ATLANTIC SALMON TRUST

SALMON IN NORWAY

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SALMON IN NORWAY

by

Lars P. Hansen and Gordon H. Bielby

INTRODUCTION

This booklet has been written to provide an introduction to the enormous and fascinating subject of salmon in Norway. As such it is intended to find its natural niche in the ever-growing and popular series of 'Blue Books' produced by the Atlantic Salmon Trust.

The author of the booklet has been Lars P. Hansen who is a well known Norwegian salmon biologist currently working out of Trondheim, Norway for the Direktoratet For Naturforvaltning. The contribution of Gordon H. Bielby, who is a member of the Council of the Trust, has been merely editorial since he knows nothing about salmon in Norway except what he has now learned from his good friend Lars P. Hansen.

ACKNOWLEDGEMENTS

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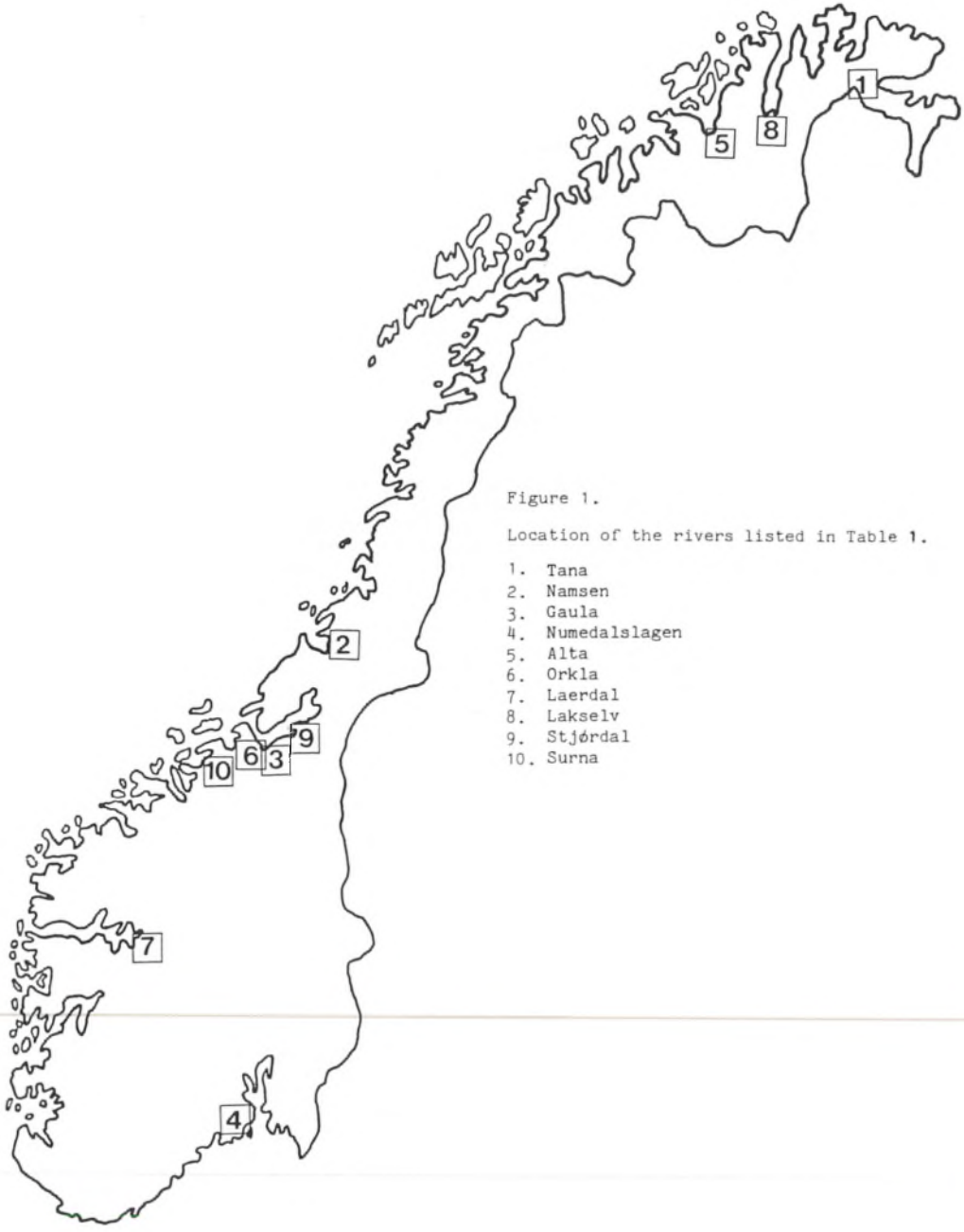


Figure 1.

Location of the rivers listed in Table 1.

1. Tana
2. Namsen
3. Gaula
4. Numedalslagen
5. Alta
6. Orkla
7. Laerdal
8. Lakselv
9. Stjørdal
10. Surna

THE RESOURCE

In Norway today there are between 400 and 500 rivers and streams populated by Atlantic salmon. The annual salmon yield from these waters varies from many tonnes to a few hundred kilos. Table 1 shows the yields of salmon, sea trout and anadromous char from ten of the best rivers in Norway for the period 1980-1985. Except for the River Tana and the River Numedalslagen where there are still some net fisheries all salmon caught are taken on rods. In principle only rod fishing is allowed in Norwegian salmon rivers. There are only a few exceptions. The locations of the rivers featured in Table 1 are shown in Fig. 1.

The most important salmon river in Norway is the River Tana with its many tributaries which are also inhabited by salmon. A large part of the river system forms the border with Finland. There is also a very important salmon fishery on the Finnish side. In total about 900 km of river is available for salmon. This is exceptional in Norway; most rivers have much smaller salmon producing areas which results in lower production and some of the relatively low yields shown in Table 1. For the rivers presented in the table, the sea trout and char component is relatively small.

Norwegian salmon rivers are highly variable in physical conditions. This has given rise to a wide variation in river stocks both in morphology and life history. Both in northern and southern Norway there are several glacial rivers in which salmon occur. These are cold, with high turbidity and low productivity. Most Norwegian salmon rivers have excellent water quality and are hardly affected by any pollution of significance for salmonids. However several very important salmon rivers in southern Norway are now seriously affected by acid rain and in a number of these the salmon have been wiped out. Several other stocks are threatened. In more populous areas and in those with high agricultural activity, some river populations have seriously declined because of eutrophication. In some rivers the salmon are also affected by wastes from industry and mines but pollution from these sources is only of minor importance. Hydro-electric power generation has also had a significant impact on a number of salmon rivers in Norway.

SALMON BIOLOGY

Each salmon river and stream is inhabited by a reproductively isolated population. This also seems to be the case between different tributaries in the larger rivers. There appears to be relatively little straying between populations. Norwegian salmon stocks are highly variable. Some small streams are inhabited by typical grilse populations, where nearly 100% of the fish are grilse weighing on average 1-2 kg. In some of these streams the size of some of the grilse can be as low as 0.5 kg. In these populations, survival from spawner to kelt is very high and, after a few months at sea, they return to their home river to spawn a second time. The larger rivers have a mixture of grilse and multi-sea-winter salmon and, in some rivers, salmon larger than 20kg are caught each year. Table 2 shows the average weight of salmon in ten of the best rivers for the period 1980-1985.

