

## Management Plan to the LIFE project

### “The re-introduction of the Allis shad (*Alosa alosa*) to the Rhine system”

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Prepared by Andreas Scharbert, Peter Beeck, Eric Rochard, Richard St. Pierre and Philippe Jatteau

Valuable contribution by David Clavé, Matthieu Chanseau, Gerard de Laak, Paul Gonthier, Thierry Rouault, Aude Lochet, Patrick Chevre and Heiner Klinger

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**Preface**

The present report aims on providing an overview on the background, achievements and perspectives of the LIFE Allis shad project. Special emphasis is given to shad rearing, marking and stocking techniques, which were developed and further improved within the LIFE project, the experiences with shad re-establishing project in the US and comparisons to the LIFE project as the first project dealing with Allis shad, and finally how the measures will be conducted after the projects termination, how the projects progress will be monitored and which criteria are set to re-evaluate, to alter or to stop the schemes.

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## 1. Background and historical perspective of the LIFE Allis shad project

### 1.1 The River Rhine

The River Rhine is one of the longest and most important rivers in Europe. It's length is 1,320 kilometers and the mean discharge at the border to the Netherlands and before splitting into the several branches of the Delta Rhine is  $2,230 \text{ m}^3\text{s}^{-1}$ .

The Rhine's origins are in the Swiss Alps in the canton of Graubünden, where its two main initial tributaries are called Vorderrhein and Hinterrhein. Both tributaries merge near Reichenau (Graubünden). From Reichenau, the Rhine flows north as the Alpenrhein passing Chur and forming the border between Liechtenstein and then Austria on the east side, and canton St. Gallen of Switzerland on the west side, then emptying into Lake Constance. Emerging from Lake Constance, flowing generally westward as the Hochrhein it passes the Rhine Falls and is joined by the Aare river which more than doubles its water discharge to an average of nearly 1,000 cubic meters per second. It forms the boundary with Germany until it turns north at the so-called Rhine knee at Basel. At its way north many tributaries drain into the Rhine, which are in contrast to the Rhine and the Aare itself mainly fed by rainfall precipitation and thus determining the pluvio-nivale discharge regime through which the Rhine is increasingly characterized when approaching the North Sea. The upper Rhine represents the border between France and Germany and downwards between the German federal states Baden Württemberg and Rhineland-Palatinate. After reaching the deepest point of water pollution in the 1970ies water quality improved due to the installation of sewage plants in the entire catchment and is not considered as limiting the recovery of original biocoenoses from 1990ies onwards. However due to hydraulic engineering measures, embankments and measures for maintaining the intensive shipping navigation (up to 600 passages per day) under variable discharge scenarios, the hydromorphological situation is heavily altered.

Table 1: The six river sections of the river Rhine

Six river sections	Alp Rhine	From the confluence of the source rivers at Reichenau (Switzerland) to Lake Constance
	High Rhine	Outlet of Lake Untersee to Basel
	Upper Rhine	Basel to Bingen
	Middle Rhine	Bingen to Cologne
	Lower Rhine	Cologne to Lobith
	Delta Rhine	Lobith to North Sea/Wadden Sea

Table 2: The major tributaries of the river Rhine

Major tributaries	Aare (CH)	$557 \text{ m}^3\text{s}^{-1}$
	Ill (F)	$54 \text{ m}^3\text{s}^{-1}$
	Neckar (D)	$145 \text{ m}^3\text{s}^{-1}$
	Main (D)	$225 \text{ m}^3\text{s}^{-1}$
	Moselle (F/D)	$315 \text{ m}^3\text{s}^{-1}$
	Lahn (D)	$47 \text{ m}^3\text{s}^{-1}$
	Sieg (D)	$53 \text{ m}^3\text{s}^{-1}$
	Ruhr (D)	$76 \text{ m}^3\text{s}^{-1}$
	Lippe (D)	$45 \text{ m}^3\text{s}^{-1}$

### 1.1.1 Former shad fisheries in the Rhine.

Yet at the beginning of the 20<sup>th</sup> century the Rhine housed one of the largest Allis shad populations in the distributional range of the species. The Allis shad fisheries were of particular economical importance for the local fishermen and many hundred thousand Allis shad were marketed along the Rhine and its major tributaries each year. Besides seining with large seine-nets several regionally specific gears were used for shad fisheries. Probably due to the effects of over-fishing combined with an increasing deterioration of water quality and spawning habitat conditions the Rhine's Allis shad population decreased sharply during the first decades of the 20<sup>th</sup> century. Although this process doesn't occur unnoticed and was well documented by the records of landings by the fisheries authorities (e.g. Bürger, 1926; de Groot, 2002) attempts to protect the spawning stock and supporting stocking measures were useless, and the population collapsed completely during the first half of the 20<sup>th</sup> century.

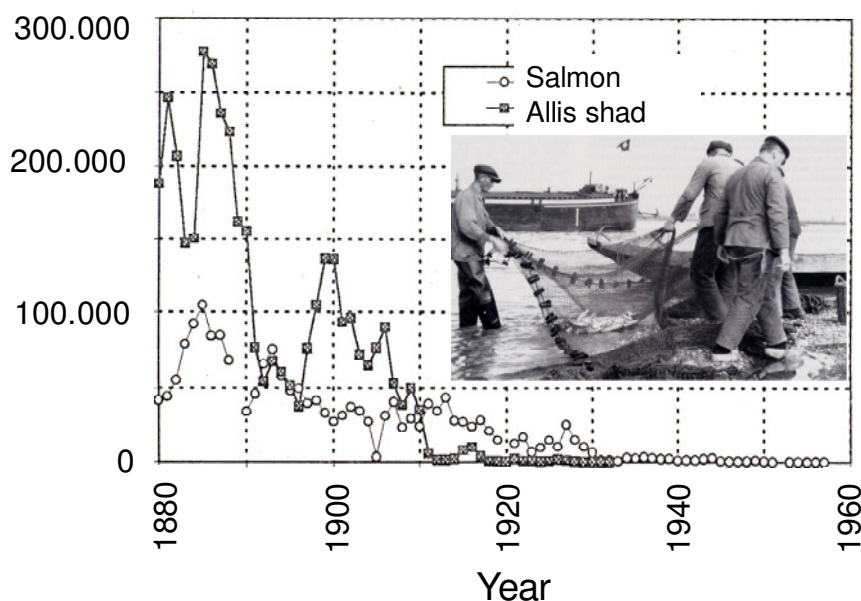


Figure 1: Landings of Allis shad and salmon in the Dutch Rhine section around 1920 (after de Groot 2002) demonstrate how quickly the populations collapsed. One of the causes was besides hydraulic engineering and the deterioration of water quality the fisheries itself.

The last noteworthy amount (approximately 60 kg) in the Rhine area was caught in 1949 near Xanten and henceforth the Allis shad disappeared from the Rhine with the exception of some single fish detected from the 1970ies until present (Bartl & Troschel, 1997). After the installation of the fish pass at the lowest dam at Iffezheim at the Upper Rhine some single Allis shad has been observed at the respective monitoring facility, which however could be proven to be genetically very closely related to and probably belong to the Garonne-population in the South-west of France, from which they apparently stray into the Rhine. This supports the hypothesis that the original shad, as being the case for most former Allis shad rivers in Europe, has actually died out from the Rhine (Beeck 2003). Although, due to the installation after the Rhine's Allis shad population had already become extinct, the several floodgates which regulate the draining of the Rhine Delta branches into the North sea and hamper natural estuarine conditions with its salinity and turbidity gradients, tidal influence and high productivity, are considered to be disadvantages for the maintenance and recovery of diadromous fish. Hence it is unknown how these modifications influence adult Allis shad during their upstream, as well as juvenile Allis shad during their seaward migration. Furthermore no information with regard to the influence of the intensive shipping traffic (alternating strong currents, wash of waves) on the different life-time stages of Allis shad during the freshwater phase exist so far. Similar to the situation at the Rhine the Allis shad stocks in the rivers of its former distributional range

decreased or even collapsed during the 20<sup>th</sup> century. Until today some populations persisted in some rivers draining into the Atlantic ocean in France and Portugal, where Shad fisheries is still of some or even high economical importance.

## 1.2. Current Allis shad fisheries in Europe

Allis shad is or was targeted with numerous gears, trammel net<sup>1</sup> (Adour, Garonne, Dordogne), beach seine (Garonne), scoop net (Garonne), fish wheel (Garonne), fly fishing rod (Aulne, Garonne), angling with fly or lure, weir net (Loire). For commercial fishermen Allis shad is more interesting than Twaite shad because of its higher weight and of its better price. For recreational fishermen the large size of the Allis shad and its defence in the current give it almost a sport fish status while the Twaite shad remains a coarse fish.

A commercial shad fishery still exists in Portugal, the Adour (Prouzet et al., 1990), the Garonne, the Dordogne (Girardin et al., 2006) and the Loire (Mennesson-Boisneau et al., 1999). While recreational fisheries, more or less important, exist in all rivers where the species is present (Marta et al., 2001). For a long time the Gironde fisheries was the most important in terms of number of fishermen and of number of fish captured.

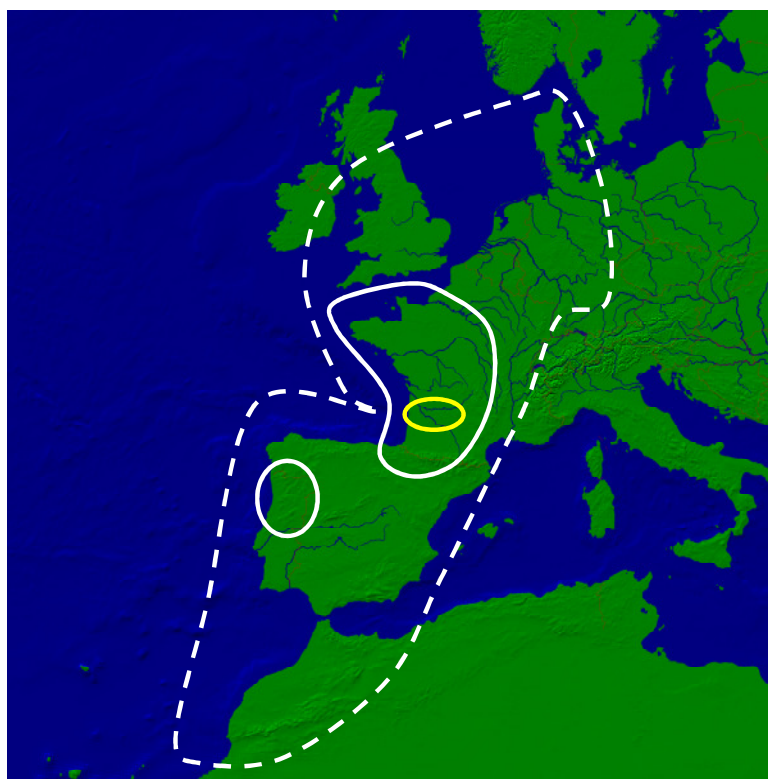


Figure 2: The distributional range of the Allis shad in Europe (and North Africa) at the beginning of the 20<sup>th</sup> century comprised almost all larger tributaries (dotted frame) draining into the Atlantic Ocean, the North Sea and the Western Mediterranean Sea. The Rhine housed a extraordinary large population of large economic importance. The Allis shad's current distribution (solid frames) is largely confined to some rivers in the Southwest of France and Portugal. The yellow frame denotes to the one of the largest remaining populations in the Gironde-Garonne-Dordogne watersheds.

