Effectiveness of measures for a successful and sustainable reintroduction of migratory fish in the Rhine watershed

Extended summary
of the
„Comprehensive fish-ecological analysis
including an assessment of the effectiveness
of on-going and planned measures
in the Rhine watershed
with respect to the reintroduction of migratory fish"

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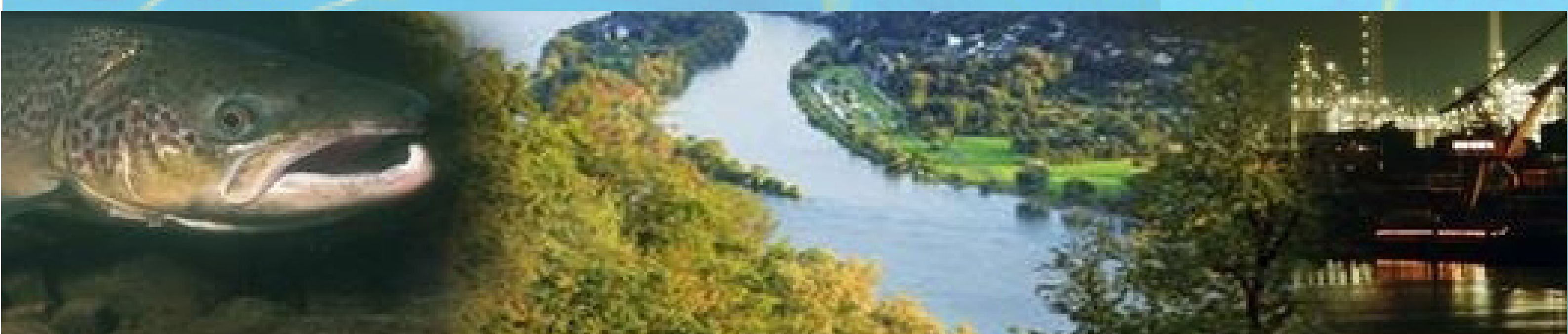

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Effectiveness of measures for a successful and sustainable reintroduction of migratory fish in the Rhine watershed

Extended summary of the „Comprehensive fish-ecological analysis including an assessment of the effectiveness of on-going and planned measures in the Rhine watershed with respect to the reintroduction of migratory fish"

This extensive summary was drafted on the basis of an expert study of the consulting engineers BFS, Frankfurt/Main entitled "Overall fish-ecological study and assessment of the effectiveness of on-going and planned measures in the Rhine area with respect to the reintroduction of migratory fish" commissioned by the ICPR (see SG-K(2)09-05-03 = comprehensive version, March 2009).
In this study, the situation of the stock of and the potential threat for the migratory fish species salmon, sea trout, allice shad and sea lamprey in the Rhine system are assessed for each of the fish species and measures are proposed aimed at sustaining the building-up of self-reproducing stocks of these fish species.

Based on these proposals, the states decide on measures, which will become part of the national programmes of measures according to the WFD and to the programme "Rhine 2020". The measures planned will be part of the "Master Plan Migratory Fish Rhine" and of the international management plan for the Rhine (part A). The implementation by the states will be phased until 2015 or 2020/2027.

The study shows:

- The entire former area of salmon distribution from the falls of the Rhine at Schaffhausen[1] is, as a matter of principle, apt for re-introducing migratory fish.
- The stocks of salmon, sea trout and sea lamprey are developing in the right direction; natural reproduction is increasing.
- The stock of allice shad is stagnating, but an on-going project (among others, stocking measures) will presumably lead to positive results.
- With improved water quality and river continuity, the stock of migratory fish has considerably recovered and spread.
- In many places, spawning and juvenile habitats are already apt for migratory fish, which return to colonize them; however, existing habitats may be further improved and new habitats may be created or made accessible more easily.
- According to present knowledge, fish passages constructed since the beginning of the 90s (programme "Salmon 2000") are well accepted. However, for different fish passages, detailed success control measures are still required.
- If the river continuity can be restored at weirs and dams with the help of further fish passages (up- and downstream migration, including the Upper Rhine and the closure embankments in the Upper Rhine) this will not only profit all migratory

[1] see map of historically proven salmon waters in the Rhine watershed

fish, but many other fish species as well. For sea lamprey, lacking river patency is the only limiting factor.

- In particular, salmon and sea trout (potentially also allice shad) suffer considerable losses due to (illegal) fishery; these must under all circumstances be reduced.

- Due to the measures proposed, the salmon – being the indicator species with considerable pilot function for the rehabilitation of the Rhine ecosystem – will again be able to settle as far upstream as the old bed of the Rhine and Switzerland.

- Measures with highest priority concern the restoration of river continuity, reduced pressure from fishery and the improvement of the quality and quantity of spawning and juvenile habitats in the Rhine area. With respect to these aspects, please refer to the implementation phases explained in more details in the chapter on measures of this extended summary.

