

The Baltic salmon (*Salmo salar* L.): its history, present situation and future

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Abstract

Large-scale releases of hatchery-reared smolts in Baltic rivers were started in regulated Swedish rivers in the 1950s. From 1988 to 1992 the countries around the Baltic released an average of 5.3 million smolts per year in Baltic rivers. The salmon fishery in the Baltic has changed since the 1950s, i.e. the exploitation rate has increased, and a major proportion of the catch is taken in the offshore fishery on mixed stocks in the Baltic Main Basin. Because of the high fishing pressure, many wild stocks have declined to the extent that smolt production is only about 20% of the estimated potential production.

This paper discusses the future management of Baltic salmon. A low total allowable catch (TAC) for the offshore fishery combined with a late and variable opening date of the coastal fishery should give wild stocks a chance to proliferate. But in 1992 and 1993 a pathological syndrome, called M74, killed 70-90% of the alevins of reared Swedish Baltic salmon stocks. Recent electrofishing surveys suggest that wild stocks in the Gulf of Bothnia are also affected by the syndrome. If this is true, drastic reductions in fishery exploitation are needed to avoid the depletion, and maybe even extinction, of wild stocks.

Keywords: salmon, Baltic, M74, review, spawning run.

Introduction

This paper describes the present situation concerning the Baltic salmon stocks (*Salmo salar* L.) and the biological and historical background that can explain recent developments. Releases of reared salmon smolts to the Baltic have increased gradually for about 40 years and the wild stocks have declined to a small proportion of their original size. Only in recent years have a similar development been apparent in other areas around the world. The Baltic experience may thus give some clues to how a situation with increasing releases of reared salmon and decreasing wild stocks ought to be handled. In addition, some current problems involved in managing Baltic salmon are also considered in more detail. Two focal points concern problems with assessment of Baltic salmon stocks, because of the large proportion of reared fish, and the closely related question of management and future changes in fishery regulations. At present, however, these questions are partly overshadowed by a syndrome which is particularly a threat to the remaining wild stocks. This syndrome, called M74, is described in some detail in the last part of the paper, and suitable means for limiting its impact on Baltic salmon stocks are discussed.

Biology

Origin and history

The Baltic salmon is a geographically isolated group of Atlantic salmon populations (*Salmo salar* L.). It is likely that North Atlantic salmon first migrated into the Baltic area about ten thousand years ago as the ice cap over Scandinavia started to retreat (Lundqvist 1965). Then a connection opened between the Baltic Ice Lake and the Atlantic Ocean to the west, and the lake became a bay of the Atlantic Ocean, the Yoldia Sea. Later, when the land started to elevate, the sea became cut off from the Atlantic Ocean, and salmon in the area were isolated. The isolation from the Atlantic lasted about two thousand years, which may explain why salmon do not migrate between the Baltic and the North Atlantic today. In Swedish tagging studies of salmon smolts in the Baltic, only about 0.04% of the recaptured salmon had migrated outside the Danish Isles (Karlsson, unpubl.). Similarly, it was concluded that the migration of salmon from Kattegat and Skagerrak into the Baltic is uncommon, since less than 0.4% of the recaptured salmon that had been tagged on the Swedish west coast were recovered in this area.

Berg (1948) did not discriminate between Baltic and other Atlantic salmon populations taxonomically, but later genetic studies have confirmed that Baltic salmon form a distinct group. Ståhl (1987) compared salmon from many rivers in the Baltic and other areas by gel electrophoresis of alleles of isozymes. He concluded that salmon from Baltic populations formed a cluster that was genetically distinct from populations outside the Baltic. He also confirmed that there were significant differences between different Baltic stocks. In a couple of cases he also found significant differences between salmon from different parts of a river. His work was partly repeated by Jansson (1993) in the late 1980s and early 1990s, who confirmed the existence of subpopulations in at least one of the few investigated Baltic rivers, the River Kalix älv in the Gulf of Bothnia (Figure 1).

