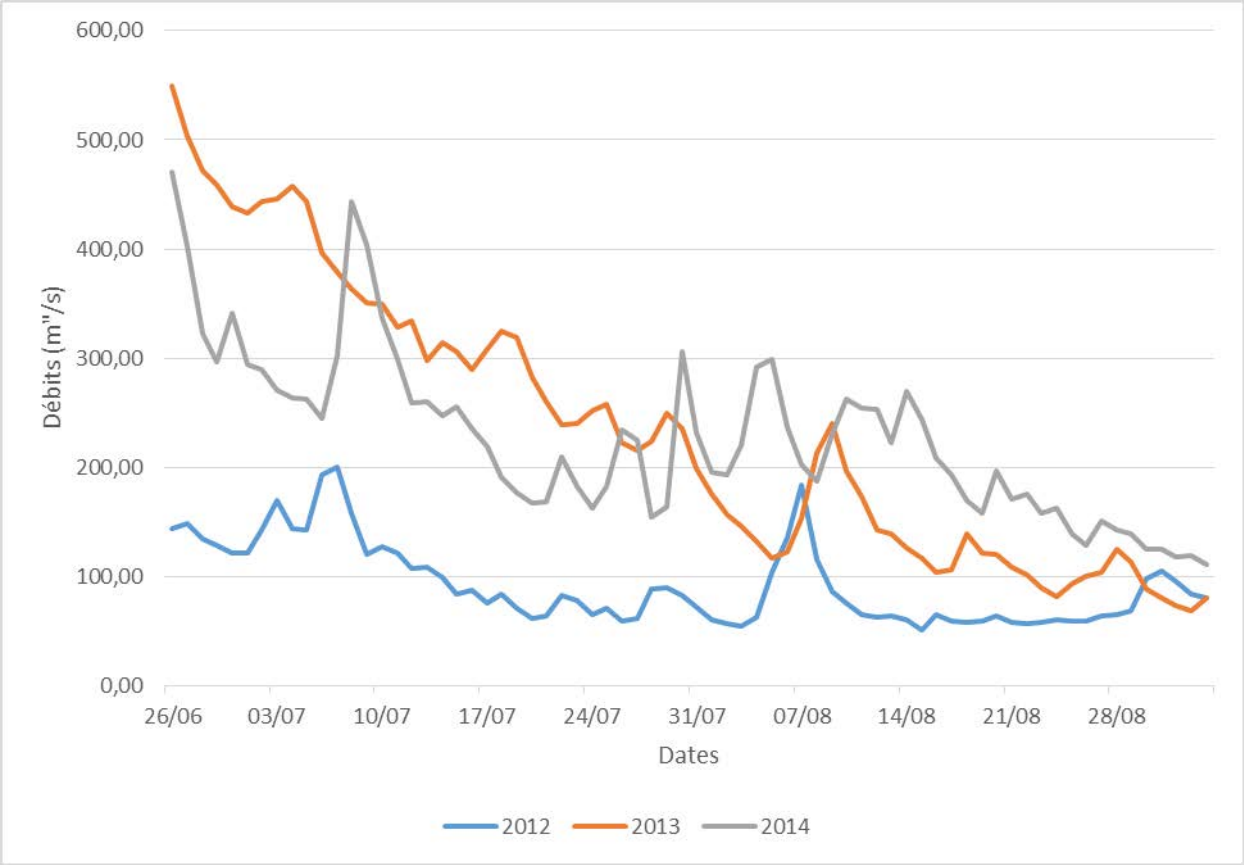


Figure 2: Flow rates for 2012, 2013 and 2014 during the sampling period.

It is evident from this graph that 2013 and 2014 were very different to 2012. The flow rates were significantly higher for the last two years of the study. This situation had a direct impact on our experiment because, with flows exceeding 300 to 400 m^3/s, this method of sampling was more difficult to conduct correctly.

Figure 3 shows the change in water temperature of the Garonne during the various sampling periods over the three years of monitoring.