The target species salmon, sea trout, allice shad and sea lamprey concerned by this report fulfil a pilot and indicator function for further fish species, and measures targeted at enhancing the stock of migratory fish are profitable for the entire fish fauna. Specific eel-related measures will be included in the "Master Plan Migratory Fish" to be accomplished by end 2009 and were no explicit part of this study. This master plan particularly focuses on the re-introduction of salmon. As for the definition of the priority of measures and later success control, the strong *homing* behaviour (returning to the home waters) makes this species particularly apt. Salmon populations almost exclusively originate from stocking measures and/or – more and more often – reproduction in the Rhine system itself or in sub-basins or individual project waters and thus reliably reflect the situation of these habitats for the entire migratory fish fauna.

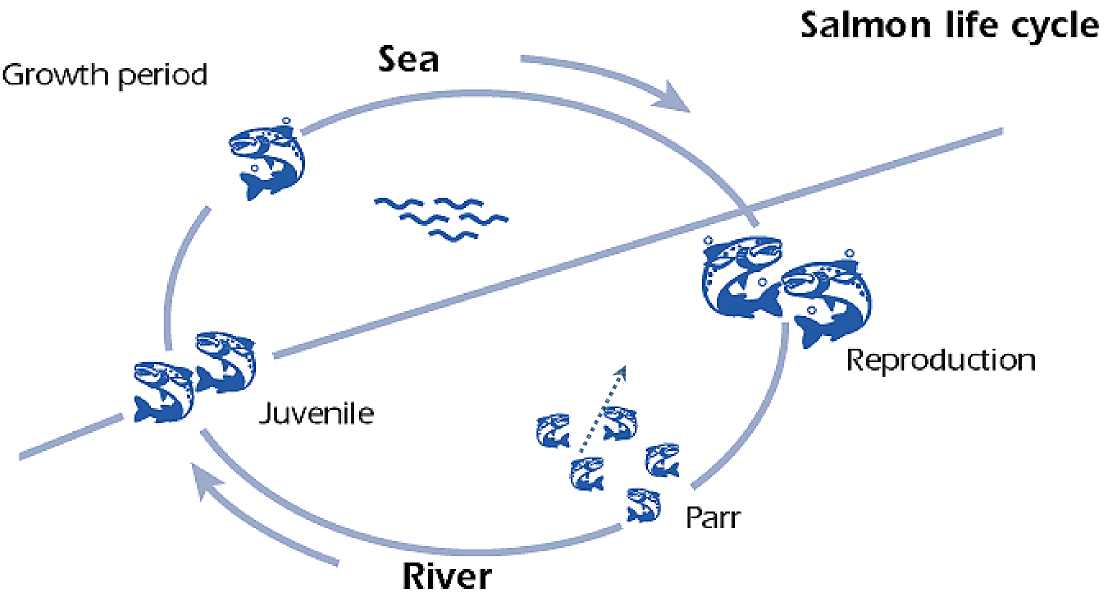


Fig. 1: Salmon life cycle. Premature male parr also contribute to reproduction. See page 4.

State of re-colonization

Normally, accessible spawning waters are re-colonized within few years and migratory fish successfully reproduce in these waters. Due to its strong *homing*, initial stocking measures are required for several years, imprinting the juvenile fish with the new home waters and establishing the basis for an initial population. All in all, **the trend of the number of migratory fish and natural reproduction is positive.** A – partly extensive – natural reproduction of salmon has already been proven in the great majority of *accessible* salmon waters or spawning areas (parts of waters). We may here even speak of a strong, increasing trend (see table 1).

The main reproduction areas of **salmon** (presumably also of **sea trout**, but their juveniles cannot be distinguished from those of the brook trout) are today to be found in the river systems of Wupper-Dhünn, Sieg, Ahr (presumably), Saynbach and Bruche (Ill). Astray salmon reproduce in the R. Nette, where there is no stocking. This underlines the high colonization pressure exerted by this species.

Table 1: Survey over identification and density of naturally appearing salmon and development or state of accessibility of spawning grounds in the Rhine system: the identification of natural reproduction is closely linked to the restoration of longitudinal continuity and the accessibility of spawning waters.

Table 2 (Summary Table 1) **Proof of reproduction of salmon returned to the Rhine system**