Life cycle of wild and reared salmon

Wild salmon spawn in September to November in rivers having rapids with coarse gravel and stones, and the fertilized eggs are buried under a layer of gravel and stones over the winter. Fecundity values from 1050 to 1500 eggs per kg female have been reported for various Baltic river stocks (Carlin & Johansson 1971, Brännäs *et al.* 1985), but fecundity is usually assumed to be in the range of 1100-1200 eggs per kg female (Christensen & Larsson 1979; H. Börjeson, Swedish Salmon Res. Inst., pers. comm.). In rivers flowing into the Baltic Main Basin the eggs hatch in March-April, while in northern rivers ending in the Gulf of Bothnia hatching occurs in April-May. The newly hatched alevins remain within the redd, where they obtain nourishment from the yolk sac for about one month. Thereafter, in May or June, the young salmon, now called a fry, emerges from the gravel where it seeks a well-protected area, often close to shore where it starts external feeding. These individuals soon establish territories which they defend. Territorial defense acts as an efficient spreading mechanism, with dominant individuals acquiring the best places (Kalleberg 1958, Norman 1987). The salmon parr habitats are found in fairly fast-

Figure 1. Baltic drainage area. Rivers and reaches of rivers supporting salmon runs in the past (thin line) and present (thick line). Adapted from Christensen & Larsson (1979).



flowing water having a bottom substratum of stones/boulders (Karlström 1977). This territorial stage during which the parr 'sit and wait' for drifting live food (Kalleberg 1958), lasts throughout the freshwater phase. In Main Basin rivers the freshwater phase lasts 1-2 years, while in Gulf of Bothnia rivers it usually lasts for 3 years, but occasionally 2 or 4 years (Alm 1934, Lindroth 1977, Karlström & Byström 1994). At the end of this period the fish undergo physiological and behavioural changes that result in a springtime smolt migration into the sea

(Kalleberg 1958, Lundqvist 1983). The smolt run peaks when the water temperature has increased to about 10°C which coincides with spring flow in the rivers, but usually slightly after the peak flow (Karlström & Byström 1994). In a southern river such as the Mörrumsån the smolt run occurs from late April to mid-June (Lindroth 1977). In northern rivers the emigration starts around mid-May and may last until mid-July (Österdahl 1969, Karlström & Byström 1994).

Eggs for artificial rearing are collected by stripping salmon in the autumn. The spawners are either caught in traps as they ascend the rivers or are kept as broodstock in the hatchery. After hatching in the spring, the fish are kept in hatcheries for two years in northern areas and for one or two years in southern areas. They are then released at the smolt stage. Reared smolts are normally larger than wild ones. For instance, the length of wild smolts in the River Mörrumsån varied from 10 to 16 cm (Lindroth 1977), and in River Torne the average length of wild smolts was between 15 to 16 cm in the late 1980s (Karlström & Byström 1994). During the same period Swedish reared smolts had a mean length of 18 cm at release (C. Eriksson, Swedish Salmon Res. Inst., pers. comm.).

For almost all salmon stocks the central and southern parts of the Main Basin constitute the main feeding area (Carlin 1969, Anon. 1992). Only River Neva salmon from the Gulf of Finland do not undergo long migration since they normally stay in the Gulf (Kallio-Nyberg & Ikonen 1992). A minor, but variable, proportion of the Gulf of Bothnia stocks stays within the Bothnian Sea, the southern part of the Gulf of Bothnia (Salminen & Kuikka 1992). According to recapture data from Finnish and Swedish tagging studies, the post-smolts migrate south along the Swedish coast, generally swimming with the weak current (Larsson & Atheskar 1979, Ikonen & Auvinen 1985), which runs counter-clockwise in the Gulf of Bothnia area. During their first period in the Baltic Sea smolts are presumed to feed on airborne insects (Lindroth 1961) but in some areas they also prey to some extent on small fish (Mitans 1970). After the post-smolts have attained a length of about 25 cm, they start eating fish, mainly clupeids (Thurow 1968). Sprat are the dominant food in the Main Basin, while herring are more common as food in the Gulf of Bothnia (Thurow 1966, Christensen & Larsson 1979).