<sup>1</sup> Stretched mesh size 90-110 mm for the inner layer

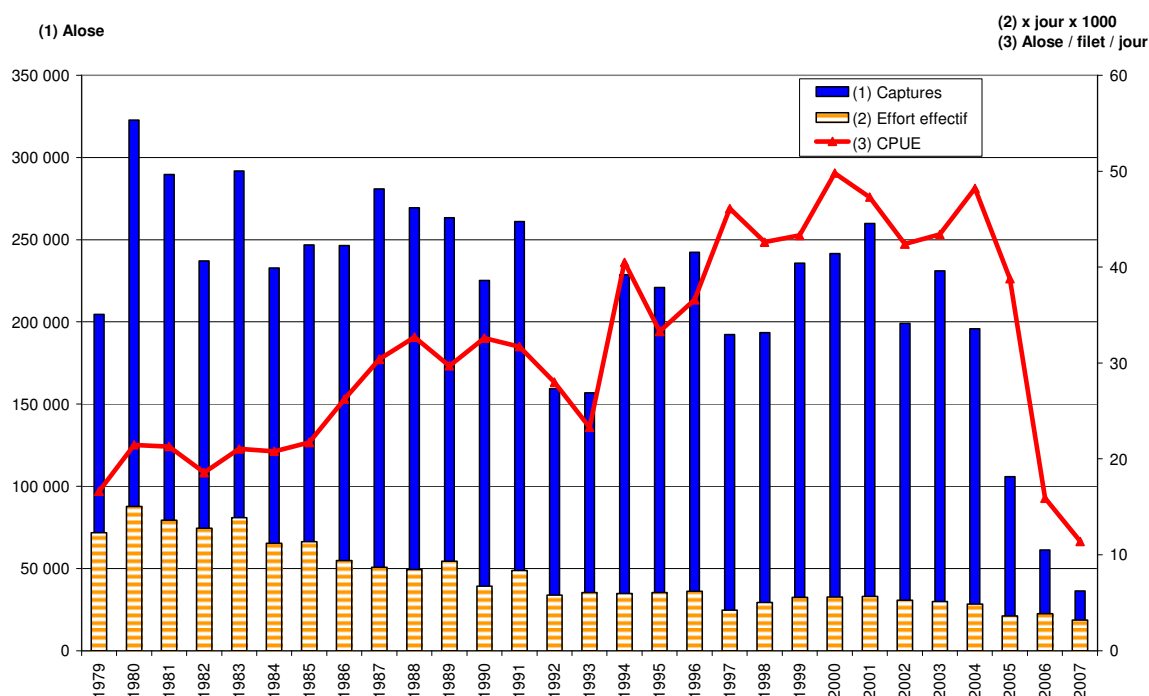


Figure 3: Gironde estuary 1978 - 2007. Evolution of the captures (number of fish, blue histogram left y axis) of the effort (number of day-fisherman \* 1000, brown histogram left y axis) and of the CPUE (number of fish caught per day per net, red line right y axis) (from Girardin, et al., 2008)

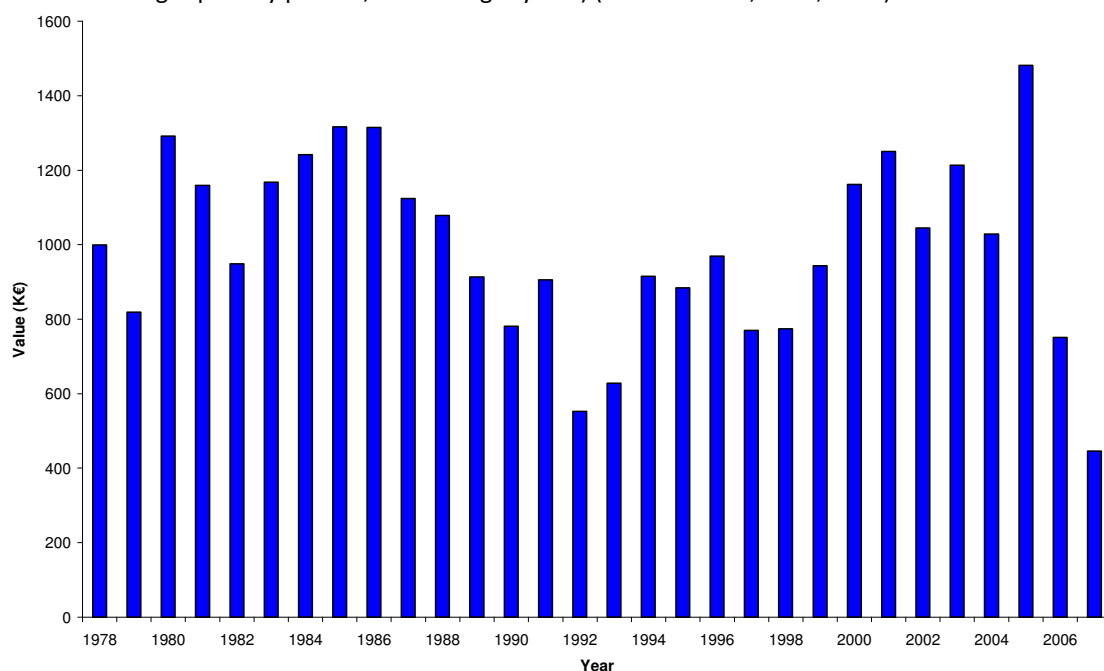


Figure 4: Gironde estuary 1978-2007. Value at the first sale of the Allis shad caught by the commercial fishermen (from Girardin, et al., 2008)



In the Gironde estuary the spawning run starts in March and extends until June with a maximum in May (Rochard, 2001). As it is more or less temperature dependant<sup>2</sup> fish appear slightly earlier in the south and later in the northern parts of the system.

### **1.2.1 Management of the Allis shad population in the Gironde system**

The Gironde population was the largest of the species with the both important commercial (trammel net) and recreational (trammel net, scoop net, rod and line) fisheries (Castelnaud, 2000). However, it is also probably the most studied population of the species (e.g. Roule, 1923 ; Dautrey & Lartigue, 1983 ; Bengen, 1986 ; Cassou-Leins et al., 1988 ; Taverny, 1990 ; Martin, 1996 ; Bellariva, 1998 ; Lambert et al., 2001 ; Locket, 2006 ; Locket et al., 2008).

According to the French law, from 1994 the management of the Gironde population is under the responsibility of the diadromous fish management committee CoGePoMi<sup>3</sup>. This basin scale committee is composed of administration's and fishermen's representatives. It examines yearly the situation of some diadromous fish species of interest<sup>4</sup> and suggests modifications of the regulation's rules. A recent analyse of this structure with a comparison between the ones of Seine and of Garonne-Dordogne basin pointed up the differences in the way they function and in their preoccupations. However in both cases some structural weakness were indentified (Pellegrini & Rochard, 2007).

Specific monitoring schemes have been established for Allis shad in order to trace the population dynamics. The main potential spawning grounds were located (Belaud et al., 2001) and during the reproduction season they are equipped with audio disposals which record the sounds ("bull") emitted during the spawning activities (Lagarigue et al., 2004). From these records it is possible to estimate the number of spawners located in the different sites monitored. One of the busiest spawning zones is located in the "Réserve naturelle de la frayère d'alose d'Agen"<sup>5</sup> in the Garonne river. This site is explicitly dedicated to the conservation of the Allis shad and is the only French natural reserve in a river system. For some few years a monitoring of the recreational fishermen targeting shads has been implemented in some sectors. It gives the first ideas about this activity which had been ignored for a long time (Chanseau, 2003).

The committee uses also data coming from the monitoring of several industrial facilities.

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<sup>2</sup> The fish move from the sea to the estuary when the temperature in this latter is higher than at sea, i.e. 11-12°C

<sup>3</sup> In French, Comité de gestion des poissons migrateurs.

<sup>4</sup> Among the diadromous fish encountered in France, smelt, flounder and mullet are not included in the list of species the CoGePoMi's have to consider.

<sup>5</sup> <http://www.ville-lepassage.fr/fr/decouvrir-passage/voir-passage/reserve-naturelle-frayere-d-aloses.html>

Five hydropower plants in the basin were equipped with upstream fish passes and video recorder devices which enable to identify and count the fish using the system<sup>6</sup>. The numbers of fish which pass the first dam on the Garonne (Golfech) or the second dam on the Dordogne (Tuillière) are particularly used<sup>7</sup>.

Important details regarding YOY shad presence and abundance in the estuary arise from the monitoring of the nuclear power plant of the Blayais, located in the Gironde estuary, which is based on two components (cf Girardin, et al., 2008 f):

The first is a monthly sampling of fish (small species and juveniles of large species) and shrimp in 12 stations located in the mesohaline part of the estuary. The gears used in the Gironde estuary (e.g. Girardin et al., 2005) have demonstrated their efficiency to sample shad juveniles (Taverny, 1991). On each station samples are taken in the near surface layers with two push-nets (one on each side of the ship) (Figures 5 and 6**Figure** ) and near the sediment with an Agassiz trawl (Figure 7**Figure** ).(see Pronier & Rochard, 1998 for more details about the sampling)<sup>8</sup>. Captured clupeids can be identified to the species level using specific criteria. Differentiation between the two shad species rely on the general shape of the fish and on the number of gillrakers on the first arch. Twaite shad while smaller in size at the same age feed on larger preys and exhibit a lower number of gill rakers. This system established before the building of the plant has been operated for 30 years and enables long term analysis of the community (Lobry et al., 2003; Lobry & Rochard, 2003; Lobry et al., 2006; Lobry et al., 2008) or of species of interest (Elie & Rochard, 1994; Lambert et al., 1997; Pronier & Rochard, 1998; Martin Vandembulcke, 1999; Locket, 2006).

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<sup>6</sup> Location and illustrations of the control stations in the Garonne – Dordogne system  
<http://www.migado.fr/php/Stations.php>

<sup>7</sup> The first dam on the Dordogne (Bergerac dam) is equipped with a fish pass but it is not a control station.

<sup>8</sup> Such gears can also be used on small boats and with regards to monitoring purposes of juveniles of other fresh water species.



Figure 5: The estuarine research vessel fitted equipped with two push-nets (out of the water)



Figure 6: Detailed view of the push-net used.



Figure 7: Detailed view of the Agassiz trawl.

The second approach is a yearly synthesis of the fishing activities established with census data from cooperative commercial fishermen. For all major fisheries (eel, lamprey, shad, shrimps) fisheries indicators (C, f CPUE) have been established and analysis are provided (see Beaulaton, 2008 for more details about this aspect).

A specific tool was designed to help the committee to identify potential difficulties in the functioning of the Allis shad population (Woillez & Rochard, 2003). We consider this tool as a major step in the management possibilities, it synthesizes and combines the useful information we have and is scientifically sound. This tool was tested and satisfied the criteria but practically was never used. After discussions with members of the CoGePoMi and sociologists of the environment we plan to deconstruct this tool and to involve it's users into the preparation of a new building phase (Work in progress – first draft of the report card planned for October 2011).