The salmon ascend Norwegian rivers and streams between May and August. In a few rivers there is an early run of large multi-sea-winter fish in April, but in most areas these fish ascend the rivers in May and early June. The grilse run reaches its peak between mid-June and the middle of July. Towards the end of the season, in August, there can be an increase in the run of larger fish.

Table 1.

Yield of salmon, sea trout and anadromous char from ten of the best rivers in Norway 1980-1985.

River	Location on Fig 1.	Yield (tonnes)					
		1980	1981	1982	1983	1984	1985
Tana	1	51.74	47.13	68.72	79.97	87.25	84.81
Namsen	2	24.50	22.19	22.17	19.22	11.12	13.60
Gaula	3	20.43	25.91	21.62	24.45	26.15	30.49
Numedalslagen	4	16.48	21.68	27.25	22.26	25.36	23.93
Alta	5	15.57	15.20	16.54	17.71	9.30	14.06
Orkla	6	14.74	13.93	5.25	6.81	13.13	14.42
Laerdal	7	12.28	10.12	9.05	12.43	8.98	8.34
Lakselv	8	9.60	6.90	9.80	4.65	3.28	2.36
Stjørdal	9	8.54	10.73	11.37	9.23	8.70	11.05
Surna	10	7.33	5.95	6.00	3.46	5.40	4.82

Table 2.

Average weight of salmon from ten of the best rivers in Norway 1980-1985.

River	Location on Fig. 1	Average Weight (kilos)					
		1980	1981	1982	1983	1984	1985
Tana	1	4.2	4.4	6.7	4.8	5.1	4.2
Namsen	2	4.4	4.2	4.6	4.9	4.9	4.0
Gaula	3	4.0	5.7	5.8	4.8	5.2	4.8
Numedalslagen	4	4.6	4.4	4.3	5.3	4.7	4.0
Alta	5	8.0	8.0	9.4	8.0	6.8	6.7
Orkla	6	4.1	6.4	7.8	5.3	4.8	4.8
Laerdal	7	7.0	7.5	6.8	7.1	6.9	6.4
Lakselv	8	8.0	7.4	9.1	7.8	6.0	5.2
Stjørdal	9	3.8	5.4	4.6	4.0	4.0	3.4
Surna	10	4.3	4.9	5.8	-	4.0	5.1

Spawning takes place mainly in October-December, being at its earliest in northernmost Norway. The eggs hatch in May-June, depending on the temperature. Most of the parr stay 2-5 years in the river before they become smolts, the youngest smolts being found in the more temperate streams in the south of the country. Rivers in the areas where the climate is extreme may produce smolts as old as seven years - as also may the glacial streams.

The production of salmon smolts in natural systems is highly variable. Based on density estimates of parr, the smolt production could be calculated to be 1-10 per $100m^2$. Some streams with excellent conditions for salmon might have a higher smolt production.

The smolt run takes place in the May-July period, being earliest in the south of Norway. Most smolts leave the river within a month. Little is known about post-smolts though stomach samples taken from smolts in the estuary and fjord outside the River Imsa, during the first few days after they had left the river, showed that aerial insects had featured in their diet. Smolt mortality is high and in some areas predation by gulls and cod is an important mortality factor.

Most Norwegian salmon feed in the north-east Atlantic although some fish migrate as far as West Greenland. There are relatively few data on their feeding habits but a study from March-June in the years 1969-1972 off the coast of northern Norway, indicated that crustaceans (euphausids and hyperiids), lantern fishes, squid and herring were important food items. On the spawning migration the feeding activity of the salmon ceases.

Atlantic salmon return to their home stream with high precision. Despite the fact that this phenomenon has been the subject of research for many years, our knowledge about the mechanisms involved is sparse.

There are few data from Norway on survival from smolts to adults but survival of grilse stocks seems to be higher than for multi-sea-winter stocks. In the River Imsa survival of wild smolts to adults has been estimated to be 20-30%. In this river a 70% survival rate, from upstream migrating spawners trapped near the mouth of the river to kelts descending in early spring, has also been observed. However, tagging experiments indicate an additional mortality of kelts soon after they have re-entered the sea. In a number of rivers, especially grilse rivers, 5-10% of the angling catch is made up of previous spawners. The grilse in these rivers will repeat spawning by leaving the rivers for the sea in early spring and returning the same year after only a few months absence until they die in the fishery or of natural causes.

THE COMMERCIAL FISHERY

Fishing for salmon has long been of great importance to the people living in those areas where the fish could be exploited. In the past, the exploitation of salmon in Norway was limited to the rivers and estuaries. However, as gear became available which could catch salmon efficiently in the fjords and coastal areas, the fishing intensity increased and at present the fisheries in these areas catch most of the salmon returning to Norway.

Many different types of gear have been used to exploit salmon. Drift nets, bend nets, bag nets and stationary lift nets are the most common legal items of gear used in salt water in Norway. Table 3 shows the number of items of each type of fishing gear annually in use since 1966 in the Norwegian home water sea fishery. It can be seen that in 1985 there were 20,329 drift nets, 1,726 bag nets, 5,848 bend nets and 34 lift nets in operation in the fishery. There were no official figures for stake nets, but these are very few in number and restricted to a small area in the south east of the country.

Table 3.

Number of items of fishing gear used in the Norwegian home water salmon fishery, 1966-1985.

Year	Seine Net	Set Net	Bag Net	Bend Net	Stationed Lift Net	Drift Net
1966			7,101		55	
1967		4,607	7,106	2,827	48	11,498(1)
1968	345	4,817	6,588	2,613	36	9,149
1969	307	3,959	6,012	2,756	32	8,956
1970	309	4,006	5,476	2,548	32	7,932
1971	288	3,980	4,608	2,421	26	8,976
1972	436	4,798	4,215	2,367	24	13,448
1973	477	5,443	4,047	2,996	32	18,616
1974	409	5,616	3,382	3,342	29	14,078
1975	349	5,877	3,150	3,549	25	15,968
1976	260	4,775	2,569	3,890	22	17,794
1977	303	4,074	2,680	4,047	26	30,201
1978	301	4,433	1,980	3,976	12	23,301
1979	-	-	1,835	5,001	17	23,989(2)
1980	-	-	2,118	4,922	20	25,652(2)
1981	-	-	2,060	5,546	19	24,081(2)
1982	-	-	1,843	5,217	27	22,520(2)
1983	-	-	1,735	5,428	21	21,813(2)
1984	-	-	1,697	5,386	35	21,210(2)
1985	-	-	1,726	5,848	34	20,329(2)

(1) Includes seine nets. (2) Number of drift nets at start of the season.

