INTERNATIONAL COUNCIL FOR
THE EXPLORATION OF THE SEA

CM 1996/T:5

Anadromous and Catadromous Fish Committee
Theme session on Anadromous and Catadromous Fish Restoration Programmes:
A Time for Evaluation

Preliminary evaluation of the restoration programme "Salmon 2000", part of the Rhine Action Programme, 1987 - 1996

by

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ABSTRACT

From the onset of the 20th century up to the mid 1950's, dramatic declines of salmon catches have been recorded for the main regions of the river Rhine (Delta-, Lower-, and Upper-Rhine) caused by ecosystem degradation.
However waterquality improved significantly since the mid seventies.
Most activities related to the restoration programme for anadromous salmonid populations in the river were started in the 1980's, initiated mainly by the Rhine Action Programme which includes the "Salmon 2000" project. The role of the International Rhine Commission to enhance national and international cooperation of riparian states has been and is still very significant.
This paper focuses on studies, measures and developments in this field of rehabilitation during the last 15 years, in The Netherlands, Germany and France.
Measures such as stocking of sea trout and salmon fry and parr together with monitoring their survival in freshwater, construction of new fish passes as well as results of migration studies in the delta region and in Germany are reviewed.
Signs of recovery of anadromous fish populations during the last two decades are described and analyzed within the limits of the monitoring tools used up to now. These signs include migration of sea trout and salmon as far as the barrage of Iffezheim in the Upper Rhine, successfull reproduction of both salmonid species in tributaries in France and Germany, survival, good growth and migration of offspring.
One of the main objectives of the Rhine Action Programme, viz. the rehabilitation of a selfsustaining salmon population in the River Rhine has not been accomplished yet.
A lot has still to be done to improve the accessibility of spawning grounds in the Rhine and its tributaries, to monitor the runs of adults and smolts and to improve biotope management.

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1. INTRODUCTION

The "International Commission for the Protection of the Rhine against Pollution" (ICPR), was founded in 1950 by the riparian states of the River Rhine. The ICPR got its official status in 1963 when Switzerland, France, Germany, Luxembourg and The Netherlands signed a treaty on its tasks. The European Community acceded to the treaty in 1976 (ICPR 1994a).
Pollution level remained high after 1950 and the worst years were in the period 1955-1965 (Beurskens et al. 1994). The last salmon in the Rhine was caught in 1957 (de Groot 1989). A major spill of Endosulfan in 1969 in the vicinity of the tributary Main river mouth (figure 1), gave rise to massive fish kills throughout the lower Rhine (Lelek & Buhse 1992, Malle 1994). This was an argument to take water quality more seriously and to implement measures for improvement (Lelek & Buhse 1992).
Although concentrations of some heavy metals and noxious organic substances started to decrease since the mid sixties (Beurskens et al. 1994), oxygen concentrations were still very low in the period 1971-1974, with minimum values of less than 2mg/l and average daily concentrations between 4 and 5mg/l at the Dutch-German border. Oxygen concentrations began to rise gradually after the mid seventies (Lelek & Buhse 1992).
The accident at the Sandoz chemical industries near Bâle in November 1986, during which large amounts of fish were killed again over a distance of about 400km (Malle 1994), was the direct reason to agree on the Rhine Action Programme (RAP) in 1987 under the daily supervision of ICPR (ICPR 1987). Restoration of the salmon population was one of the main objectives. This part of the RAP named "Salmon 2000", started officially in 1992 when the EC began subsidising projects. Clearly, restoration might only bring back a relative small population, because over the years many tributaries had become unaccessible. However, even a small but self-sustaining salmon population could play an important role as a bio-indicator for the ecological condition of the Rhine.

Pollution has been significantly pushed back nowadays and oxygen levels are close to saturation (e.g. Admiraal et al. 1993, Beurskens et al. 1994, Lelek & Buhse 1992, ICPR, 1994 a, b). However, the Rhine ecosystem has been severely disturbed by river-engineering and gravel extraction as well for at least two centuries (e.g. Bürger 1926, Kuhn 1976, Lelek & Buhse 1992, Steinberg & Lubieniecki 1991). In order to establish stable anadromous salmonid populations, an inventory of the remnants of former spawning places and nursery areas had to be made, as well as an assessment of the barriers in the main river and its tributaries. A great deal of this work has been completed by now. Evidently potential spawning places and nursery areas are still available in Germany and France but there are still numerous barriers for ascending salmonids to cope with, many of which require the construction of a fish pass (Schulte-Wülwer-Leidig 1993, 1994). Although the target has not been achieved yet, several studies have revealed important signs of recovery: Salmonids appear to be on their way back, river lamprey populations are recovering and sea lamprey is no longer rare. However, twaite shad and allis shad are still seldom seen and Atlantic sturgeon and houting have not been captured at all (Brink et al. 1990, Cazemier 1984, 1988, 1994, 1995, Dekker & van Willigen 1996, Freyhof 1996, ICPR 1994b, Schmidt 1991, Steinberg & Lubieniecki 1991, Steinberg et al. 1991, 1996, Volz & Cazemier 1990, Weibel 1991).

This paper focuses on the rehabilitation of salmon (*Salmo salar* L.) and sea trout (*Salmo trutta* L.) populations in the Rhine basin in Holland, Germany and France , but only part of the total work done could be covered here. Additional projects are going on in the river Wupper, the Saynbach and in the river Lahn in Germany. Moreover, Switzerland and Luxembourg participate in Salmon 2000 with stocking young salmonids and carrying out habitat studies. Quite a lot of studies on fish releases and river engineering have been carried out in Belgium to restore anadromous salmonid populations in the river Meuse, a confluent of the Rhine in the lower delta region.

Most investigations in France, Germany and Holland were started in the eighties and the results and developments during the last 15 years are described, starting with the status quo.

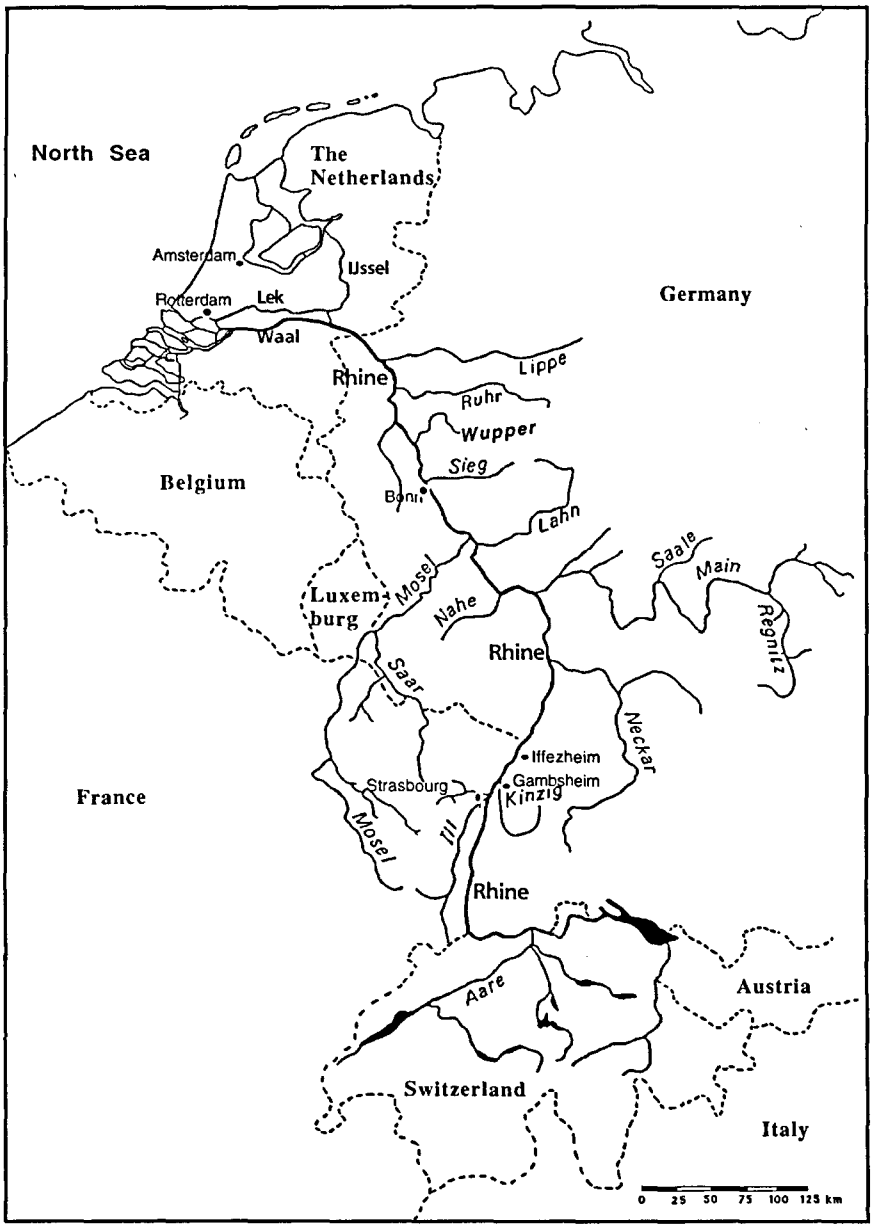

Figure 1. River Rhine drainage-basin

2 ECOLOGICAL STATUS OF SALMONIDS IN THE EARLY 1980'S BY REGION

2.1 The Netherlands

The Rhine splits in the Netherlands in a number of separate arms, forming a delta together with the river Meuse. These represent the potential migration ways for both adults and smolts, linking the fresh water environment to the marine environment. No tributaries of importance for anadromous salmonids discharge into the river (Hoek 1913).
Rhine water runs through approximately 570km of river branches (IJsselmeer included) towards the North Sea. Smolts may reach the North Sea at 4 main discharge points nowadays (figure 2). Although three are blocked by sluices, smolts may easily pass here if they find the exit. When adults start their spawning run they find these sluices on their way except when they enter the Nieuwe Waterweg. Moreover there are three barriers in the river Lek, one of the three main routes. The only completely open connection is formed by the Nieuwe Waterweg-river Waal route. Almost 50% of the Rhine discharge is drained through the Waal. Therefore this connection is considered to be the main migration route for adults.