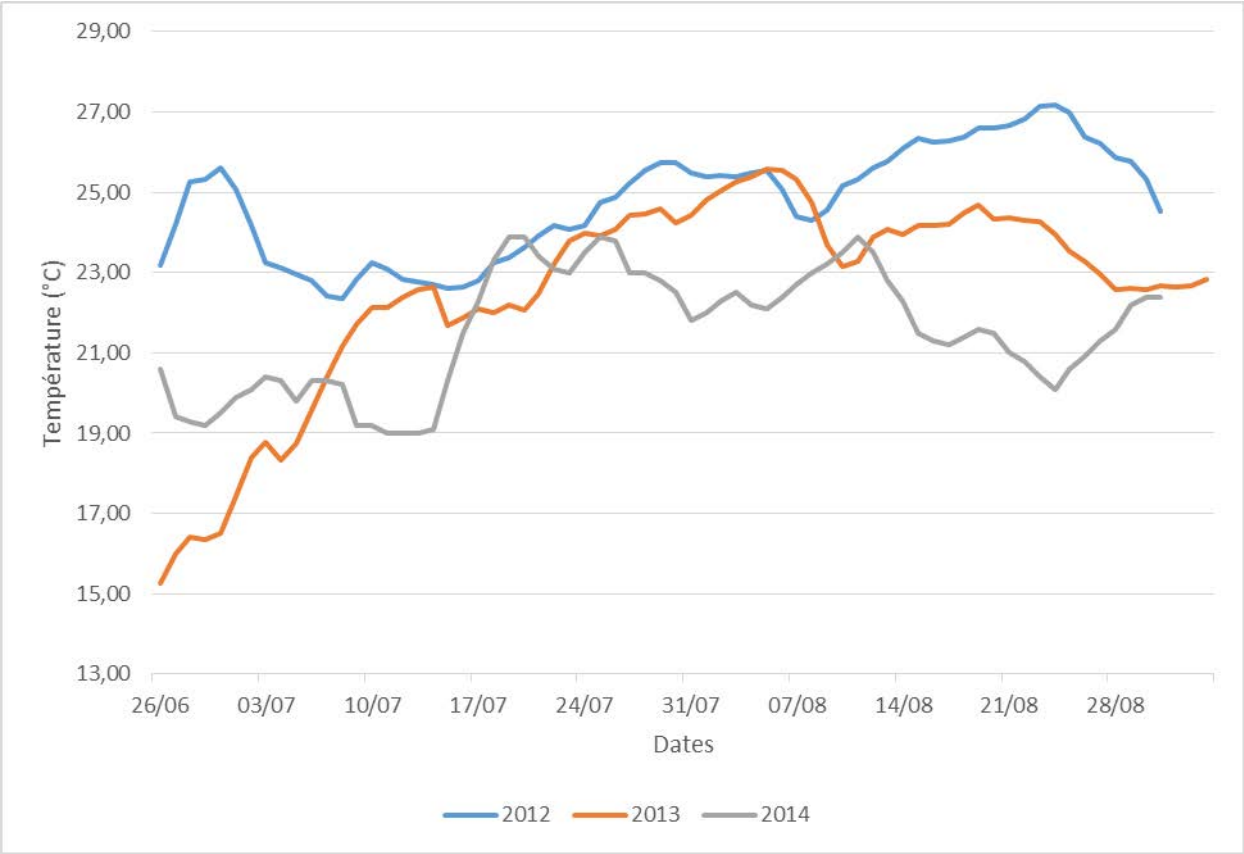


Figure 3: Temperatures for 2012, 2013 and 2014 during the sampling period.

It is evident from this graph that the temperatures varied slightly from one year of study to the next. Generally speaking, the water was warmer in 2012 during the sampling period than in 2013 and 2014. Although the temperatures were lower in 2013 than in 2014 at the beginning of the season, they increased from the third week of July onwards. This should be compared with higher flow rates over the same period.

Comparing the environmental conditions with the catches, it can be said that, very generally speaking, 2012 was the warmest year and had the lowest flow rates. It was also the year in which the largest number of fry was caught.

II.3.2. The Dordogne

II.3.2.1. Push nets

On the Dordogne, sampling was conducted:

- in 2012, from 27 June to 25 July;
- in 2013, from 7 August to 2 September;
- in 2014, from 10 July to 25 August.

For each year of sampling, Table 6 shows the environmental conditions (flow rate and water temperature), the total number of fish caught and the number of fry caught when sampling with push nets.

	Sample	1	2	3	4	5	6	7	8	Total
2012	Flow (m^3 /s)	126	94	82	65	-	-	-	-	
	Temperature (°C)	22.6	20.7	22	23	-	-	-	-	
	Nb fish	33	62	43	69	-	-	-	-	**207**
	Nb fry	0	0	0	0	-	-	-	-	**0**
	Volume filtered (m^3)	5176	5364	6142	3948	-	-	-	-	**20630**
	Nb fish/m^3	0.006	0.01	0.007	0.02	-	-	-	-	**0.043**
2013	Flow (m^3 /s)	60	63	55	58					
	Temperature (°C)	24.7	23.3	23.7	21.3					
	Nb fish	100	240	200	150					**690**
	Nb fry	0	0	0	0					**0**
	Volume filtered (m^3)	2724	4533	4789	4026					**16072**
	Nb fish/m^3	0.04	0.05	0.04	0.04					**0.17**
2014	Flow (m^3 /s)	81	102	119	114	115	130	111	91	
	Temperature (°C)	19.6	19.2	19.4	19.4	19.3	19.1	19.3	18.7	
	Nb fish	7	47	110	140	125	235	78	108	**850**
	Nb fry	0	0	0	0	0	0	0	0	**0**
	Volume filtered (m^3)	4518	6133	4418	5314	5370	6395	1881	5414	**39443**
	Nb fish/m^3	0.002	0.008	0.02	0.03	0.02	0.04	0.04	0.02	**0.15**

Table 6: Summary of results obtained with push nets in 2012, 2013 and 2014

Over the three-year monitoring period, we effected a total of 16 push net runs, catching approximately 1,750 fish but no fry. It was, therefore, impossible to catch fry on the Dordogne using this method. Generally speaking, we observed that the number of fish that could be sampled here using this system was very small, as it was on the Garonne. Using this method, the ratio of number of fish caught to cubic metres filtered was very small (less than 0.2). Moreover, the likelihood of

catching fry was very low, given the drop in shad spawning figures over the past few years.

It should also be noted that, during push net runs, most of the fish caught were young carp, hence the very high numbers of fish caught.

II.3.2.2. Driftnets

On the Dordogne, it was difficult to conduct this type of sampling because it is seldom used by professional fishermen here. The method was therefore used only in 2012 and 2014:

- in 2012, on 25 July;
- in 2014, on 23 July and 20 and 25 August.

For each year of sampling, Table 7 summarises the environmental conditions (flow rate and water temperature), the total number of fish caught and the number of fry caught in the driftnet samples. To compare the data from this method with the data provided by push net sampling, we calculated the volume fished based on the length of the driftnet run. The net had a drop of 1 metre and a mean length of 25 metres.

	Sample	1	2	3	Total
2012	**Flow (m^3 /s)**	65			
	Temperature (°C)	23			
	Nb fish	100			**100**
	Nb fry	0			**0**
	Volume fished (m^3)	14000			**14000**
	Nb fish/m^3	0.007			**0.007**
2014	**Flow (m^3 /s)**	119	111	91	
	Temperature (°C)	19.4	19.3	18.7	
	Nb fish	100	100	4	**204**
	Nb fry	0	0	0	**0**
	Volume fished (m^3)	11250	9650	11375	**32275**
	Nb fish/m^3	0.009	0.01	0	**0.019**

Table 7: Summary of results obtained with driftnets in 2012 and 2014 on the Dordogne.

Over the three-year study period, 4 runs were effected with driftnets. A total of 304 fish were caught, but no fry. It was therefore impossible to catch fry on the Dordogne using this method. Generally speaking, we observed that the number of fish that could be sampled here using this system was very small, as it was on the Garonne. When we compared the number of fish caught with the cubic metres filtered, the ratio was very small (less than 0.02). Moreover, there was very

little likelihood of catching fry given the fall in shad spawning figures over the past few years.

II.3.2.3. Flow rates and temperatures

Figure 4 shows the flow rates during the sampling period over the three-year study.