Microsoft Excel - Logiciel TDB alose

Fichier Edition Affichage Insertion Format Outils Données Fenêtre 2

90%

Tableau de bord Grande Alose V1.0

Cochez les indicateurs souhaités

Choisir une année: 1998 RUN 0.708

Choisir l'année de départ: 1978 Evolution du tableau de bord

Choisir l'année de fin d'exercice: 1989

N°	Nom de l'indicateur	Résultats partiels	Pondération	Détail si l'indicateur est mauvais	Check
1	Fréquence moyenne annuelle de juvéniles	3	1	détail	✓
15	Abondance annuelle des géniteurs	2	1	détail	✓
16	Passages aux barrages	3	1	détail	✓
22	Effort effectif total	1	1	détail	✓
23	Capture par unité d'effort (CPUE)	2	1	détail	✓
24	Capture annuelle totale	1	1	détail	✓
30	Proportion relative des géniteurs en amont des premiers barrages	3	1	détail	✓
38	Nbre de kilomètres cumulés de linéaire ouvert	3	1	détail	✓
62	Effectif des pêcheurs professionnels	2	1	détail	✓
64	chiffre d'affaire annuelle de la production	1	1	détail	✓
65	Structure démographique de la profession	4	1	détail	✓
73	Prix moyen annuel de l'aloise	2	1	détail	✓

Evolution du tableau de bord

0.0 - 0.2 I [0.0 - 0.2] [0.2 - 0.4] II [0.4 - 0.6] III [0.6 - 0.8] IV [0.8 - 1.0] V

Mauvais état de la population, Risque majeur d'extinction

Situation inquiétante, population menacée, actions de restauration nécessaires

État satisfaisant, accompagnement de mesures de gestion strictes

Bon état de la population, accompagnement de mesures de gestion minimum

Très bon état de la population, accompagnement de mesures de gestion minimum

(Cemagref)

Figure 8: The main window of the Allis shad report card built for the Gironde population (see Woillez & Rochard, 2003 for more details)

## 2. Present status of the Allis shad in Europe

The distribution range of Allis shad in the beginning of the 20<sup>th</sup> century extended from Morocco (Sabatié, 1993 ; Sabatié et al., 1996) to Germany (Vincent, 1894). Northern populations (including the Rhine population) declined first (de Groot, 2002) and more recently populations from the southern part (Wadi Sebou and Portuguese populations) declined, too (Baglinière & Elie, 2000 ; Costa et al., 2001 ; Baglinière et al., 2003). From 2000 onward the Gironde population, formerly the most numerous of the species (Castelnaud et al., 2001) exhibited a drastic decline (Chanseau et al., 2005), and in 2008 a fishing moratory was implemented. The identification of the causes for the decline of this population will be inter alia the subject of a LIFE+ Allis shad project from 2011 onwards. The respective actions aim on identifying possible bottlenecks which are considered to take place mainly in the freshwater phase (obstructions for unhindered spawning run/ migration barriers, assessing the role of YOY habitat on recruitment). At the same time as the Gironde-Garonne-Dordogne populations declined, a stabilisation in the abundance of Allis shad populations in the Loire and in the Adour and an increase in Brittany (Aulne and Vilaine) and in Normandy (Orne, Vire) was noticed. On this last river 7000 individuals were counted in 2007 compared to only 1700 in 2002.

Recently Lassalle et al. (2008) modelled the distribution of Allis shad in the European watersheds. The environmental variables which explained the presence or the absence of this species at the beginning of the 20<sup>th</sup> century are: longitude at the mouth of the basin, mean air temperature, surface of the watershed (km<sup>2</sup>).

Using the same model in environmental conditions corresponding to 2100 with one of the most pessimistic emission scenarios (A2) and using HadCM3 GCM the authors provided a map of what could be the evolution of the suitable basin for that species (Figure 9) (Lassalle et al., 2009a). We

notice that according to this work the distribution range of this species in 2100 could be restricted and slightly moved north. From the temperature increase expected (the 2070–2099 annual temperature in the Rhine basin is projected to be 3 °C warmer than the 1900–1910 level) the Rhine system would become more suitable for Allis shad in the future than it was in the past. However in the same time several large basins located in the Rhine surround would not be suitable for this species (i.e. the Meuse and the Weser).

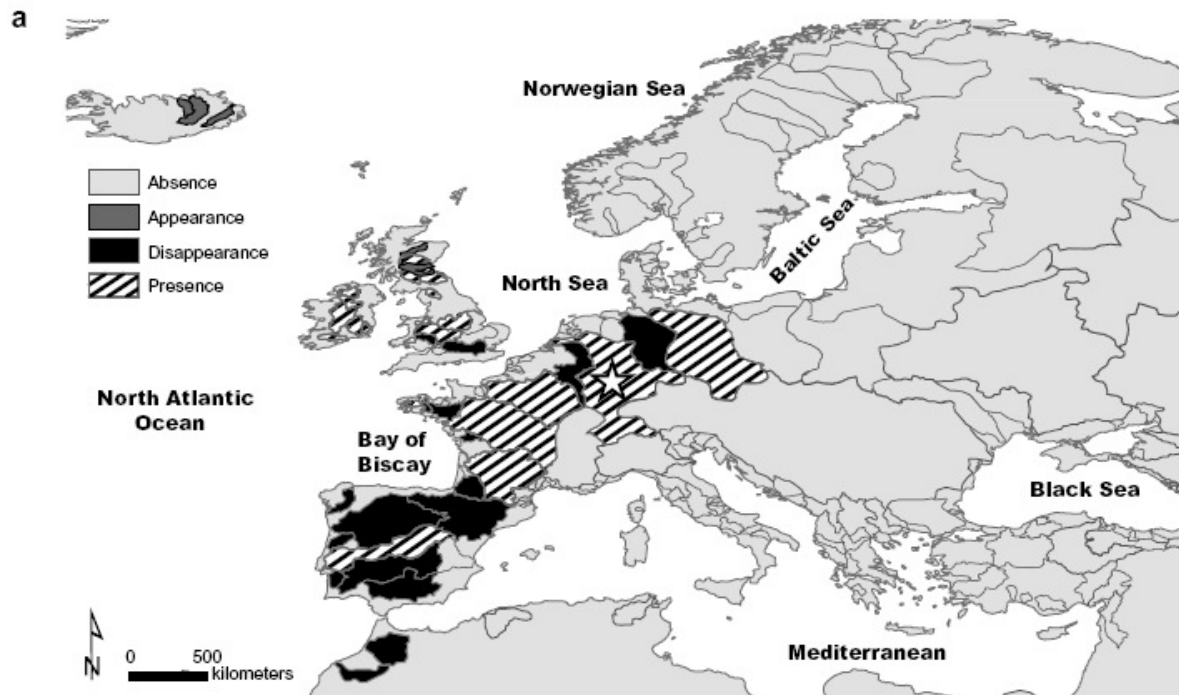


Figure 9: Potential distribution range *Alosa alosa* under projected climate conditions at the end of the 21<sup>st</sup> century. The projections were computed using biogeographical models (from Lassalle, et al., 2009a), the pessimistic A2 emission scenario and HadCM3 GCM. The Rhine basin is shown with a white star

The same authors also developed a semi quantitative model to analyse the distribution of this species around 2000 (Lassalle et al., 2009b). The presence of the species was classified to three classes of abundance (missing, rare, common, abundant). This model selected the same variables (longitude at the mouth, surface of the basin and annual temperature) than the presence-absence model. The response curves of the species to these three factors are presented in Figure 10. The bell shape of the response curve of the species to the temperature clearly indicates that an increase of the temperature of drainage basins with annual air mean temperature below 15°C leads to an increase in the suitability of the basin for Allis shad. Even though several authors postulated the influence of human activities to explain the reduction of abundance and the restriction of the distribution range of the species, none of the anthropogenic regional pressures we tested at large scale (i.e. density of human population, metrics derived from large dams) was retained to explain the present situation.

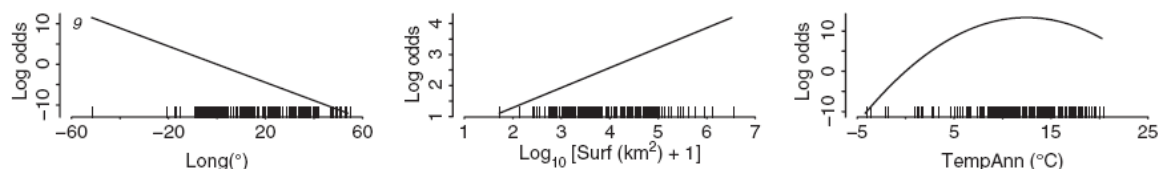


Figure 10: The partial effect of each predictor on the log odds, holding non-plotted predictors adjusted to zero. Intercepts were omitted from consideration. X-axis tick marks showed the distribution of the predictor values (from Lassalle, et al., in press-b).

The present conservation status of the species “Vulnerable” (habitat directive appendix II, V, Bern Convention appendix III) requires a close monitoring of its abundance when fishing is authorized. Commercial exploitation of Allis shad is now restrained to few Atlantic basins: Minho, Adour, Loire. Recreational fisheries are also very limited and located in the same basins.

### 3. Restoration of shad populations

Major experiences with successful re-introductions of shad species to rivers where the species had formerly died out come from North America. The reasons for the decline of shads in the USA are almost identical to those in Europe: North American populations of the alosines have been severely impacted by construction of dams, habitat alteration, pollution and over-fishing. Successful restoration of depleted populations has occurred through transplanting of sexually mature, pre-spawn adults or stocking of cultured larvae or juveniles. Transplanting of fertilized eggs has been attempted with little success. Reproducing populations of *Alosa aestivalis*, *Alosa pseudoharengus*, and *Alosa sapidissima* have been established in many locations in Eastern North America by transplanting pre-spawn adults.

Major efforts to culture alosines for restoration purposes have centered on *A. sapidissima* with less effort directed toward *A. aestivalis*, *A. mediocris*, and *A. pseudoharengus*. Culture of alosines has historically relied upon strip-spawning eggs from running ripe adults, collected on the spawning grounds. Fertilized eggs for culture can also be obtained by natural spawning in a tank environment, with or without the use of hormone injections. The most challenging aspects of working with members of this group include: their sensitivity to handling and stress in all life stages; and, for some species, the adhesive nature of the eggs and an inability to provide sufficient food, small enough to be utilized by first-feeding larvae.

#### 3.1. American Shad Restoration in the Susquehenna River

The Life Project primary goal of the Life Project was to achieving 20,000 spawning adult shad in the river and tributaries based on culture and release of 5 million marked larvae in 2008-2010. Much of the technology used and basis for optimism of achieving the goal comes from similar work done with American shad (*A. sapidissima*) in the Susquehenna River USA.

At 70,000 km<sup>2</sup> the Susquehenna River basin is the largest on the East Coast of the U.S. The river flow averages 1,000 m<sup>3</sup>s<sup>-1</sup> as it courses 705 km from its source in New York, across the breadth of Pennsylvania, and terminates at the head of Chesapeake Bay in Maryland. American shad historically used most of the Susquehenna and its large tributaries and supported extensive commercial and subsistence fisheries through the 19<sup>th</sup> century. Gear improvements led to overfishing in Maryland waters and construction of hydroelectric dams in the lower river between 1904 and 1931 stopped all shad migrations into the river.

In the 1970s, state and federal fishery resource agencies and the four Susquehenna dam owners joined to initiate an effort to restore shad to the river. A trapping device was built at the first dam, Conowingo, 16 km above the mouth and an intensive culture shad hatchery was developed in a major upstream tributary, the Juniata River. The remnant shad population of the upper Chesapeake

Bay collapsed following an extensive flood (1972) and trap catch at Conowingo averaged fewer than 300 fish per season during 1972-1984. Maryland closed its shad fisheries in 1980.