Country	System	Project water - Selection of the most important tributaries (* no stocking)	First salmon stocking	Year of spawning proof (reproduction during the preceding autumn/winter) 1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Surface of habitat in ha
D	Wupper-Dhünn	Wupper	Salmon stocking Wupper/ Dhünn system	/	/	/	/	/	/	/	/	0	/	/	/	/	/	(X)	25
		Dhünn		/	/	/	/	/	/	/	/	0	/	/	X	X	/	/	
		Eifgenbach		/	/	/	/	/	/	/	/	/	/	/	/	0	/	/	
D	Sieg	Sieg NRW	Salmon stocking measures in the Sieg river system since 1988, since 1998 in addition to classical umber and barbel regions also in selected smaller and medium sized brooks	X	/	/	/	/	/	/	X	0	XX	/	/	/	/	/	190
		Agger (lower 30 km)		X	/	/	/	/	/	/	0	0	XXX	XXX	XXX	XX	XXXX	XXXX	
		Naafbach		/	/	/	/	/	/	/	XX	0	/	XXX	XXX	XXX	XXXX	XXXX	
		Pleisbach		/	/	/	/	/	/	/	0	/	/	0	/	/	X	/	
		Hanfbach		/	/	/	/	/	/	/	/	0	/	0	X	/	/	/	
		Bröl		X	/	/	X	/	/	/	0	0	XX	XX	0	XX	XXX	/	
		Homburger Bröl		/	/	/	/	/	/	/	0	0	/	XX	XXX	XX	X	/	
		Waldbröl		/	/	/	/	/	/	/	0	0	/	0	0	XXX	XXX	/	
		Derenbach		/	/	/	/	/	/	/	/	/	/	/	/	0	/	/	
		Steinchesbach		/	/	/	/	/	/	/	/	/	/	/	/	0	/	/	
		Krabach		/	/	/	/	/	/	/	/	/	/	/	X	/	/	/	
		Gierzhagener Bach		/	/	/	/	/	/	/	/	0	/	/	/	/	X	/	
		Irsenbach		/	/	/	/	/	/	/	/	0	/	/	/	/	/	/	
		Sülz		/	/	/	/	/	/	/	0	0	/	/	/	XX	/	/	
		Schlingenbach		/	/	/	/	/	/	/	/	0	/	/	/	/	X	XXXX	
		middle Sieg RLP	1994	/	/	/	/	/	/	/	X	0	0	0	X	X	X	XXXX	
		Nistersystem	1991	/	/	/	/	/	XX	0	X	X	X	X	X	XXX	XX	XXXX	
		Wisserbach	1991	/	/	/	/	/	/	XXX	XX	XX	0	X	XX	XXX	XX	XXXX	
		Elbbach	1995	/	/	/	/	/	/	/	/	0	X	0	/	/	XX	XX	
		Heller-Daade	1998	/	/	/	/	/	/	/	/	0	0	/	/	/	X	X	
		Asdorf	1997	/	/	/	/	/	/	/	/	0	0	/	/	/	/	/	
D	Ahr	Ahr	1995	/	/	/	/	/	/	X	0	0	X	X	0	0	0	?	80
D	Nette	Nette *	-	/	/	/	/	/	/	/	X	0	XX	X	X	X	0	X	10
D	Saynbach	Saynbach	1994	/	/	/	/	/	/	XX	XX	XX	XXX	XXXX	XXXX	XX	XXXX	XXXX	10
		Brexbach	1994	/	/	/	/	/	/	XXXX	XX	X	X	0	0	0	0	XXX	
D	Mosel	Elzbach	2005	/	/	/	/	/	/	/	/	/	/	/	0	0	0	0	170
		Kyll	1996	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
		Prümsystem	1996	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
Lux/D		Sauer	1992	/	/	/	/	/	/	/	/	/	0	/	/	/	/	/	
		Our	1992	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
D	Lahn	Mühlbach	1994	/	/	/	/	/	/	(X)	0	/	/	/	/	/	/	/	19
		Weil	1995	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
		Dill	1995	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
D	Nahe	Nahe	2004 (unique)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	?
D	Wisper	Wisper	1999	/	/	/	/	/	/	/	/	0	XX	XX	0	0	XX	XXXX	2
D	Main	Schwarzbach *	-	/	/	/	/	/	/	/	/	/	/	/	/	/	0	0	12
		Kinzigsystem (Hessen)	2001	/	/	/	/	/	/	/	/	/	/	/	/	0	/	/	
D	Alb	Alb	2001	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	10
D/F	(Wies)Lauter	(Wies)Lauter	1991	/	/	/	/	/	/	/	/	/	/	/	/	/	/	?	?
D	Murg	Murg	2001	/	/	/	/	/	/	/	/	/	/	/	X	X	X	/	36
F/D	Rhine	Rhine downstream Iffez	-	/	/	/	/	/	/	/	/	/	/	X	/	/	/	/	50 (?)
D	Rench	Rench	2001	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	11
F	Ill	Bruche	1991	/	X	X	X	X	X	X	X	X	X	X	X	X	X	X	72**
		Upper Ill system	1991	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
D	Kinzig	Kinzig (Baden-Württem	2001	/	/	/	/	/	/	/	/	/	/	X	/	/	/	/	68
D	Elz-Dreisam	Elz	2005	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	59
		Dreisam	2008	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
F/D	Rhine	Old branch of the Rhine	1991	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	88
CH	Wiese	Wiese	1984	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	24
CH	Birs	Birs	1995	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	17
CH	Ergolz	Ergolz	1995	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	3
				1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	

LEGEND

quality proof / individuals detected / samples taken from individual locations	X
quality proved / returning fish stocked upstream migration obstacle	(X)
little success of reproduction (1 to ≤ 5 parr/100 m2)	XX
considerable success of reproduction (> 5 - 50 parr/100 m2)	XXX
extremely high rate of success of reproduction (> 50 parr/100 m2)	XXXX
Investigations carried through, no cases detected	0
no investigation	/
Investigation planned for 2009	?