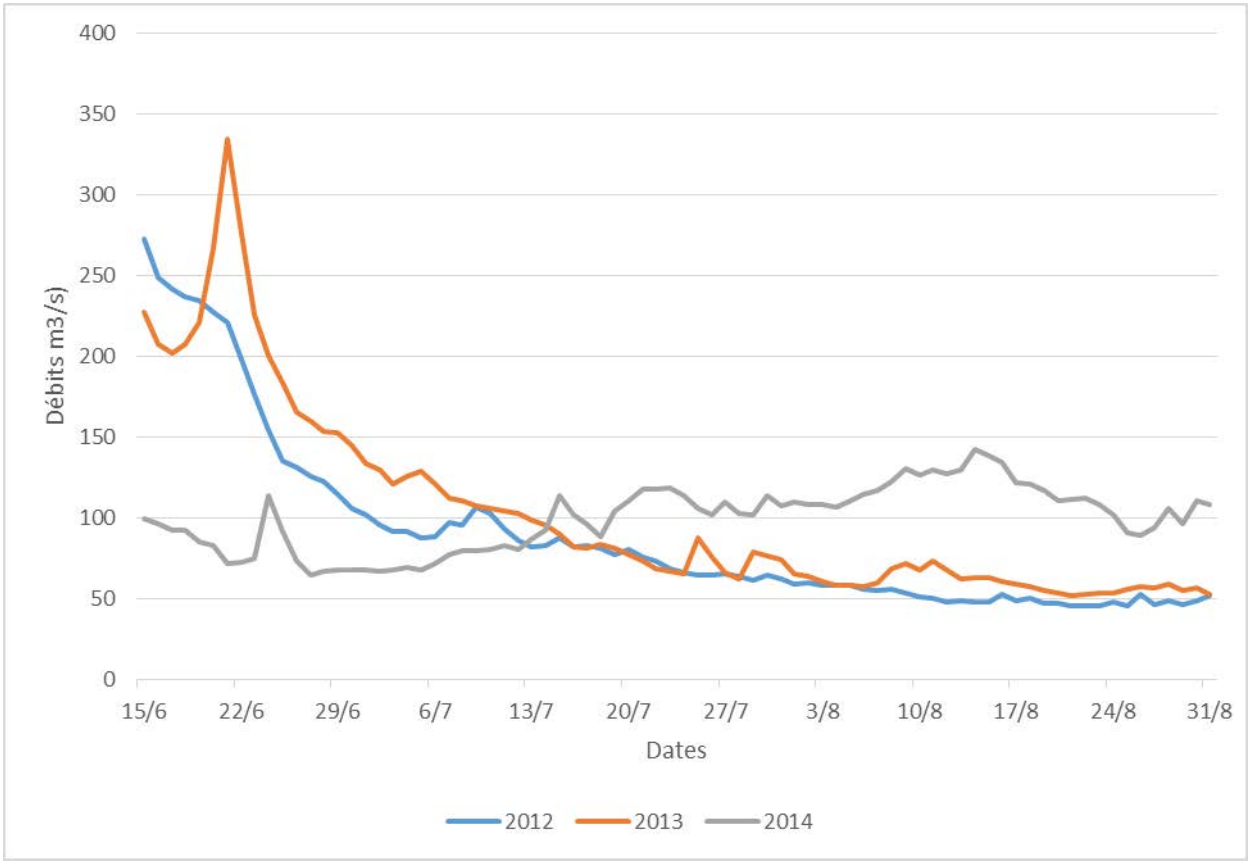


Figure 4: Flow rates for 2012, 2013 and 2014 during the sampling period.

It is evident from the figure that 2012 and 2013 were fairly similar. Flow rates decreased regularly over the sampling season, although they remained very slightly higher in 2013 than in 2012 without the difference being significant. On the other hand, flow rates in 2014 were fairly low from the beginning of the sampling period. They increased markedly after the second fortnight in July, to a level greater than in the two previous years. The flow rates observed during the three years of study did not impact on the satisfactory completion of the sampling operations.

Figure 6 illustrates temperature changes on the Dordogne in 2013 and 2014 (we were unable to recover the data for 2012).

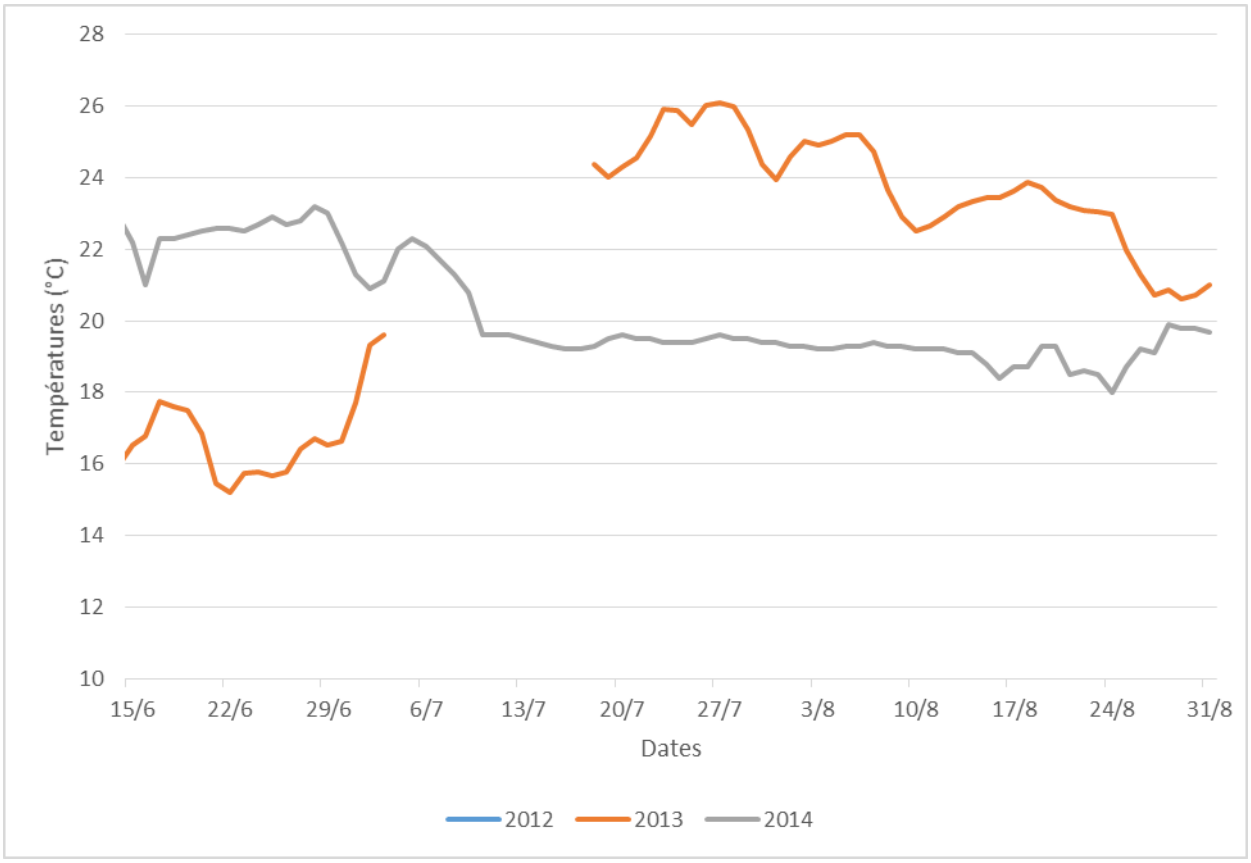


Figure 6 : Temperatures for 2013 and 2014 during the sampling period.