Feeding salmon remain in the sea for 1-4 years before returning to their native rivers. They leave the southern Baltic in April-June (Thurow 1966), and Gulf of Bothnia stocks migrate at least partly along the Finnish coast until becoming close to their home river (Carlin 1969, Anon. 1992). The spawners seem to maintain a high speed while swimming towards their rivers, at least in the Gulf of Bothnia. Tagging studies of spawners reveal that migration speeds of about 40 km · d⁻¹ are common (Carlin 1969). As the salmon approach their home river their speed decreases and they seek the river mouth (Westerberg 1982). They remain at the mouth for some time where they gradually enter a new migration phase adapted to fresh water. Thereafter, they ascend the river in June-August. Wild salmon stay in the river until spawning time, but in rivers having reared salmon stocks, spawners may be caught for use as broodstock in hatcheries. Earlier, when the fishing exploitation was lower, some spawners survived to spawn a second time, but nowadays repeat spawners are rare.

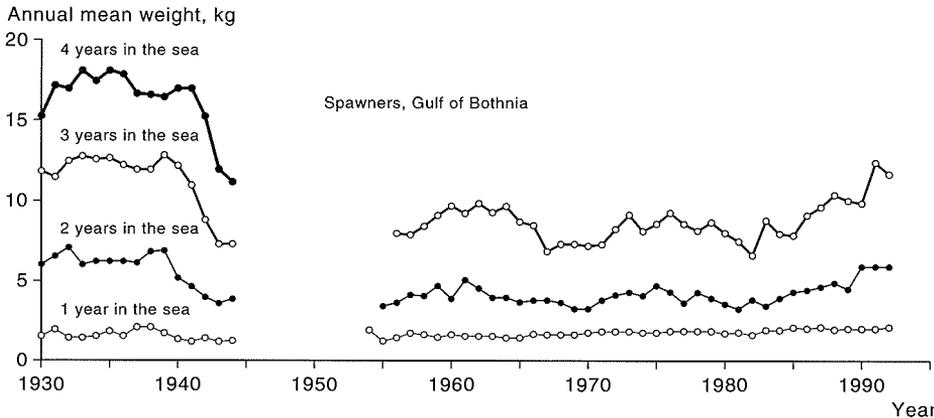


Figure 2. Annual mean weights of spawners in the Gulf of Bothnia. Values from 1930 to 1944 are based on catch statistics for the Rivers Oulu and Torne. Values from 1953 to 1992 are based on Swedish tagging records. Because of the low number of 4 year old salmon in the tagging records they were excluded from the figure.

Growth at sea

The growth pattern of Baltic salmon is well documented (Järvi 1948, Lindroth 1965, Larsson 1983). A pronounced, and prolonged, change in mean weight occurred in 1939, when the mean size at all ages diminished considerably (Järvi 1948) (Figure 2). In recent years mean weights have started to increase again and are now approaching weights recorded before 1940.

There are probably several reasons for the high growth rate observed between 1988 and 1992. The winters in recent years have been very mild, and the feeding rate of A1+ salmon in particular, has evidently not decreased in the manner observed earlier when the winters were colder (Anon. 1993a). Moreover, reared smolts leaving the rivers have been larger than in earlier years, and smolt size is a relevant predictor of future growth rate (Karlsson *et al.* 1991). The main part of the offshore catch is taken by drift-nets which are highly size selective. In recent years the drift-netting effort in the Main Basin has decreased considerably. It is probable that a reduction in effort will give rapidly growing salmon a better chance of surviving, thus resulting in higher mean growth rates. Furthermore, the abundance of sprat and herring has been very high in recent years. In 1992 the relation between growth rate and the abundance of herring and sprat in the Baltic was studied (Anon. 1992). In the final multiple regression 55% of the variation in growth rate was explained by various indicators of food availability. Since there is a considerable covariation between smolt size, winter severity and food availability, it is, of course, difficult to know how much any of these factors influence growth rate.