The hatchery began slowly, producing 1-5 million larvae and fingerling shad each year. Eggs were stripped and fertilized on the spawning grounds of numerous east and west coast U.S. rivers and delivered nightly to the hatchery. By 1986, Pennsylvania researchers refined mass-marking techniques using oxytetracycline antibiotic. As egg collections improved so did larval production. During 1984-2000, hatchery production for the Susquehanna averaged over 10 million fry per year. As quality shad eggs became more difficult to acquire from the rivers each season, Susquehanna partners added hormone-induced tank spawning using fish taken at the Conowingo trap. Though millions of eggs have been taken in recent years using LHRH injections, viability has been poor – about 20%, compared to 60% for strip-spawned eggs.

In 1991, a fish lift was built at Conowingo Dam and during 1991-1996 about 171,000 adult shad were transported by truck and stocked above all dams. Fish lifts were completed at the next two dams in 1997 and the final blockage received a fish ladder in 2000. As a result of these cultured larvae and adult shad stockings, numbers of shad returning to Conowingo increased sharply. From a few hundred fish a year in the 1970s and early 1980s, trap catches improved to many thousands in the late 1980s, tens of thousands through the 1990s, and peaked at over 200,000 fish in 2001. Most fish return to the river at ages 4 and 5 and about 60% are carrying hatchery tags. The rate of return for hatchery fish in this program is one adult for each 200 larvae stocked (0.5%). In recent years numbers of shad in the lower Susquehanna River have decreased for unknown reasons, as have shad populations in most Atlantic Coast rivers.

Other aspects of the Susquehanna River shad program have included extensive monitoring of juvenile shad distribution, abundance and growth; radiotelemetry studies to help define adult shad movements; and, turbine mortality studies at all dams to develop safe downstream passage alternatives for juveniles. A detailed history of this project, including annual stocking numbers is provided in Hendricks and St. Pierre (2002).

### **3.2. Comparing the River Rhine and the Susquehanna**

The Rhine River basin is over twice the size of the Susquehanna (185,000 km<sup>2</sup>) and about twice the length (1,320 km) and average flow (2,230 m<sup>3</sup>s<sup>-1</sup>). While water quality is adequate, the Rhine system is characterized by industry, heavy shipping and barge traffic (with wake affect on shoals), tide gates and confusing delta tributaries in the Netherlands. Although Allis shad are a protected species it cannot be excluded that some are taken incidentally in Dutch fisheries as confused with the recently recovering Twaite shad. There are only few dams in the Rhine itself, but those at Iffezheim and Gamsrhein need to improve passage conditions for shad.

Unlike the Rhine, the Susquehanna River has no industry or shipping, the river is open from Conowingo to the sea (330 km), but is blocked above river kilometer 16 (as measured from the river mouth at the head of Chesapeake Bay) by four large hydroelectric dams. Fish lifts and a fishway at these dams are not fully effective for shad and passage is still needed at several upstream dams. There are no shad fisheries in Pennsylvania, Maryland, Virginia or offshore along the Atlantic Coast. Program problems include lack of sufficient numbers of high quality eggs (and the need to improve hormone spawning results), a need for fish passage improvements, especially under high spring flows, and a need to identify causes and possible cures related to reduced adult returns in recent years.

### **3.3 Comparing Allis Shad and American Shad**

These two species are very similar in appearance, size, life history strategy (anadromous), age structure at maturity (mostly 4-5) and migration timing. Both species likely make extensive nearshore ocean migrations but the River Rhine is near the northern edge of the Allis shad range while the Susquehanna is in middle of the American shad range. Allis shad are known to hybridize with twaite



shad (*A. fallax*), but this situation is not known for American and the co-occurring hickory shad (*A. mediocris*). Allis shad spawning occurs at night with peaks (in the Garonne) at 02:00-03:00 hours, whereas the American shad spawning peak occurs before midnight. Allis shad apparently continue to migrate at night (based on fishway observations) but American shad stop, and usually drop downstream from dark until dawn.

Allis shad may be more fecund and CEMAGREF results of hormone spawning in 2005-2006 suggest much higher gross egg production (30-40k per female) than American shad using this method. Allis shad adults and juveniles may be somewhat more sensitive to handling stress. Most Allis shad die after spawning while American shad in the middle and higher latitudes of their Atlantic Coast range display varying amounts of repeat spawning, as much as 35% in the Susquehanna and 75% in Canada. Allis shad are reported to spend a short time in estuaries (2-3 weeks) before reaching the ocean (Lochet 2006). American shad typically migrate to the ocean as young-of-year in their first autumn.

#### **4. Current achievements of the Life Allis shad project**

##### **4.1. Culture, marking and stocking of nearly 5 million shad larvae**

###### **4.1.1. Collection of shad eggs and breeding of larvae**

The parent fish are caught at fish lifts, which were actually constructed to help the fish overcome the lowest transverse obstacle on the Garonne (Golfech) and the Dordogne (Tuilières – in operation since 2009) but which also function as monitoring. The removal of spawning fish from the fish lifts has the particular advantage that the fish can be caught in migration and guarantees that the gametes are already virtually ripe. The fish can be transferred directly from the fish lift into suitable transport containers without having to remove them from the water, thus reducing mortality rates caused by capture and transport. The controlled removal of pre-spawning fish at the transverse structures also ensures that the necessary proportions of each sex can be removed and that only a few vital representatives of the entire spawning population are caught. In order to guarantee smooth transportation of the sensitive Allis shad from the fishing ground to the breeding facility, special spacious round channel containers were developed in which the fish could be kept in the dark and transported particularly carefully while ensuring oxygen inflow and keeping salt concentrations low.

Spawning in captivity is induced by injecting a stimulating hormone into both sexes to initiate spawning. The gentlest method found was to transfer the fish to a transparent, water-filled plastic bag and to inject them through the bag.

After this treatment, the spawning fish are transferred to special round channel spawning pools. These are darkened in order to simulate the conditions under which fish spawn in the wild. The eggs and sperm are released synchronously by both sexes at a temperature of 20°C about 24 to 72 h after the hormone is injected. The highest fertilisation rates are achieved by a ratio of 2:1 to 3:2 (males to females) between the sexes. The fertilised eggs then sink down, and are siphoned off through a bottom outlet and collected in net sacks before being transferred to special incubation jars, after being treated with a hydrogen peroxide solution in order to reduce fungal attacks. The incubation jars are integrated into a water circuit to ensure that the eggs receive sufficient oxygen, thus guaranteeing an optimum embryonic development and high hatching rates. The first Allis shad larvae hatch after just four days. Soon before hatching, the incubation jars are placed next to the breeding basin. Once hatched, the Allis shad larvae swim to the top of the incubation jars and reach the breeding basin by passing over the rim of the jar with the current. As soon as the larvae have hatched and consumed the yolk, they are supplied with *Artemia* nauplii. Since 2008 the specialised Allis shad fish farm in Bruch (approximately 45 minutes drive away from the Golfech dam) is in operation and further great improvements on the different level of larvae rearing have been made compared to the feasibility studies carried out in the CEMAGREF St. Seurin facility. The number of eggs per female

averages about 310,000. The proportion of viable eggs was increased to 65% and the proportion of freshly hatched larvae relative to number of viable eggs was increased to 96%. After all the number of viable larvae per female averages 26,000 and in 2010, when the LIFE Allis shad project was terminated, only 255 (148 male, 107 female) adult Allis shad were required to produce 2,64 Mio larvae for stocking the Rhine. Since the method of artificial spawning and rearing of larvae turned out to be more effective than with regards to the American shads programmes in the USA, the method of strip-spawning after catching ripe adults from their spawning grounds, which is considered to be most effective with American shad, is not further pursued in the LIFE-Project. Due to the lessons learned in the first year of Allis shad rearing and transporting to Germany and to the improvements made, it was possible to climb the mark of 2 Mio shad larvae for stocking the Rhine per year.

#### **4.1.2. Marking of Larvae**

Marking of larvae is a prerequisite to be provided with the opportunity of drawing conclusions on the project's success in the future, e.g. by identifying adult returners as formerly stocked fish. Due to their small size when getting stocked it is impossible to apply external marking techniques. Thus larvae are marked by getting immersed to an oxytetracycline (OTC)-solution, which is deposited in bony structures like the otoliths and can later be recognised under a fluorescence microscope as ring-shaped inclusions. The best results (highest marking quality, lowest mortality) were obtained by exposing the fish to a 300 ppm OTC solution for 4 hours. Examinations of juvenile Allis shad kept in an outdoor pond for the 4 months following the marking showed that the markings can also be easily identified in Allis shad which mature in the wild. The majority of larvae were marked at an age of 2 to 7 days. The overall mortality (post-hatching plus marking) is about 5,4%. With increasing age larvae are fed with particular dry food (e.g. caviar) additionally to *Artemia* nauplii.

#### **4.1.3. Delivery of Larvae to the River Rhine**

Larvae are transported to Germany at an age of 3 to 10 days. In few cases larvae were up to 26 days old, which however suffer at this higher age increased transport mortalities compared to younger stages and contributed only to a very small share to the total of delivered larvae. Larvae are given at numbers of 5,000 to 12,000 into plastic bags which are filled to one third with water and two thirds with pure oxygen. It has turned out beneficial to put an additional bag around the actual transport bags in order to maintain pressure stable. The bags are stored between ice packs and transported in vans, which can cover the distance between the Aquitaine region and North Rhine-Westphalia and Hessen cheaply and within a relatively short time. Because of the lower temperatures and traffic volume, it has turned out to be beneficial if the larvae are transported during the night, usually arriving in Germany early in the morning. So far single transports comprised up to one hundred bags and 1.2 Mio larvae, respectively. Meeting points with the responsible stocking teams were arranged in advance in order to reload the bags and to approach the preselected stocking sites without further delay.

#### **4.1.4. Selection of Shad Larvae Release Sites**

The stocking locations firstly have to be within easy reach and secondly have to be particularly suitable in terms of current and depth as well as being away from currents and wash caused by shipping. This is why the larvae have not yet been released directly into the Rhine current. Instead, the fish were released into the Sieg, a relatively natural Rhine tributary in NRW, the Rhine channel at Erfelden, a moderate-flowing and also quite natural branch of the Rhine in Hessen, and former gravel-pits connected to the Rhine, all sites which allow the Allis shad larvae to become accustomed to their new habitat before they have to tackle the strong currents in the Rhine itself. Factors taken into account when making the preliminary selection included the existence of structures as natural as

possible in the habitats in question, low current, changing depths and the lack of potential predators. From the end of May onwards, the fry of indigenous fish species is often so developed that they may prey on the tiny Allis shad larvae. As the Allis shad larvae also have to receive nourishment fairly quickly after their long journey so that they can find their way and survive in their new habitat, two different release strategies have been followed over the years. If possible, the larvae are only released at dusk or in complete darkness, as the risk of being eaten is much lower at night. Shady round channel containers have turned out to be very suitable for keeping and feeding the larvae during the day; in these, the Allis shad larvae can adapt to the water into which they are to be released and be fed with *Artemia* nauplii. In this way, the larvae can adjust well to local conditions before they are actually released. If there is no interim storage possibility, the larvae are released into open waters during the day after adjusting to the prevailing temperature. This strategy is used at the gravel-pits connected to the Rhine, which contain a wealth of plankton on which the Allis shad can feed immediately after their release. Observations made by divers have shown that the larvae also actively avoid the areas close to the banks and the levels close to the surface, presumably to minimise the risk of being preyed upon, as the potential predators, mainly other YOY fish, are more abundant in habitats along the banks.