On this figure, it is noticeable that the temperatures varied slightly between the two years for which data is available. 2013 showed a gradual rise in water temperature until the beginning of August (although some of the data for the month of July is missing) then a downward trend from that point onwards. In 2014, on the other hand, there was a drop in temperatures throughout the sampling period, with mean temperatures higher than in 2013 until the beginning of July then lower. This can be compared with the changes in flow rate over the same period.

II.4. AGE OF FRY

All the fry caught during the study period were caught in the Garonne, between Couthures sur Garonne and Saint-Sixte. Every year, a summary was drafted, indicating locations, dates of capture and the lengths of the individual fish sampled. Table 8 shows the catches of fry on the Garonne during sampling periods and the mean length of the fish sampled.

Years	Dates	Couthures sur Garonne	Marmande	Saint Nicolas de la Balerme	Saint-Sixte
2012	7 Aug.			**3** (69.3 mm)	**2** (69.5 mm) **3** (75.3 mm)
	14 Aug.			**10** (80 mm)	
	17 Aug.		**11** (100.3 mm)		
	20 Aug.		**1** (85 mm)		
	24 Aug.	**2** (82.5 mm)	**8** (79.4 mm)		
	28 Aug.		**14** (80 mm)		
2013	26 July	**5** (99 mm)			
	29 July	**6** (100.8 mm)			
	12 Aug.	**1** (68 mm)			
2014	21 May	**1** (130 mm)			
	30 May	**1** (112 mm)			
	2 June	**1** (120 mm)			
	18 June	**2** (112 mm)			
	19 June	**6** (109.3 mm)			
	21 July		**3** (124 mm)		
	11 Aug.		**3** (122 mm)		
	18 Aug.		**1** (152 mm)		

Table 8: Catches of fry on the Garonne, number of fish and mean lengths (in blue: catches with push nets, red: catches with driftnets, green: catches with a sweep net)

Over the three years, a total of 84 fry were caught, ranging in length from 68 mm to 152 mm. Most of the catches occurred well downstream from the main spawning grounds listed and monitored (Lamagistère, Saint-Sixte and Agen). Fry were only caught upstream in 2012; there were none in 2013 or 2014. Note, too, that the dates of the catches have little significance. Outside the sampling period defined in the study, professional fishermen only caught shad while fishing for bleak. There was no attempt to specifically target shad. It is also noticeable that, in 2014, large juveniles were being caught as early as May, a situation that had not previously been observed. Likewise, in August, the use of a beach sweep net enabled us to catch a fish measuring more than 150 mm in length.

Based on this information and the growth curve previously established by JJ Cassous-Leins using shad from the natural environment, we attempted to estimate the age of the various shad caught. These calculations should be viewed with caution because of the uncertainty in the method of calculation.

The equation used to calculate the age of the shad caught was based on Figure 7.

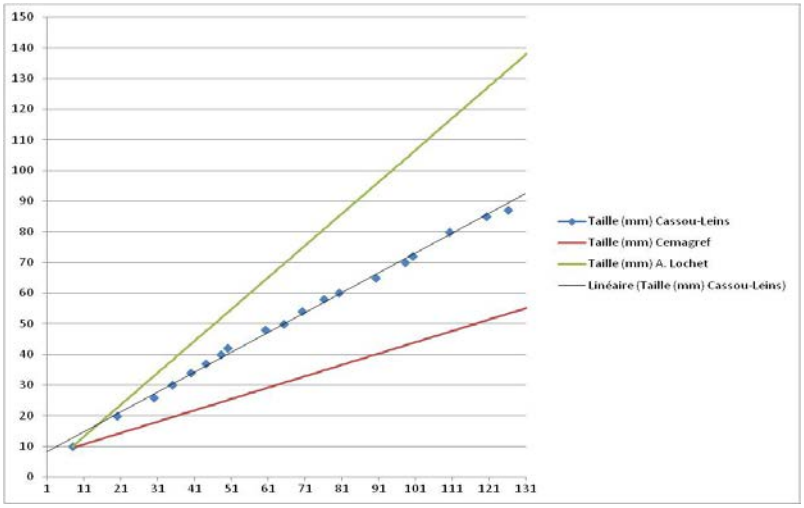


Figure 7: Growth curves of shad

According to the Cassou-Leins curve and the observations and corrections made in 2012 and 2013, age at a given size may be given by the following:

Age (days) = [(Length (mm) - 7.61) / 0.66] - 25

Table 9 gives the minimum and maximum lengths of the fish by catch date. It also gives the age, estimated using the above formula. We also postulate that the curve was drawn as of the hatching date. To obtain the hatching date, we add 5 days to the calculated date (estimating that, on average, the fish hatch 5 days after laying, Cassou-Leins and Cassou-Leins, 1981).

Year	Date of catch	Min.-max. length (mm)	Estimated age (days)	Estimated laying date
2012	**7 Aug.**	64-79	60-82	8 June-16 May
	14 Aug.	69-87	67-95	7 June-11 May
	17 Aug.	80-95	84-107	25 May-2 May
	24 Aug.	70-95	69-107	16 June-9 May
	28 Aug.	70-85	69-92	20 June-28 May
2013	**26 July**	95-105	107-122	10 April-26 March
	29 July	95-110	107-129	13 April-21 March
	12 Aug.	68	66	7 June
2014	**21 May**	130	160	12 December 2013
	30 May	112	133	17 January
	2 June	120	145	8 January
	18 June	110-114	130-136	8 February-2 February
	19 June	106-110	124-130	15 February-9 February
	21 July	130	160	11 February
	26 July 2014	115-132	138-163	10 March and 13 February 2014
	11 Aug. 2014	90-145	100-183	3 May and 1 March 2014
	18 Aug. 2014	152	194	5 February 2014

Table 9: Estimation of laying date

Based on these retrospective calculations, it is noticeable that, in 2012, the fry hatched between the months of May and June, a period that we consider usual based on our current knowledge. In 2013, the hatching period extended from the end of March to the beginning of June, again a relatively conventional period. The results for 2014, however, are strange, again based on what we know of this species. The table suggests that, in 2014, the hatching period extended from December 2013 to early May 2014, with the greatest frequency between February 2014 and May 2014. These various observations led us to believe that the retrospective calculation method used had showed its limitations and that only a study of the age of fry based on a study of otoliths would shed more light on the question.