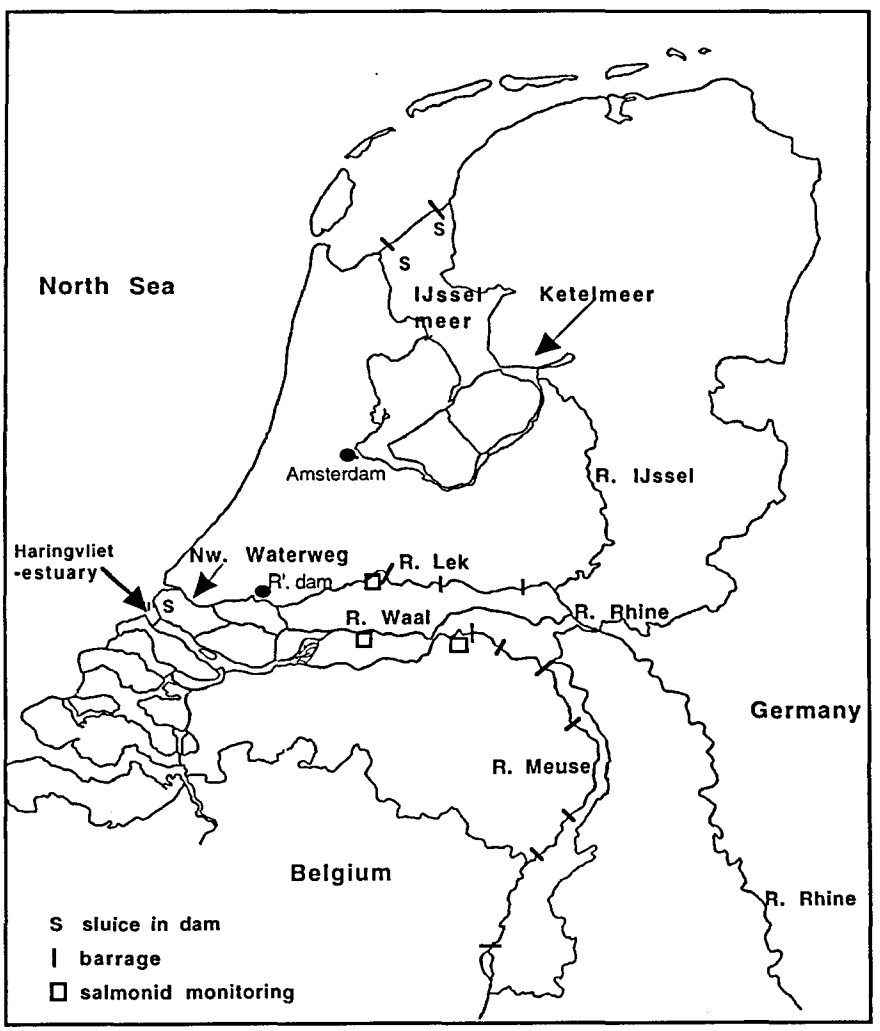

Figure 2. The Netherlands with the rivers Rhine and Meuse

Sea-trout has been present along the Dutch coast, as well as in the estuaries in the south-western part of the country and in the IJsselmeer, even during the years when the river was severely polluted. Official landings on Dutch markets amounted to about 5000kg per annum (Lieuwes & Fonds 1983). Their origin was not known. During the second half of the seventies, when oxygen concentrations began to rise, sea-trout reappeared in the rivers Rhine and Meuse. This phenomenon was first noticed by fishermen fishing for eel with fyke nets. Descending smolts were seen by fyke fishermen in those years too. A few salmon were captured in inland waters from 1970 onward (Cazemier 1994).

The main questions to be answered included:
-What is the origin of sea trout and salmon, present along the coast as well as in some river stretches and in the IJsselmeer? They might partly originate from higher stretches of the Rhine or Meuse, but they might also use these waters only temporarily and return to rivers that enter into the North Sea in neighbouring countries.
-If the adult sea trout originates from the smolts that were observed descending the Rhine, what proportion was able to find its way back despite the obvious barriers?
-Which barriers cause the most serious problems for upstream migration and how might these conditions be improved?
-Have the measures taken in the riparian countries had a significant effect on the numbers taking part in spawning runs?
-How successful is smolt migration through the Delta region and are there differences between cohorts from naturally spawning populations and released cohorts in different tributaries?

2.2 Germany

When salmonids on their spawning run arrive at the German border they enter a river section without barriers up to the barrage of Iffezheim, a length of 525 km (figure 1). Most of them are expected to spawn somewhere in tributaries entering this section. In former days, the affluents Ruhr, Sieg, Ahr, Mosel, Main and Neckar were the most important tributaries for salmon in the Middle and Lower Rhine sections (Hoek 1913), but they all lost their populations already for decades.
However, the number of sea trout reported by anglers increased gradually from the beginning of the eighties. They were captured in the Rhine and in the lower parts of some tributaries. Only the smaller rivers Sieg, Wupper/Dhünn, Lahn en Saynbach were thought to have a potential for anadromous salmonids to reproduce, although quite a number of barriers existed in these rivers (Marmulla 1992a, Schmidt 1991, Steinberg & Lubieniecki 1991, ICPR 1994a).
A special study was started in the river Sieg (figure 1) because this affluent appeared to be the most promising one for stocking young salmonids (Schmidt 1991, Steinberg & Lubieniecki 1991).

Important problems to be resolved with regard to the Sieg included:

- Restoration of migration ways by building new fishpasses, well adapted to the local circumstances.
- An inventory of potential spawning places and nursery areas.
- Assessment of the water quality for spawning by measuring survival and hatch rate of eggs artificially placed in the gravel, and growth and survival of offspring.
- Do smolts succeed in reaching the delta region once they have left the river, despite of industries, heavy shipping, predators and the not always favourable water quality conditions?
- Do adult salmonids on their spawning run enter the potential spawning areas in the Sieg and where do they spawn.
- Is there natural offspring and do they develop from egg to smolt?

2.3 France

The Rhine serves as the border between France and Germany over a distance of 180km. This part, called southern Upper Rhine, has been divided in ten parts by building barrages. There is little chance for salmonids to pass these dams and to migrate to tributaries on the French and German side or to Switzerland. To get more information about this, first stocking of Atlantic salmon in the Rhine system began in the early eighties (1982 to 1986 in France and from 1984 onward in Switzerland). Results were not very promising. Sea trout have been caught in this region, particularly near the Iffezheim dam, since 1983 (Maire, 1989). Conditions in some tributaries in the lower French part (Ill basin, Lauter, Moder), might be suitable for spawning and growing up as well as in parts of the original Upper Rhine riverbed in the dammed up region (Roche 1991, Schulte-Wülwer-Leidig 1994).

The main questions were:
-What is the status and origin of sea trout captured below the Iffezheim dam?
-Could stocking of the French part with young sea trout and salmon contribute significantly to the rehabilitation the salmonid populations?
-Which part of the Upper Rhine and its tributaries draining into the lower part (north from Strasbourg), are suitable for the reproduction of salmonids and will survival and growth be adequate to contribute substantially to the rehabilitation of stable, self sustained salmonid populations in the region?
-Which type of fishpass should be built at the weirs in the tributaries to restore free migration to the spawning places?
-Will the construction of new, more effective facilities at the huge barrages of Iffezheim and Gambsheim be possible and will they give enough salmonids the opportunity to get to spawning places in the southern Upper Rhine region?

3 STUDIES AND PRESENT STATUS BY REGION

A major part of the research is co-ordinated by the ICPR. Besides funding by national authorities, programmes have partly been subsidised by the Sandoz Rheinfonds and the European Community.

3.1 The Netherlands

3.1.1 Salmon catches till 1993

After the extinction of salmon in 1957, no catches of salmon in the river have been reported for 13 years. In 1970 and 1972 two salmon tagged in Sweden were recaptured in Dutch inland waters (Cazemier 1984, Larsson 1984). In 1984 anglers and fishermen were invited to report their catches of salmon in inland waters. From that year to 1988, 4 salmon were reported, of which one was tagged in Norway. From 1990 onwards, the numbers captured began to rise rapidly. Obviously "something had happened" in the eighties (figure 3). The first artificially raised sea trout alevins (5000) were released in the river Sieg basin (Germany) in June 1985, followed by approx. 8000 salmon parr in April 1988 and 16500 in 1989 (Steinberg & Lubieniecki 1991, Schmidt 1996). Since that time, the releases have been continued (table 2, Schmidt 1991, 1996).
It seems very likely that the increased catches of salmon in Holland reflect the stocking programmes in the Sieg and the programmes started already some years earlier in Switzerland and France. Therefore, a special monitoring programme of the migration of adult salmonids was started in 1994 (3.1.3). Consequently, the number of salmon caught has increased considerable, but these data cannot be compared with the incidental catches before.