#### **4.1.5. Monitoring for juvenile shad survival, growth and distribution**

Accompanying monitoring studies and observations on the post-stocking behavior of shad larvae so far provided valuable information with regard to the optimization of stocking site selection and stocking operation itself. The release of larvae from the transportation bags (after temperature adjustment) to habitats close to the bank and during daytime might involve an increased predatory pressure exerted to the larvae through larger YOY fish. Experiments have proven that it is apparently beneficial to keep the shad larvae in round channel tanks supplied with river water and feed them with *Artemia* in order to enhance adaptation and fitness and releasing the larvae after dusk, when the risk of predation is reduced. This particularly applies when the stocking is conducted at the beginning of June or even later and fry of other species are already highly abundant. At least after dusk Allis shad larvae obviously are drifting with the current from the site where they have been released and couldn't be detected in the close vicinity in the days after stocking. Drift investigations accordingly found numerous Allis shad larvae close to the place where they were released, whereas no Allis shad larvae were found in the driftnets placed much further downstream. An experiment during which observers in a boat watched the Allis shad shoals drifting downstream after their release revealed an identical picture: the size of the shoals, which initially drifted close to the surface, decreased steadily as they moved further downstream from the place where they were released. After several kilometres of drift, there were no more Allis shad larvae to be seen. The results of the monitoring measures were however unable to reveal where the larvae spent the following weeks and grew into fry before migrating down to the delta so far.

Due to financial restrictions additional measures aiming on closing this information gap were brought on its way by mainly using existing infrastructures, like monitoring programmes of the authorities in Germany and the Netherlands. In Germany particular stretches of waters stocked, i.e. the lower river Sieg, are subject to electric fishing surveys in several contexts. This circumstance wasn't sufficiently utilised in the last years, however, such investigations can provide valuable data when fishing dates and sites can be arranged or even slightly modified by involving the project management. This can be easily implemented by applying at the authorities responsible for the permissions of electric fishing surveys, that paragraphs are to be incorporated that request the processors (mostly planning offices



Fig. 11: The first juvenile Allis shad from the stocking on their seaward migration were detected by means of an anchored stow-net situated at the Lower Rhine a few kilometres upstream of the border to the Netherlands

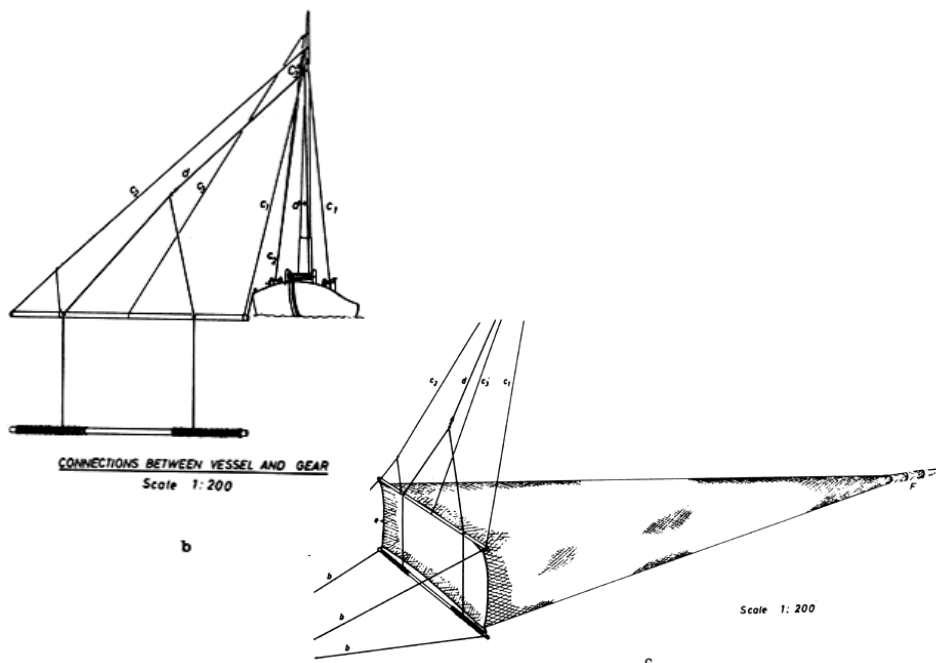


Fig. 12: Anchored stow-nets are still used by some fishermen in the German and the Dutch sections of the Rhine. Their original purpose is to catch downstream migrating silver eels. Depending on the clearance of the gear it is also well suited to catch pelagic fish or those from close beneath the surface (pictures taken from Klust, 1970).

and fisheries associations) to inform the project management in the run-up to the field studies. Additionally the Rhine and the stocked tributaries are subject to periodical investigations carried out by authorities of federal states (e.g. LANUV NRW department of fish ecology, field research team) themselves and data gathered will be forwarded to the project management on demand. At the German and the Dutch section of the river Rhine still some professional fishermen go out their daily business. Most of them are supervised by authorities (e.g. the Rhine fisheries cooperative North Rhine-Westphalia, the IMARES institute in the Netherlands) and many additionally work on a collaborative basis with research institutes, so that exceptional records are announced immediately and the data in general is forwarded to involved organisations on a regularly basis. These fishermen often use traditional gears and methods (fyke-nets, trawling, stow-nets, gill and drift nets), which are different from those of the standard monitoring measures and thus better suited to detect individuals that prefer offshore habitats.

Actually it was a professional fisherman who proofed the first juvenile Allis shad from the stocking measures of the LIFE project migrating downstream to the delta in autumn of 2010 by means of an anchored stow-net. Between the beginning of September and the end of October a total of 30 juvenile Allis shads (a sub-sample of 11 shads were proven to origin from the stocking after the OTC marks in their otoliths) was caught in total, and these attained a mean total length of 124 cm. Despite the stow-net due to its marginal width (10 meters) probably detected only a small fraction of the Allis shad passing the location (width of the Rhine ~ 600 meters in respective period) it is impossible to calculate a reliable projection of the actual number so far. However, these findings demonstrate that the shads apparently survive and grow well and moreover perform migratory patterns as their ancestors. Since the respective gear will be operating in the coming years, we are confident of providing additional information on the number and timing of seaward run. Although even in the Dutch Delta Rhine section some fishermen are still working, the fishing effort in the last years was reduced due to restrictions imposed with regards to the protection of silver eels, the target species of fyke- and stow-net fisheries. The same applies for monitoring schemes carried out in the framework of monitoring investigations conducted by the Dutch authorities, which imply hauls with large trawl-nets, which are considered to be well suited to representatively cover the large Delta branches and lakes and thus to detect juvenile Allis shad when being conducted during the estuarine phase of the juvenile shads. An agreement was made that the Dutch authorities will be informed as soon as the first downstream migrating fish are detected in the German section in order to provide them with the opportunity to intensify and to specify their efforts. As between the authorities of the other federal states Germany along the Rhine, information on Allis shad records will be forwarded to the responsible authorities in North Rhine-Westphalia immediately. We are confident that these measures will provide proofs for juvenile Allis shads in the future particularly in the Netherlands, as they did with juvenile Twaite shad and North Sea houting, which exhibit close parallels with regard to their life-cycle and which stocks increased considerably in the recent years. Arrangements with the Dutch authorities were made, that conspicuous juveniles of the genus *Alosa* will be stored deep frozen and delivered to the responsible authorities in North Rhine-Westphalia for detailed investigations and inspections of the otoliths for OTC marks. Proceeding so, i.e. when OTC marks are missing it is expected to be able to receive first indications for successful reproduction of Allis shad in the wild.



#### 4.1.6. Identification of Shad Spawning Sites

Many of the historically reported important spawning grounds of Allis shad in the Rhine were situated at gravel banks below the mouth of the major tributaries or in the tributaries themselves. The majority of these habitats diminished due to the construction of dams, which blocked henceforth the spawning migration on one hand and interrupted sediment load forming the in-stream banks on the other. Furthermore many of the gravel banks were extracted actively for the maintenance of shipping purposes. These measures may have had their share within the complex situation, which finally led to the extinction of the Rhine's Allis shad population. In these premises the question whether there still exists a sufficient range of habitats required for spawning in order to maintain an Allis shad population which recruits from natural reproduction is of particular importance. The parameters which determine suitable spawning habitats are well known from rivers which house large and healthy Allis shad populations. Allis shad release their sexual products in the open water and do not, unlike most other freshwater fish, attach their eggs to certain substrates. Nevertheless, spawning is restricted to particular habitats, mostly at stretches at the transition from pools to faster flowing riffles (compare Table 3) with gravel substrate. Most likely this active site selection aims on the opportunity of eggs to be kept in gravel interstices where the current and thus oxygen supply and embryogenesis is enhanced.

The first step in the identification of potential spawning habitats was done with the assistance of experts from active shad rivers in France and the USA during their visits at the Rhine. These confirmed that habitats along the inner bend banks of meanders as well as gravel banks provide identical conditions with regard to current, depth and substrate composition like active shad spawning sites (see Table 3). In a second step these sites were identified by means of aerial pictures and additional assessments were made in the field. A total of at least 66 potential spawning habitats were identified in the free flowing section of the Rhine (below the Iffezheim dam). At mean water-levels these habitats extend from many hundred to many thousand meters length along the course. However, due to the large water-level dependent fluctuations of habitat area, which alter the current area of these slightly inclined habitats even at moderate water-level changes considerably, no further efforts were made to quantify the available area of potential spawning sites. It is however stated, that their area in the Rhine alone, is sufficiently high to maintain a self-sustaining population. Even at the lower stretches of tributaries below the first migratory obstacles single potential spawning habitats are present.

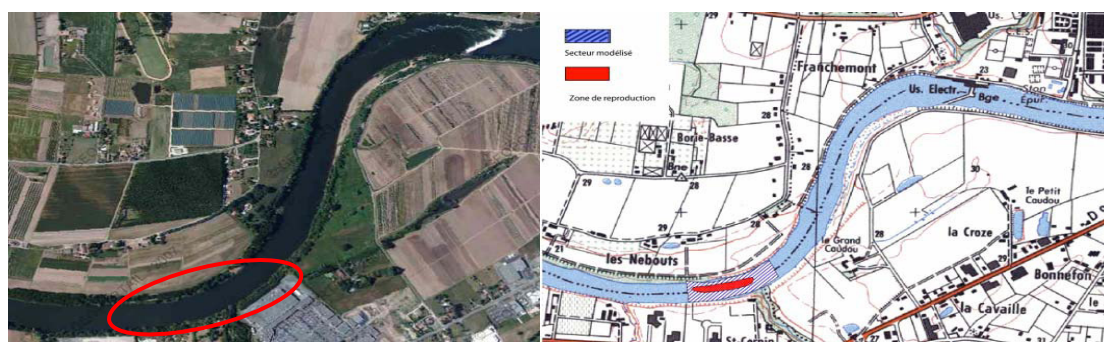


Figure 13: Allis shad spawning site in the Dordogne River "La Frayère des Nébout's"

Table 3: Characteristics of Allis shad spawning sites in French rivers (modified after Migado, 2007)

Reference	Water depth (m)	Current velocity (m/s)
Belaud et al. (2001) Belaud in Baglinière et Elie, 2000	0,9 - 2	0,4 - 1,5
Cassou-Leins et Cassou-Leins (1981)	0,5 - 3	0,9 - 2
Boisneau et al., 1990	0,9 - 2	0,45 - 0,9
Aprahamian (1981) in Baglinière et Elie, 2000	<3	?
Migado, 2007	1,5 - 4	0,4 - 1,1