Using fry caught in 2014, and independently of the present study, SMEAG ordered an analysis of otoliths. This was performed by Gilles Segura, Ichtyosys and Jean-Luc Bellariva, with the Museum d'Histoire Naturelle. The study of fish that were already large for the season (including 120 mm fry caught at the end of May) revealed ages of between 127 and 245 days (i.e. 4 to 8 months). This would set the estimated hatching dates between early December 2013 and late March 2014. These observations also go against commonly-accepted beliefs but confirm the hatching dates estimated using the above retrospective method of calculation.

II.5 - CONCLUSION

Over the three-year period of sampling of fry in the two rivers (Garonne and Dordogne), we tried to apply the various methodologies defined at the beginning of the study, making a few adjustments based on experience gained over time. These modifications concerned mainly the sampling period. In 2012, it appeared that catches were more frequent at dusk than in the afternoon. This led us to undertake sampling at that time of day. We also changed the position of the push net frames, moving them from the middle of the boat towards the front based on the hydraulic measurements taken in 2012. We adapted the speed of the boat to the environmental conditions, which differ from Garonne to Dordogne, and to the frequency of catches. Finally, on the Dordogne, we were forced to change site, following a change in professional fishermen between 2012 and 2013 and for biological reasons (the spawning ground at Mouleydier was used more than the one in Prigonrieux selected at the outset).
Despite all our efforts, the method proved very inefficient as regards catches of fry. Only 2 young fish were sampled in three years of monitoring, out of the 84 shad caught using the entire range of techniques. Moreover, the results depended on the choice of site. It is impossible to "push" nets below a certain depth (it is impossible to use them along riverbanks). The area has to be relatively uniform and flow rates must not exceed certain values (above 400 m3/s, it is difficult to obtain samples safely). On the other hand, the technique and equipment used proved to be very efficient in catching young fish and, even though all the young fish caught during the sampling work were carp, the technique might be useful in the search for young shad if used at the right time and in the right place.

On the Garonne, the site at Saint Sixte was initially given priority for driftnet sampling. In 2013, we added the zone located between Sainte Bazeille (downstream from Couthures sur Garonne) and upstream from Marmande. In doing so, we made use of the observations of professional fishermen who regularly caught fry in this area. It was also selected because, in 2013, the River Lot saw higher levels of shad breeding than the River Garonne. On the Dordogne, the technique was used on a very few occasions, causing problems with implementation. No fry were caught.
On the Garonne, the technique resulted in the catching of 10 fry during the sampling period and 65 additional fry outside our period of study and outside the initially selected zone, when professional fishermen were fishing for bleak. This gives a total of 75 fry caught over a three-year period using this method. There is no doubt, in the light of these results, that this is one of the most appropriate methods for catching juvenile shad. It can also be used across the entire width of the river, even along shallow banks. The mesh used over the three-year period (9.5 to 10 mm) allowed us to catch only a well-targeted portion of the river's fish stocks (60 to 120 mm approximately). By adapting the method and using a wider range of mesh sizes (e.g. 6 to 14 mm), it would be possible to catch a wider range of sizes of fry and obtain a more accurate picture of the structure of the fish stock present at any given time in terms of length.

One last technique was tested in 2014. The use of a beach sweep net resulted in the catching of 7 fry in very few trips. The advantage of this method is that it can catch a wide variety of size categories since the pouch formed acts as an impenetrable barrier. Its downside is that it can only be used in areas that are free of obstacles (submerged rocks, tree branches etc.).

It would therefore appear, from the various observations made over the three-year study period and from the results obtained, that:

- using these methods, it is difficult to catch fry with lengths of less than 50 mm and, therefore, to answer one of the initial questions which was the location of the juvenile shad after hatching;
- the only fry that we could catch were probably fish migrating downstream;
- most of the fry caught (whatever their length) were far from spawning grounds;
- the push net method is much too random as regards catching fry and could be usefully replaced by other, more efficient techniques;
- driftnets are relatively efficient but selectivity was fairly poor and should be extended in order to increase the fish sizes that could be caught;
- sweep net fishing also proved effective in catching fry but we would have to locate other zones along the Garonne suitable for sampling using this method in order for it to achieve its full potential.

Further to all these observations, a number of areas of work have become clear for the next few years, on both the Garonne and the Dordogne:

- a more in-depth analysis of the literature is required to learn more about the behaviour of the species during the various phases of its growth in a river environment;
- an analysis of the distribution of eggs across spawning grounds or further downstream depending on flow rates might be useful in pinpointing sampling zones with greater accuracy;
- an analysis of the larval and juvenile stages is required to determine how long the fry remain on site and whether there is active downstream migration within a certain period or rather a gradual displacement towards the estuary depending on environmental conditions (flow rate, temperature, food etc.). Such an analysis would better target the best zones for a study of the early stages in the fry lifecycle;
- in our opinion, it is not worthwhile continuing with the use of push nets to sample fry. It would be preferable to use only driftnets and sweep nets. Wider mesh should be used in the driftnets (6 to 14 mm) to increase the range of fish sizes that can be sampled;
- the sampling period should be extended. The two summer months are not sufficient;

- the catch zone should also be carefully chosen. It may not necessarily be located immediately downstream of spawning grounds;
- finally, a more long-term study of the age of fry should be undertaken based on otoliths. Conducted over several years, it would undoubtedly give a more accurate picture of fish growth and increase our knowledge of this essential phase in the lifecycle of the Allis shad on the Garonne and Dordogne rivers.

