Literature survey into the possibility of restocking the River Rhine and its tributaries with sea trout (Salmo trutta trutta).

Dr. S.J. de Groot

NETHERLANDS INSTITUTE FOR FISHERY INVESTIGATIONS (RIVO)
Haringkade 1 - P.O. Box 68 - 1970 AB IJmuiden - The Netherlands
Tel +31 2550 64646

Publications and reports vol. **1989-12** of the project "Ecological Rehabilitation of the river Rhine".

Participating institutes:

On behalf of the Ministry of Transport and Public Works:
Institute for Inland Water Management and Waste Water Treatment (DBW/RIZA), P.o.box 17, NL 8200 AA Lelystad.

On behalf of the Ministry of Housing, Physical Planning and the Environment:
National Institute for Public Health and Environmental Protection (RIVM), P.o.box 1, NL-3720 BA Bilthoven.

On behalf of the Ministry of Agriculture and Fisheries:
Netherlands Institute for Fishery Investigations (RIVO), P.o.box 68, NL-1970 AB IJmuiden.

Report (RIVO): MO 88-206/89.1
Date of publication: April 1989

Contents:

Foreword

This report contains the findings of a literature survey into the possibility of restocking the Rhine and its tributaries with migratory freshwater fish such as salmon, and sea trout. It deals principally concerned with the possibility of reintroducing trout into the Rhine basin. The report has been prepared as part of a joint study undertaken by the Institute for Inland Water Management (DBW) of the Dutch Department of Public Works (Rijkswaterstaat) in Lelystad and the Netherlands Institute for Fishery Investigations (RIVO) in IJmuiden.

I would particularly like to thank Dr. J.E. Thorpe (Pitlochry) for the advice and support he gave during the preparation of this report.

IJmuiden, April 1989.

S.J. de Groot.

1. ECOLOGY

Although in the past some authors have regarded sea trout and brown trout as distinct subspecies, biologists are now able to prove that this is incorrect. Salmo trutta trutta have a resident freshwater population (brown trout) and a migratory population (sea trout). Interbreeding between the two populations produces fish that, after migrating downstream to the sea once and returning, spend the rest of their lives in freshwater. Until Henking proved that sea trout are directly related to brown trout in 1929, it was generally thought that sea trout were actually a hybrid of salmon and brown trout. In fresh water, trout reach a maximum length of 90 cm, whereas at sea they can attain a length of 1.4 m.

Sea trout have a brown back, silver-coloured flanks tinged with light brown, and a silvery-white stomach. Many dark cross-shaped markings are to be found on the body, mainly above the lateral line, while a large number of reddish brown markings are present on the flanks. The anal and adipose fins have an orange colouring, while the dorsal and caudal fins hardly have any pigmentation. Typically, 13-18 short firm gill-rakers are to be found on the inside of the first gill-arch. In general, trout in lakes have a more marked pigmentation than those in rivers and estuaries. The high caudal root is flattened in a lateral direction.

Brown trout have a bronze-coloured back and flanks, and a yellowish-brown stomach. Many distinct black markings are to be found on the back and flanks, mainly above the lateral line, whereas those below the lateral line are often edged with white or blue. The caudal fin has hardly any pigmentation (Nijssen & de Groot, 1987; Mills, not dated).

Six subspecies of trout can be distinguished, the first four of which have populations that remain in fresh water and populations that migrate to the sea.
Salmo trutta trutta - northwest Europe;
Salmo trutta labrax - Black Sea and associated rivers;
Salmo trutta caspius - Caspian Sea and associated rivers;
Salmo trutta aralensis - Lake Aral and the River Oxus;
Salmo trutta macrostigma - Mediterranean Sea.
The main focus of the present report is the sea trout. For an overview of the similarities and differences between young sea trout and salmon reference is made to Jones (1959).