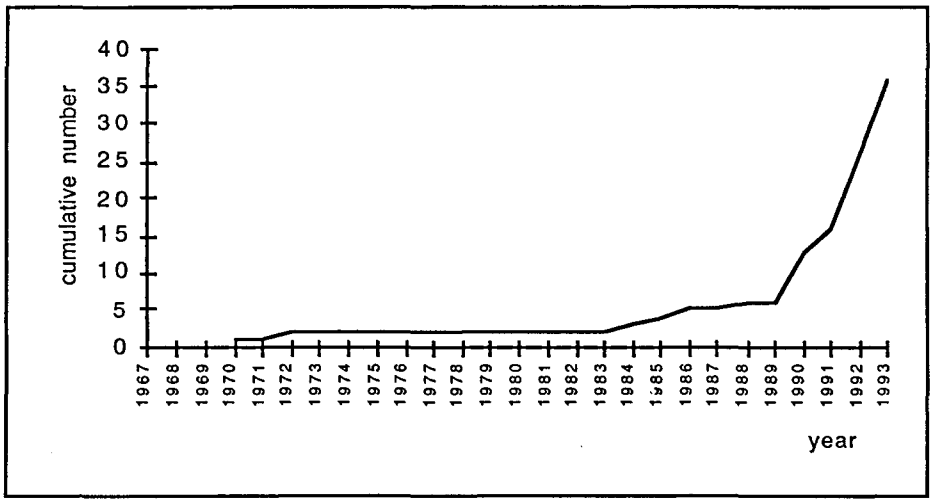

Figure 3. Cumulative salmon catches in the Rhine branches, 1967-1993

3.1.2 Information on sea trout.

Reports on sea trout increased in Dutch waters in the mid seventies. Information on their origin was not available, but no stocking took place in German waters (Steinberg, pers. comm.) or in Dutch waters. To get better quantitative information and to investigate their migration pattern, monitoring eel fyke net catches was started and two successive tagging experiments have been carried out (Cazemier 1992, 1994).

In 1981, a fisherman in the Ketelmeer, where the IJssel flows into the IJsselmeer (figure 2), was asked to record bycatches in his eelfykes on a daily basis. In 1984 another fisherman fishing a stationary (anchored) eel trawl in the Rhine close to the German border was asked do so as well.

The programme was continued until 1988, but no data are available from the Rhine for 1985 and 1986. The results are given in figure 4 and 5. There is no marked trend in the sea trout catches over most of the period, but 1988 stands out as a particular abundant year in both series.

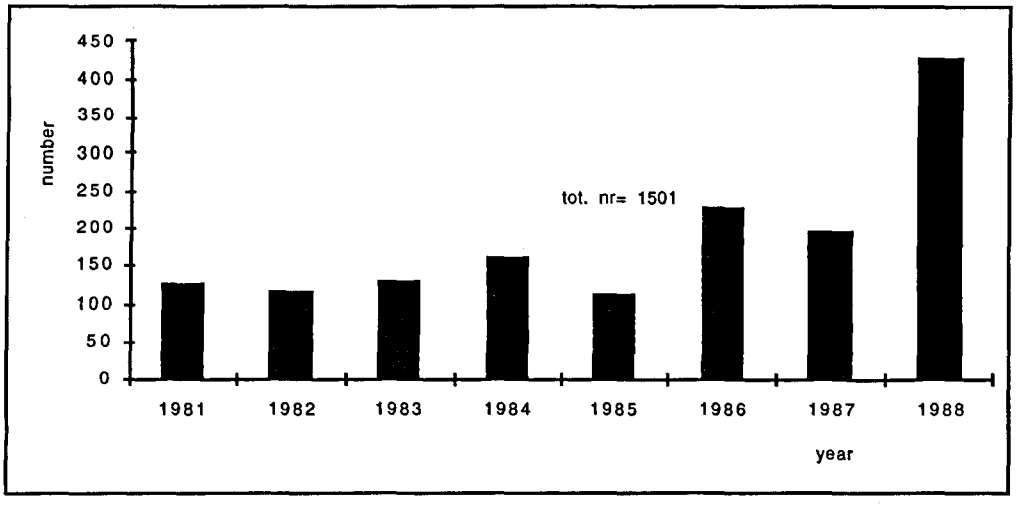

Figure 4. Numbers of sea trout caught by year in Ketelmeer, 1981-1988

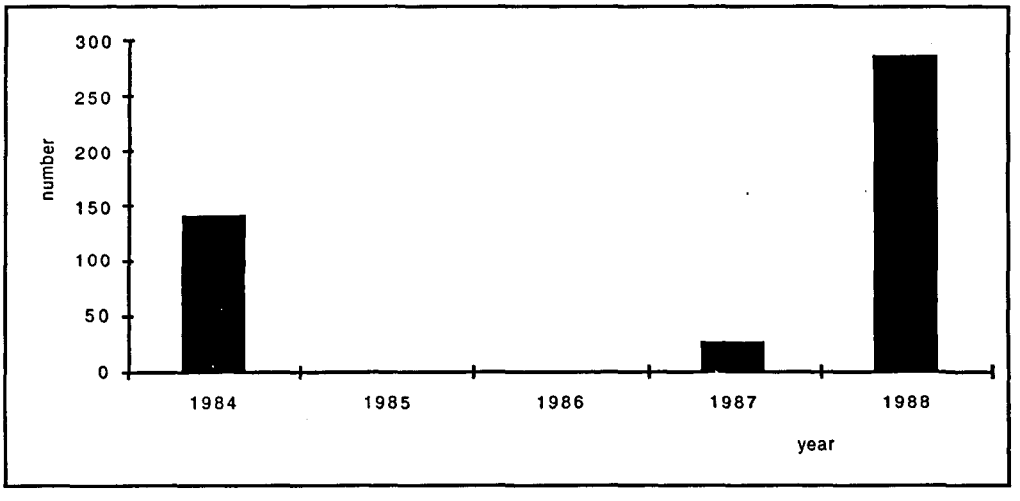

Figure 5. Numbers of sea trout caught by year in the Rhine, near the Dutch-German border, 1984-1988
(NB In 1985 and 1986 not fished)

The monthly catches fluctuate (figure 6). However, this picture is biased, because the fishery generally is stopped during winter time. Nevertheless, there appears to be a peak during april - june at the time when smolts normally migrate towards the sea.

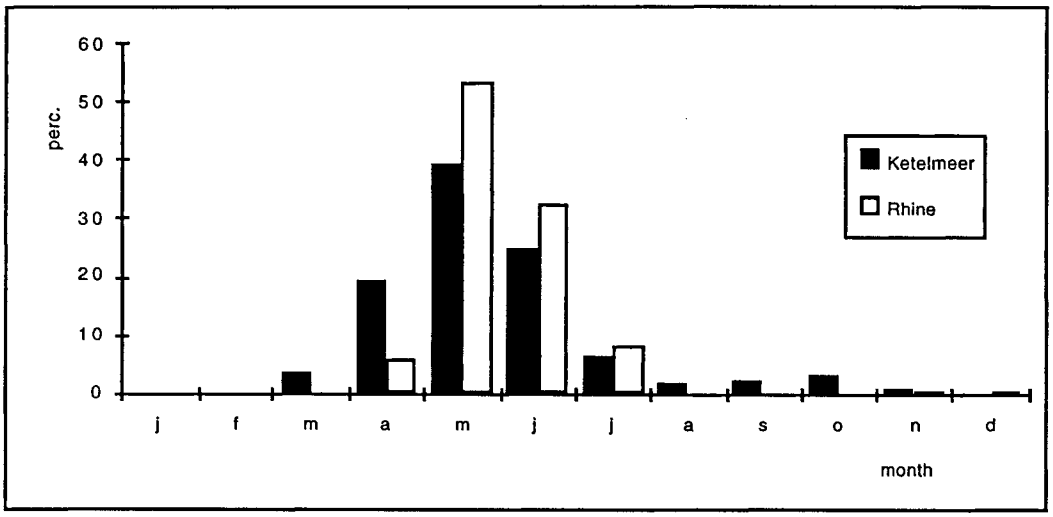

Figure 6. Average monthly catch (in percentage of total) of sea trout in Ketelmeer and Rhine in the period 1981-1988, 1984-1988 respectively

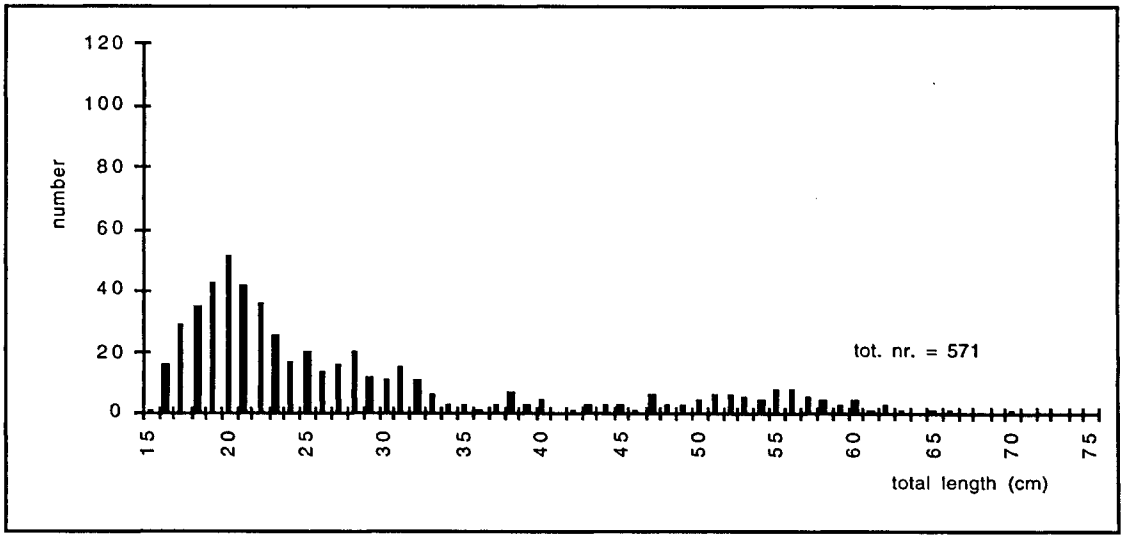

Figure 7. Length frequency of Ketelmeer sea trout in 1989.