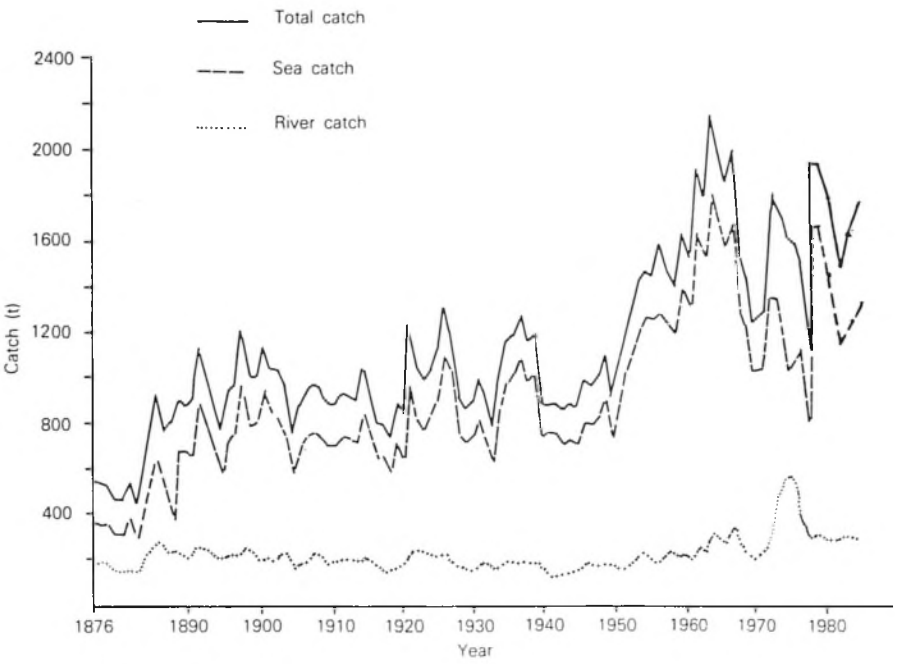


Figure 2.

Reported catch of Atlantic salmon in Norway from 1876 (Salmon caught in the Northern Norwegian Sea by Norwegian fishermen included).

Drift nets are mainly manufactured from monofilament twine and can be operated between the national baseline and the 12 mile limit. All other gear is operated inside the baseline and the materials used include spun nylon for bag nets and lift nets and monofilament nylon (mostly) in bend nets. The legal minimum mesh size is 58mm knot to knot (116mm stretched mesh) and most bag nets and lift nets have this size of mesh. The mesh size of bend nets can vary. More than 70% of drift nets have mesh sizes of 65-70mm knot to knot.

Drift and bend net fishing is permitted during the period 1 June to 5 August and bag nets and lift nets may operate from 15 May to 5 August. There is a weekly closed time for all nets extending from 1800 hours on Friday to 1800 hours the following Monday. The drift net fishermen also require a licence to operate and in 1984 a total of 623 licences were issued. The number of drift nets which can be fished per licence is restricted to 20, 35 and 50 in vessels with 1, 2 and 3 fishermen respectively. Bend, bag and lift net fisheries belong to the owners of the adjoining land and at present do not require a licence.

In Norway systematic collection of data from the different salmon fisheries began in 1876. At first fewer than 100 rivers were included and the sea fishery data were very incomplete. Although the reliability of the data has improved since that time, obtaining reliable figures still presents problems.

The country is divided into 33 salmon districts, each one with its own salmon board. The board collects data from the fishermen and summarises figures for its own district. Until 1979 all catch statistics were based on this source. After that date, drift net fishing was regulated by licence and from that time the drift net fishermen had to keep a record of their catches. These data are now sent directly to the Central Bureau of Statistics which is responsible for preparing and publishing all the catch data. The submission of catch statistics is a legal requirement under Norwegian law. Despite this the quality of the statistics is somewhat uncertain. Fishermen have to pay a tax based on catch and this could result in poor quality information or the complete lack of it in certain areas. A sample survey was carried out by the Central Bureau of Statistics in 1977. This indicated that actual salmon catches were, in most instances, higher than the figures issued by the boards. Although therefore the official statistics seriously underestimate the actual catch, it is nevertheless generally accepted that they show the fluctuations in catches and the development of the fisheries.

Figure 2 shows the river catch, sea catch and total catch of salmon in Norwegian home waters from 1876. The catches show great variations between years. Initially total catches increased, but between 1900 and 1950 catches were remarkably stable. However, from the beginning of the 1950's, the total catch increased considerably and reached a peak in the middle of the 1960's. This increase was probably due to the combination of several factors including improved catch statistics, increased abundance of salmon due to stock enhancement and an increased fishing effort. Towards the end of the 1960's catches declined despite improved statistics. The downward trend may have been caused by natural factors, but it may also indicate that a smaller proportion of the Norwegian salmon run returned to home waters because of the development of a long line interception fishery in the Norwegian Sea. In addition there is some evidence to suggest that there could have been an over-exploitation of several salmon stocks in home waters and a subsequent reduction in smolt production.

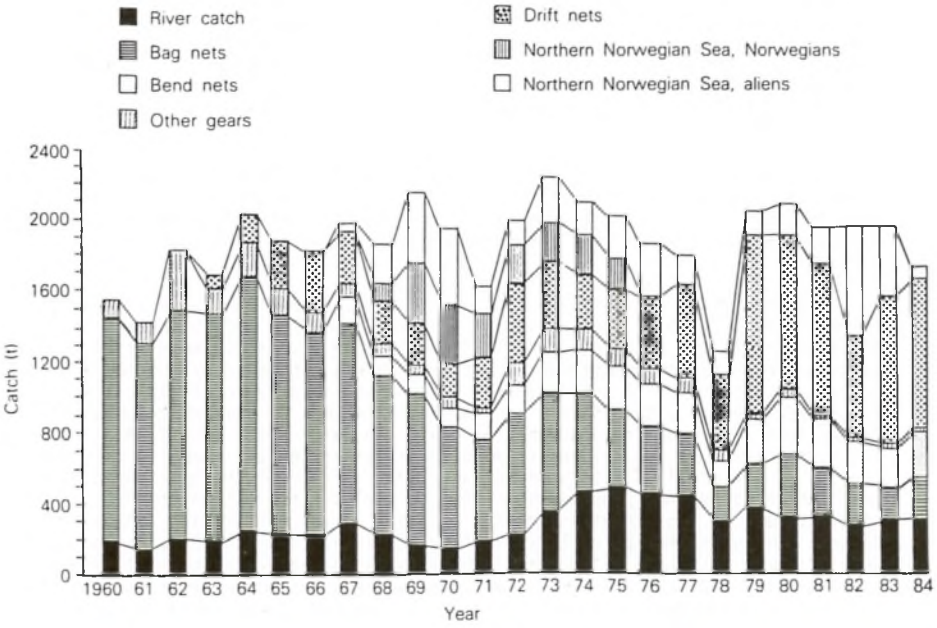


Figure 3.

Reported catch of salmon by different methods 1960-1984.

Catches by the different fishing methods are shown in Fig. 3 and this illustrates the development and decline of these methods in recent years. The decline in the bag net fishery is very pronounced as is its replacement by drift and bend nets. The reported increase in catches by drift nets after 1978 was probably partly due to the introduction of a licencing system which required log books to be kept and subsequently the resulting improvement in catch statistics.

