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International Council for
the Exploration of the Sea

North Atlantic Salmon
Working Group
Working Paper 2007/26

Study of downstream migrating salmon smolt in the River Rhine using the NEDAP Trail System: 2006 and preliminary results 2007

by

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Running headline: Downstream migrating salmon smolt in the River Rhine

Key words: Salmon smolt, downstream migration, River Rhine, Nedap Trail system, Delta

Abstract

Downstream migration of Atlantic salmon smolt was studied in the River Rhine in 2006 and 2007 using the NEDAP Trail system. In 2006 10 fish and in 2007 78 fish were released into two tributaries of the River Rhine (R. Sieg in 2006 and R. Wupper in 2007). The smolts (> 150 g) were tagged with a transponder (length 3.5 cm, weight 11.5 g) by surgery and introduction into the body cavity. After a recovery period of three days (2006) and ten days (2007), respectively in the hatchery the fish were released into the river.
The transponder equipped fish can be detected by fixed antenna stations when leaving the tributary and during their migration through the Rhine delta to the sea. The NEDAP trail system is based on inductive coupling between an antenna loop at the river bottom and the ferrite rod antenna within the transponders. Each transponder gives its unique ID-number when the fish is passing a detection station.
Until now 64 fish left the river of release (5 in 2006 and 59 in 2007, respectively). Out of this 64 individuals at least 24 (1 in 2006 and 23 in 2007, respectively) reached the sea after passing the Rhine delta. The study aims to investigate the success of downstream migration under the actual condition of the partly dammed Rhine delta (especially at the Haringvliet sluices). It will be repeated after re-opening the Haringvliet dam which is scheduled by the end of 2008 aiming at improved conditions for migratory fish species during their passage from freshwater to sea and vice versa.

Introduction

In the River Rhine, a former important salmon river, Atlantic salmon was extinct by late 1950. When starting an ambitious program for the ecological rehabilitation of the Rhine the member states of the International Commission for the Protection of the River Rhine (ICPR) agreed that migratory fish species as the Atlantic salmon should again colonize the River and its tributaries (ICPR 2004). To achieve that goal a restocking program was started in several areas of the Rhine basin especially in Germany, France and Switzerland. Since 1990 adult salmon are regularly recorded in some tributaries of the River Rhine (River Sieg) and at a fish pass in the Upper Rhine (Iffezheim). But numbers and return rates are actually still to low for the establishment of a self-sustaining salmon population (MUNLV 2004). There are several potential bottle-necks identified actually hindering a higher number of salmon to return to the rivers where stocking takes place.

One potential bottle neck is free migration of fish from freshwater to sea and vice versa in the Delta part of the Rhine in the Netherlands. During last decades the Delta has been partly dammed from the sea especially in the Ijsselmeer area in the northern part and in the Haringvliet in the southern part of the Delta. Both water bodies have turned into complete freshwater and salt water is no longer able to penetrate into the Delta at these locations. Especially on the sea side of the Haringvliet adult sea trout and salmon are known to aggregate and searching their way into the Delta when the sluices are open to discharge freshwater from the Rhine to the sea. In an earlier transponder study a high proportion of sea trout tagged at Haringvliet moved further north and migrated via the “Nieuwe Waterweg” the only open migration pathway into the Rhine delta (bij de Vaate et al. 2002).

The present study aims to follow the downstream migration of Atlantic salmon smolts through the Delta to the sea. Downstream migration is a crucial moment of the life cycle of salmon when in spring juveniles are leaving their freshwater habitats in smaller tributaries in order to migrate and to adapt to the particular conditions in the sea. Hatchery reared two year old smolts have been tagged with transponders using the NEDAP trail system. The study takes advantage of a large network of detection stations strategically chosen along the River Rhine (delta) and established to study upstream migration of adult sea trout and salmon. The transponder gives its unique ID-codes to a data storage unit when the fish is passing a detection station. The presence of a detection station at the confluence of the tributaries with the Rhine makes it possible to detect the fish when leaving the river and starting its downstream migration.

In the context of the reintroduction of salmon into the River Rhine it is important to learn more about the downstream migration especially about migration routes in the Delta and the proportion of migrants successfully reaching the sea. Additionally from 2008 onwards the opening of the Haringvliet sluices will be modified. Actually the sluices are only opened to discharge a surplus of freshwater from the Rhine into the sea and are closed to avoid salt water penetrating into the freshwater area of the Haringvliet. After 2008 at least two sluices out of 18 will be permanently kept open on a slit in order to create a migration route for fish passing between both sides of the Haringvliet dam. This will re-

establish a small mixing zone for freshwater and saltwater in the vicinity of the delta side of the Haringvliet. All these measures are intended to partly recreate the estuarian functions of the Haringvliet area and by this to contribute to the ecological rehabilitation of the Rhine delta. After re-opening of the Haringvliet, studies such as the downstream migration of smolts will be replicated in order to evaluate the consequences of this rehabilitation measure and the possible improvement of fish migration in the Rhine Delta.