Out of 571 trout caught in 1989 (May -October) in the Ketelmeer by local fyke-fishermen, 374 > 19cm were tagged probably (internal numbered metal tag, with alcyan blue spot at the abdomen of the fish). The majority (81%) belonged to the group of (post-)smolts (figure 7), falling within a length range between 15-35cm. No salmon has been detected amongst these in 1989, nor in the years before.
Over the next two years, 13 recaptures have been reported, 12 of which from in the Ketelmeer/IJsselmeer region (figure 2) in the first year, whereas one was caught next year near the barrage of Gambsheim in the Upper Rhine (figure 1), about 700 km upstream.

These catches of hundreds of sea trout, mainly smolts, in the eighties, at two locations in the delta as bycatch in eel fishing gear, indicate that sea trout succeeded in spawning somewhere in the basin and that offspring got suitable environmental circumstances to grow up. According to Steinberg (pers. comm.), there was no evidence that smolts could originate from brown trout populations in those years. Releases of young sea trout in the river Sieg since 1985 has most probably raised the numbers in the years thereafter.
Recaptures of tagged fish revealed good growth in the IJsselmeer. None of these trout were recaptured in the western part of the IJsselmeer or outside the lake, in the marine environment. This region seems to function like an estuary for the trout. The one recaptured near Gambsheim indicates that IJsselmeer trout (partly) originates from Upper Rhine tributaries, however they might be from lower tributaries as well, see also 3.2.1.

Since sea trout were known to gather also in the Haringvliet estuary, especially during June and July, the next experiment was carried out in that region in 1990 (figure 2).
River water is discharged through 17 sluices in a huge dam into this estuary at an average rate of $3x10^{10}m^3$ per annum, the second largest in Holland. Sea trout are attracted by this flow of freshwater. A total number of 1068 trout have been captured by commercial trawlers, of which 963 were tagged (carlin tag) and released into the estuary.
According to the length frequency-distribution (figure 8) the majority of the sea trout (92%) was within the length range of 16-36cm and immature. The average length of immature estuarine trout was clearly greater than in the Ketelmeer (figure 7)
All recaptures (52, viz. 5.4%) were made within about two years after tagging, mostly within the estuary itself (34: 25 in 1990 and 9 in 1991). Eight were reported from the Dutch North Sea coast (7 in 1990 and 1 in 1991). Ten were recovered in inland waters: 2 just inside the Haringvlietdam; 2 in Dutch Rhine branches; 1 in the Rhine in Germany, near the Iffezheim barrage in the Upper Rhine; 1 in the river Meuse; and interestingly 4 were caught in a special trap for salmonids in the river Bresle in north-western France (Euzenat, pers. comm). Overall, the results indicate, that young trout remain partly in the estuary until the winter, while another part migrates along the coast to the north as well as to the south. Trout reported from rivers in 1990 belonged all to the cohort of over 40cm, except for one, with an average total length of 54cm at the time of tagging.
The conclusion can be drawn that sea trout staying in the Haringvliet-estuary have partly been born (or released) in the basins of the rivers Rhine and Meuse, but also partly in small rivers in the north western part of France. Euzenat et al. (1991) report recaptures of tagged trout-smolts from these rivers from the coastal zone of north-western France, but also from as far as Denmark from the North Sea. This suggests, that catches of sea trout in former decennia, when water quality in the rivers Rhine and Meuse was poor, may have originated from those French rivers.

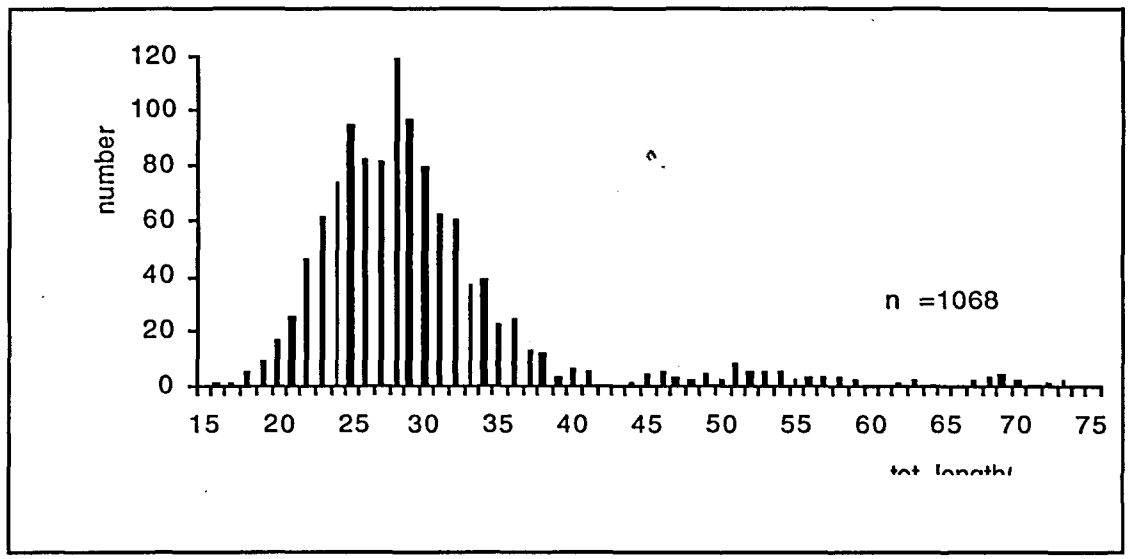

Figure 8. Length frequency of Haringvliet sea trout in 1990

In 1992, a similar experiment was carried out in the Haringvliet-estuary. A total of 436 sea-trout, 11 rainbow trout and 2 salmon were tagged with carlin tags in July. Recaptures, 17 in total (3.7%), have confirmed the findings in the 1990 experiment, although no recaptures were reported from the river Bresle.

3.1.3. Monitoring catches in salmon fykes

Since 1994 special salmon fykes are used for a couple of weeks at three places (c.f. figure 2) in the rivers Lek (near Hagestein, just below an unpassable barrage), Waal (near Woudrichem) and Meuse (near Lith, below a sluice with a fish pass). Monitoring takes place both in springtime and in the autumn when most of the migration takes place. Fishing with these large meshed nets (stretched mesh 7cm in the cod end and 14cm in the front parts) is carried out by fishermen, with special instructions for handling and storage of the fish. Migration over the fish pass at Lith is monitored as well. The aims are to monitor upstream migration of salmon and sea trout, to gather scales for growth studies and to tag all individuals.
Table 1 lists the numbers of salmonids caught, indicating that salmon represent a significant component in these catches, particularly in the rivers that belong to the Rhine system.

Table 1. Numbers of adult salmonids captured during monitoring 1994, 1995

Species	River Lek		River Waal		River Meuse		
	1994	1995	1994	1995	1994	1995	Total
Salmon	9	17	15	6	7	1	55
Sea trout	50	85	80	22	60	74	371
Rainbow tr.	4	1	10	4	3	0	22
Total	63	103	105	32	70	75	448

Length frequency of salmon shows, that the majority had lengths between 60 en 95cm, although 12% was less than 50cm (figure 9). Partly these smaller ones might have been small males (precocious males?).
The upstream migrating sea trout have lengths between 30 and 90 cm, with few exceptions (figure 10). The proportion of sub-adults (whitlings or post smolts?) lappears to be very small. Length distribution has a lot in common with that of adults in the river Bresle (Fagard et al. 1993) and with that of "big" trout in the IJsselmeer (Dekker & van Willigen 1996). No determination of sexe or growth has been carried out so far.

Recaptures of salmon (10) from Lek and Meuse were made mainly by professional gear, within 1- 42 days after release. In fact salmon were caught mainly in the same nets as they were captured before tagging, suggesting that they partly stay for up to about 6 weeks in the stretch below a barrage. No recaptures came from the river Waal cohort, obviously because of the open way to the Rhine they do not remain in that section. One salmon went to the Haringvliet-estuary. Fishing pressure is very low in the higher regions of the Rhine, what might be the reason why recaptures from this region are so scarce. Nevertheless one salmon, tagged below the obstacle in te Lek was recaptured after 40 days by electric fishing in the river Bröl, a tributary of the river Sieg. No salmon tagged in the Rhine arms were recaptured in the river Meuse or the other way round.