1.1 Life cycle

The life cycle of the sea trout resembles that of other migrating fish such as the salmon. However, an important difference is that both sexually mature and immature trout ascend the river together in autumn on their return from the sea (Shearer, 1955).
Trout can reproduce several times over their life-span, with the eggs being laid in gravel beds in the upper reaches of the river (Stuart, 1953; Frost & Brown, 1967).
Hybridisation is quite common amongst sea trout, which intermix with brown trout. In general, trout are less adept than salmon in negotiating fast-flowing streams and are rarely found in rivers with currents in excess of 60 cm/s. Compared with salmon, trout are less affected by pollutants as they do not have to rely purely on their sense of smell during their journey upstream to the spawning grounds.

Spawning takes place in November and December usually between the hours of 10.00 a.m. and 2.00 p.m. (Eliott, 1984).
The spawning areas of the trout have the same characteristics as those used by salmon. A full account of the reproductive behaviour of trout is given by Jones and Ball (1954). Each female is accompanied by 2-4 males during spawning, but only one of these fertilises the eggs. The female

sheds the eggs into a nest pit or redd, which she has prepared beforehand. During the deposition process, up to 2% of the eggs are lost. The eggs are then covered over with gravel.
Trout redds are about 17 cm deep - somewhat less than the depth of an average salmon redd - and can contain up to 5 batches of eggs.
Female trout generally deposit 2000 eggs per kg body weight, resulting in between 700-1550 eggs per redd. It should be understood however that one female can loose their eggs in more than one redd. The number of redds in a given area can be used as a basis for estimating the size of the spawning population. Hay (1984) has used this method successfully for both salmon and sea trout.

The young larvae (alevins), which emerge from the eggs after 852 days/degree, gradually disperse over the upper reaches of the river. Under normal conditions, densities of between 12 and 22 alevins per m^2 would be expected. If the stream offers ample amounts of shelter, more of the larvae survive. Stones and overhanging banks provide excellent cover and help to maximise the territorial advantage. Turbulence and strong currents in the water column promote dispersion. The high mortality of trout at this stage of their life cycle is largely a function of density. Removing the natural cover provided by the stream will accentuate aggressive territorial behaviour. This will increase mortality and reduce the density of trout in that part of the stream.

In May of the first year in which the larvae emerge from the eggs, the density of alevins in the river is about 2-7/m^2, which subsequently declines to 1-2/m^2 in August. After this stage, mortality rates of between 3% and 5% are to be expected. The young trout that survive, can remain in the river for 1, 2 or 3 years, after which time they leave for the sea.
The process of smolting, which prepares the trout for its new environment, is similar to that which occurs with salmon. Observations by Leonko and Chernitsky (1986) show that trout descend the river predominantly at night. They found that between 4.00 p.m. and 4.00 a.m., 73% of salmon smolts and 84% of trout smolts moved down stream, whereas in the preceding 12 hours between 4.00 a.m. and 4.00 p.m., only 27% of the salmon smolts and 16% of the trout smolts were active. The migration rate was found to be highest between the hours of 8.00-12.00 p.m.

Mortensen, (1977d) has indicated that in the upstream areas of rivers, 80-90% of the population is made up of fish in the 0-1 year age group, whereas the proportion of trout that are 2 years old and over increases in downstream areas.

While in fresh water, trout feed on insect larvae, freshwater shrimps and worms, which explains their preference for gravel rather than muddy river beds. Once at sea, trout feed on sand eel (54%), clupeids (39%), other fish (5%) and shrimps etc. (2%) (Liewes & Fonds, 1983). Smolts travelling down to the sea via Dutch rivers, generally measure 17-20 cm long (50-80 g). After 1, 2, 3 and 4 years at sea, they would be expected to reach 30-40 cm (250-600 g), 50-60cm (1250-2200 g), 60-70 cm (3 kg) and 70-80 cm (3.5-5.5 kg), respectively. After two years, most of the sea trout are sexually mature.

The production of salmonids has been shown to vary between 0.1 and 55 g/m^2 /year (Craig, 1982; Kalleberg, 1958; Le Cren, 1961, 1973; Mortensen, 1977 a, b, c, 1979). From a nominal 800 eggs, 750 alevins would be expected to emerge (94%), which would give rise to 20 1-year-old fish (2.7% survival rate). Assuming 50% mortality, 10 fish would remain after 2 years, and 5 fish after 3 years. A 40% survival rate in the subsequent year, would mean that 2 4-year-old trout (one male, one female) would be left to spawn and produce 8000 fertilised eggs.