Development of naturally reproducing stocks

Prior to anthropogenic changes in the life cycle of Baltic salmon, it spawned in 60-70 rivers (Figure 1). About 40 of these rivers are Swedish and most of them flow into the Gulf of Bothnia (Christensen & Larsson 1979). Natural recruitment to the

Baltic was then estimated to be 8-10 million smolts (Lindroth 1965). The decline of Baltic salmon stocks started when German salmon stocks began disappearing in the middle of the 19th century. They were almost extinct by the end of the 19th century. Damming and pollution have caused a serious decline in wild Scandinavian stocks during the 20th century. The rate of this decline has been especially fast since the late 1940s, when there was a rapid expansion of hydroelectric power production in Sweden, and many of the country's rivers were dammed. This caused suitable rearing habitats for parr to disappear and decreased the accessibility of spawners to upper parts of rivers where suitable rearing habitats could be found. Conditions in Estonia, Finland, Latvia, Lithuania and Russia deteriorated in a similar way with a considerable decline during the same period or a little later. Poland lost its famed River Vistula stock in the 1960s, probably owing to pollution but salmon were still present in a few other rivers such as the River Drawa (Bartel 1976). A weak stock may still occur in this and in a neighbouring river, but there is no current information on the status of these stocks (R. Bartel, *Inl. Fish. Inst. Gdańsk, Poland, pers. comm.*).

As a result of human intervention, natural salmon smolt production has decreased from about 8 million smolts at the turn of the century to about 0.4 million at present (Table 1). Of the original 44 naturally reproducing salmon stocks in the northern rivers emptying into the Gulf of Bothnia only 12 remain in the wild. Some of the original stocks are also maintained in hatcheries. The smolt production in the northern rivers amounts to only about 20-25% of the potential production (Table 1). Low production can be attributed to the high exploitation by the fisheries from the 1950s and onwards. The situation improved slightly in the late 1980s, but there are still stocks close to extinction. For instance, River Lögde and Öre stocks produce only a few hundred or thousand smolts per year. All but two of the rivers (i.e. Åby and Kalix) have been stocked with eggs, fry, parr or smolts to supplement the natural stocks. Some of these stocking efforts have been carried out at a rather large scale.

The production of stocks in many of the rivers emptying into the Main Basin is also considerably below potential levels. Here the main reason for the low productivity seems to be the pollution-caused reduction in the quality of the spawning grounds and rearing habitats rather than overexploitation (Anon. 1993a). Most of the salmon rivers in the Main Basin are situated in Latvia, where natural reproduction occurs in about 10 rivers. Larger rivers there have been stocked with hatchery-reared smolts every year such that none of the Latvian salmon rivers have stocks of entirely natural origin. To improve conditions for natural reproduction in some of the larger rivers, some potential rearing areas have been restored.

Of the Main Basin rivers, the Mörrum seems to be the only one where the salmon stock is producing close to its maximum potential capacity (Anon. 1993a). However, there is a serious problem in this river as well, where the disease furunculosis has resulted in high mortality among spawners during the last three autumns.

To summarize, the situation for the Baltic natural reproducing salmon stocks is serious. Almost all of the stocks have suffered from various types of human activities. Some of the stocks have disappeared, a few are close to extinction, and in 1992 only one was producing at full capacity.

Table 1. Estimates of natural smolt production (thousands) by country and area in Baltic rivers having natural stocks in 1992. Swedish names of rivers in the Gulf of Bothnia are followed by potential production figures within parentheses. Based on Anon. (1993a) and A. Johlander, Regional Fisheries Office of the National Swedish Board of Fisheries, Jönköping, Sweden.

Gulf of Bothnia						
<i>Finland</i>	<i>Sweden</i>	<i>Russia</i>	<i>Estonia</i>	<i>Latvia</i>		Total
Tornio 23	Torne (500) 75	—	—	—		
Simo 17	Råne (30) •					
Kiiminki •○	Kalix (250) 75					
Pyhäj •○	Pite (150) •					
	Åby (6) •					
	Byske (60) 18					
	Sävarån (5) •					
	Rickleån (5) •○					
	Vindel (200) 20					
	Öre (5) •					
	Lögde (5) •					
	Ljungan (45) 10					
Sum of • 2	Sum of • 15					
	Sum of potential (1261)					