Sea trout recaptures (30) showed a complex pattern of migration; 22 were caught after 5 days up to about 6 weeks in the vicinity of the site were they were released after tagging, mainly in the same nets; 2 returned to the barrage in the Meuse after periods of 330 and 835 days respectivily. Another 3 were recaptured at the Dutch coast after 7, 224 and 338 days. A remarkable migration was completed by a 57 cm sea trout, tagged near the barrage in the river Meuse, which was recaptured after 26 days in the river Bresle in north western France. 3 migrated to higher stretches of the river Meuse. The whole picture seems to reflect the dozens of "life strategies" of sea trout (Mills 1992). None of the Rhine trout was captured in the river Meuse and no one from the Meuse in the river Rhine branches. There are no indications that the barrages in the river Lek might be passable by salmonids on their upstream migration. The new fishways in the river Meuse seem to give the fish good possibilities to continue migration.

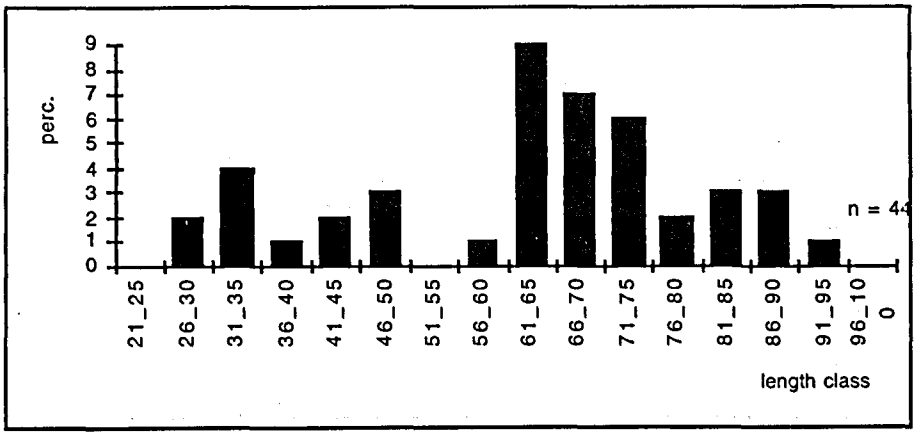

Figure 9. Length frequency salmon (Lek, Waal, Maas 1994/spring 1995)

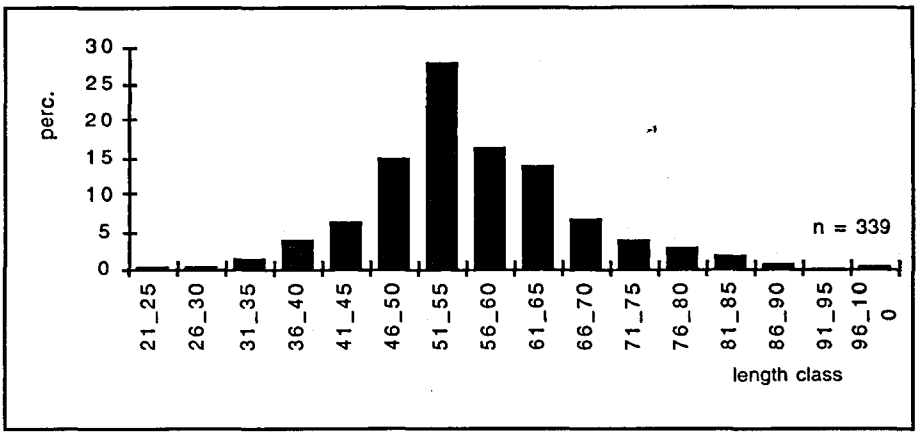

Figure 10. Length frequency sea trout (Lek, Waal, Maas 1994/spring 1995)

3.1.4 General remarks on the upstream migration

The problems which salmonids encounter when trying to enter the rivers are not yet solved. Drainage sluices to the Wadden Sea and the Haringvliet (figure 2) are only opened when sea water level is more than about 20cm below freshwater level. When the difference in water level exceeds 45cm, flow velocity in the sluices exceeds 3m/s over a distance of 50-60m. Moreover, they are not opened at all for prolonged periods during dry seasons. That means that,at these three sites upstream migration might be a problem. However, catches of both larger sea trout and salmon in the IJsselmeer near the sluices (Dekker & Van Willigen 1996) suggest that at least some salmonids do succeed in passing these sluices, although the possibility cannot be ruled out, that they enter the lake through the river IJssel. Migration along the IJssel river and the Nieuwe Waterweg has not yet been investigated.

A new type of fishway, designed as a channel with V-shaped weirs and running alongside the obstruction and suitable for all river species, including small ones, has been applied at locations where headwater level varies between narrow limits of about 30cm. So far five have been built in the river Meuse, which proved to be suitable for a variety of river fish, including salmonids (Cazemier 1995, Lanters 1995). However the river Lek has still three barrages (figure 2) without these facilities. Although they are planned to be built before 1998, this route is virtually blocked at present.

3.2 Germany

3.2.1. Smolt migration experiment

Eel fyke net catches and anchored trawl net catches in Holland, close to the German border, demonstrated that smolts migrated seaward from Germany since at least 1981. Young sea trout have been released in the rivers Dhünn and Sieg in the German province of Nordrhein-Westfalen from 1985 onwards (Schmidt 1991, Steinberg & Lubieniecki 1991). Therefore there could not be the origin of the captures in the period 1981-1984 in Holland, but might be, at least partly, the source of the smolts seen in years thereafter. In that case they would have to pass the formerly heavily polluted Ruhr-area. In order to get evidence that this was

possible, a joined project was started with marked (alcyan blue) smolts of sea trout and salmon in 1988 released in the river Sieg (figure 1). Recaptures in Holland in 1988 and 1989 revealed that smolts were able to complete their downstream migration successfully to the North Sea and the IJsselmeer (Steinberg & Lubieniecki 1991). This has been an important argument to continue releases in German tributaries.

3.2.2 New fish passes in the river Sieg

The efforts for re-opening the migratory routes of salmon and other migratory fishes within the Sieg subsystem has resulted in the construction of modern and effective fish passes alongside of the four lowest weirs of the river Sieg and along the lowest weirs of one of its tributaries, the river Agger (figures 1 and 11), between 1987 and 1994 (Städtler & Schaa 1996, Steinberg & Lubieniecki 1991). Thus, more than 100 km of river stretches with at least 14,2 ha potential spawning grounds and 46 ha nursery habitats (Marmulla 1992) have been made available for salmon . The construction of further passes is considered.

3.2.3 Attempts to establish natural salmon reproduction.

The suitability of the Sieg subsystem for reintroduction of salmon has been assessed in detail by Marmulla (1992, 1993). Since 1988, juvenile salmon have been released in selected nursery habitats. This initial stocking phase is still going on. The material originates from wild populations from Norway, Ireland and Scotland, selected according to biogeographical and ecological criteria (Schmidt 1991 and 1996). Generally, fry fed for 1-4 weeks in the hatchery were released at densities of 1-2 individuals/m^2 nursery ground. A small number was reared in the hatchery to 1+ fish to allow marking or tagging. Adipose fin-clipping, blue spots (alcyan blue) and visible-implanted (VI) tags were used to study the migration of smolts within the river system (Steinberg & Lubieniecki 1991) and the survival rates of the cohorts of different origin (Schmidt 1996). The various activities related with the programme are given by Schmidt, 1996.

About 2 millions of young salmon in total had been released into all the suitable stretches of the Sieg basin by the end of 1995 (table 2). According to the first monitoring results, the fry grows up in this catchment and reaches 15cm by the end of the first year. Because of this good growth it is assumed that most fish smoltify in their second year (Schmidt 1996).

Since the Sieg basin is relative large, quantitative work on growth and survival in the different sections is rather laborious and good data are still scarce. More detailed monitoring is planned for the next years. This applies also to the assessment of returning adults. In November 1990, the first adult specimen of Atlantic salmon (male; TL 81,0 cm, 4.1 kg) was caught in the same tributary of the Sieg into which the first batch of marked yearlings had been introduced in 1988, representing the first record of an adult salmon since more than three decades. The data indicate that there has been a small yearly run from 1990 onwards (Steinberg et al. 1991). About 50 adult salmon have been identified in the Sieg and its affluents until today (Schmidt 1996), but true numbers might be quite larger. To get more complete data, the construction of permanent control stations in the fish passes of the lowest weirs of the Sieg and the Agger is being prepared.