Spawning grounds (largely) accessible

Spawning grounds partially accessible/accessible to a limited extent

Spawning habitats not accessible/accessible in exceptional cases

** Ill river system without rivers Thur and Lauch

In 2007/2008, considerable natural reproduction was for the first time documented for the R. Wisper (Middle Rhine). Based on the survey of natural reproduction, it may be assumed for certain river systems on the Lower and Middle Rhine (R. Sieg, Saynbach, ev. Ahr and Wisper) that between 5 and 20 % of the returning adults during 2007 and 2008 result from natural reproduction of wild salmon.

Redds of **sea lamprey** have, among others, been found in the R. Ill system, in the R. Wieslauter, Murg, Wisper, Saynbach, Nette and in the river systems of Sieg and Wupper-Dhünn. It is highly probable that the species also directly reproduces in the Upper Rhine as far upstream as the Strasbourg barrage. There is no proof of reproduction or juvenile fish of **allice shad**; it seems as if the species will not establish without stocking measures, which began in the Upper and Lower Rhine within an EU-LIFE-project.

If all conditions for migratory fish are optimized, that is, if all proposed measures are consequently implemented, the number of salmon annually returning into the Rhine system may, on the long term, reach 20.000 to 30.000 salmon. On the medium term, some 10 000 to 15 000 salmon may be expected. This presupposes a rate of returning salmon of 3 % starting with the smolt stadium. At the time being, the rate of returning salmon is below 1 %.
The homing of salmon leads to populations of salmon specific to the tributaries or sub-systems. This means that the required adapting processes must occur in the sub-populations which should be considered as complementary management unities. Therefore, it does not make any sense to fix a minimum population size for the Rhine as a whole. From a genetic point of view, the minimum size of the population concerning the sub systems is:

- 50 individuals for short term maintenance of stocks (max. 5-10 generations),
- 500 individuals for a sustainable preservation of stocks,
- > 500 – 1 000 individuals for an expanding stock.

The number of returning individuals must *not* be considered to correspond to the size of population. The following parameters describe the „effective population size" (individuals which *successfully* reproduce):

- In the spawning areas, about 75 % of the returning individuals successfully reproduce.
- Premature males (parr mature before beginning their downstream migration) must be added to the population; in spawning waters, their number is the 5- to tenfold of the number of returned males (see fig. 1).
- For salmon in the Rhine, the average generation corresponds to about 4 years.

That means that, in order to preserve the stock (population of about 500 individuals), <u>about 100 individuals must return per year and sub-system (presupposing at least 50 mature female fish).</u> In smaller sub-systems with contact to neighbouring systems, the required number of returning individuals may be considerably lower, taking into account immigrating stray fish (added to the size of population). Therefore, smaller salmon waters should be linked to larger waters in geographical vicinity in order to avoid incest and to increase genetic variability. If the prerequisite of genetic exchange is given, even very small stocks with a population < 50 individuals may be able to survive. However, in order to be able to preserve the population in case of emergencies (accidents, fish mortality) and strong variations of the stocks, populations of > 500 – 1000 individuals (corresponding to > 100 – 200 returning adult per year) should be granted.
In order to achieve 100 returning individuals per year and sub-system (= minimum population size of about 500 individuals including premature males) and 3 % of returning fish (management target) for each sub-system, a habitat surface of at least 3.3 ha is required (production: about 1 000 smolt/ha).

Iffezheim and Gambsheim
After the fish passages at the barrages Iffezheim and Gambsheim were taken into service in 2000 and 2006, the river systems Rench, Kinzig and Ill (and the Rhine as far as the Strasbourg barrage) are again accessible to migratory fish. According to the present

state of knowledge, both fish passages are well accepted; the delay in time for upstream salmon migration seems to be negligible. If further passages were built, the upstream migration of fish as far as Basle would thus be possible within the time available. However, both in Gambsheim and in Iffezheim there are potential problems during high runoff which temporarily make it more difficult to find the fish passages. This may lead to retarded upstream migration (or even to abandoning upstream migration).

Limiting factors in their order of priority

1.1 Upstream river patency: It is evident that **accessibility of spawning and juvenile habitats** is clearly a limiting factor for all migratory fish in the Upper Rhine (upstream Strasbourg) and in the Moselle as well as in different tributaries. Due to their strong homing capacity, **salmon** constitute reproduction units isolated in space in the different project waters. Therefore, any interruption of the life cycle inevitably entails the breakdown of the stock of a partial (highly differentiated) population adapted to specific waters. The potential of re-colonization by stray fish is very low and depends on the proximity and size of neighbouring populations.
In the Rhine area, due to stocking measures, there are two separately managed founding populations: Upstream the mouth of the R. Main, salmon of **"Allier"** origin (France, long home water) are stocked, downstream the mouth of the R. Main, individuals of the **"Ätran"** stock are used (Sweden; short home river). For the „Ätran" stock, river patency was sufficient in 2008 to preserve the stock (accessible habitat surface of about 150 ha); however, so far, a considerable potential (e.g. the R. Moselle system as greatest tributary with about 170 ha, parts of the particularly apt R. Sieg system with about 100 ha) has so far not been developed. In order to develop a sustainable population in the stocking area of "Allier" origin, the Elz-Dreisam system (59 ha) and the old branch of the Rhine (88 ha) will have to be developed. The tributaries Ill (72 of the existing 95 ha juvenile habitat are to be reconnected) and Kinzig (in all 68 ha) are already connected to the Rhine by the fish passages in Iffezheim and Gambsheim, but the systems are not completely uninterrupted so that, so far, only a minor part of the salmon habitats is accessible. On the medium term, the reconstitution of river patency as far upstream as the Swiss tributaries Birs, Wiese and Ergolz is supposed to increase the stock and to secure the population (see figure 2, extensive version fig. 16).
When restoring river continuity, **sea trout** and **allice shad** with a greater number of straying fish will step by step spread to the Upper Rhine and the Moselle. For the exclusively straying **sea lamprey,** an immediate and independent re-colonization of the afore mentioned water bodies or their sections is expected, as the lacking upstream river continuity is the only limiting factor. Even in cases of reproduction deficits and high mortality rates during downstream migration this re-colonization would hardly be affected, as, every year, a sufficient number of sea lamprey will migrate upstream the Rhine from the Atlantic Ocean. This also applies to the **river lamprey.**