In contrast to the migratory behaviour of salmon, sea trout generally remain closer to the coast. Most of the trout leaving Dutch waters head northwards (Svärdson & Fagerström, 1982) and stay within 100-350 km of the coast. Liewes and Fonds have correlated the length and weight of trout caught off the coast of Texel. They found that 10 cm was equivalent to 8 grammes; 20 cm to 71 g;

30 cm to 251 g; 40 cm to 617 g; 50 cm to 1240 g; 60 cm to 2191 g; 70 cm to 3546 g; and 80 cm to 5381 g. Although these data can serve as a useful guideline, it should be borne in mind that trout often vary considerably in appearance and size.

2. HISTORICAL DEVELOPMENT

The first Dutch publication on sea trout in the Rhine basin is that of Hoek (1893). At the time, marine biologists were unaware of the fact that brown trout and sea trout are variants of the same species. Fishermen were convinced of the inherent differences between these fish and likened sea trout to salmon. Catches of sea trout landed at Kralingse Veer between 1886 and 1891 averaged 594 per annum. The distribution over the year was typically: J-20; F-22; M-31; A-46; M-29; J-13; J-29; A-96; S-146; O-114; N-4; and D-44, showing that the period between August and October was the most productive.

Compared with salmon catches, the numbers of sea trout caught in the River Rhine were relatively small. Hoek (1893) commented: "Es werden verhältnismassig wenige Meerforellen bei uns gefangen; selbst in einem guten Lachsjahr schwerlich mehr als tausend Stück". The sea trout caught at the time had an average length of 50 cm and weighed approximately 1 kg. Data from 1919 indicate a shift in the period over which the highest trout catches were recorded to the month of May and the period September-November. The significance of this finding is, however, difficult to assess. In autumn, ripe and sexually immature sea trout ascend the river, only to leave in the following April and May. The timing of these movements has much in common with those of the salmon. The catching of sea trout throughout the year would imply that the ascent of the river, which starts in May/June, continues until January/February. Similarly, the descent of the river, which commences in January/February lasts until May/June.

The fact that a significant proportion of sea trout that are landed never appear in the fisheries statistics is not new. As early as 1920, officials noted that many of the sea trout caught were not sold at market and therefore not included in the catch statistics. Nevertheless, using information from Hoek and catch figures from the Fisheries Inspectorate, which later became known as the Fisheries Division and the Department of Fisheries, estimates can be made of the number of trout landed between 1886-1986 (Fig. 2.1, Table 2.1).

Reference to Figure 2.1 shows that annual trout catches over this period varied considerably, but that no evidence can be found to suggest that there has been a systematic decline in numbers. However, Van Ruremonde (1988), in reviewing the changes that have taken place in the fish population in Dutch rivers over this century, claims to have been able to detect such a decline in the Rhine. Whether this claim is justified is debatable since the basis of comparison is not the same. For instance, the number of fishermen operating in the 1960s was only a fraction of those active in the first thirty years of this century. Moreover, attempts by the former Association of Sport Fishing and Professional Inland Fisheries to quantify the trout population by sampling with trawl nets have proved to be futile. In a rider to the 1983 report published by this group, it was stated that because of the clear water conditions, catches were too small to be representative. The sampling method chosen was also felt to be inappropriate in view of the distribution of fish over the lower reaches of the river. Moreover, choosing the correct time for such sampling operations is particularly important. Sea trout generally travel at night and spend the day in the quiet, still waters of inlets and shallows.

Reports from professional fishermen are too infrequent to allow firm conclusions to be drawn about trout stocks, but do provide an indication of the continuing presence of trout in the river. In 1987, for instance, the following data were collected: on the River Amer, 1 salmon (4.25 kg) and 1 sea trout; on the Rhine near Spijk: 2 sea trout; on the River Maas (Belfeld): 2 salmon (one of which 46 cm long) and 2 sea trout; at the Hollands Diep: 3 sea trout (12 cm). As trout swim relatively quickly and fishing gear does not always close off the river completely, the majority of fish can often avoid being caught.