ANNEXES

Annex 1: Environmental conditions during sampling

On the Garonne (in italics, sampling at Couthures-sur-Garonne)

Year	Dates	Flow (m3/s)	Temperature (°C)	Weather	Wind	Water colour	Miscellaneous
2012	**26 June**	144	25	Fine	None	Clear	-
	3 July	170	23.7	Fine	None	Clear	-
	10 July	127	23	Overcast	None	Clear	-
	17 July	76	22.8	Fine	None	Clear	-
	24 July	67	26	Cloudy	None	Clear	-
	31 July	73	27	Cloudy	None	Clear	Full moon
	7 Aug.	184	28	Fine	None	Clear	Hatching
2013	**9 July**	351	21.3	Cloudy	None	Turbid	-
	15 July	*363*	*24.8*	*Fine*	*None*	*Clear*	-
	16 July	289	23.7	Cloudy	None	Turbid	-
	22 July	*278*	*24*	*Fine*	*None*	*Turbid*	*Full moon*
	23 July	240	23.8	Stormy	Average	Turbid	-
	29 July	*313*	*24*	*Fine*	*Light*	*Clear*	-
	30 July	235	24.2	Fine	None	Clear	-
	5 Aug.	*173*	*25.5*	*Fine*	*None*	*Clear*	-
	6 Aug.	123	25.6	Stormy	Average	Clear	-
	12 Aug.	*182*	*24*	*Cloudy*	*Light*	*Turbid*	-
	13 Aug.	139	24.1	Cloudy	Light	Turbid	-
	20 Aug.	120	24.3	Fine	None	Clear	-
	27 Aug.	104	23	Cloudy	Light	Clear	Hatching
	3 September	80	22.8	Fine	None	Clear	-
2014	1er July	294	19.9	Cloudy	Light	Turbid	-
	7 July	*323*	*21*	*Fine*	*None*	*Clear*	-
	8 July	444	20.2	Cloudy	Light	Turbid	-
	14 July	*316*	*20.5*	*Fine*	*None*	*Tinted*	-
	15 July	255	20.3	Fine	None	Clear	-
	21 July	*211*	*23*	*Fine*	*None*	*Clear*	-
	22 July	209	23.1	Fine	None	Clear	-
	28 July	*224*	*22.9*	*Fine*	*None*	*Clear*	-
	29 July	164	22.8	Fine	None	Clear	-
	4 Aug.	*311*	*21.5*	*Fine*	*Light*	*Clear*	-
	11 Aug.	*312*	*21.9*	*Fine*	*None*	*Clear*	-
	18 Aug.	*235*	*22.3*	*Fine*	*None*	*Clear*	-
	19 Aug.	158	21.6	Fine	None	Clear	-

Dordogne

Year	Dates	Flow (m3/s)	Temperature (°C)	Weather	Wind	Water colour	Miscellaneous
2012	**27 June**	126	22.6	Fine	None	Turbid	-
	11 July	94	20.7	Cloudy	Light	Clear	-
	18 July	82	22	Fine	None	Clear	-
	25 July	65	23	Fine	None	Clear	-
2013	**7 Aug.**	60	24.7	Rain	Average	Clear	-
	14 Aug.	63	23.3	Fine	None	Tinted	-
	19 Aug.	55	23.7	Fine	None	Clear	-
	26 Aug.	58	21.3	Fine	None	Clear	-
	2 September	52	21.2	Fine	None	Clear	-
2014	10 July	81	19.6	Fine	None	Clear	-
	16 July	102	19.2	Fine	None	Clear	-
	23 July	119	19.4	Cloudy	Light	Clear	-
	30 July	114	19.4	Fine	Light	Clear	-
	6 Aug.	115	19.3	Fine	None	Clear	-
	13 Aug.	130	19.1	Cloudy	Light	Tinted	-
	20 Aug.	111	19.3	Fine	None	Clear	-
	25 Aug.	91	18.7	Fine	None	Clear	-

Annex 2: Fry sampled

Summary of fry catches on the Garonne with lengths in mm.

Year	Dates	Couthures sur Garonne	Marmande	Saint Nicolas de la Balerme	Saint-Sixte
2012	**7 Aug.**			**3** (64-70-74)	**2** (67-72) **3** (70-77-79)
	14 Aug.			**10** (69-74-78-80-80-82-82-84-84-87)	
	17 Aug.		**11** (80-83-85-85-90-90-90-90-95-95-120)		
	20 Aug.		**1** (85)		
	24 Aug.	**2** (75-90)	**8** (70-75-75-75-80-80-85-95)		
	28 Aug.		**14** (70-75-75-80-80-80-80-80-80-80-85-85-85-85)		
2013	**26 July**	**5** (95-95-100-100-105)			
	29 July	**6** (95-95-100-100-105-110)			
	12 Aug.	**1** (68)			
2014	**21 May**	**1** (130)			
	30 May	**1** (112)			
	2 June	**1** (120)			
	18 June	**2** (110-114)			
	19 June	**6** (106-110-110-110-110-110)			
	21 July		**3** (115-125-132)		
	11 Aug.		**3** (90-130-145)		
	18 Aug.		**1** (152)		

Annex 3: Results of the otolithometric study of fry caught in 2014 on the Garonne

The aim of this study was to highlight the data on the age and growth of the fry caught on the Garonne and, in particular, to study the parameters of fry that hatched early. The study was conducted on the sample of fry caught in 2014 on the Garonne by Jean-Luc Bellariva and Ichtyosys, working jointly with the Museum d'Histoire Naturelle.

Of the 19 otoliths collected, 15 could be counted. The otoliths were read by a minimum of 2 operators. A third reading was required for more difficult cases.

The following table shows the number of increments counted. The mean difference between operators was of the order of 5%. The number of increments found was between 127 (#074 – LT = 91 mm) and 245 (#089 – LT = 159 mm).