1.2 Downstream river continuity: The **downstream fish migration** passing through the turbines of hydro power plants causes damage depending on the individual fish species, the size of the fish and technical parameters of the plant. In the Rhine and its tributaries with the numerous hydro power plants, damages to fish cumulate in the course of their migration (**cumulating effect**). In particular for salmon mortality poses a threat to the survival of the population, as salmon almost always return to their home waters and losses of the partial population must almost exclusively be balanced by the reproducing population upstream the hydro power plant. In order to be able to build a self sufficient population, at least 1 % of the downstream migrating smolt should return to their spawning grounds. A higher rate of returning individuals is possible and strived for. Losses of sea lamprey do however not endanger the population as explained above.
In the numerous **small hydro power plants** mortality is particularly high compared to the production of the plant, may however be reduced much easier by ecological improvements, as is the case in great power plants in the main stream. Presumably,

smolt mortality in **water intake structures** for cooling thermal power plants is low, as smolt migrate towards the middle of the stream; lampreys are however found comparatively often in intake structures. For demanding rheophile species, the **impounded parts** preceding hydro power plants are, as a matter of principle, not able to colonize.

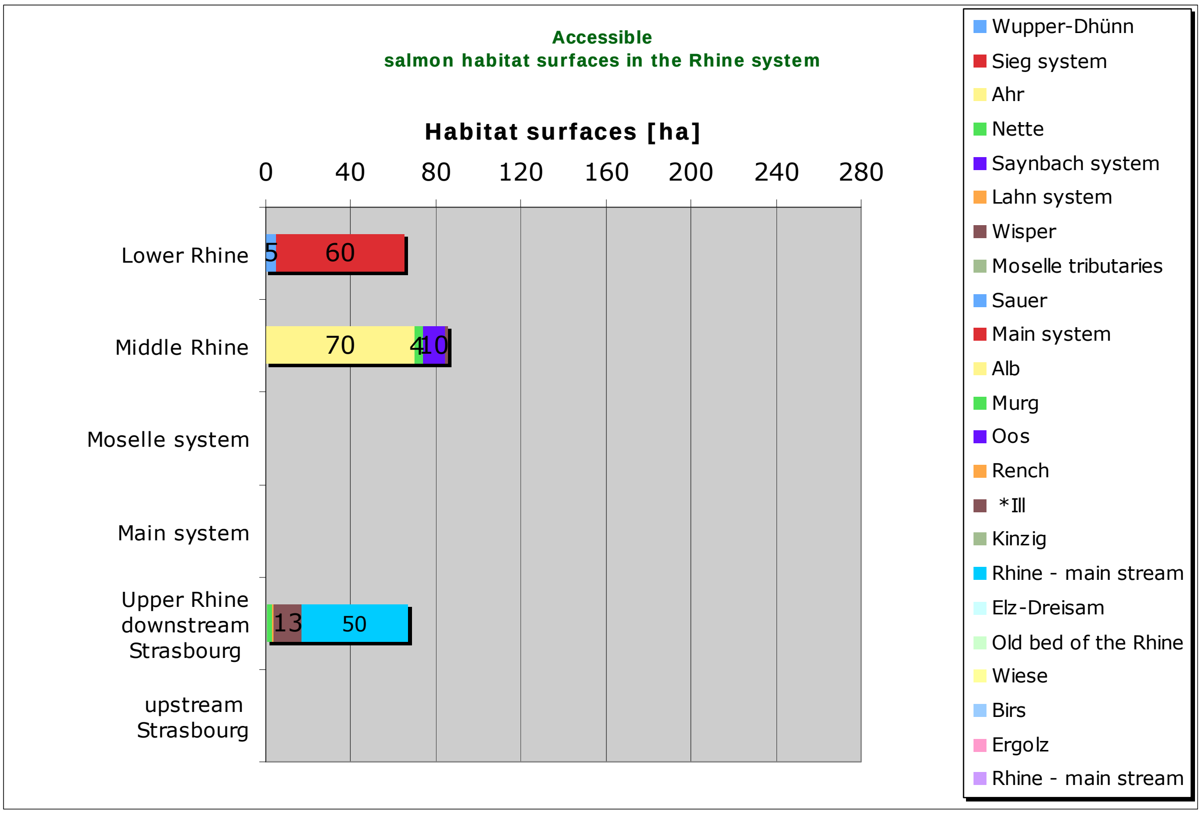
2. Fishery: In the entire Rhine watershed and in the Dutch coastal area taking and possessing salmon and sea trout is forbidden by law. Nevertheless, from today's point of view, fishery must be considered as a limiting factor for big salmonids and allice shad, as implementation is deficient. For sea lamprey, negative effects can be excluded, as this species is of no interest for fishery. Losses concern the entire Rhine watershed and the coastal area and are due to mortality during catches, e.g. injuries and stress, to accidental catches (inadvertent by-catches) and to poaching. In particular, there are no reliable data on targeted illegal catches. The ICPR is drafting recommendations concerning the improvement of implementation, in order to reduce losses due to professional fishery and angling.