The action that has most affected the sea trout and other migratory fish in the Rhine is the closure

of the sea inlets in the southwest of the Netherlands. It is therefore particularly important to assess to what extent fish can negotiate the barriers that have been erected.
The positioning of extremely large nets across the watercourse during the day and at night in the right season could provide a direct answer this question. The fact that trout still appear in Dutch waters, particularly in the Lake IJsselmeer, could be due to restocking operations.

In other countries, both brown and sea trout are regularly released into the local river systems. Richard (1988) and Tisser (1987) have described restocking operations in the French rivers Orne and Touques, respectively. Tisser has pointed out that of the 4600 trout released, 10% were brown trout. The target density chosen for the exercise was 25 fish/10 m^2, with 0+ and 1+ fish making up 90% of the stock (Phillipart, 1987).

Anglers' clubs in Belgium, the south of the Netherlands and Germany have released trout into local rivers for many years. However, it is not always certain that all the fish that are released will remain in the area. After a number of years, some of the trout could migrate to the sea.
The presence of trout in a section of the Maas, the Grens Maas (the Netherlands), and in the belgian section can, for instance, be explained either by fish that have been released into the river or crosses with sea trout, the hybrid of which only migrates to the sea once (Phillipart 1987, 1988). The converse is also true if sea trout are released into river systems. Tisser (1987) has revealed that up to 10% of the sea trout released in a recent trial did not subsequently migrate to the sea.

The presence of sea trout in the IJsselmeer could be due to trout entering via the rivers Rhine and IJssel that decide to remain in the vicinity of the power station on the lake side. However, it is also plausible that sea trout enter via the sluices in the Barrier Dam at Kornwerderzand and Den Oever. The fact that intensive trout fishing is only practised on the lake and not in the rivers is not sufficient justification for assuming that trout are only present in large numbers in the IJsselmeer and that this serves as a catchment area for trout. At present, there are far too few data about the presence of sea trout in rivers to draw firm conclusions on this matter.

Thorpe has proposed a hypothesis, which can be used to explain the migratory behaviour of trout and in particular to help clarify why such fish are present in Dutch coastal waters and inland waterways (Rhine and Maas) as well as in Belgium and Germany (Thorpe, in preparation).

Over the years, many researchers have remarked on the lack of significant differences between brown trout and sea trout. Although Day (1887) was convinced of the existence of various species of trout, he did concede that the differences were sometimes unclear. In his book, Day also quotes the opinions of W. Anderson-Smith (pp. 173-174, note) who viewed matters differently and was of the opinion that sea trout mixed with brown trout, but then went on to say: "....., while we could not find a single point of specific distinction between the silvered specimens amongst the shoals of sea trout and their dark coloured congeners in the burns." ..... "We have also taken in certain streams fishes which we should have called sea trout for their complete absence of silver colouring, the markings pointed to them as bull trout. Those we are disposed to consider sea trout that have remained long in fresh water, and lost their silver coat, as the *Salmo fario* acquires it in salt water".

Thorpe's hypothesis is based on the existence of an "archetypal" salmonid, a sea fish that travels to fresh water to spawn because this offers its offspring the best chance of survival. After spawning, the adult fish returns to the sea. As a pelagic species, this fish is silver-coloured to give it the best protection against predators.

In general, the primary aim of fish is procreation and the earlier this can occur the better. Although a certain size is essential for spawning further growth is not necessary. If fish are forced to choose between growth and reproduction, they will always choose the latter. Should reproduction not be

possible at that time the fish will continue to grow until the opportunity to spawn is once more presented.
This type of behaviour is typical, for instance, of 1 sea winter salmon (grilse), 2 sea winter salmon or multi sea winter salmon.