Table 2. Salmon (*Salmo salar* L.) releases in the River Sieg basin, a German Rhine tributary, 1988-1995 (Schmidt 1996)

Province	Year	Number released	Age	Origin
Nordrhine-Westfalia	1988	8000	parr	Norway (Vosso)
	1989	16.500	parr	Norway (Vosso)
	1990	51.000	fry	Norway (Vosso)
		4000	parr	Norway (Vosso)
	1991	88.000	fry	Norway (Vosso)
		1.500	parr	Norway (Vosso)
	1992	760	parr	Norway (Vosso)
	1993	163.000	fry	Ireland (Burrish. Shannon), Norway (Drammenselva)
		13.600	parr	idem
	1994	393.850	fry	Ireland (Burrish. Shannon, Delphi)
		14.950	parr	idem
	1995	652.000	fry	Ireland (Burrish., Delphi, Costello), Scotland (Conon)
		6.800	fry	Germany (Bröl)
		815	parr	Ireland
Rhineland-Palatinate	1991	42.000	fry	Norway (Vosso)
	1993	85.000	fry	Ireland (Burrish. Shannon), Norway (Drammenselva)
	1994	90.375	fry	Ireland (Burrish. Shannon, Delphi)
		65.000	fry	Sweden
		6.500	parr	France
	1995	37.700	fry	Sweden
		180.000	fry	Ireland
		64.400	fry	France
		50.000	parr	France/Sweden

During the reproduction period of 1993/94, evidence for the first successful natural reproduction of Salmo salar in the Rhine basin for many decades has been observed. In that period 19 redds, distributed over 10 spawning sites were found in the Sieg system (figure 11). Because they could originate from salmon or sea trout, five were checked carefully. In three of those, representing spawning sites in the Sieg, Agger and Bröl respectivily, living yolk-sac larvae of salmon could be identified (Schmidt et al. 1994, Marmulla & Ingendahl 1996). Possibly because of unfavourable weather conditions and large river discharges, salmon redds could not been found in the following two winters, but the catch of three spent females in the winter of 1995/96 indicates the likelihood of natural spawning in that winter.

3.2.4 Telemetry of salmon and sea trout migration.

Although the number of adult salmon reported increased in 1991 and 1992 and the efforts towards finding clues for natural reproduction were intensified, no spawning redds could be detected by means of direct observation in the Sieg basin. Therefore, a radio telemetry study was planned (Marmulla, 1992b) to elucidate the spawning migrations and, possibly, spawning site selection by recolonizing salmon and sea trout.

Radio telemetry is a well known and successful tool for tracking salmonids and has been widely used. Three different methods are in use to attach tags, viz. external attachment, stomach implant and body cavity implant (McKinley et al. 1992). Based on a thorough

literature study, the stomach inplant was selected. Radio telemetry receivers of the Canadian brand LOTEK Eng. Inc. were either used as stationary automatic data recording devices or in mobile mode.
Since autumn 1993, three campaigns have been undertaken. In total 6 salmon and 14 sea trout have been radio tracked, with different degrees of success (Marmulla 1994, Marmulla & Ingendahl 1996, Marmulla 1996).
One tracked male salmon was traced up to less than 100 m from one of the spawning sites in the Sieg, mentioned earlier, but was never found on a redd. The same fish may have been involved in mating further downstream where, according to tracking data, it had spent some time in the vicinity of a redd, detected from a helicopter. The behaviour of this male matches spawning behaviour observed in other studies (Dulude et al. 1992, Bomassi & Brugel 1991).

In autumn 1994, a female sea trout was tracked for more than 50 km into the Sieg's affluent Nister. It had passed four weirs with fishways, two of them without major delay, but was held up by an obstacle of approx. 1,8 m of height in the Nister. After having been caught and moved over the weir, the fish resumed its migration (figure 12, sea trout no. 064). Some days later, two redds were found in the river stretch where the female had been located for several days. Unfortunately, due to exceptionally heavy flooding the structure of the spawning sites changed radically and no larvae could be detected during a check-up. A tagged male sea trout had made approx. 20 km in only a few days, passed a weir with fishway and was found active in the vicinity of a small affluent into which juvenile sea trout had been released in previous years. Although telemetry data indicated that participation in mating was probable, the fish could not be seen on a redd nor was a redd found after the fish had left. As shown by automatic data recording stations, the fish had covered a distance of almost 60 km in 24 hours during its downstream migration (figure 12, sea trout no. 115), which is a strong indication of completed spawning (Marmulla & Ingendahl 1996).

During the spawning season 1995/96, 17 spawning sites have been detected (figure 11). From one spawning ground in the Agger, yolk sac larvae were collected in early 1996 and genetically identified as sea trout. The highlight of this campaign was the observation of a tagged male sea trout on a redd together with a female and smaller rival male. This was the first time that the spawning act of migrating salmonids was observed in the catchment basin of the Sieg and that a redd could be attributed to an identified fish (Ingendahl & Marmulla 1996).

The study showed unambiguously that particular sites within the existing gravel zones have already been accepted for natural spawning by migrating salmonids. Moreover, the radio telemetry data indicate, that even rather low weirs may constitute severe obstacles to salmonids whereas fishways always proved passable.

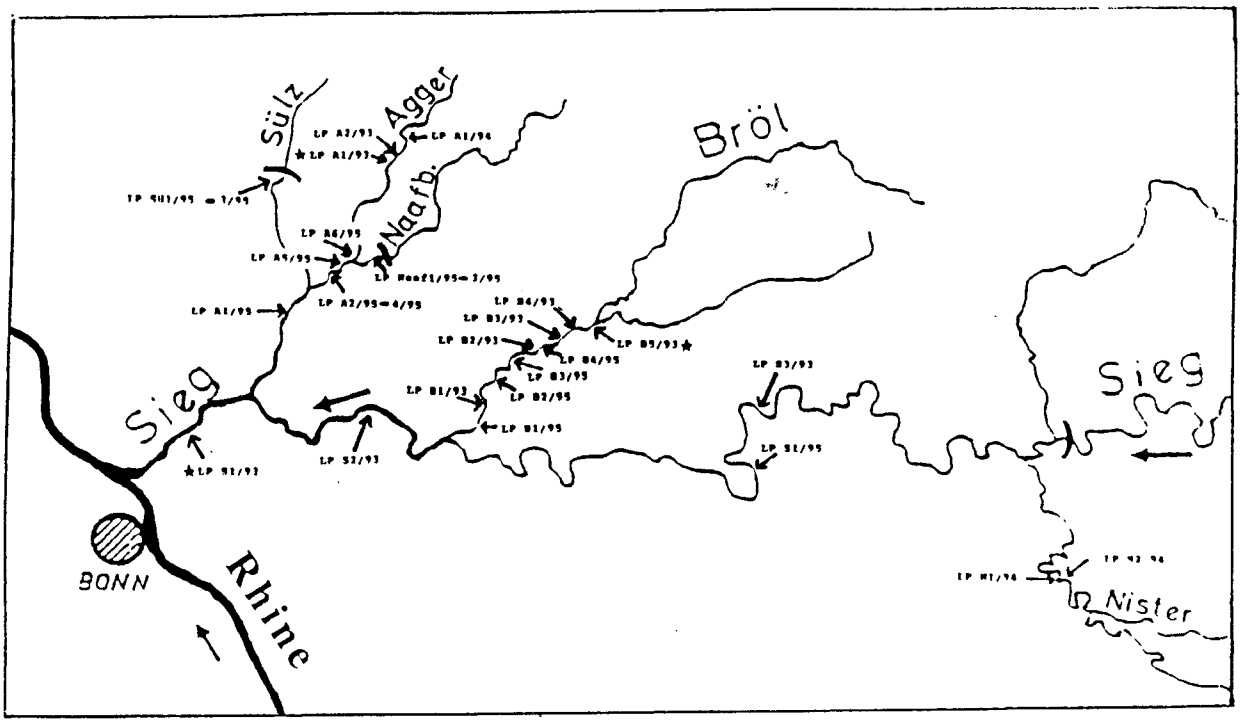

Figure 11. Study area in the lower Sieg and its major tributaries Agger, Bröl and Nister. LP: Salmonid spawning grounds (S: Sieg, A: Agger, B: Bröl, N: Nister, Naaf: Naafbach, Sü: Sülz; number before stroke: order in upstream direction; number after stroke: year of spawning; stars: natural reproduction proven).

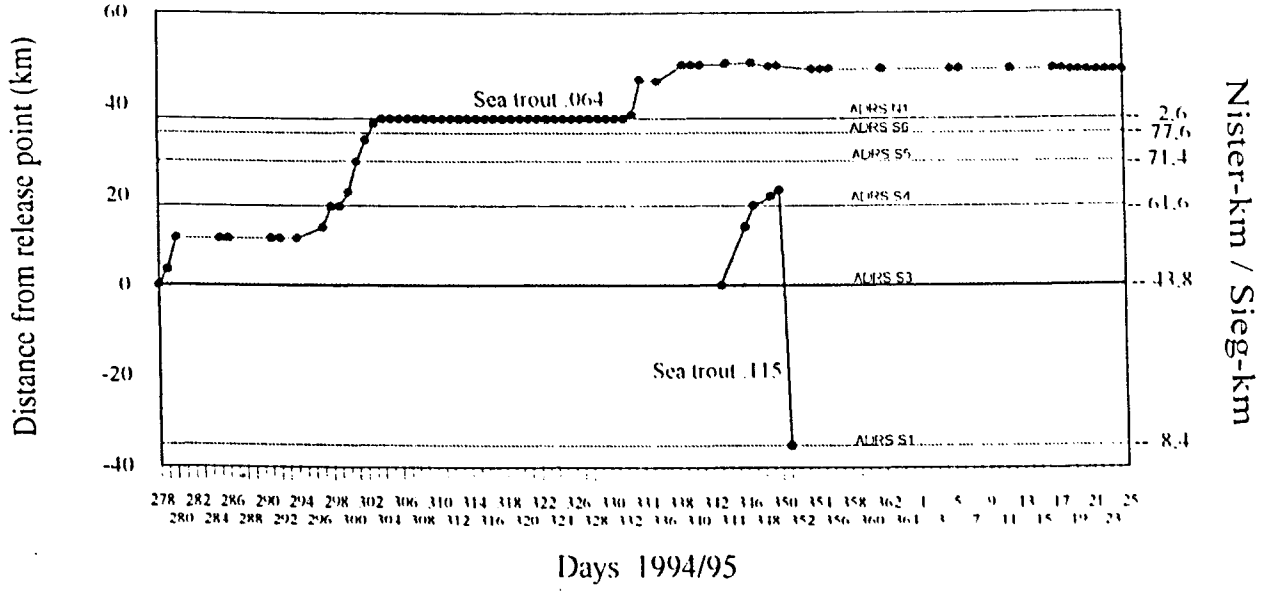

Figure 12. Migration patterns of two sea trout from October 1994 through January 1995. Left ordinate: migration distance from release point (0) in km; right ordinate: Nister-km from confluence with Sieg and Sieg-km from confluence with Rhine. Locations of automatic data recording stations (ADRS) shown. (from: Marmulla, G. & Ingendahl, D., 1996).