3. Spawning and juvenile habitats: In many, but not in all project waters, the structural quality of these habitats is already good or satisfactory. Thus, habitat quality is no limiting factor. In isolated project areas many new habitats may still be developed or designed and existing ones can be improved and made more easily accessible.

4. Predation / grazing pressure At the time being, **predation** certainly has considerable influence on stocked smolt; with increasing presence of naturally produced smolt, this factor should become less important. Predators of importance for downstream migrating smolt are cormorant, asp, pike, pikeperch and catfish. A more rapid up- and downstream migration would also diminish the grazing pressure on salmon and smolt.

5. Water quality: In general, the water quality of the Rhine system is good. However, in some project waters, **input of fine sediment** and **nutrient pollution** pose a threat to the quality of salmon habitats and thus successful reproduction of salmon as well as the growth period of sea lamprey ammocoetes.

6. Temperature: High water temperature in summer (≥ 25°C water temperature) is a stress factor for salmonids and implies an increased risk of infections and a temporary interruption of upstream migration. Salmon do not tolerate temperatures exceeding 30 °C. However, increased mortality (e.g. in during the hot spells in 2003) could neither be excluded, nor proved. So far, the temperature factor has not been relevant for smolt.



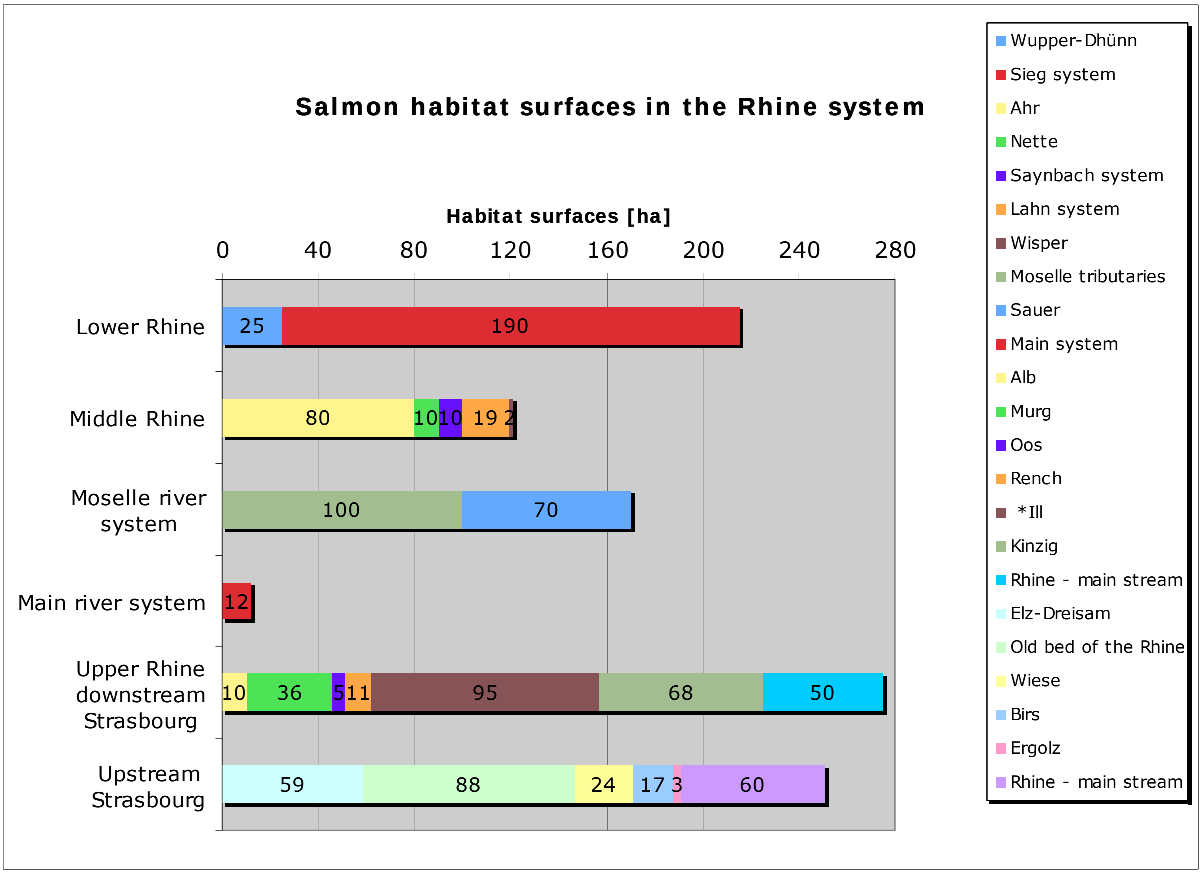


Fig. 2: Habitat surfaces (potential spawning areas and juvenile habitats) for salmon and sea trout in the Rhine system classified according to watersheds and tributaries (above: Habitat areas accessible today, below: Total habitat surfaces; *Ill: Here including the tributaries R. Thur and R. Lauch, for which it is not planned to restore river patency). Remark: The calculation does not base on any assessment of the habitat *quality*.

Table 2: Priorities for the proposed measures classified according to important watersheds

Legend:	Highest priority	Average priority	Low priority	No priority

Water body / Water system		Restore river patency	Reduce pressure from fishery	Improve habitat quality	Regulate predators	Improve water quality	Reduce discharge of fine sediments	Reduce thermal pollution
Delta Rhine	Rhine	*Haringvliet*	*incl. coast*					
Lower Rhine	Rhine							
	Sieg							
	Wupper-Dhünn							
Middle Rhine	Rhine							
	Ahr							
	Nette							
	Saynbach							
	Lahn		*Estuary*					
	Wisper							
Moselle system	Moselle		*Lower reaches*					
	Moselle tributaries							
Upper Rhine downstream of Strasbourg	Rhine							
	Alb							
	Murg							
	Rench							
	Ill (incl. Bruche)							
	Kinzig							
Rhine upstream of Strasbourg	Rhine							
	Elz-Dreisam							
	Old branch of the Rhine			*Vivification*			*Vivification*	
	Wiese							
	Birs							
	Ergolz							

Measures

Table 2 (table 17b in the extended version) illustrates the priorities for the proposed measures. On the one hand, the matrix shows that all factors indicated act together and are important. On the long run, objectives will not be achieved by taking individual measures (e.g. fish passages) and ignoring other limiting factors (e.g. pressure form fishery, downstream fish migration, habitat quality). On the other hand, the matrix gives differentiated indications for the importance of implementing measures along the different sections of the Rhine and in sub-basins. In addition, figure 3 gives an overview in space of the necessity of measures.