Further specialisation of the archetypal salmonid has enabled it to adapt to fresh water. A silver colour is a disadvantage in such situations as it makes the fish more conspicuous. Its colour therefore becomes darker effectively camouflaging it for the freshwater environment.
Provided that the conditions are favourable throughout the year until the next spawning season (i.e. sufficient food, correct temperature etc.), it is not necessary for the fish to leave fresh water for the sea. Precocious male parr and landlocked salmon exhibit this type of behaviour, as do brown trout. Only when the environmental conditions in the river or the food supplies are insufficient are such salmonids forced to leave fresh water. At that moment in time, not only must the brown colouring be changed but physiological adaptations are required for the salmonid to survive in salt water. The urge to migrate manifests itself and the fish reverts to its silvery archetypal colouring. Once the fish enters the marine environment, it becomes a fully adapted sea fish and the process of smolting is complete. The growth function predominates until a "window" of choice occurs. Should the fish opt to reproduce, it must return to fresh water.

Thorpe's hypothesis is supported by experiments carried out by Zalewski in 1985 in Poland. "Brown" trout from a lake in the Tatra region, which has been landlocked for many thousands of years, were released into lakes that form part of the Vistula river system. These lakes support their own trout populations that are known to migrate to the Baltic Sea if the supply of food falls below a certain level. It was shown that not only did the local trout population transform into silver-coloured sea trout, but that the imported Tatra trout also underwent the same changes and subsequently made their way to the Baltic Sea. This shows that even though these trout had been isolated for thousands of years they had not lost the ability to undergo the basic behavioural transformation.
Further corroborative evidence was forthcoming from experiments whereby Newa salmon (Leningrad, Baltic Sea, USSR) were transferred to South Norway. Normally, after descending the river, Newa salmon remain in the brackish coastal waters of the Baltic Sea for a period of three years before migrating to Greenland. They can therefore be classified as 6 sea winter fish. However, the salmon that were transferred to Norway as fry from the Newa showed identical behaviour to that of the indigenous population by returning to Norwegian waters as either 1 or 2 sea winter fish.

Thorpe's hypothesis places the occurrence of sea trout in the Rhine and Maas in a different light. Sightings of silver-coloured trout in Nordrhein-Westfalen or in the Maas can no longer be taken as proof that trout have swum upstream from the sea. These fish could equally well originate from brown trout populations and have been forced to leave their environment because of insufficient food supplies or inadequate conditions.

Similarly, the presence of sea trout in the lower reaches of the rivers Maas, Lek, Merwede or in the Rhine-Maas-Scheldt estuary cannot be viewed as conclusive evidence that these fish are intending to ascend the river. In contrast to the behaviour of the salmon, young sea trout often undertake what are known as "dummy runs". Sexually immature trout that inhabit coastal waters often accompany their sexually mature counterparts some of the way up the river before returning to the sea.

Although it is generally agreed that trout enter Dutch rivers from the sea, it is difficult to establish to what extent this occurs. The irregular catch statistics merely provide an indication of such movements. Only by using electrophoretic techniques or by demonstrating the presence of specific marine oils in the fatty tissue of fish caught in the upper reaches of the Maas and Rhine will it be possible to show that trout still ascend these rivers from the sea.

3. FUTURE PERSPECTIVE

The water quality requirements for trout are comparable with those given in the atlantic salmon report (Report 1989-11). The threat to the purity of salmon stocks that rearing operations pose is not considered to be a serious problem for trout as these fish are not farmed in this way. Gjedrem & Gunnes (1978) have pointed out that the slow growth rate of trout makes them less attractive than salmon for commercial fish farming. In addition, sea trout are more susceptible to disease than salmon and are more difficult to protect against infection (Mills, 1984).