Material and Methods

The NEDAP trail detection system is used for the study of downstream migrating salmon smolts in the River Rhine. It is based on inductive coupling between an antenna loop and a ferrite rod antenna within the transponder. A number of detection stations are situated at strategically chosen locations along the River Rhine (Fig. 1). When a fish passes a detection station its unique ID-codes is registered by a data storage unit. More (technical) information can be found in recent publications (Breukelaar et al. 1998; bij de Vaate et al. 2002).

Due to technical reasons (especially the antenna coil within the transponder) the size of the tags could not further reduced (length: 3.5 cm, diameter: 13 mm and weight: 11.5 g in air, Figure 2). Therefore hatchery-reared 2 year old smolts from three salmon rearing stations were selected with at least 150 g weight and a length of 25 cm at minimum. These fish had not been smoltified at age 1. According to Lacroix et al. (2004) tag length should not exceed 16 % of the body length and tag weight should be less than 8 % which was respected during the study.

The surgical procedure followed was described by Vriese (1995) and already used for larger (adult) salmonids. Fish had not been fed 24 h before tagging. They were individually anesthetized using a 40 mg/l benzocain solution. After surgery the fish was shortly hold for observation in a small recovery tank and later on in a larger holding tank. Ten fish were released three days after surgery in the River Sieg in 2006 and 78 smolts were released 10 days after surgery in 2007 in the River Wupper, both tributaries of the River Rhine, Germany.

Results

In **2006** ten fish were released in the River Sieg on May 5th about 20 km upstream of the confluence with the River Rhine. Five smolt were reported leaving the River Sieg within two days after release. On their way downstream to the sea three fish were registered at the detection station in Xanten about 160 km downstream of the River Sieg (No 13, fig. 1) This detection station is situated about 35 km upstream of the Rhine delta where the Rhine splits of into the Waal and the Nederrijn (branches). Out of these three fish at least two individuals progressed further into the Delta. One reached the sea via the "Nieuwe Waterweg" within 4 days after leaving the Sieg River (No 6011, fig. 3). The second fish arrived in the Dordsche Kil a river branch leading to the Haringvliet area. It made several progressions up and down in that river stretch as indicated by 6 registrations on May 12th and May 13th (6002, fig. 3). This smolt was not detected at following stations neither at the Haringvliet sluices and is therefore not believed to have reached the sea (fig. 3).

Preliminary results 2007

In 2007 three batches of smolts were released into the River Wupper, a right-bank tributary of the River Rhine downstream of Cologne. One batch with 28 individuals went into the Wupper approx. 20 km upstream of the mouth to the Rhine. Two batches, 25 fish each, were transported to the River Dhünn, a small tributary of the Wupper and released about 7 km upstream of the Rhine. The study started earlier than in 2006 and all fish were liberated during the first half of March (2nd, 8th and 13th of March 2007).

Until the mid of April already 59 out of 78 tagged fish left the River Wupper (76 %). The last fish was detected on March 28th about 26 days after release into the River. As the detection station is located only about 1 km upstream of the Rhine the 59 fish have probably reached the Rhine and are expected to have been starting their downstream migration to the sea. At the first detection station in the Rhine about 120 km downstream the River Wupper so far 43 fish have been registered (55 %, station 13).

At least 30 of 43 fish did progress further into the Delta as they have been detected at other detection stations within the branches of the Delta (38 %). 27 fish followed the Waal in the southern part of the Delta. Only three fish migrated into the Nederrijn of which one followed the Ijssel and probably arrived into Lake Ijsselmeer (detection at station 2, figure 1). One of the two other fish migrated along the Nederrijn and reached the Lek downstream of the last dam (Hagestein). This fish probably migrated to the sea via the "Nieuwe Waterweg".

Five teen of 27 salmon that migrated along the Waal reached the sea by passing the Haringvliet sluices so far. This passage and their progression through the Delta coincided with very high water discharge of the River Rhine. Therefore the Haringvliet sluices were kept open over a long period to evacuate the freshwater supply from the Rhine. Another 7 fish migrated further down the Waal and were registered at other detection stations before probably arriving at sea (station No 7, 8 and 14). At the actual status of the study all together 23 out of 78 tagged fish are assumed to have reached the sea (29 %). But as fish are still moving in the River Rhine, the results are still preliminary.

Discussion

In 2006 the study started with only a relatively small number of fish. The first essay was performed to test the new available smaller transponder and to evaluate if the two year salmon smolt could be used for this kind of experiment. When following the minimum length and weight criteria given by Lacroix et al. 2004, smolt could successfully be tagged and transported to the River Sieg. When the fish were released at the beginning of May downstream migration of the "wild" smolt population was nearly terminated as observed by using a rotary screw trap (Limnoplan 2006). Only half of the tagged smolts left the Sieg River within two days. The fate of the other non migrating fish remained so far unknown. Three fish were detected 180 km downstream in the lower part of the Rhine indicating an active downstream migration in the Rhine. At least two fish migrated

through the Delta and one successfully arrived at the North Sea. These results confirmed the feasibility of the study using the NEDAP trail system.