The following **measures** undoubtedly have **highest priority:**

1. Restoration of river patency (up- and downstream): Apart from the target species salmon, sea trout, allice shad and sea lamprey, river lamprey and the so-called middle distance migrating fish needing much space, such as nase and barbel would profit from this measure.

2. Diminish pressure due to fishery: Information and the consequent use of penal law as well as intensive controls may considerably reduce salmonid mortality due to fishery.

3. Quality and quantity of spawning and juvenile habitats: At all events, existing surfaces must be safeguarded; furthermore, according to the water framework directive (hydro-morphological measures to achieve the objective of the "good ecological state" or "potential") these as well as new habitats are recommended to be developed with respect to quantity and quality. Under all circumstances, in salmon project waters losses due to further extension of small hydropower plants must be avoided.

These measures are of great importance for the entire R. Rhine and/or its sub-systems and may be implemented in two phases according to their priority. Table 18 a-g (in the extended version) illustrates in a theoretical calculation, how the implementation may impact the development of stocks in different watersheds and when a self sustaining salmon population may be reckoned with. In the following, arguments are presented backing up the results of this calculation.

Proposals for measures from the point of view of fish ecology:

Phase I (realisation proposed by 2015):

Upper Rhine: In phase I, the priority objective is to restore the river patency of the Upper Rhine as far upstream as the Elz-Dreisam system. To this end, it is urgent to equip the barrages in Strasbourg and Gerstheim (including mobile weirs and loops; 59 ha habitat to be made accessible) with fish passages. Following the conversion, it is to be expected that salmon, sea trout and sea lamprey will immediately return to the Elz-Dreisam system. Thus, the increased accessible habitat will immediately contribute to stabilizing and distributing salmon of Allier origin. However, the implementation must also be considered as important intermediate step towards restoring access to the old branch of the Rhine and to tributaries in Switzerland (completion in phase II). Since river patency at obstacles to migration not only concerns upstream, but also downstream migration (in particular of smolt) and there is a considerable lack of knowledge in this field, mortality of downstream migrating fish (hydro power plants, grazing pressure) must be examined. The results of this examination will contribute to developing solutions for the problems of downstream migration. In order to be able to quantify the success of this and other measures already implemented and to integrate new insight into the planning for new fish passages (number, situation, importance of sluices) telemetric studies on the upstream migration behaviour of returning fish and on the traceability of fish passages should be carried out in parallel. So far, too little is known about mortality