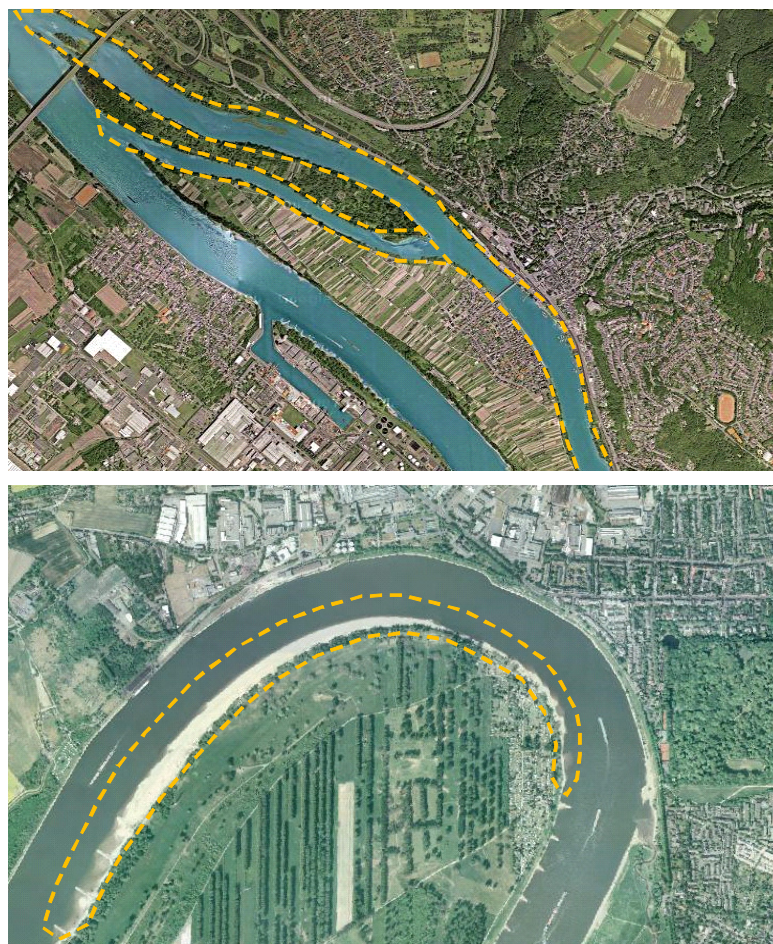


Figure 14: Potential Allis shad spawning sites e.g. in secondary channels (here at the Middle Rhine near Koblenz, above) and inner bend banks (here at the Lower Rhine near Düsseldorf, below)

#### 4.1.7 Identification of nursery habitats

To our knowledge the nursery habitats and their significance on the juvenile's survival has never been studied before. Consequently nothing is known about YOY Allis shad habitat preferences or even requirements. From the monitoring investigations accompanying the stocking measures during the LIFE Allis shad project it can be concluded, that shad larvae drift downstream soon after being released. However, there are also indications that the larvae niche in particular riverine habitats, which can be concluded from a) direct observations of larvae leaving the drift, b) the absence of larvae from the drift with increasing distance from the site they were released at, c) the occurrence of well grown Allis shad juvenile stages in the drift of the Rhine months after they have been stocked, probably hundreds of kilometers upstream, d) records in the Gironde estuary in France in not before late summer and e) otolith chemistry (Lochet et al 2009). The identification of the freshwater habitats and an assessment of their significance for recruitment will be the subject of studies carried out in the LIFE+ Allis shad project. Furthermore the accompanying investigations to stocking measures in the Rhine watershed will be continued and specified to close the still existing gap of knowledge. Nevertheless and despite the scarce knowledge, the findings of juvenile shads on their downstream migration in the Rhine demonstrate that there must be adequate habitats that support YOY Allis shad survival and fast growth (compare 4.1.5).

### 5. After-Life Conservation Plan

#### 5.1 Continuation of re-introduction measures

The primary objective of this 4-year Life Project was to produce 20,000 adult Allis shad returning to the River Rhine. The 20,000 fish estimate was based on a likelihood that releasing 5 million cultured shad larvae in 2008-2010 will produce a rate of return of one adult for each 250 larvae stocked ( $5,000,000 \div 250 = 20,000$ ). This return rate has been achieved and surpassed for American shad in the Susquehanna River USA. Full realization of the 20,000 fish return will take six years after the conclusion of the Project. If it is assumed that 10% of the fish return at ages 3 and 6 and 40% each at ages 4 and 5, adult returns by year would be as shown in the following table. Due to the unexpected decrease of the adult stock and a lower than number of adults recruited for artificial rearing in the fish farm in Bruch, the number of larvae stocked to the in 2008 and 2009 was however smaller than planned. Based on the above calculations the number of expected returners is reduced to 19,400 rather than 20,000, and particularly in 2011 the number will be only half of the planned. Nevertheless a substantial increase of adult Allis shad returning to the Rhine is to be expected from 2013 onwards.

Table 4: Expected number and schedule of adult Allis shad returning from the stocking measures carried out in the LIFE Allis shad project duration.

Production Year	Number of stocked larvae	Expected adults returning in year						Total returns
		2011	2012	2013	2014	2015	2016	
2008	500.000	200	800	800	200	-	-	2.000
2009	1.711.000	-	684	2.738	2.738	684	-	6.844
2010	2.642.500	-	-	1.057	4.228	4.228	1.057	10.570
Totals	4.853.500	200	1.484	4.595	7.166	4.912	1.057	19.414

From all shad restoration programs currently underway in the United States the conclusion can be drawn that at least two decades are needed to achieve substantial recovery of lost populations. Thus, the Life Project is viewed as an initial effort to develop culture and stocking techniques and monitoring programs, and to identify essential shad nursery and spawning habitats. In order to



achieve a large effective population size that can maintain itself with natural reproduction in the Rhine system, the actions started in the Life Project will be pursued and refined in future years. For the years 2011 until 2015 the stocking measures will be part of a LIFE+ project, in which inter alia the achievements and infrastructures are going to be used by the approved rearing team and 1,5 to 2,0 Mio Allis shad larvae will be reared and stocked to the Rhine system. For the years after 2015 it is planned to integrate the measures into North Rhine-Westphalia's migratory fish program. The amount of larvae stocked to the Rhine-system for the next years strongly depends on the development of the donor populations from the Gironde watersheds. Unless the population won't decrease further the amount of larvae produced in France and transferred to Germany will be as scheduled or could be even raised in case of a significant recovery. From 2015 onwards it is scheduled to increase larval production in Germany. This is planned to be realized by obtaining sexual products for rearing from ex situ stocks and some day additionally from returning adults. The further continuation or modification of the schemes depends on how successes with regard to a significant increase of adult records, proofed natural spawning, increasing numbers of juvenile Allis shad from natural reproduction will be proofed and at latest adults from these will be found to return to the Rhine system.

## **5.2 Returning adults to the Rhine system**

After stocked larvae were proven to grow into juveniles and migrating to the estuary the confirmation that these will return as adults to the Rhine system is the next essential step for the project's main objective. Based on the likelihood that 250 larvae are required to produce one adult returner and on the stocking schemes carried out so far an increase substantial increase of adult returners is to be expected from 2013 onwards. Theoretically the number of adults is supposed to increase to amounts which shouldn't remain undiscovered. In the recent years single and up to seven Allis shads were observed at the monitoring stations of the fish passage facilities on the upper Rhine. Both, the Gambsheim and the downstream situated Iffezheim fish pass facilities are equipped with devices which allow determining each fish climbing the fish pass year round. Since the shads went so far upstream (although suitable spawning sites are sufficiently available in stretches below) in the recent years, it seems probable that an increase of adults run will result in increasing shad records at the dams in the Upper Rhine section. Even the lowest weir at the river Sieg, to which Shad larvae had been stocked from 2008 onwards and into which thus adult shads might immigrate, is equipped with a modern fish pass facility and furthermore with a monitoring device, a VAKI counter and video surveillance device, being in operation year round. Even the fish pass at the lowest weir of the river Moselle will, after it has become modernized with regard to the requirements of migrating shad, be equipped with a VAKI counter device. Potential Allis shad recordings at these surveillance facilities will be immediately forwarded to the authorities in North Rhine-Westphalia. The lowest dam at the river Moselle will be equipped with a modernized fish way and a VAKI monitoring device in 2011.

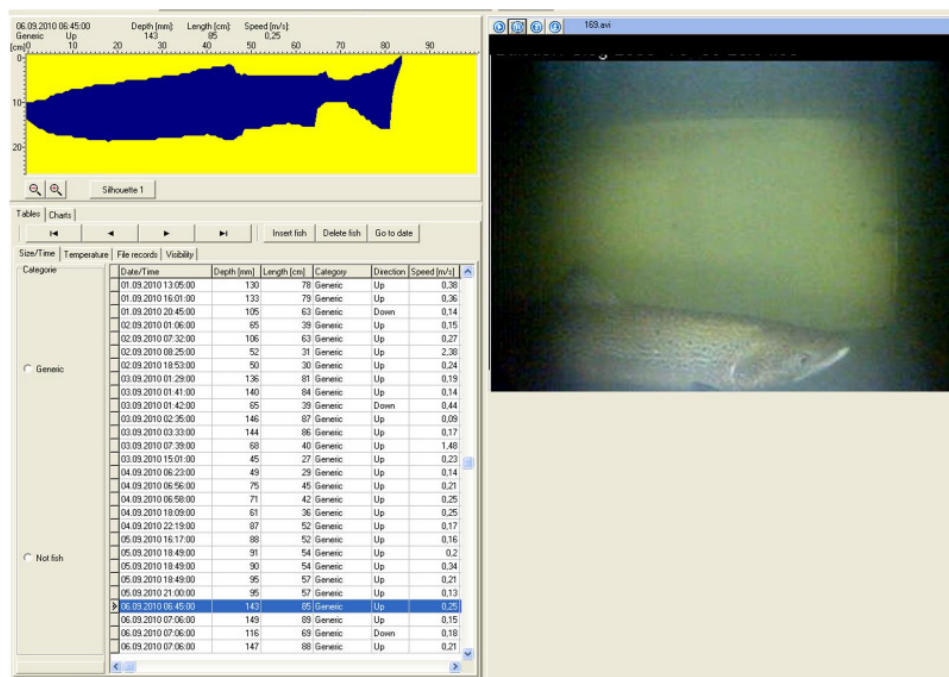


Figure 15: The lowest dams at the river Rhine and some tributaries are equipped with fish ways and surveillance devices (here outputs of the VAKI device at weir at Buisdorf/Sieg). These allow detecting and determining fish that climb the fish ways and will thus probably provide data on returning Allis shad in the future years.

Adult North Sea houting and Twaite shad, both anadromous species with close life-cycle related parallels to the Allis shad, appeared increasingly often in the by-catch of stow-, fyke-, and gill-net fisheries of fishermen in the Dutch and German section of the Rhine. Since a determination sheet helping to discriminate between the closely related Twaite and Allis shad was prepared during the LIFE-project and distributed to professional fishermen, the chance that potentially caught Allis shad will be identified correctly is increased. Notwithstanding the latter years extraordinary or indefinable recordings were immediately forwarded to the national authorities. The same applies to accidental catches by anglers. Since the sport-fisher associations in both states are project partners to the LIFE (and even the LIFE+) Allis shad project such recordings will be forwarded immediately. Even the monitoring schemes of the Dutch authorities, e.g. the “Zeldzame Vissoorten” monitoring during which adult Twaite shad and Houting had been recorded, are potentially well suited to detect adult Allis shad.