4. ASSESSMENT OF FUTURE PROSPECTS

At this moment in time, it is not possible to say with any degree of certainty whether the sea trout population in the Netherlands has declined over the last hundred years. Catch statistics are unreliable for estimating the size of current stocks now that professional fishing activities have ceased along the river. Today, anglers catch many of the sea trout that in the past would have been caught by professional fishermen. Although knowledge of these matters is rather fragmentary, most experts agree that trout entering the Rhine on their return from the sea do not spawn in Dutch waters. The same is also true for trout in Belgian and German rivers, where the occurrence of silvered trout can be explained using Thorpe's hypothesis. The presence of trout in the IJsselmeer could be connected with releases of trout in the Rhine basin, but could also be explained by trout from the Waddenzee entering the IJsselmeer when the sluices are opened to control the water level in the lake. In certain parts of the Netherlands indigenous brown trout are still to be found, more particularly in the IJsselmeer. Sea trout are also caught on a regular basis in Dutch coastal waters. However, the origins of these fish are largely unknown. In view of the tendency of trout to stray, it is quite plausible that these fish have come from France, Denmark and Northern Germany.

5. RECOMMENDATIONS FOR FURTHER STUDY

It is recommended that:

- the impact of hydraulic engineering works in the southwest of the Netherlands on the movements of salmonids, such as the trout should be studied. Particular attention should be paid to how structures such as the Haringvliet Locks, affect the trout's ascent and descent of the river and whether modifications could be introduced to lessen the harmful effects to the fish population;
- the influence detergents can have on the sense of smell of sea trout should be investigated in parallel with a similar study on salmon;
- genetic research should be conducted to determine the origins of particular trout. This type of study is to be preferred to tagging experiments, which, considering the small numbers involved and the limited survival rate, would be less suitable. Although experience with this type of research is not readily available in the Netherlands, such methods are already widely used in France, Ireland, Norway and West Germany;
- attempts should be made to detect the presence of specific marine oils in trout found in the upper reaches of the Rhine and Maas in the Netherlands, Nordrhein-Westfalen and the Ardennes to prove that trout still ascend the river system from the sea.

6. REFERENCES

Craig, J.F., 1982. A note on growth and mortality of trout, Salmo trutta L., in afferent streams of Windermere. J. Fish Biol. 20: 423-429.

Day, F., 1887. British and Irish Salmonidae. London, Edinburgh. Williams and Norgate, pp. 173-174.

Elliott, J.M., 1984. Numerical changes and population regulation in young migratory trout, Salmo trutta in a Lake District stream, 1966-83. J. Anim. Ecol., 53: 327-350.

Frost, W.E. & M.E. Brown, 1967. The trout. New Naturalist, especially Vol. 21 London, Collins. p. 286.

Gjedrem, T. & K. Gunnes, 1978. Comparison of growth rate in Atlantic salmon, pink salmon, Arctic char, sea trout and rainbow trout under Norwegian farming conditions. Aquaculture, 13: 135-141.

Hay, D.W., 1984. The relationship between redd counts and the numbers of spawning salmon in the Girnock burn (Scotland). ICES C.M. 1984/M: 22, 4 pp.

Hoek, P.P.C, 1893. Über die Meerforelle des Rheingebietes. Z. f. Fisch. 1: 3-20.

Jones, G.W. & J.N. Ball, 1954. The spawning behaviour of brown trout and salmon. British J. Anim. Behav. 2: 103-114.

Jones, J.W., 1959. Specific characteristics and hybrids; Appendix 1, in: The salmon, New Naturalist,especially Vol. 16. London Collins, pp. 153-156

Kalleberg, H. 1958. Observations in a stream of territoriality and competition in juvenile salmon and trout (Salmo salar L and S. trutta L.). Rep. Inst. Freshw. Res. Drottningholm, 39: 44-98.

Le Cren, E.D., 1961. How many fish survive? Yearbook Riv. Bds. Ass. 9: 57-64.

Le Cren, E.D., 1973. The population dynamics of young trout (Salmo trutta) in relation to density and territorial behaviour. Rapp. P. v.-Réun. int. Explor. Mer. 164: 241-246.

Leonko, A.A. & A.G. Chernitsky, 1968. Comparative analysis of smolt migration of Atlantic salmon, Salmo salar, and sea trout, Salmo trutta. Voprosy ikhthiologii 26(5): 795-801.(Journal of Ichthyology 26(5): 113-120).

Liewes, E. & M. Fonds, 1983. De zeeforel, zijn biologie en betekenis voor de kust- en binnenvisserij. Rapport Centrilab. b.v. Soest p. 13 (mimeo).