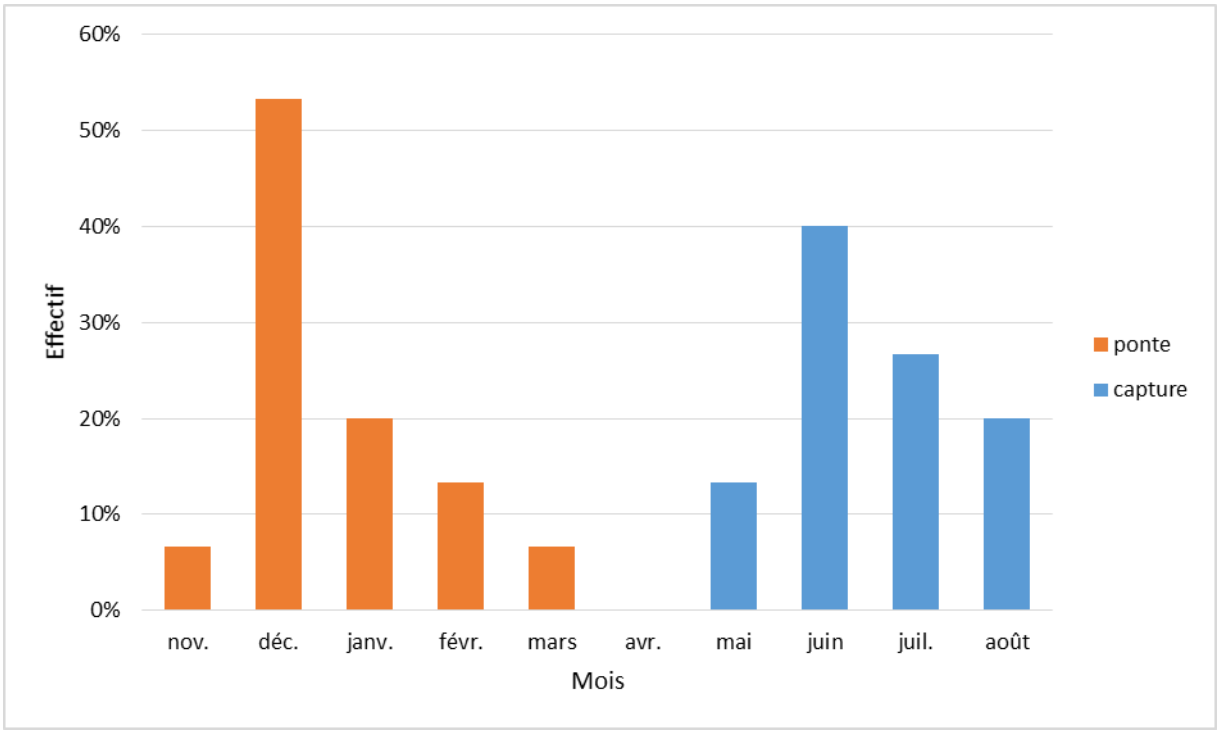
Table 1: Number of increments, estimated hatching and laying dates

Fry	Date of catch	LT (mm)	Operator1	Operator2	Average	Hatch date	Laying date
#036	21/05/14	97	149	142	146	26/12/13	19/12/13
#028	30/05/14	113	156	154	155	26/12/13	19/12/13
#063	02/06/14	120	163	156	160	24/12/13	17/12/13
#093	18/06/14	109	148	155	152	17/01/14	10/01/14
#031	19/06/14	107	162	169	166	04/01/14	28/12/13
#027	19/06/14	107	152	147	150	20/01/14	13/01/14
#087	19/06/14	109	183	209	196	05/12/13	28/11/13
#062	19/06/14	117	186	197	192	09/12/13	02/12/13
#033	21/07/14	135	197	212	205	28/12/13	21/12/13
#097	28/07/14	118	151	164	158	20/02/14	13/02/14
#073	28/07/14	125	168	170	169	09/02/14	02/02/14
#067	28/07/14	134	230	218	224	16/12/13	09/12/13
#074	11/08/14	91	128	125	127	06/04/14	30/03/14
#096	11/08/14	147	202	215	209	14/01/14	07/01/14
#089	18/08/14	159	245	259	252	09/12/13	02/12/13

Analysis of data – estimation of age

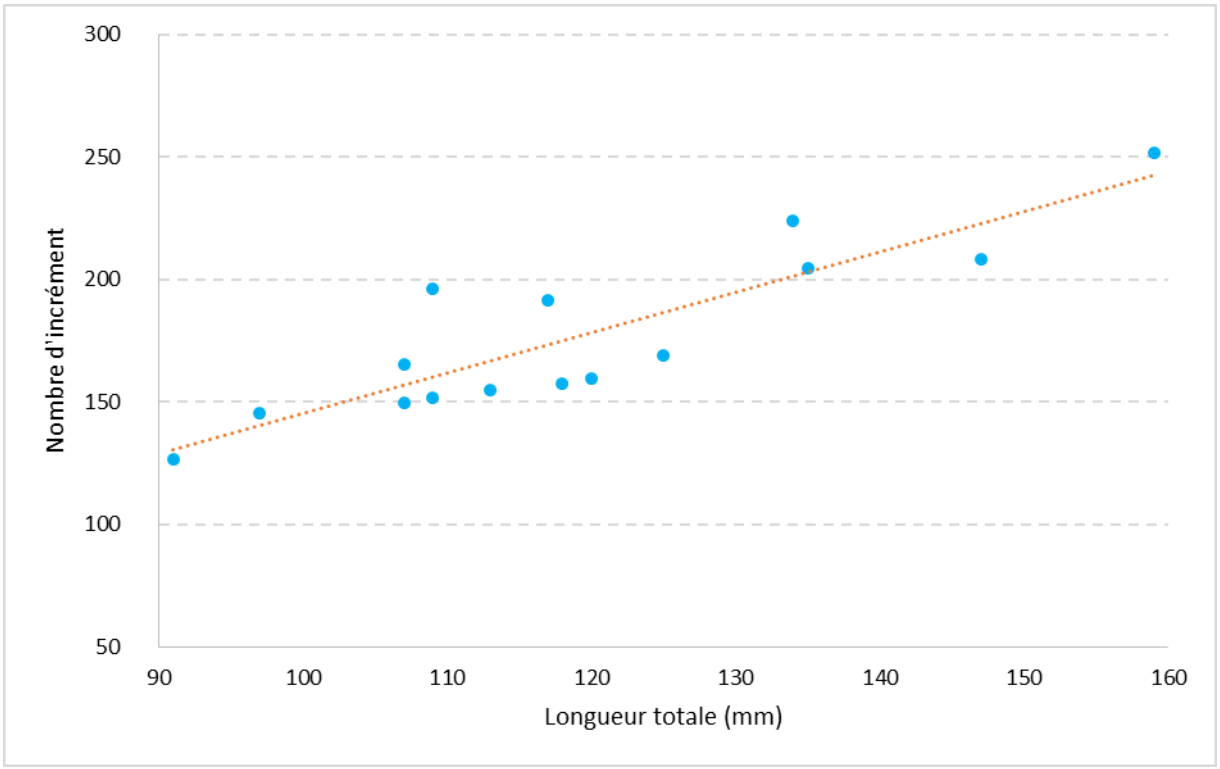
By counting one day per increment, it is possible to calculate, retrospectively, the hatch date of the fry caught.
The fish were aged between 3 and 8 months. It is interesting that Lochet *et al.* (2008) found an average period in fresh water of between 58 and 123 days. These 2 results do not concur, confirming the unusual nature of the fish caught in 2014.
According to Taverny *et al.* (2000), incubation lasts for 4 to 8 days depending on water temperature. To simplify the calculations, we set the incubation period at 7 days for all the fish. This meant that the fish caught would be the result of spawning between the end of November 2013 and the end of March 2014, again

producing a marked difference compared to the results of Lochet (2006) who obtained hatch dates between early June and the end of July.