3.3 France

3.3.1 Investigations on sea trout

Catches of sea trout since 1983, mainly at the Iffezheim barrage (Maire 1989), drew attention to this species first. In 1989 and 1990, some characteristics of the population were described from scale samples collected by anglers (Roche 1992). Strontium level and structure of the scales of a sample of 22 out of 26 large trout caught in the area were indeed typical of sea trout. The mean total length of these sea trout was 63 cm and their age was estimated at 1 to 2 years in freshwater and 1 to 3 winters at sea. Six out of these 22 were on their second spawning migration. Since 1992, electric fishing has been carried out at the dam on a regular basis from mid-June to November, the period when most of the migration occurs. Until 1995, the majority was kept in holding ponds to provide eggs for enhancement measures before a new fishway could be built at the Iffezheim dam. Adipose fin-clipping of the juveniles before stocking has shown that at least some returning sea trout originated from stocking (Roche, 1994b).

3.3.2 Preliminary studies on potential salmon habitat

A survey of the Rhine between France and Germany as well as its tributaries on the French side, conducted in 1990 and 1991, indicates 113 hectares of suitable nursery habitat for salmon (shallow running waters on rough substrate), together with six hectares of spawning habitat associated with pools (Roche, 1994a). Since 1991, stocking tests followed by electric fishing surveys were undertaken to estimate the densities that these habitats might carry. The results indicate that the habitat in most streams was suitable for juveniles, although survival and growth were affected by low flows and excessive temperatures in the old Rhine (old channel) where half of the rearing areas are located, during warm years as a result of hydroelectric exploitation. Pollution, mostly of organic origin, was relatively low in the selected areas and was not considered a major cause of mortality.
The carrying capacity in the French area was estimated to be 56 000 to 112 000 smolts (5 to 10 smolts per 100 m^2).

3.3.3 Obstacles to migration

The 11m high dam at Iffezheim is equipped with a Borland type fishway with almost no attractivity. An assessment of this device in 1989 showed that hardly any fish made their way upstream (Roche 1990, Roche and Bénéat 1991). Most anadromous fish appear to migrate to the outlet of the hydroelectric power plant where a new fishway will be built in 1998. A similar situation occurs 25 km upriver at the Gambsheim dam, planned to be equipped with a new fishway in 2002. Another 8 similar obstacles dam the river up to the border with Switzerland, where more dams are to be found. All these dams are equipped with turbines, which cause mortality on downstream migrating smolts and eels. Mortality of smolts has been estimated at less than 5% per dam (Larinier and Dartiguelongue 1989), which might be lowered by using some existing by-passes.

The new fish passage in Iffezheim will enable migratory species to enter the Ill river, the biggest tributary on the French side of the Upper Rhine. Since a sufficient amount of suitable salmon habitat still exists in this catchment area, all obstacles are being equipped with new fishways, because the old ones are usually too small and unattractive. Ten fishpasses have

been constructed since 1992 and six more are foreseen in the next four years. Downstream by-passes will be built next to the four hydroelectric dams still in operation.

In 1996, a first evaluation of the obstruction by existing obstacles has been started by radio tracking returning salmon and sea trout. The fish are captured below the dam, tagged and released upstream from Iffezheim. This study is aimed at studying the behaviour of these fish before spawning as well.

3.3.4 Releases of fry and parr

From 1991 to 1996, a total of more than 917,000 juveniles of Atlantic salmon fry (81% fed, 19% unfed), were released in the French part of the Rhine system. The objective is to release 500,000 fry each year, based on the estimated carrying capacity of the area (565,000 spring fry). The juveniles are released at an early stage in order to favour natural selection versus hatchery selection, to favour acquisition of homing accuracy and to reduce expenses and risks of desease while in hatchery. 2860 fish have been adipose fin-clipped for estimating survival during the freshwater stage. 924 parrs have also been tagged with visible implants near one of the eyes.
Eggs were purchased from various sources in order to increase genetic diversity (table 3), mostly from Britany (France) in the three first years, later on also from the river Nive (south-western France), and from Denmark, Scotland and Ireland.
In 1996 only eggs from three origins (Loire, Britany and Nive) were used in order to try to make comparisons in terms of return rates and the age of the returning fish. Eggs from the river Loire-Allier were obtained from a domestic brood stock raised in freshwater and being the progeny of wild parents. All released juveniles of two of the three origins (Allier and Britany) were marked by immersing them in two bone marking solutions, which had been successfully tested on trout and char. Fish from the Nive were not marked.

Table 3. Numbers of Atlantic salmon fry released in the French part of the Rhine from 1991 to 1996

	Bretagne	Scotland	Ireland	Adour-Nive	Denmark	Loire-Allier	Total
1991	6980	8000	0	0	0	0	14980
1992	83420	0	0	0	0	0	83420
1993	82850	13730	0	14500	0	0	111080
1994	19500	14400	13400	0	30900	0	78200
1995	74600	9430	22210	250550	163460	0	520250
1996	9730	0	0	65900	0	33860	109490
Total	277080	45560	35610	330950	194360	33860	917420

In addition, a total of 60,485 juveniles of sea trout (87% of Rhine origin) were also released from 1991 to 1996. 23,105 juveniles (38%) were marked by adipose fin-clipping, for recognition from the other trout during juvenile surveys. Two adipose fin-clipped adults were recaptured in 1993 at the Iffezheim dam, among a total of 35 caught. They probably originated from the stocking of 3150 marked juveniles in 1991 in the river Bruche. Two other marked trout from the same batch were caught in a small tributary of the Bruche without having migrated to the sea (Roche, 1994b).
There are no plans for further stocking of sea trout because the access to the Ill basin is considered to be more valuable for restoring the existing population than stocking.

3.3.5 Assessment of the survival of juvenile salmon

Since 1991, an assessment of freshwater survival of stocked fry is done on an annual basis by means of electric fishing surveys (Roche and Gerlier 1996). 15 to 20 rifles (300-800 m^2 each) are fished each September and densities of 0+ and 1+ parr are estimated. Comparison with stocking allows estimates of survival of 0+ parr during the 3-4 first months of the freshwater stage (table 4).

Table 4. Parr densities and survival from release to the end of September in various Alsacian streams.

Stream location	Parameter	0+ parr					1+ parr				
		91	92	93	94	95	91	92	93	94	95
Lauter	n/100 m^2	29	0.3		2.9	1.6		2.3			
	survival %	8*/17	1		5	1					
Bruche (Molsheim)	n/100 m^2	50	70	50	18	29	5	6	21	18	12
	survival	83	88	83	29	23					
Bruche (Dinsheim)	n/100 m^2	42	31	14	12	15		3	16	1.4	0.3
	survival %	58	39	20	29	18					
Giessen	n/100 m^2		0	1	2	8				0	
	survival %		0	3	2	8					
Fecht	n/100 m^2	10	0	18	20	21				0	
	survival %	19	0	24	25	53					
Doller	n/100 m^2			25	33	22				0	0.7
	survival			21	77	22					
Rhine (Fessenheim)	n/100 m^2				20	3.6					
	survival %				35	6.0					
Rhine (Blodelsheim)	n/100 m^2		27	1.6	0	22			0	0	
	survival %		45	3*	0	70*					
Rhine (Chalampé)	n/100 m^2		2	3.9	1.6	7.4			0	0	
	survival %		2*	43	3	23*					
Rhine (Kembs, km 185.7)	n/100 m^2					31					0
	survival %					85*					
Rhine (Kembs, km 182.5)	n/100 m^2		25	0.5	0.2	7.7			0	0	
	survival %		31	10	0.3	10					

* unfed fry

The numbers of smolts migrating each year are also estimated from the number of parrs at the end of September (table 5), based on the method described by Roche and Gerlier, 1996.