Mills, C.P.R., 1984. The results of a questionnaire on sea trout (Salmo trutta L.) rearing techniques in Europe. ICES C.M. 1984/M: 2, p. 11.

Mills, D.H., no date. Atlantic salmon facts. The Atlantic Salmon Trout (Pitlochry), 24 pp.

Mortensen, E, 1977a. The population dynamics of young trout (Salmo trutta L.) in a Danish brook. J. Fish Biol., 10: 23-33.

Mortensen, E, 1987b. Population, survival, growth of trout (Salmo trutta L.) in a small Danish stream. Oikos, 28: 9-15.

Mortensen, E, 1977c. Density dependent mortality of trout fry management of small streams. J. Fish Biol., 11: 613-617.

Mortensen, E, 1977d. Fish production in a small Danish stream. Folia Limnol. Scand., 17: 210-26.

Mortensen, E, 1979. Population dynamics regulation and production of stream salmonids. In: The use of ecological variables in environmental monitoring. The National Swedish Environment Protection Board. Report PM/151: 220-227.

Nijssen, H. & S.J. de Groot, 1987. De vissen van Nederland. Natuurhistorische bibliotheek KNNV, Vol. 43, Hoogwoud, KNNV, pp. 107-108.

Phillipart, J.C., 1987. Histoire de l'extinction et problématique de la restauration des salmonidés migrateurs dans la Meuse. In: Restauration des rivières à saumons. eds. M. Thibault & R. Billard, Paris INRA, 125-137.

Phillipart, J.C., 1988. Fish and their environment in large European river ecosystems. The River Meuse. Sciences de l'Eau, 7(1): 115-154.

Richard, A., 1988. The stock restoration of Orne, river migratory salmonids (Low Normandy France). EIFAC Symp. on Management Schemes for Inland Fisheries. Göteborg, Sweden, 31 May-7 June 1988, pp. 211.

Ruremond R. Van, 1988. Veranderingen van de visfauna in het Nederlandse rivierengebied, een historisch overzicht, Doctoraal scriptie 87, March 1988. Lab. Aquat. Oeco. Kath. Univ. Nijmegen/RWS-DBW/RIZA, p. 9 (1-65).

Shearer, W.M., 1955. "Homing Instinct" in Sea Trout. Nature, 176: 171-172.

Stuart, T.A., 1953. Spawning migration, reproduction and young stages of Loch trout (Salmo trutta L.). Sci. Invest. Freshw. Fish. Scot. 5: 1-39.

Svärdson, G. & A. Fagerström, 1982. Adoptive differences in the long-distance migration of some trout (Salmo trutta L.) stocks. Inst. Freshw. Res. Drottningholm, Rep. No. 60: 51-80.

Thorpe, J.E. (in preparation). Sea trout: an archetypal life history strategy for Salmo trutta L. In: Sea Trout Symposium, Oban, Scotland, June 1987. Eds. W.M. Shearer & M. Ricker.

Tisser, J. 1987. Restauration d'une rivière à truites de mer, la Touques. Perspective d'avenir. In: Restauration des rivières à saumons. eds. M. Thibault & R. Billard, Paris INRA, 387-392.