Most Norwegian salmon populations are heavily exploited. For the rivers Laerdal and Eira in western Norway, it has been calculated that more than 80% of the salmon available to the fisheries are caught. In the River Imsa a permanent trap at the river mouth catches all descending smolts and ascending adults. Based on the tagging of wild smolts and recaptures in the different fisheries, an exploitation model on this stock has been developed taking into account several important factors such as non-reported tags, natural mortality, mean dates of capture in the different fisheries etc. This model was used on wild smolts tagged and released in the River Imsa in 1981 and Fig. 4 shows the fate of these fish. It demonstrates that total exploitation in the sea is very high and that relatively few adults survive the fishery and return to their river of origin.

As a result of the increased effort in the use of salmon nets in the Norwegian home water fishery in the 1970's an increased proportion of net-marked fish was observed in Norwegian rivers and streams. A systematic survey showed a very high frequency of the marked fish; the highest frequency was for grilse which are small enough to pass through the mesh of the netting but which are marked as they do so. In 1978, 30% and 84% respectively of grilse in the River Namsen and the River Ørsta were net-marked. For larger salmon the net-marked frequency was lower but a larger proportion of these fish is actually caught.

The effect of net damage on survival of salmon is not well known. Most of the salmon are however only slightly damaged. Some experimental work in Norway does indicate that net damage effects are greater in salt-water than in brackish water. This supports the contention that fish damaged in a high seas drift net fishery would have lower survival than those damaged in home water or river mouth fisheries.

Despite the relatively hard regulations applying to the commercial salmon fishery, it is likely that several Norwegian salmon populations are over-exploited. If optimum production is desirable, even stronger regulations have to be considered. Management of the salmon fishery should be carried out on stock level. Therefore steps have to be taken in order to reduce the mixed stock fisheries and reduce the effect of size-selective harvesting. It is important that the separate populations have a sufficient number of spawners and that these spawners are representative of the total stock.

To counter the feared over-exploitation of the stocks, the Norwegian Government, in April 1986, announced new measures to tighten control on the Norwegian home water fishery. These included:-

1. A total ban on the drift net fishery from 1989.
2. A total ban on the use of monofilament in salmon nets from 1988.
3. A licensing scheme for anchored gear from 1988.
4. A shortening of the fishing season for bag and lift nets.

It was also announced that consideration would be given to banning salmon fishing altogether in rivers where the populations were weak.

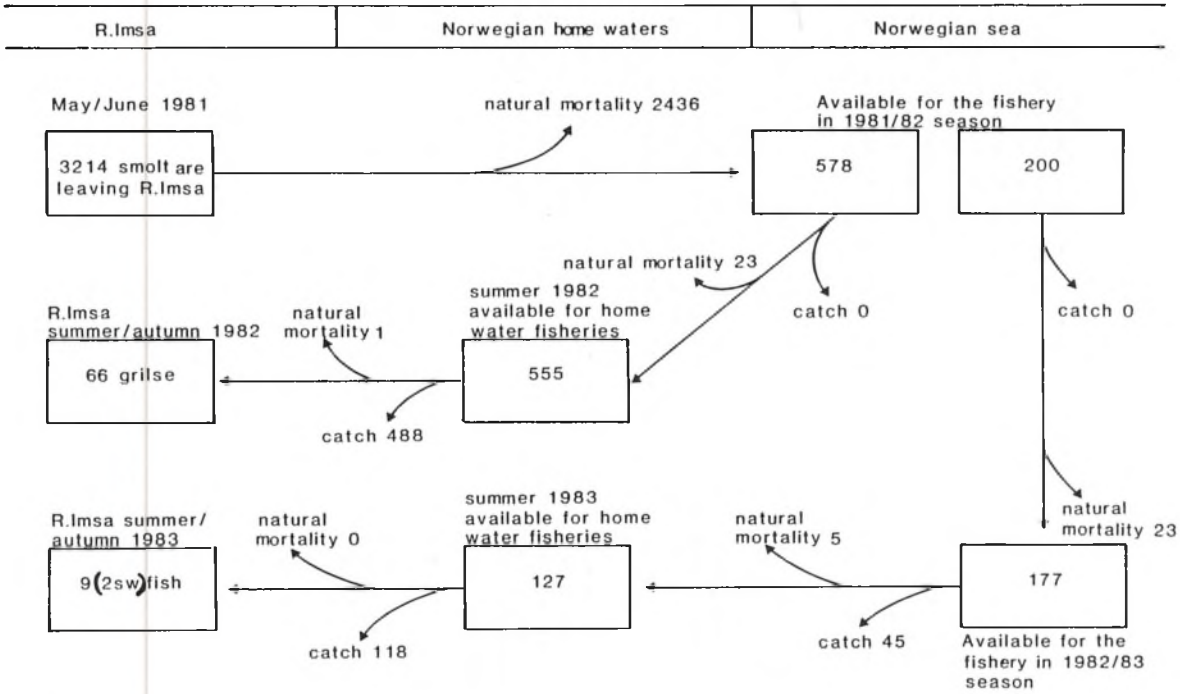


Figure 4.

The fate of 3214 wild Atlantic salmon smolts, all individually tagged, which left the River Imsa in 1981. The number of returns to the river should supply both the river fishery and spawning escapement.

THE RECREATIONAL FISHERY

Recreational fishing for salmon in Norway is mainly carried out by anglers in the rivers and streams, although there has been an increased angling effort from boats in the fjords.

Sport fishing for salmon in Norway is not very old. There is evidence that it started around 1800, the pioneers being British and Irish (Fig. 5). In Norway they discovered excellent salmon fishing. Large catches were reported back to the British Isles and during the century angling for salmon in Norwegian rivers became very popular among wealthy British people. At first the most attractive rivers were the Nidelv, Namsen, Drammen, Rauma, Tana, Stjørdal and several others. Within a few years the Norwegians themselves learned the art of angling for salmon and today this form of recreation is very popular among the local people. Every summer, anglers from all over the world come to Norwegian rivers to fish for salmon in valleys with steep mountains and beautiful scenery.

Angling in Norwegian rivers may be carried out from boats in the larger rivers or from land. In most rivers the angling season starts on 1 June but in some it may start a little earlier. The fishing season lasts till 1 September, but in a few rivers with a late run of salmon the season can be prolonged for some weeks.

Early in the season, when the river discharge is high, spoon, prawn and worm are most efficient. However, fishing with large wet flies can also give good results. Later in the season, when the water discharge has decreased and the water has become clearer, different types of fly fishing can give excellent catches.

In Norway the salmon fishing rights in the rivers and streams are owned by private landowners or by the Government. The private owners may hire their rights to small angling clubs, companies, or individuals. A number of private owners, individuals or organised groups, may also sell fishing licences to the public. The Government's fishing rights are hired for a symbolic sum of money to local angling clubs, who have to sell licences to the public at a reasonable price. Most such clubs are members of the Norwegian Association of Hunters and Anglers, PO Box 98, 1364 Hvalstad, Norway.