In 2007, 100 smolt should be tagged but the number of fish available bigger than 150 g was limited to 78 individuals. At the moment already 76 % left the river of release, a higher percentage than observed in 2006. More than half of the tagged fish migrated down the Rhine and was detected about 150 km downstream of the River Wupper on their way to the Delta. In the period of release high discharge especially in the River Rhine allowed for a rapid downstream migration and the first fish arrived in the Delta within a few days. As the freshwater of the Rhine discharged through the Haringvliet during a long period a high proportion of tagged smolts probably following the strong currents arrived into the Haringvliet area and passed through the open sluices.

As the study is far from being completed it is too early to draw final conclusions. But it seems very likely that salmon are following the main currents and arrive into the Waal branch receiving the major part of the discharge of the Rhine during high flow conditions. As this freshwater is discharged in a significant proportion via the Haringvliet sluices a number of salmon could take advantage of this particular condition and reached the sea via that route in March 2007. As a consequence it will be useful to renew the experiment in spring 2008 before opening the Haringvliet sluices in order to study downstream migration under a potentially different discharge regime of the Rhine.

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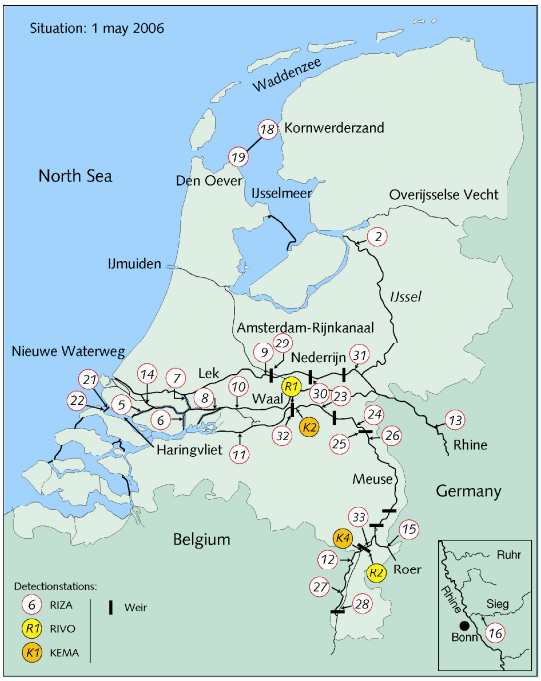

Figure 1: Map of the Rhine delta indicating the location of transponder detection stations.

Figure 2: Size of transponder used for migration studies, smolt transponder on the right.

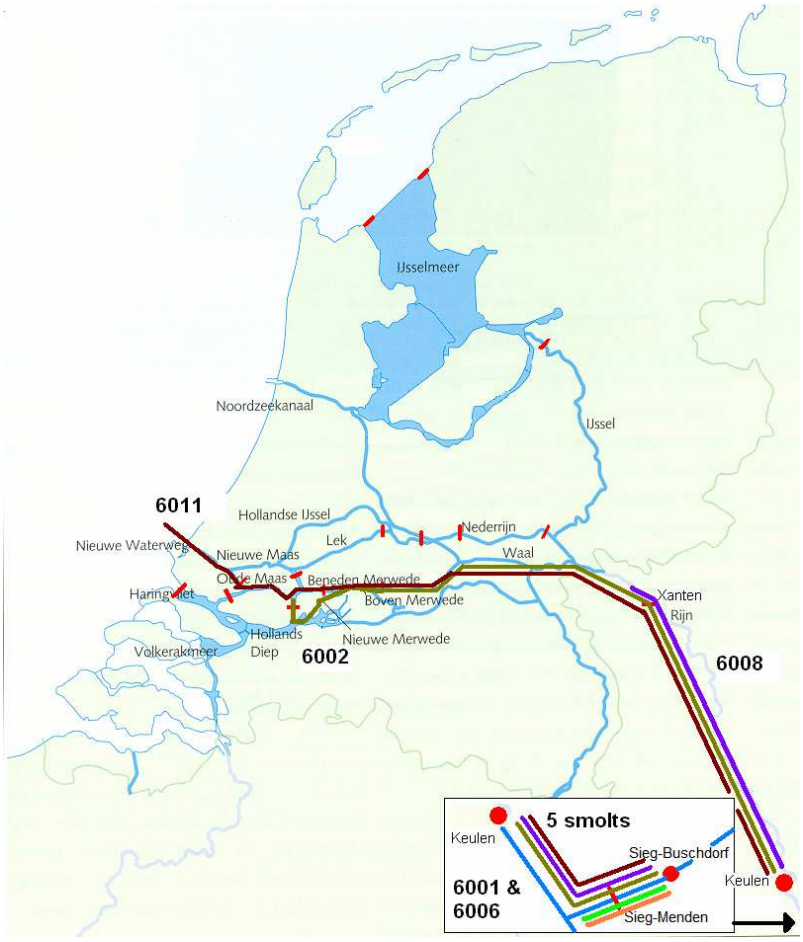

Figure 3: Summary of smolt migration pattern in 2006.