Table 5. Estimated numbers of parrs and smolts produced in all Alsacien streams stocked with salmon

Year of release	1991	1992	1993	1994	1995
parr 0+			46002	18883	144504
parr 1+			8803	3472	13526
smolt 1+	1199	5687	11378	3507	33426
smolt 2+	175	5421	5542	2456	9221

Year of migration	1992	1993	1994	1995
smolt run downstream all turbines	981	5504	15634	8438

A smolt trap was installed in a small side channel of the Rhine collecting mostly ground-water fed tributaries. Smolt counts of salmon, sea trout and brown trout (both marked) and electric fishing surveys were done from 1994 to 1996 (Roche et al. 1995, Gippet 1996 in prep.). Survival of unfed salmon fry from release to the smolt stage was estimated at 6.5% in 1993, 2.5% in 1994, and 11.7% in 1995 (years of release). Survival of sea trout was much lower in comparison, even when taking in account a proportion of non-migrating sea trout.

3.3.6 Assessment of adult returns

No counting station is yet available to assess the size and composition of the adult salmon run. A video counting station is planned at the new fishway to be built at the Iffezheim power station in 1998. For the time being, electric fishing gives some information on the number of salmonids blocked by the obstacle. However, some fish apparently manage to pass this barrier through the ship locks as the catch upstream of the dam of a sea trout tagged in Holland showed.

In 1995, nine adult salmon were caught with electricity at the Iffezheim dam, all one sea-winter fish (total length 62-78 cm) (Roche et al. 1996). These were the first salmon caught here since decades. Three of them had spent two years in freshwater, and thus probably originate from the juveniles released in 1992, which were all from Britany origin. Six others had spent one year in freshwater, thus probably originate from either Britany (75% of the stocked fish that year) or from Adour-Nive or Scotland.

The stream where most salmon fry were stocked in 1992 and 1993 (Bruche) was surveyed in early December 1995, in order to assess if any salmon had reached the area by themselves despite one major obstacle and two smaller ones on their way. Within the 33 kilometres of the lower Bruche surveyed by helicopter, seven large redds were found. The upper limit of this stretch is an unpassable dam. A 6.5 km stretch of the middle Bruche, an area where three adult salmon caught at Iffezheim were released, was also surveyed with kayaks. No large redd was found in this area. Only brown trout redds were observed.

Egg samples were collected from four large redds in the lower Bruche and analysed for species identification. Genetic analysis revealed that three samples were *Salmo salar*, and the

other was *Salmo trutta*. (Guyomard et al., in prep.). This was the first evidence that Atlantic salmon had reproduced in the area near Strasbourg since the 1950's.

4 DISCUSSION

Improvement of the water quality, reappearance of sea trout and other sensible fish species at the beginning of the 1980's initiated new activity regarding fish and fisheries in the Rhine. After 15 years of research, the status and problems of anadromous salmonids are now clearer. Possibilities exist to enhance self sustaining populations in the Rhine and some of its tributaries. The ICPR played an important role in the process as a stimulating and co-ordinating international organisation.

The measures taken in Germany and France to restore populations by stocking a number of tributaries, and building fish passes have probably had a positive effect on the numbers of smolts passing the delta in spring time. However, it is not possible to distinguish them without marks or tags or genetical indentification methods. Unfortunately, proper monitoring has not been possible since 1989. That is also a main reason why tagged or marked smolts from the different tributaries are hardly detected in Holland. However an experiment in 1988 revealed that at least part of stocked smolts in the river Sieg succeeded in finding its way to the North Sea.
Tagging experiments at the coast, monitoring spawning run at three sites in the delta and subsequent tagging and moreover catches of adults in the German and French region have revealed that adults are able to migrate upstream the Rhine and Meuse. Those having been released in the river Meuse, do not seem to mix up with Rhine populations.
The proportion of adults succeeding in passing the sluices at the Dutch coast is not known yet. There are still good reasons to assume that the majority migrates through the Nieuwe Waterweg. No evidence has been found that migration along the river Lek might be possible for adult salmonids and thus the relative large numbers which enter this river arm during upstream migration have to return to the lower delta to find their way to higher stretches of the Rhine. It seems that they mostly return, because recaptures revealed that they stay below the lower dam for only a few days up to about 4 weeks.
Sea trout at the Dutch coast originates partly from north western French rivers and they will find their way back through the southern North Sea and the Channel.
Quantitative and/or qualitative effects of measures in Germany and France on the home run of salmon and sea trout have not been yet established in Holland. The relative short monitoring period, the complex life strategy of sea trout and the still low numbers of salmon may be the main reasons. Furthermore, no tagged fish from abroad has yet been detected. The IJsselmeer/Ketelmeer might be an area for sea trout to grow up from smolt to adulthood, but it is also possible that is a transit area between the North Sea and the Rhine to a certain extent. Significant evidence has been found that sea trout may pass the sluices of the IJsselmeer in upstream direction since the operating schemes of the sluices have been adapted to improve passage of migratory fish. Thus, the IJsselmeer population might be a mixture of real sea trout and landlocked trout.

Developments in German and French sections of the Rhine are promising. Results presented on the Sieg-basin are largely qualitative, but all data indicate that there is a real chance that a viable population of salmon can be re-established. The released juvenile fish grow well and are obviously able to adapt to another river. As smolts they find their way to the open sea and

some fish come back as adults to their new "home" water. There, they can pass new fishpasses, as shown by radio telemetry and find appropriate conditions for spawning and their progeny seem to develop successfully; 14.2 ha of potential spawning ground and 46ha of nursery habitat has been found in the Sieg basin. However, radio telemetry showed, that even low weirs without fish passes constitute severe obstacles to migrating fish. Therefore, all efforts should be made to construct adequate fish passes, even at small weirs.
The observed spawning sites with identified redds of both trout and salmon raises the expection that the Sieg basin will get back its quality as a salmonid river. However, more consideration should be given to appropriate management of the salmonid stocks that is aimed at protection during all life stages. Also, steps should be taken to compensate for remaining anthropogenic impacts on the spawning and nursery habitats. Studies of possibilities for reconditioning sediments of less suitable sites are presently initiated. This might lead to improved biotope management.
It is still uncertain whether the numbers necessary for a self-sustaining population will be attained under the present conditions. Thus, studying the quantitative aspects has to be enforced now.
Reliable data about trends in population size and the order of magnitude of natural reproduction are urgently required for deciding when to stop releases. Undoubtely, it will take time beyond the year 2000 before fish from different origin will have developed a stable population by natural selection and adaptation. Therefore the release of allochthonous material should be stopped as soon as possible. According to Krueger et al. (1981), Thorpe (1988) and Waples (1991), there should be at least 30 reproductive parents of each sex to avoid dangers of inbreeding. As long as there are not enough returnees that spawn successfully, stockings with appropriate allochthonous material should aim to extend the genetic variability of the progeny from the salmon population.

The findings in the Upper Rhine region, from Iffezheim towards Strasbourg give also reason for optimism. Most trout caught below the Iffezheim dam were found to be typically sea trout, according to the strontium content of their scales. In 1995, salmon have been captured at the Iffezheim dam for the first time since decades. These captures show that the Rhine as far as the Upper Rhine is suitable again for salmon as well as sea trout to complete their total migration. The estimated 6ha of spawning grounds and 113ha of nursery habitat in the Upper Rhine section could yield an important part of the total salmonid population. Survival of 0+ parr released during a 5-year period varied by section and year, but some sections proved to be very good, even in relative warm years.
The new fish pass at Iffezheim to be built in 1998, will give salmonids the opportunity to enter the Ill basin. Because 16 fishpasses will also be built in this basin, anadromous salmonids will be able to spawn in this tributary in the years to come. Salmon redds of artificially introduced individuals have already been found in the river Bruche, the main tributary of the Ill.
However, for the time being releases of hatchery reared salmon fry from a variety of origins will be continued at a rate of half a million per year.

5. CONCLUSIONS

- Restoration of anadromous fish populations in the Rhine started in the early 1980's, when sea trout made their re-appearance in the river after pollution had decreased significantly. Tagging experiments show that sea trout caught along the coast and in the lower delta originate most probably from the Rhine and the Meuse, but also from rivers in northwestern France. Sea trout have shown to be able to undertake a spawning migration up to the Iffezheim dam, 700 km from the sea.
- Assessment of the migration possibilities in the basin showed that serious obstructions still exist, especially in the river Lek, in Holland, and in the Upper Rhine from Iffezheim onward. The two sluices near the IJsselmeer seem to be passable to some extent, but there is hardly any evidence that those in the Haringvliet-dam are. Programmes for building new fish passes in Dutch, German and French rivers have been partly completed. The new passes seem to meet their requirements.
- Stocking of juvenile Atlantic salmon in the early eighties (France and Switzerland), followed by Germany in 1988 and since that time carried out on a yearly basis at different places, is considered the origin of increasing salmon catches.
- Assessment of returning adults since 1990 in the river Sieg, revealed that salmon and sea trout have been able to reach spawning grounds and to reproduce successfully in this river system. Quantitative data are not available yet except for redd counts in three consecutive years.
- In the French section adult salmon were caught for the first time in 1995 and salmon redds have been found in the Ill river system during the following winter.
- Young salmonids grow and survive well in most sections of tributaries in Germany and France. There has been a significant increase of smolt densities in French tributaries; quantitative data for German tributaries and the Dutch section are still scarce.
- The anadromous fish populations provide clear signs of recovery of the Rhine ecosystem. The results mark the first step towards the rehabilitation of a viable, self sustaining salmon population in some tributaries, which will probably not be accomplished before many years. However, the first part of the objective of the "Salmon 2000" programme is met: salmon can live in the Rhine again. Continuation of this process needs adequate monitoring and management of fish stocks and their habitats.

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