of downstream migrating fish and the traceability of the existing fish passages in Iffezheim and Gambsheim in order to assess the success of measures taken so far. Telemetric studies on the traceability of the two existing fish passages in Iffezheim and Gambsheim will not begin until after the 5th turbine has been installed (i. e. about 2011). Moreover, in phase I, habitats must be improved and, above all, patency of most tributaries of the Upper Rhine (R. Alb, Murg, Rench, Ill and Bruche, Kinzig as well as Elz and Dreisam) must be restored.
All in all, costs for re-designing the barrages on the Upper Rhine in order to open the access to the Elz-Dreisam system (59 ha spawning habitat) are estimated to near 39 million Euro (scenario 2 of the STUCKY study). As a matter of principle, two fish passages (left and right bank) must be planned for the five sills in both loops; the total additional costs arising only amount to 3.8 million € (average of 0.76 million € per transverse structure). With a view to granting up- and downstream fish migration in the Elz-Dreisam system itself, the implementation of measures planned to 2015 will presumably cost 4.7 million Euros.

Middle Rhine and Lower Rhine: The restoration of river patency (up- and downstream migration) should also be speeded up in these river sections, at least as far as tributaries with the highest potential (among others R. Moselle, Sieg, Wupper-Dhünn river system) are concerned. Presumably, a distinct reduction of pressure due to fishery is required in parallel. These measures will support the population originating from R. Ätran. According to present data, it is even possible to achieve a self sustaining population at the end of phase I (see table 18g in the extended version).

Delta Rhine: In the Delta, it is important to step by step open the Haringvliet (expenses ca. 36 million €) and to distinctly reduce pressures due to fishery. These measures have a key function for all migratory fish species (including allice shad), for both populations used to restore the salmon population (Allier and Ätran) and for all sub-systems in the Rhine watershed.

Entire system: The thermal situation in the Rhine should be followed with great attention and possibilities of further reducing man-made thermal inputs into the Rhine and its tributaries should be examined (see communiqué of Conference of Rhine Ministers 2007, ICPR 2007). Furthermore, building up a separate stock of parent fish of Ätran and Allier origin contributes to granting the availability of suitable stocking fish on the long term.

Phase II (realisation proposed by 2020/2027):

Upper Rhine: The priority objective in phase II is to restore river patency as far upstream as the old branch of the Rhine (including mobile weirs, loops; 192 more ha of habitat to be made available) as well as up to the rest of the tributaries as far as Basel (R. Birs, Wiese and Ergolz). To this end, fish passages are required at the barrages Rhinau and Marckolsheim and a solution must be found for the problematic area Vogelgrün/Breisach. During phase II, a solution should be found for the problem of downstream migration and upstream migration should eventually be optimized (taking into account the findings of telemetry studies).
For the modification of the hydropower plants and the mobile weirs further upstream the Rhine between Rheinau and Vogelgrün (inclusive), investments are estimated to another 62 million Euros. These expenses do not include measures aimed at opening the barrages in the Grand Canal d'Alsace to fish migration. Originally, the old Rhine was preferred as possible upstream migration route for migratory fish on their way towards Switzerland (Stucky study). The average expenses for the 4 barrages in the Grand Canal d'Alsace would amount to about 13 million Euros.

Middle Rhine and Lower Rhine: Measures of salmon reintroduction into the tributaries R. Sieg, Wupper-Dhünn, Ahr, Saynbach, Elzbach/Moselle and Wisper might (almost) be concluded, if the limiting factor of pressure due to fishery and patency of the Delta (Haringvliet) are considerably reduced or eliminated in phase I. This means that restoration of the patency of the R. Moselle as far upstream as the Sauer river system should have utmost priority.

Delta Rhine: In the delta, the opening of the Haringvliet should be accomplished and the successive transition from salt to fresh water should be established with a brackish water zone. Pressure due to fishery must be low. As described, these measures have a key function for all sub-projects in the Rhine system.

Conclusion

The example of the salmon makes it particularly clear that the restoration of the river patency is a prerequisite for the reintroduction of migratory fish into the Rhine area. In order to be able to establish a sustainable salmon population, measures must be implemented aimed at eliminating further limiting factors (such as downstream fish migration, pressure due to fishery, habitat quality) in individual systems.

Furthermore, the measures mentioned are also apt to sustainably improve the entire ecology of the Rhine (snowball effect for further fish species and other organisms equally at risk). Thus, achieving the objectives of the EU Water Framework Directive (EU-WFD) would also be more probable.

From a technical point of view, the results of this analysis complete the important proposals for measures aimed at an ecological improvement of the Rhine watershed with respect to the reintroduction of migratory fish. The presumable effects of the measures proposed have been described on the basis of the present state of knowledge. In cases, where experience and concrete investigation results are not available, the impact of possible measures has been assessed with the help of precisely defined assumptions and model calculations based on expert knowledge and indications in literature.

With the comprehensive in depth analysis of the BFS consultancy, the states, regions and Länder in the Rhine watershed have received a basis in order to decide, which proposals for measures are of priority importance for the objective “restoration of migratory fish”.

Fig. 3: Survey over the proposals for measures in the Rhine catchment. The size of symbols represents the priority of the individual measures to stimulate stocks of migratory fish in the Rhine system.