<i>Sum Gulf of Bothnia</i>						
<i>Finland</i> 44	<i>Sweden</i> 213					257

Main Basin						
<i>Finland</i>	<i>Sweden</i>	<i>Russia</i>	<i>Estonia</i>	<i>Latvia</i>		Total
—	Emån 5	—	Pärnu •	Irbe 10		
	Mörumsån 90			Venta 15		
				Saka 10		
				Salaca 26		
				Vitrupe 5		
				Peterupe 5		
				Gauja 20		
				Daugava 5		
				Others 4		

<i>Sum Main Basin</i>	<i>Sweden</i> 95		<i>Estonia</i> •	<i>Latvia</i> 100		195

Gulf of Finland						
<i>Finland</i>	<i>Sweden</i>	<i>Russia</i>	<i>Estonia</i>	<i>Latvia</i>		Total
Vantaa •○	—	Neva •	Kunda 4	—		
Kymi •○			Loobu 7			
			Pirita 1			
			Keila 2			
			Vasalemma 1			

<i>Sum Gulf of Finland</i>		<i>Russia</i> •	<i>Estonia</i> 15			15
<i>Finland</i> 0						

Total Baltic						
<i>Finland</i> 44	<i>Sweden</i> 308	<i>Russia</i> •	<i>Estonia</i> 15	<i>Latvia</i> 100		467

• = low and uncertain production; •○ = original stock extinct. Present production based on stocked fish.

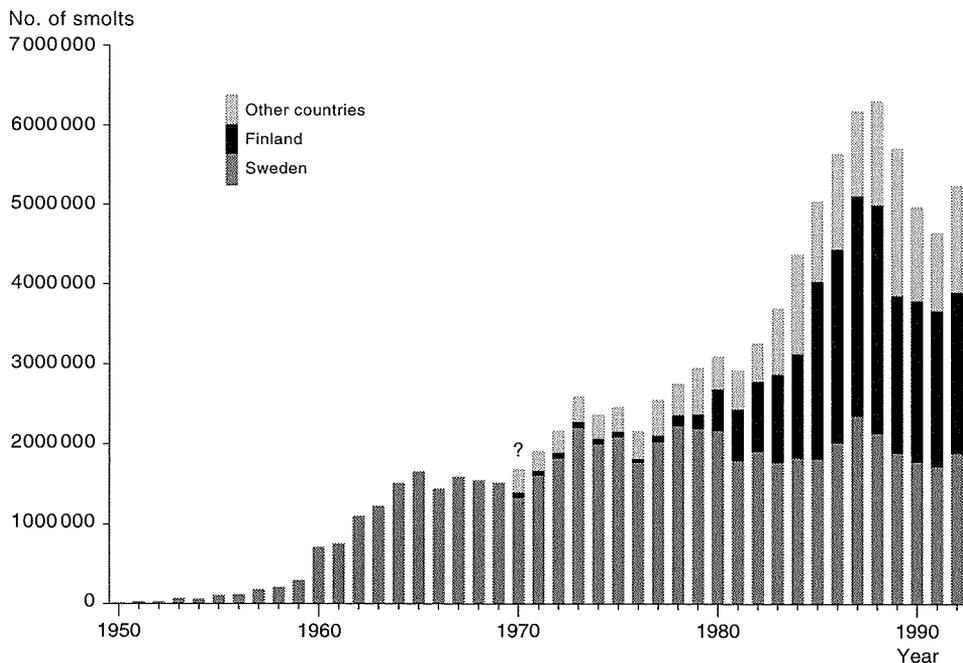


Figure 3. Releases of reared salmon smolts to the Baltic, 1950-92. '?' indicates that in 1970 release of smolts from 'other countries' was of uncertain magnitude.