Table 4 shows total payments for fishing rights and fishing licences in Norway 1972-1985. The annual income is somewhat larger for the hire of fishing rights than for selling licences. The most attractive fishing rights can be very expensive but, on the other hand, angling for salmon in most Norwegian rivers and streams can be obtained at quite reasonable prices. On many rivers a day's licence could cost as little as 50-100 Norwegian kroner and in most cases no bag limits exist. In 1985 payments for fishing rights and licences exceeded nineteen million Norwegian kroner and the first-sale value of salmon caught by angling was estimated at about fourteen million Norwegian kroner. In addition to the (unquantified) recreational value, salmon angling also has beneficial and very important side effects on e.g. fishing equipment manufacturing and locally on hotels, restaurants, camping sites and so on.

Angling and trolling from boats in the fjords have expanded over the past few years. Each boat may use several spinners or spoons at the same time, but the use of fresh sprat with a treble hook at the tail-end has become very popular and is probably very efficient. This fishery, which also takes large numbers of sea trout, is open for the public between 1 June and 5 August except in Finmark County where the fishing can start on 15 May.

Figure 5.

A large number of British anglers came to Norway in the last century. Their great enthusiasm and strange equipment were now and then caricatured like this illustration from 'Ny Illustrert Tidende' in 1874.

Table 4.

Payment (1000 kr) for fishing rights and sport fishing licences in rivers 1972-1985.

Year	Fishing Rights	Fishing Licences	Total
1972	3908	1475	5383
1973	4071	1826	5897
1974	4463	2480	6943
1975	4458	2789	7247
1976	5269	3305	8574
1977	5227	3293	8520
1978	5859	3796	9655
1979	5920	4593	10513
1980	6568	5773	12341
1981	6842	7072	13914
1982	7996	6722	14718
1983	9683	6917	16600
1984	10419	7310	17729
1985	11018	8463	19481

Salmon caught in the recreational fishery may be sold, or otherwise disposed of, by their captor without restriction.

SALMON CULTURE

Salmon Enhancement

For many years there have been attempts to increase the very valuable salmon resource of Norway. In addition, attempts have been made to maintain populations suffering from pollution, over-exploitation and/or reduced production following the implementation of river regulation schemes.

It is very difficult to achieve optimum enhancement of salmon stocks. Experience has shown that it requires very extensive knowledge of the biology of the stock under consideration and its adaptation to the local environment. In salmon enhancement in Norway the local stock is now used as a basis.

In many cases strategies of enhancement where salmon are to reproduce naturally might be a better way to increase the stock than the release of fry and underyearlings. The most important and best documented enhancement measure in Norway is the construction of salmon ladders which have extended the spawning areas for adults and the feeding areas for fry and parr. In many Norwegian rivers there are now very efficient salmon ladders and the smolt production in these rivers has increased. However, there has to be very careful consideration of all aspects before salmon are introduced into areas where there are valuable brown trout stocks. This is because of the protection afforded to salmon under the 'salmon law'. Thus if, for example, salmon were to be given access, maybe by construction of a salmon ladder, to waters where they had not been before, then the salmon law would apply perhaps resulting in severe restrictions on angling for the resident brown trout. Exceptions are however possible where fishing for other species can be carried out without adversely affecting the salmon.

Planting fry

The most common method used in Norwegian salmon enhancement programmes is the stocking of unfed fry. At present 10-15 million fry are hatched annually in Norway for this purpose. The results of such stockings have been difficult to evaluate, but in very few cases have significant effects been documented. In a small stream in south east Norway, stocking 200 unfed salmon fry per $100m^2$ upstream of the natural salmon spawning areas resulted in a production of 25-35 smolts per $100m^2$. The only fish species naturally occuring in the area are brown trout and minnow. This stream is however excellent for the production of salmon smolts and the results cannot be regarded as typical for Norwegian streams and rivers. Smolt production by stocking fry in most Norwegian rivers and streams is significantly lower.

It is clear that the release of unfed fry in the presence of predators gives poor results. One way of increasing survival is to feed the fish for some time before release. This is done in several Norwegian localities where feeding facilities are available, most of the fry being fed during summer and released in the autumn as underyearlings.

Planting fry and underyearlings in lakes and tarns has been practised in Norway for many years. Planting fry in fish-free lakes in northernmost Norway has proved especially to give high survival to smolts. A controlled experiment with the release of underyearlings into a lake in the River Imsa catchment, which has dense populations of brown trout, arctic char, whitefish, eels and three-spined stickleback, resulted in 9.4% of the underyearlings released migrating as smolts. But the timing of migration of these smolts was

Table 5.

Production of salmon smolts in Norway for release 1967-1985.

Year	No. of rearing stations	Smolts <14cm	Smolts ≥14cm	Total
1967	2	22,750	134,530	157,280
1968	2	18,450	138,250	156,700
1969	2	35,000	161,540	196,540
1970	3	36,000	187,500	223,500
1971	3	95,000	135,000	230,000
1972	3	48,000	213,000	261,000
1973	3	15,000	292,000	307,000
1974	4	22,000	257,000	279,000
1975	4	-	297,000	297,000
1976	4	49,000	414,000	463,000
1977	8	17,000	407,000	424,000
1978	4	100,000	251,000	351,000
1979	5	25,900	170,500	196,400
1980	7	122,500	216,500	339,000
1981	14	109,000	289,000	398,000
1982	14	172,000	293,000	465,000
1983	14	127,000	202,000	329,000
1984	11	216,000	228,000	444,000
1985	17	211,000	225,000	436,000

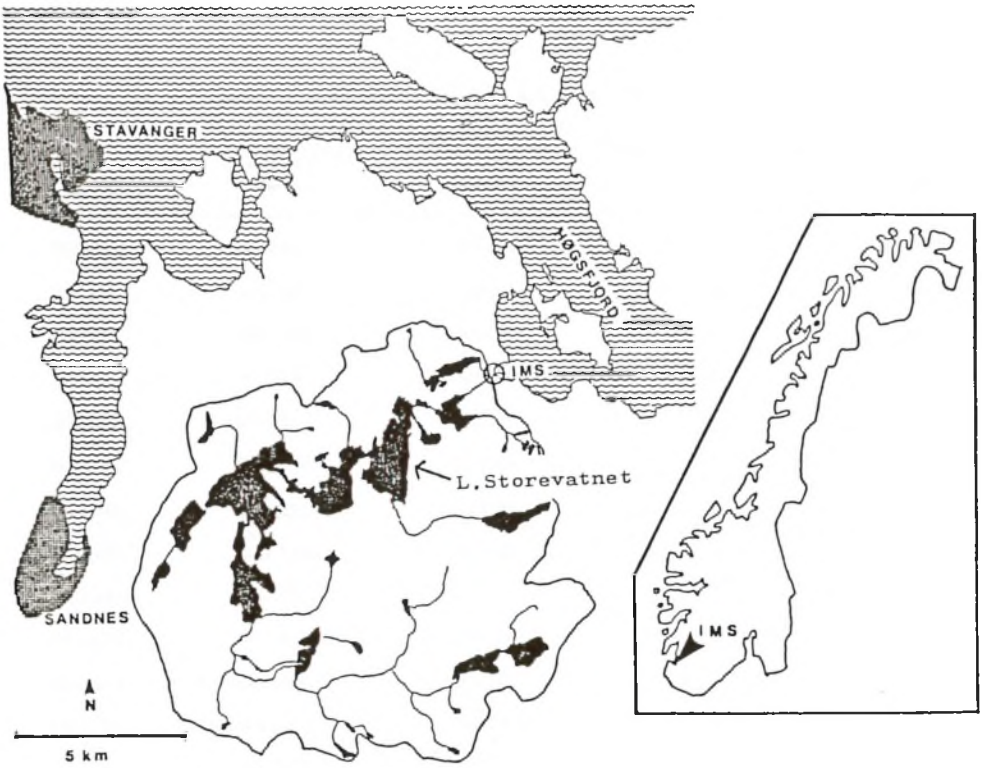


Figure 6.