The project carrier of the Allis shad project, the LANUV NRW, is inter alia responsible for monitoring the fish fauna of the Rhine and electric fishing surveys on the Rhine are carried out on a regular basis. It is planned to extend, intensify and modify these surveys during the Allis shad upstream migration in May and June unless the discharge isn't inappropriately high, e.g. by fishing at potential spawning habitats (see 4.1.6) after dusk from 2013 onwards. Additional planning aims on the conduction of drift-net surveys with the assistance of the shipping authorities in order to rule shipping traffic flow at the bank site, where the drift-net survey conducted. This method and the way of cooperation had already been approved in former years. These additional samplings could be implemented without additional costs. It is planned to intensify the investigation effort depending on the likelihood of returner rate (see 6.1) and current indications. From the moment it will become possible to catch adult returners they will be transferred to the ex situ stock and breeding facilities for artificial rearing. It is planned to increasingly stock larvae reared from returners to the Rhine system.

### 5.3. Confirmation of shad spawning ground utilization

The act of spawning in Allis shad is very noisy and thus theoretically quite well perceivable without additional gears. In France techniques have been developed which even allow to draw conclusions on the number of Allis shad involved in the spawning, the so-called “*bull*”, by acoustic surveillance measures. Hence an identification of a shad spawning site might turn out comparably simple. Despite the high number of potential spawning habitats it is virtually impossible to monitor these sites over an extended period of some weeks and night per night in detail without an army of volunteers. Thus it is planned to gather indications, e.g. regarding conspicuous splashes during May and June nights, by raising the awareness of shareholder groups which are considered to be potentially present at the respective locations at nighttime anyway. This will be done by preparing specific information material and distribute this to anglers, and to distribute audio-visual material of bulls over the project’s homepage. In recent years the information flow from anglers to the fisheries associations and the Rhine fisheries cooperative, which both are involved into the Allis shad project, was repeatedly proved efficiently, so that good chances exist to get informed about striking spawning activities. Additionally it is planned to provide the offices of the water police, which are patrolling the entire Rhine stretch with demonstration material to enable the officers to potentially identify a *bull* and forward the location to the project management. After receiving such hints the respective sites will be more intensively inspected in the remaining spawning season. A duly observation/acoustic monitoring of pre-selected potential spawning habitats by students is moreover a key task of a LIFE+ Allis shad project. In case of doubt additional electric fishing or drift netting surveys could be taken into account for proving the splashes to originate from Allis shad. Almost all habitats considered as potential Allis shad spawning sites are already under protection in the sense of the EU habitats directive. Identified spawning habitats will be put under protection immediately.

### 5.4. Monitoring and improving adult shad migrations through the Rhine Delta

If this Life Project is to achieve its desired result, adult shad returning to the Rhine system must find their way through the complex delta system in the Netherlands. Currently only the main entrance to the Rhine is open to migration, though in times of storm tides the movable flood gates at the Maeslant surge barrier could be temporarily closed. Floodgates in the River Lek at Driel, Amerongen and Hagestein have natural fish bypass channels. Monitoring these for use by shad should be considered in future years, and some modifications to accommodate shad may be desirable. The furthest upstream project at Driel provides some flow control to the rivers IJssel and Waal, both of which may be important migration corridors for Allis shad. Finally, large drainage sluices at Haringvliet, Volkerak and at other coastal entries, as they operate now, prevent saltwater intrusion and block fish migration through several historically important Rhine delta estuaries. Although an arrangement was made with Dutch authorities that the sluices at Haringvliet will be partially opened to enable a slight salt water intrusion and to re-establish a kind of estuarine conditions, this contract was skipped by the current Dutch government in the autumn of 2010. The further development is unclear.

Atlantic salmon and sea trout, and more recently Houting are the focus of efforts to track fish through the complex system of tributaries and cross channels in the Rhine delta. Fish are purchased from commercial fishermen, surgically implanted with radio transmitters and recorded as they pass fixed receiving stations. Forty such stations are located from tidal barriers and lower Rhine delta tributaries in the Netherlands to near Bonn, Germany and the lower Rivers Lippe and Sieg. With such an elaborate concentration of radio receiving stations it may be possible in future years to apply this technology to shad. However, Allis shad is known to be even more sensitive and fragile compared to the species which have been subject to NEDAP trail implantations so far and it is not known how shads cope with the surgery. An experimental transportation of adult Allis shads from France to the Netherlands and implanting them NEDAP transponder will be realized in the following up LIFE+ project. If it should turn out, that transportation of adults over such long distances and times is

impossible or that political restrictions occur, it is planned to realize the study by means of returning adults to the Rhine system in future years.



Figure 16: Fixed detection stations for NEDAP trail transmitters in the branches of the Dutch Rhine and Meuse delta and the lower parts of the Meuse and the German Rhine as well as its major tributaries in North Rhine-Westphalia allow to tracing the routes of up- and downstream migrating fish equipped with the respective transmitters. In the future the NEDAP system could even provide information on the migration routes of adult Allis shads.

### 5.5. Increase of hatchery production

Successful re-introduction of Allis shad to the River Rhine after the conclusion of the Life Project will require continued and expanded shad culture and stocking efforts. In the Susquehanna River USA, adult shad returns to the river, based largely on hatchery releases averaging 10 million larvae per year, increased over 200-fold over the 19-year period 1983-2001. As shown in the Susquehanna graph below, in spite of occasional ups and downs, response to stocking of shad larvae progresses over many years. Unfortunately, most American shad populations on the U. S. Atlantic coast have declined since 2002 with commercial harvest reaching an all time low in 2006. With annual hatchery production reduced due to lack of spawners adult shad returns to the Susquehanna River now show a downward trend.

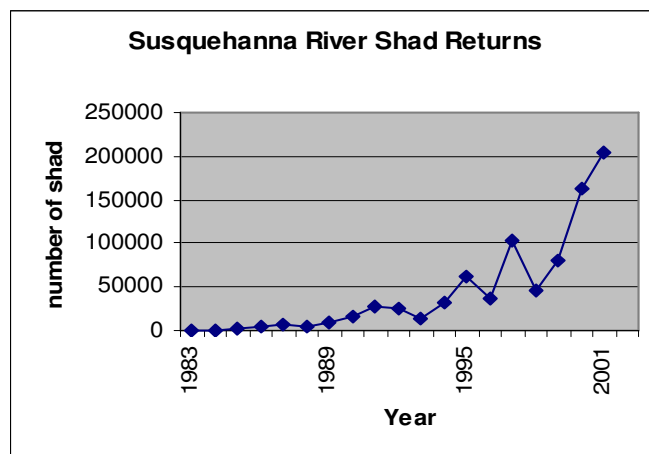


Figure 17: Increase of adult American shad in the Susquehanna river as a consequence of stocking about 10 Mio shad larvae per year

Improvements in the rearing techniques in the fish farm in Bruch allowed to raising net larval production and thanks to these enhancements it seems not unlikely that the amount of larvae stocked to the Rhine might be further increased. However, the Gironde-Garonne-Dordogne population, the donor population for restocking the Rhine watershed decreased substantially from 2005 onwards and only slightly recovered in 2009 and 2010. Thus an ongoing negative trend as observed in the years from 2005 to 2009 and decreasing numbers of adults taken from the system for artificial rearing in the worst case might, regardless of the recent improvements, not be fully compensated by the higher net larval output from the fish farm in Bruch. Although it seems not likely that the Gironde's Allis shad population will decrease to an extent that the removal of adults to produce up to 2 Mio larvae won't be possible anymore, attempts will be undertaken to develop ex situ adult stocks for rearing larval independently from the wild stocks and regardless the state of recovery. Such facilities are planned to operate in France and in Germany. First experiences for the European Allis shad were made in the La Rochelle Aquarium in France, where fish from the 2008 rearing batch were transferred from the fish farm in Bruch to La Rochelle and successfully kept in captivity. These are expected to successively reach maturity from 2011 onwards. In Germany an ex situ stock will be founded in 2011 by even transferring larvae from Bruch into a newly developed facility in order to make them reaching maturity in the future. From the moment it will become possible to get hold of returners to the Rhine system these or their progeny are planned to step by step replace fish from the Gironde area in order to be able to maintain off-spring with an increasingly better adaptation to the conditions in the Rhine system on a long term scale. These fish are considered to successively reduce the need of exploiting the Gironde wild stock for stocking larvae to the Rhine. Since Allis shads need to be kept under temperatures considerably higher than 10°C to survive and to reach maturity in a comparable time as their conspecifics growing in the wild, the facility will require high energy input, particularly during winter. It is planned to raise the facility in or close to a power-plant, in which cooling water accrues along the operation and is usually discharged without further use. The original agreement to include the ex situ-stock to an existing fish farm on the company ground of the nuclear power plant in Biblis/Hessen will depend on the political decision on the future of the plan. The search for plan B locations is in operation.

### 5.6. Transfer of Allis shad rearing techniques to Germany

Great improvements in Allis shad breeding and rearing have been during the LIFE projects duration and techniques and devices are widely established. A breeding handbook, which gives a detailed insight into the techniques and device specifications, was provided by the project partner MIGADO, who will be furthermore directly involved in the transfer of knowledge of Allis shad rearing from France to Germany. In the coming years it is planned to increasingly rear Allis shad larvae in Germany, in the direct vicinity to the Rhine, in order to pursue the long-term aim of stocking Allis shad for many years and the more when aiming on increasing the number of the stock. It is thus planned to install the facility required for rearing from 2011 onwards. The eggs are going to be obtained from the fish farm in Bruch in the coming years. Water-hardened shad eggs handle very well if properly prepared for shipment and transport times are limited to 12 hours or less. In the Susquehanna River program, tens of millions of American shad eggs were successfully shipped via air from the Columbia River near Portland, Oregon to Harrisburg, Pennsylvania, a distance of over 4,000 km, so that transport from Bruch to North Rhine-Westphalia or Hessen by private car or mail order service is feasible. The long-term objective will be to obtain eggs from adults returning to the Rhine system and/or the ex situ stock (see 5.5), respectively.