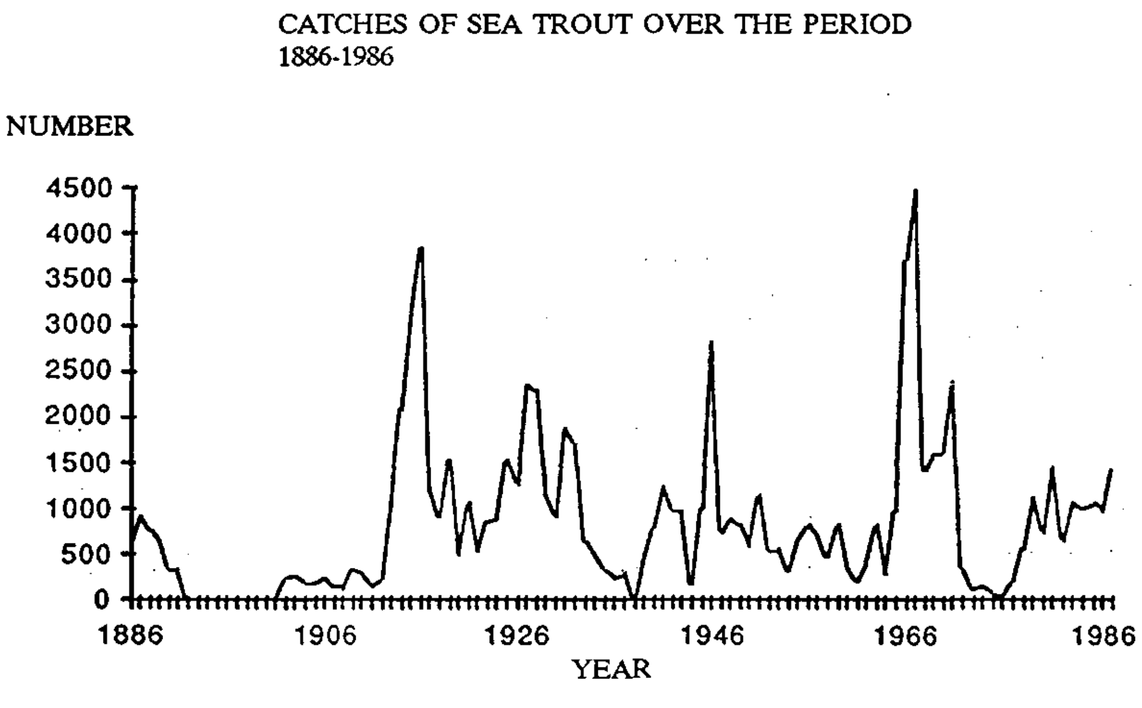

Fig. 2.1 Catches of sea trout over the period 1886-1986 (data not available for 1892-1901)

		AANVOER ZEEFOREL					
JAAR	AANVOER		JAAR	AANVOER			
1886	612		1937	300			
1887	912		1938				
1888	765		1939	450			
1889	644		1940	800			
1890	338		1941	1225			
1891	312		1942	975			
1892			1943	950			
1893			1944	175		JAAR	AANVOER
1894			1945	1000			
1895			1946	2800		1946	105
1896			1947	750		1947	178
1897			1948	900		1948	716
1898			1949	825		1949	679
1899			1950	600		1950	486
1900			1951	1150		1951	538
1901			1952	542	KG		
1902	233		1953	566	KG		
1903	266		1954	331	KG		
1904	179		1955	657	KG		
1905	176		1956	821	KG		
1906	257		1957	703	KG		
1907	145		1958	467	KG		
1908	129		1959	815	KG		
1909	347		1960	373	KG		
1910	294		1961	221	KG		
1911	168		1962	421	KG		
1912	233		1963	817	KG		
1913	1082		1964	292	KG		
1914	2086		1965	989	KG		
1915	3098		1966	3707	KG		
1916	3845		1967	4484	KG		
1917	1212		1968	1415	KG		
1918	912		1969	1588	KG		
1919	1527		1970	1606	KG		
1920	500		1971	2373	KG		
1921	1050		1972	335	KG		
1922	525		1973	124	KG		
1923	850		1974	153	KG		
1924	900		1975	82	KG		
1925	1525		1976	49	KG		
1926	1275		1977	213	KG		
1927	2350		1978	568	KG		
1928	2275		1979	1123	KG		
1929	1150		1980	755	KG		
1930	925		1981	1442	KG		
1931	1875		1982	664	KG		
1932	1700		1983	1072	KG		
1933	650		1984	1002	KG		
1934	500		1985	1053	KG		
1935	325		1986	976	KG		
1936	250						

Table 2.1 Catches of sea trout over the period 1886-1986 (data recorded on a weight basis 1946-1986 and in terms of numbers 1886-1891 and 1902-1951).

(Source: Hoek, 1983 - Fisheries Inspectorate, Fisheries Division, Department of Fisheries)