The River Imsa drainage.

irregular; most descended during summer and autumn. Individual tagging of these smolts demonstrated a very poor ocean survival compared with the wild smolts in the system. The irregular timing of the smolt migration seems to be general for salmon which are stocked in lakes with a small through-put of water.

Smolt releases

In Norway, systematic releases of salmon smolts have been carried out since the middle of the 1950's. The purpose has been primarily to compensate for damage to spawning and feeding areas caused by river regulation for the generation of hydro-electric power. Table 5 shows the number of smolts released in Norway from 1967 to 1985, and at present 400,000 - 500,000 smolts are released annually. Most released smolts are 2 years of age, but a substantial number of 1 year old smolts is also released. Great efforts are made to use the local stock as breeders.

Individual tagging of large numbers of these smolts produced at three hatcheries have given average reported recapture rates between 2.5 and 3.0% of the number of smolts released which is equivalent to about 100 - 125 kg of salmon per 1,000 smolts released. But taking into consideration non-reported tags, tag loss and tagging mortality there is evidence to suggest that these figures can be doubled.

In recent years increased research effort has been put into ocean ranching of Atlantic salmon in Norway as has been done in several other countries. The main purpose has been to understand the great variations in survival from the different releases and to improve the survival and return of hatchery-reared smolts. This research requires a long period of experimental rearing and release and for this purpose there is a research station which is situated at Ims, near Stavanger in south west Norway. Within the area, there is also the River Imsa the drainage of which is shown in Fig. 6.

The River Imsa has a catchment area of 128 km^2, of which approximately 12% is lake surface. Because there are several large lakes there are no sudden floods and the flow remains relatively high even during long periods of dry weather. According to preliminary observations, the average flow is approximately 4.5 m^3/sec.

The water quality is excellent for salmonid fishes and there is no pollution of any significance to fish.

About 100 m above the river mouth a fish trap was built and started operating in May 1975. All descending smolts and ascending salmon are caught. The trap for descending fish is a Wolf trap with an inclination of 1:10. The apertures in the screen are about 10mm. The trap for ascending fish consists of a fish pass in three levels ending in a catching chamber. The water flow is controlled by a gate which is closed when the trap is to be checked.

The salmon spawning grounds are mainly in the river between the river mouth and the first lake, a distance of about 1 km. In total the natural reproduction area for salmon is very limited and the number of ascending mature salmon has varied between 39 and 119.

The first release of smolts was carried out in 1981 and annually 30,000-40,000 smolts are now released and used in many different experiments. Among these are experiments concerning selection of brood stock, age and size of smolts, smolt quality, age and maturity, growth, migration and homing. Different releasing techniques, stress in connection with handling, transport and stocking are also tested. The wild stock at Ims is used as a reference.

So far, it has been learned that smolts should be released at the same time as the natural smolt run occurs. Delayed releases have not given the improved returns that have been observed in the Baltic. Transport of smolts in a well-boat from the river mouth to the open ocean, through areas with high predation, has greatly improved the survival to adults when compared with smolts released direct into the river. However, straying increased considerably.

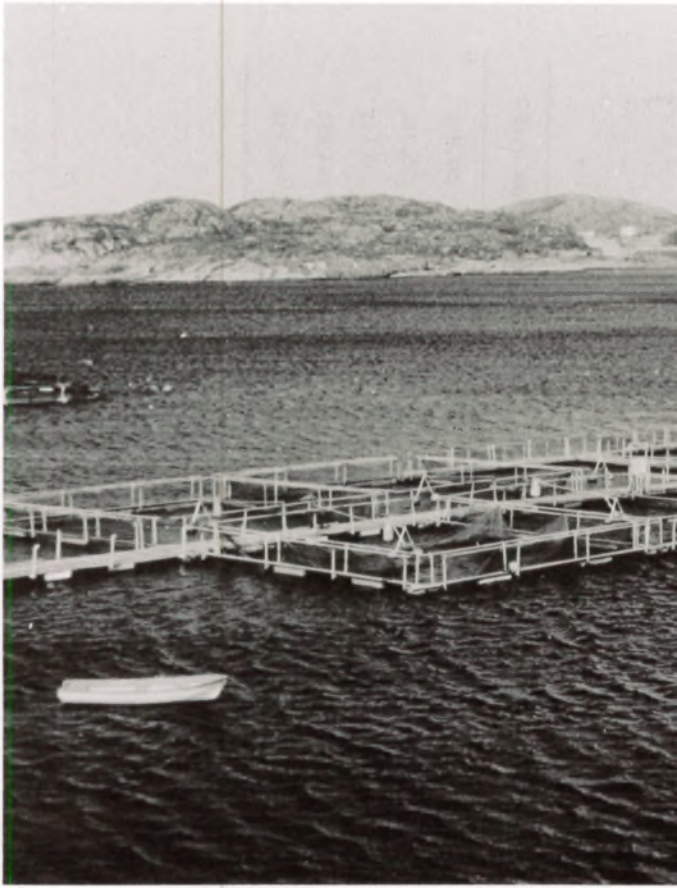
There are also important genetic differences in growth and age at maturity between stocks. This might also be the case with regard to survival. The survival and return of 2+ smolts is significantly higher than for 1+ smolts and within the 2+ smolts there is an increase in survival with increasing smolt size up to a certain limit. The biggest smolts show a reduced survival.

Private ocean ranching of Atlantic salmon in Norway is at present non-profitable, mainly because of the heavy fishing pressure for salmon in the sea, both at the feeding grounds and in Norwegian home waters. Based on smolt production costs, first sale values of salmon and the reported recapture rate of Carlin-tagged fish, the cost-benefit ratio for salmon ranching in Norway is greater than 1:1 when including the sea fishing. When non-reported tags, tagging mortality and tag loss are taken into consideration the picture seems to be more promising and the experiments carried out at Ims have shown that salmon ranching is, on average, profitable for Norway.