### 5.7. Improvement of fish passages in the Rhine System

Unobstructed access to the habitats required during life cycles is a prerequisite for healthy and best possible maintaining populations of riverine fish in general and diadromous fish in particular. This applies to exchange between salt, estuarine and freshwater habitats as well as to upstream and downstream migrations to and from spawning and nursery habitats. The Rhine provides a free flowing route from the mouth into the North Sea and the Rotterdam harbor via the Nieuwe Waterweg, the Waal and upstream from the splitting into the Delta Rhine branches until the Iffezheim dam. Fish taking this route won't experience any obstacles of migration and furthermore a kind of estuarine conditions, with regard to quasi natural tidal influence, turbidity and salinity gradients, in the lower part of the Waal and the Nieuwe Waterweg. However, from the further branches in the Lek/Nederrijn section three weirs were built (all equipped with modern fish ways for upstream migrating fish) before merging with the Nieuwe Waterweg, the IJssel drains into the lake IJsselmeer which is closed for exchanging fish towards the North Sea through the Afsluitdyke and the Haringvliet which receives a notable share of the Rhine's and the Meuse's discharge is also blocked for intruding saltwater and most probably even fish by the Haringvliet dam. During low tide conditions fresh water pours with high speed and pressure into the North Sea through narrow sluices. For emigrating fish passage through the sluices implies a rapid transfer from fresh to saltwater conditions. Data gathered for fish of many diadromous species which received NEDAP trail transmitters by the Dutch Imares Institute demonstrate the complex situation for migratory fish caused by the Haringvliet dam and maintenance of discharge in the delta. Most attempts of fish entering the Haringvliet fail and only some of them succeed in finding the eastward situated entrance to the Nieuwe Waterweg via the Europoort/Rotterdam harbor. Even those fish successfully entering the Haringvliet often don't find the way upstream due to alternating currents in the branches draining to the Haringvliet as a consequence of the measures of discharge control. Thus the situation at the Haringvliet is considered as a key issue for the recovery of diadromous fish in the Rhine basin. An agreement between the Dutch government with the ICPR and the authorities of Rhine bordering states was made, that implied a partial opening of the Haringvliet sluices and aims on a restoration of estuarine conditions to a certain degree (salinity gradient), however emphasizing the priority of flood control. This agreement was annulled by the current Dutch right conservative government in the autumn 2010. Although recently the stocks of Twaite shad and Northsea Houting recovered in some waters of the delta, this does apparently not apply to the Haringvliet. For Twaite and Allis shad from the Gironde population it is known that both inhabit the estuary for weeks to months (Lochet et al 2009), either during juvenile seaward migration and spawning run, which gives hints for the



importance of the estuarine habitat for their populations. All authorities involved into the Allis shad project will thus do their best to persuade the Dutch government to return to the former way and to implement the partial opening of the sluices soon.

Although habitat availability in the free flowing section of the Rhine is considered to maintain a self-sustaining Allis shad population, it is aspired to provide shads and other migratory fish access in the Upper Rhine and tributaries on a long term scale. The Upper Rhine upstream of Gamsheim and almost all tributaries are blocked by dams close the mouth into the Rhine. If at all, these are equipped with obsolete fish ways or those which were built for the purposes of salmon upstream migration, but most often untraceable or insufficiently passable for Allis shad. However, these fish ways could be substantially improved with better flow control to reduce turbulence, air entrainment and velocities between pools. If and when these facilities are rebuilt, pool sizes should be enlarged to provide more resting areas and care should be taken in properly siting entrances away from hydroelectric turbine discharges. For the construction of the new fish way at the lowest dam of the river Moselle at Koblenz, which is planned to go into operation in 2011, the state of the art knowledge on specific requirements of shads has already been taken into account. The knowledge on specific requirements of shads for fish passages will be further expanded through a visit of a expert team at American shad rivers in order to transfer the state-of-the-art know how to Europe as an action of the following LIFE+ Allis shad project and taken into account for the construction and modernization of fish passages in actual and potential shad rivers in Europe.

## **6. Long-term Management Plan**

### **6.1 Re-evaluation after 15 years**

All measures listed in chapter 5 are totally or at least to a share subject of the LIFE+ Allis shad project and their financing is secure until 2015. The measures listed which are not directly listed in the LIFE+ proposal are based on existing infrastructures and monitoring measures without additional charge. These can be carried out over an extended period. The financing of basic tasks which are essential for the long-term projects success, above all stocking of 1.5 to 2 Mio Allis shad larvae per year, is not fixed in a signed agreement so far, however, it is planned to integrate them into the migratory fish program in North Rhine-Westphalia, under which umbrella the implementation of the measures will be based on a solid foundation. The objective is to continue the stocking for at least another 9 years after the termination of the LIFE+ Allis shad project (until 2024). Including this time frame stocking of up to 2 Mio shad larvae would then have been carried out from 2009 onwards which amounts to 15 years and hence three life-cycles of Allis shad (compare 5.1)<sup>9</sup>. This time frame is considered as being sufficient to allow drawbacks on the projects process.

The above mentioned monitoring schemes are considered as being feasible to measure developments on the different stages in the Allis shad's life-cycle spent in the fresh or brackish water. The first milestone, well grown and numerous juvenile shads detected on their seaward migration, was already reached in the autumn of 2010 at the end of the LIFE projects durations. The next step would be to proof juveniles passing the Delta Rhine to the sea/ marked pre-matures in the Sea, what couldn't be provided yet, although a respective monitoring was carried out in November 2010. However, this particular year an unusual cold winter period began extraordinary early and juvenile shads apparently already left the Delta when the monitoring was carried. If this could not be confirmed repeatedly it is to consider to raise the stocking effort and/or to modify stocking site selection and stocking strategy. A confirmation of seaward migrating shads at the lower and the

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<sup>9</sup> Stocking number and efficiency in 2008 was apparently too insufficient to already affect a substantial increase in potentially returning adults.

delta Rhine in the coming years will be an important indication that the basis for recruitment in the juvenile freshwater phase is provided, and after some years of successful stocking and increasing numbers of juveniles entering the marine phase and increase of adults originating from the stocking measures entering the Rhine system should indicate that reaching the adult stage and entering the Rhine system is feasible (see Fig. 18).

A marked increase of adult Allis shad in the Rhine as a consequence of the stocking measures carried out by that time is to be expected from 2014 onwards. A significant increase of detected adult Allis shad and getting hold of adult Allis shads marked with OTC will be the key issues for the time period from 2014 until 2024 in order to get clues if the conditions for transition from the delta to the sea, the marine growing phase and finally the return to the Rhine system is sufficient to provide the basis for the formation of a population in the future years. Unlike many active shad rivers in the USA and even to the rivers in Gironde watersheds, where counting at or below dams enhance estimating the size of the spawning stock, no such transversal obstacles are present at the Rhine itself downstream of Iffezheim. Hence detecting adult returners and all the more a quantification of the spawning stock will be even more difficult and will doubtless require additional sampling schemes as mentioned above. Probably these need to be intensified in the course of time frame from 2014 until 2024. If it won't be possible to detect adult returners despite juveniles three to six years before were found to migrate downstream, it needs to be questioned whether there are major sources of mortality and where these might occur (Delta before seaward migration, marine phase, transition to freshwater upstream migration). After addressing the most probable cause it is to question whether conditions can be improved. Possible causes could be increased predation or fisheries related mortalities, or impairments occurring during migrations.

## 6.2 Criteria to alter or stop specific operations

From experiences with re-introduction programmes of diadromous migratory fish world-wide and particularly with shad reestablishment projects in the USA, it is known, that it needs a long breath and even often modifications of the original program design to prove substantial success. However, for the LIFE Allis shad project unless no clear indications are given that can explain why either a sufficient number of juvenile shads (with regard to the number of stocked larvae) reaches the sea each year stocking takes place as planned. A second criterion providing hints to the long term prospect of the project would be to proof adults from the stocking operations to return to the Rhine system. If despite intensive monitoring and proper stocking measures (at least 1.5 Mio. shad larvae stocked 5 years before) couldn't be proven to migrate into the Rhine system between 2014 and 2024. Both criteria indicate to question whether the design of the re-introduction programme needs to be modified or if the project should be even stopped. The latter case would arise when, despite intensifying and altering stocking operations with regard to number of larvae, time and place won't entail in a regular sea run of juvenile shads, which would indicate that habitat conditions are after all unsuitable or mortality is too high to allow a sufficient recruitment.



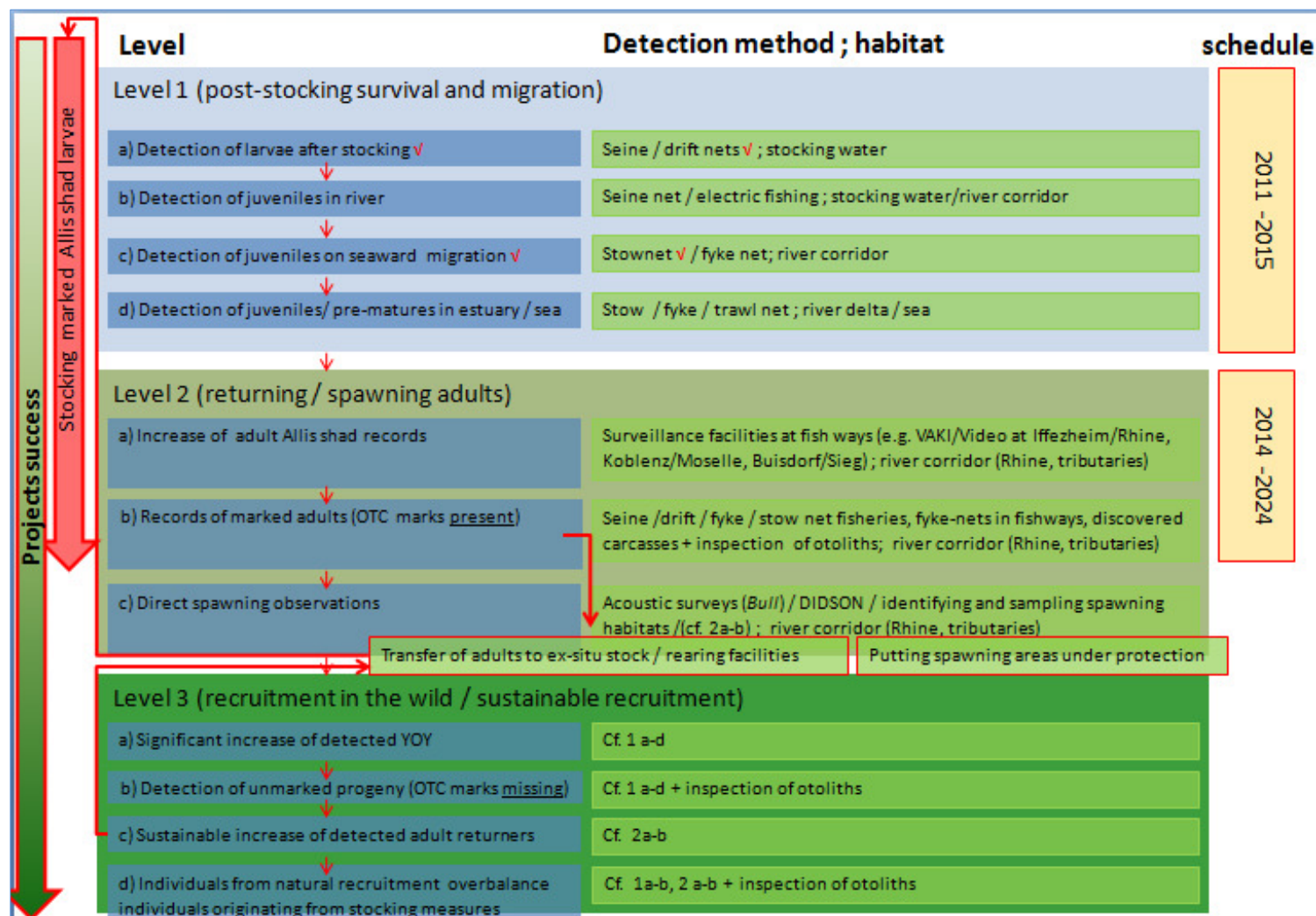


Figure 18: Definition of hierarchical milestones for the projects process and success, and comments on probably suitable monitoring schemes and habitats for detecting, as well as the time frame (right) in which these are expected to be reached. Red ticks indicate milestones that have been already achieved until the end of 2010 and with which method this was proven. Bold red arrows indicate positive effects on another level.

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