Distribution of fry depending on catch and laying dates

Fish growth



Link between the length of the fish caught and the number of increments on the otoliths.

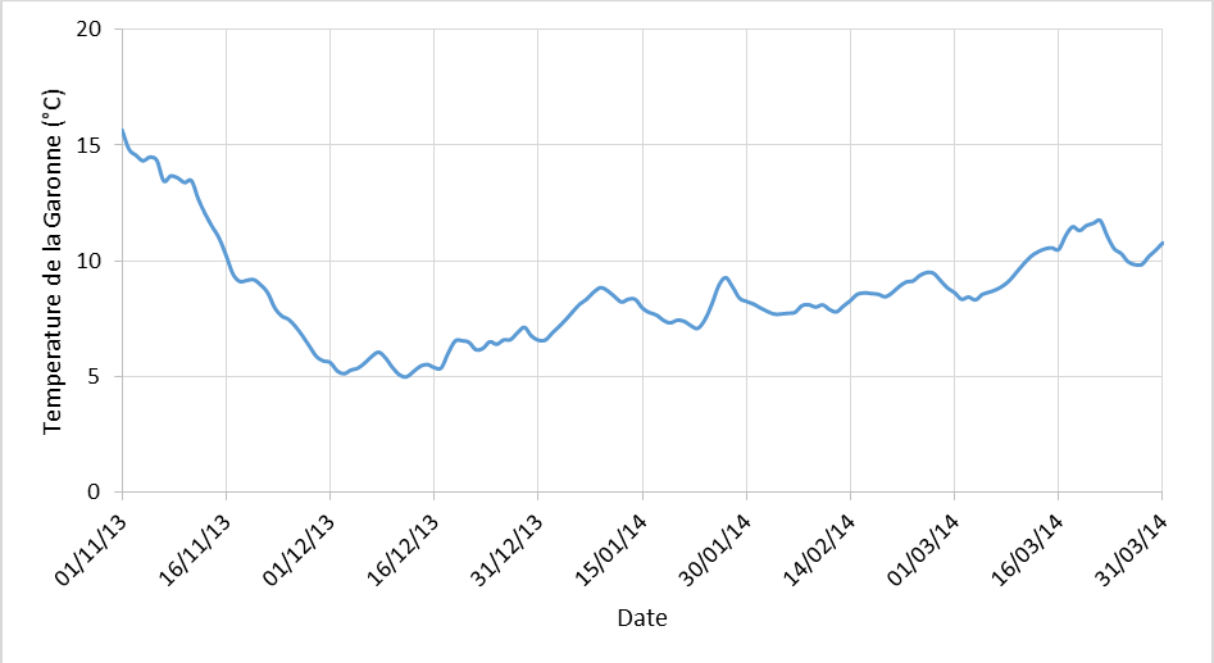
It is evident that the number of increments increases in a linear manner with the size of the fish, indicating regular growth.

Discussion

In 2014, sampling enabled us to catch large fry very early in the season, larger than those observed in the estuary by Lochet (2006). The presence of young fish early in the season is described in the literature but was not taken into account in studies because their existence did not seem to be compatible with the biological characteristics of the species.

Although the adult fish migrate upstream in winter (> 10°C), the temperature threshold would appear to be 12°C. The work of Charles and Jatteau (2010) on the impact of temperature on the survival of embryos and larvae showed that the most effective temperature range for the development of the first stages of the life cycle lay between 15°C and 25°C. However, they also showed that the survival rates of larvae were 0% at 5°C and 8% at 10°C for non-acclimatised fish.

Considering the temperature data from Golfesh provided by EDF (Figure 7), it is clear that the temperature remained above 5°C throughout the winter. In these conditions, the development of larvae was apparently possible on the Garonne during the winter of 2013-14, albeit with a very low success rate.



Temperature of the Garonne in Golfech (Source: EDF)

The proven existence of fry early in the season indicates that there were early laying periods, although they were not observed. The present study therefore tends to contradict the hypothesis of juveniles spending more than a year in fresh water.

The small number of spawners in fresh water and the very low survival rates for larvae in winter allow us to confirm that early spawning is minimal in winter compared to the springtime. However, with the significant reduction in the numbers of spawners swimming upstream and the subsequent decrease in spawning in spring, there may be a noticeable increase in winter spawning *i.e.* it will become visible in samples as it was in 2014.

The monitoring of spawning grounds on the Garonne, which has been conducted since the 1970s, focuses on the spring period, during breeding peaks. There do not appear to be any *in situ* observations of early spawning and, in any case, such spawning is minimal compared to the breeding season in spring.
In the absence of any additional information, the reasons for early spawning during a period in which environmental conditions are fairly unfavourable for the species are unknown. In terms of strategy, however, it is not unreasonable to suggest that the extension to the breeding season is one means of overcoming the effects of years during which catastrophic floods may destroy the springtime cohort. Last but not least, winter breeding has the advantage of occurring during a period when the wels catfish, which appears to be a major predator for adult shad, is inactive.
Given the very limited breeding, the overall cost to the species is very low. Even if larvae survival rates are very low, the early hatching and relatively large size of the juveniles in spring may, in the long term, be an advantage for building stocks.

Conclusion

This study confirms the hypotheses put forward during sampling in 2012-2014 viz. that some of the fry sampled came from eggs laid in winter, an unusual situation that would explain data deemed inconsistent in other publications.
The preponderance of these fish in the 2014 samples is astonishing but may be the result of a number of factors:

- Sampling began very early in that year,
- None of the fry was caught using push nets, the only system likely to catch small fish i.e. fish resulting from spring spawning,
- The use of a beach sweep net enabled us to catch large fish that are not usually found in samples.

The protocols for the monitoring of shad in fresh water (spawning, fry, downstream migration) were developed in the 1990s when stocks were expanding in the Garonne Basin. Now, with the collapse of fish stocks, it may be that certain factors linked to the accumulation of spawners at certain points along the course of the river are of prime importance.
Finally, the status of winter breeding remains unexplained. We know almost nothing about it other than that it produces viable fry, which are found in the Garonne and in the estuary.

- Why and how can we detail this situation?
- What effect does the choice of spawners used for the reintroduction of the species have on the adaptability of the strain?
- Etc.

Further consideration of study protocols is no doubt required to obtain relevant data that would enable us to define measures for the management and protection of the species.