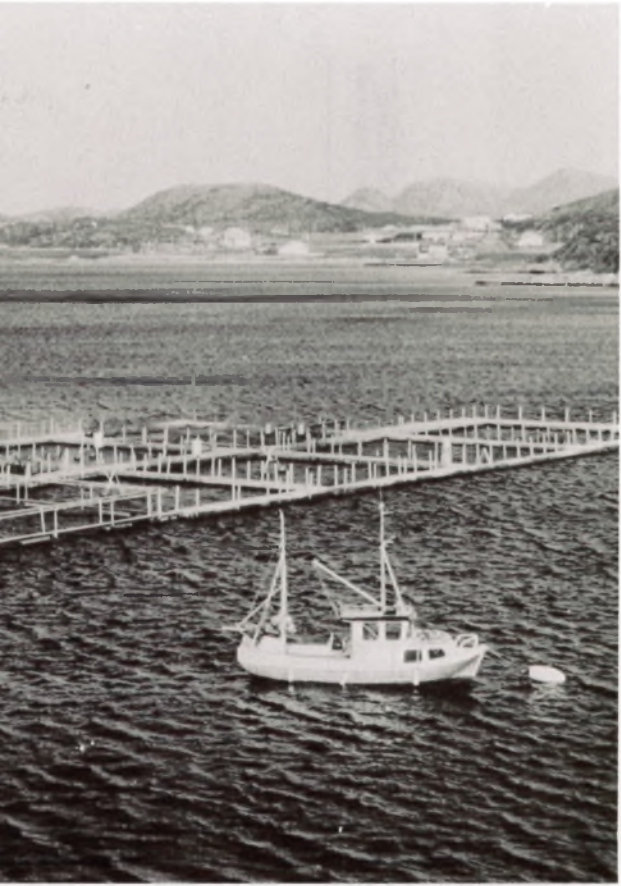
Salmon farming

In Norway, farming of salmon in sea cages developed rapidly from the 1960's and today is an enormous industry in the coastal areas. The salmon are reared to the smolt stage in fresh water and then transferred to net pens in the sea. At present the official catch of wild salmon is very small compared to the production of farmed salmon (Fig. 7) and a further increase in the production is expected. By using stocks selected for growth and late maturity and intensive feeding schemes, growth in captivity is faster than for wild fish and a skilled fish farmer can keep mortality in the pens relatively low. This may however be seriously affected by outbreaks of disease. A case in point is that of Hitra disease - named after the island where it first appeared - which has recently become a serious problem for many fish farmers causing heavy fish mortalities, especially in winter. The cause of the disease is still under debate.

The farmed product is of high quality. The slaughtering of the fish can be regulated to suit the market and the salmon are put on ice a few minutes after being killed and gutted. So far the farmed salmon have been easy to sell and most of the Norwegian production is exported. A clear indication of the size and growth of the industry is given in Table 6 and the export destination of one year's production (1984), which was worth around one hundred million pounds sterling, is given in Table 7. This table also shows how much growth there had been only one year later, in 1985. All sales of farmed salmon are controlled by the Norwegian Fish Farmers Sales Organisation (NFFSO) which has a monopoly on the trade and gives authorisation for slaughtering, processing and exporting to companies which fulfill high hygienic and other standards with regards to their handling and packing facilities. By the end of 1986, 32 companies - about half of the authorised exporters - were marking their fish with small (about 3cm) golden-coloured, metal, opercular tags bearing on one side the NFFSO logo and the word 'Superior', denoting the official top quality 'export' class of product and, on the other side, the company's own logo. Although not compulsory, more and more companies are wanting to use these tags and it is expected that in the near future virtually all official exporters will be using them.



A Norwegian salmon farm.



(photo. courtesy of Roar A. Lund).

Table 6.

Exports of Norwegian Salmon 1971-1985.

Year	Weight (tonnes) Total	Farmed Component	Value (1,000 kroner) Total	Farmed Component
1971	866	-	24,785	-
1972	1,015	-	35,242	-
1973	1,111	-	32,902	-
1974	1,215	-	30,387	-
1975	1,481	-	37,821	-
1976	1,910	-	72,539	-
1977	2,284	-	90,634	-
1978	3,664	-	129,308	-
1979	4,966	-	230,456	-
1980	4,292	-	243,065	-
Up to this year no distinction was made between wild and farmed fish				
1981	7,894	7,452	317,710	292,851
1982	9,636	9,200	422,715	395,319
1983	15,897	15,398	743,731	709,132
1984	20,365	19,643	988,499	944,831
1985	24,856	23,992	1,385,776	1,308,753

Table 7.

Destination of Norwegian Salmon Exports - 1984.

Country	Weight (tonnes) Total	Farmed Component	Value (1,000 kroner) Total	Farmed Component
France	4,562	4,414	219,932	208,865
USA	4,800	4,726	247,259	239,767
Japan	275	274	13,487	13,389
Germany, Fed. Rep.	2,760	2,669	138,960	131,079
Denmark	2,384	2,360	104,238	102,367
United Kingdom and N. Ireland	1,746	1,706	80,984	78,553
Sweden	1,083	955	57,116	50,068
Spain	787	751	36,158	34,084
Switzerland	605	563	31,052	27,357
Others	1,363	1,225	69,313	59,302
Total	20,365	19,643	998,499	944,831
		1985		
France	5,030	4,917	276,243	265,029
USA	6,740	6,552	400,490	380,577
Japan	395	385	22,341	21,431
Germany, Fed. Rep.	3,052	2,973	171,869	164,157
Denmark	2,861	2,788	138,319	135,055
United Kingdom and N. Ireland	1,914	1,853	98,705	94,892
Sweden	1,206	1,078	74,387	65,308
Spain	1,122	1,113	57,784	57,053
Switzerland	684	625	38,775	32,977
Others	1,852	1,708	106,863	92,274
Total	24,856	23,992	1,385,776	1,308,753

There have been many problems, both technical and biological, during the development of salmon farming in Norway. Many have been solved relatively quickly, but some are more difficult. Several farms are big sources of pollution and undesirable diseases have developed. Salmon are also escaping from the farms, but the possible effects of these escapees on natural populations is not known. Biologists are however most concerned about this question and research has been initiated.

The salmon farming industry in Norway has come to stay. It is moreover supported by a considerable research effort, both private and governmental, in such areas as the technical development of equipment, food, diseases, pollution, genetics and genetic manipulation. The Norwegian authorities have indicated increased input in aquacultural research in the coming years.

In the past salmon was very expensive in Norway. Now, the availability of large quantities of farmed salmon has lowered the price to the consumers and therefore contributed to reducing the profit in the commercial salmon fisheries. Salmon farming has also brought new optimism to small villages on the Norwegian coast which suffered because of the reduction in income from saltwater fisheries.

PROBLEMS

Human activities often interfere with salmon. During this century many Norwegian salmon rivers and streams have been regulated in order to produce hydro-electric power. Great damage has been done to some salmon stocks. In some streams the annual flow patterns have been altered and thus the upstream migration behaviour of their salmon has been changed. In other instances spawning and parr rearing areas have been lost, resulting in a reduction in smolt production. However, the hydro-electric companies have to pay compensation to the river owners for the lost salmon production and have to release fry, parr or smolts in order to maintain the stocks.

Most Norwegian salmon rivers have excellent water quality. However, in some rivers, particularly in southern Norway, the salmon populations have been wiped out or severely reduced because of pollution by sewage and industrial wastes. In some of the rivers the stock has only been kept alive by releasing young salmon above the original salmon producing area.

In southernmost Norway several salmon populations have been wiped out by acid rain. This represents an annual loss of about 100 tonnes of salmon. A possible connection between mortality of salmon and acid water was indicated in Norway as far back as the 1920's and further evidence has been accumulating since that time. The granitic areas of southernmost Norway were the first to be affected but the problem is expanding and at present several salmon populations on the west coast are in danger. The acidification is thought to be caused by acidic components in the atmosphere being transported across the border of Norway and then falling to the ground with the precipitation. Both alevin and smolt stages of salmon seem to be very sensitive to this phenomenon. Labile aluminium in the acid waters seems to be the most important mortality factor. In general, pH values between 5.5 and 5.0 are critical for salmon. Liming of affected waters is very expensive and is limited to but a few small river systems.

Diseases and parasites which have turned up in hatcheries and fish farms do not seem to have caused severe problems to the natural stocks so far, except in one case, that of the fluke Gyrodactylus salaris. The fluke attacks salmon parr and a very high proportion of those attacked subsequently die. It reproduces both sexually and asexually and the number of individual flukes in

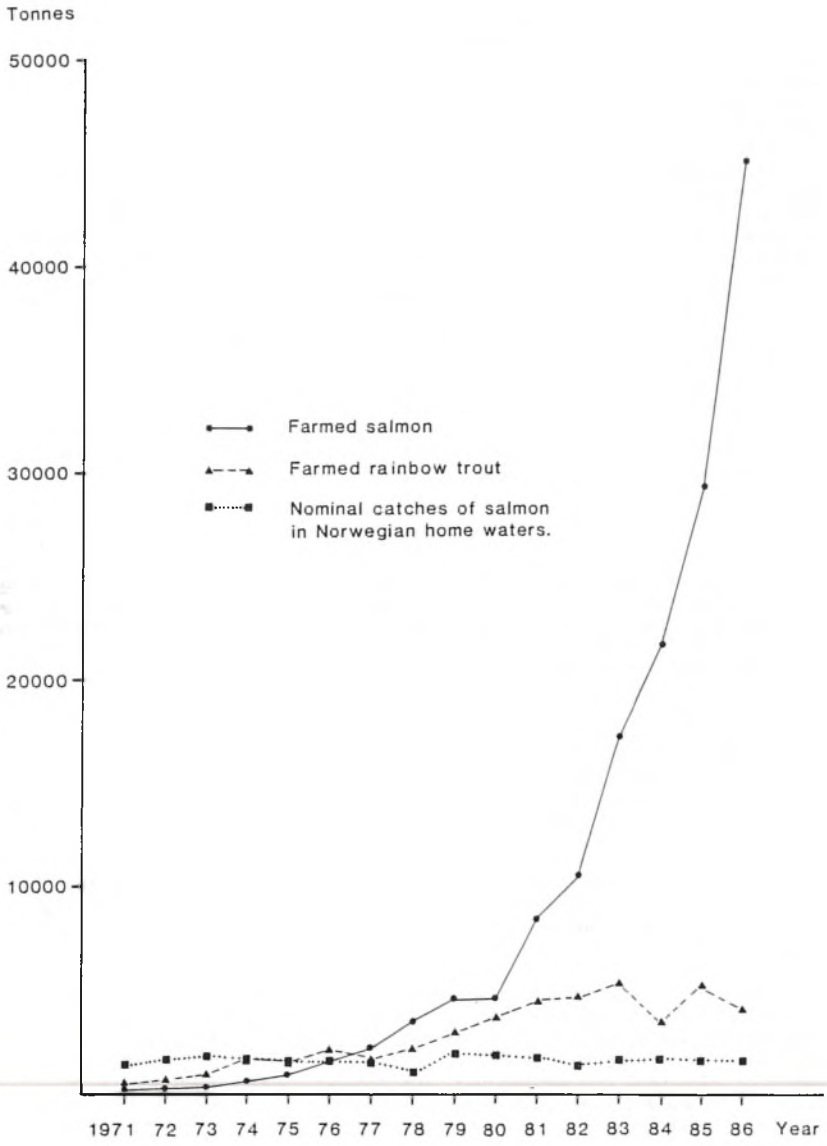


Figure 7.

Production of farmed Atlantic salmon and rainbow trout in Norway 1971-1986 compared with the nominal catches of salmon in Norwegian home waters.

an area can rise very rapidly. The fluke is probably spreading from parr to parr. This parasite was first observed in 1976 in a river in northern Norway. A survey of parr from 212 Norwegian salmon rivers and streams in 1980-1984 revealed that 28 rivers were infected. The geographical distribution of the infected rivers is correlated with releases of young fish from infected hatcheries. Parr densities in these rivers declined seriously during these years and this has resulted in a great decrease in returning adults. The annual salmon loss is estimated to 250-500 tonnes. There are strong indications that the parasite has only recently been introduced to Norwegian rivers, probably from another geographical area. The dramatic effect on the infected salmon stocks might be explained by a possible lack of resistance in the salmon parr to the parasite. The parasite has had no effect on brown trout and the sea trout populations in the infected rivers have increased. At present there is no good solution to the Gyrodactylus problem although a few small rivers have been treated with rotenone to clear out the infected parr population. In one river, the Vikja in western Norway, the parasite has disappeared. Because salt water is a barrier for the parasite there is no re-infection of the river with the returning adults from the sea.

In order to maintain and store genes from valuable and unique salmon populations the Directorate for Nature Management has recently started a gene bank, where sperm from male salmon are frozen and stored in liquid nitrogen. This sperm can be used many years later.

ADMINISTRATION

The salmon fisheries in Norway are administrated by the Directorate for Nature Management (formerly the Directorate for Wildlife and Freshwater Fish) under the Ministry of Environment. The Directorate is situated in Trondheim. In each county there is a freshwater fisheries officer to whom some of the local questions are delegated.

The salmon boards, as mentioned earlier, have an important role in collecting catch statistics. They have several other tasks such as collaborating with the local district officers and superintendents, giving recommendations on salmon questions, carrying out of salmon enhancement projects and calculating salmon tax. This tax has to be paid by all commercial fishermen and is calculated on a small percentage of the first sale value of their catch, the actual figure being decided by the salmon boards.

The local and central fishery authorities very often work in close collaboration with angling clubs, river owner associations, tourist boards, The Fishermen's Association and The Association of Landowners (in fjords and coastal areas).

The salmon fisheries are still regulated by a law passed in 1964. However, a committee was appointed in 1981 to review this law, especially the organisation and structure of the mangement of Atlantic salmon and inland fish in Norway. The committee's report has recently been published. It has made a number of important recommendations; for example, that salmon should be conserved on a population level and not as one single stock. Furthermore, a more up-to-date organisation and management structure has been proposed.

Salmon research is carried out at the universities in Oslo, Bergen, Trondheim and Tromsø, at the Agricultural University at As, at the Institute of Marine Research in Bergen and several other research agencies. Most of the salmon research in these agencies is focused on salmon farming. The Directorate for Nature Management has a Fish Research Division which works mainly with applied research on natural salmon stocks, enhancement, salmon ranching and

salmon fisheries. The Ims Research Station is a very important part of this Division. This research is mainly financed directly by the Ministry of Environment. The Directorate has also a Hydropower Research Division which is doing applied research on fishery stocks in regulated streams and lakes. This research is mainly financed by the hydro-electric companies.

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