Development of hatchery-reared stocks

In Sweden and other countries the artificial propagation of salmon began as early as the 1860s with stocking of alevins. From about 1930 onwards, fry were retained in ponds for autumn releases. Beginning in the late 1940s, many of the Swedish salmon rivers were dammed. In order to replace the production displaced by the hydrodams, methods for rearing salmon up to the smolt stage were developed, and the first smolt releases were made around 1950 (Figure 3). Once these were successful, fishery authorities requested, and water courts decided, that power companies had to compensate for reductions in natural smolt recruitment by artificial smolt production. It was also decided from the beginning that the different river stocks should be kept separate. For a given river, this was accomplished by only releasing smolt of the stock native to that river and by using spawners returning to the river as broodstock in the hatchery. At present, about 2 million smolts are introduced annually in Sweden. Production levels are maintained by annually catching and stripping fish from the spawning run.

Beginning in the early 1980s, Finland increased its compensatory smolt production considerably and nowadays Finnish releases are of about the same magnitude as Swedish releases. The Finnish rearing programme is, however, mainly based on brood stocks kept in hatcheries. Other countries around the Baltic supply about 1 million smolts annually. On average over the period 1988-92, 5.33 million reared

smolts have been released annually in Baltic rivers. About 0.52 million smolts were released in the Gulf of Finland although, as these fish do not leave the Gulf, it is considered a separate management unit. Of the remaining 4.81 million hatchery-reared smolts, about 75% were released in rivers flowing into the Gulf of Bothnia. Because reared smolts account for about 85-90% of the total smolt production in the Baltic region, the Gulf of Bothnia continues to dominate as a smolt-producing area even though the status of the wild stocks is presently very weak.

Fishery and regulatory measures

Development of fisheries

Salmon fishing in the Baltic was originally confined to the capture of ascending spawners in the rivers. This way of exploiting salmon stocks dominated until the end of the 19th century. Between 1915 and the mid-1940s, the total catch was relatively constant, at about 1000 tonnes·year⁻¹ (Figure 4A). Thereafter it increased rapidly to about 3000 tonnes as a consequence of an increase in the intensity of offshore drift gill-net fishing for feeding salmon. Offshore fishing primarily takes place in the Main Basin since this is the main feeding areas for almost all salmon stocks. Between 1945 and 1990, the offshore fishery steadily increased its share of the total

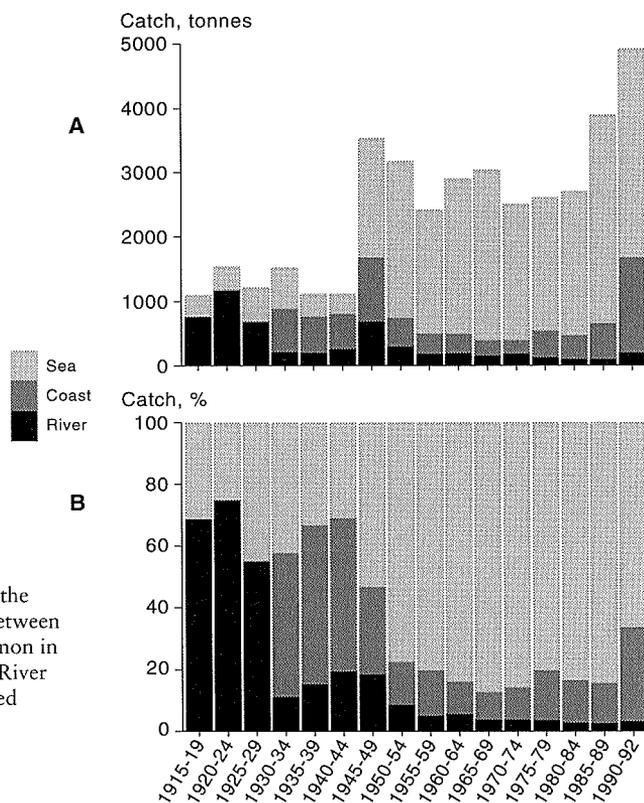


Figure 4. A: catch of salmon in the Baltic (5-year means) by area between 1915 and 1992; B: catch of salmon in the Baltic, in per cent, by area. River and coastal catches not separated before 1930.

catch to about 80% (Figure 4B) although it has decreased since 1990. At present about 75% of the offshore catch is taken with drift-nets, and the remainder with long lines. There is a closed season in the summer, from 15 June-15 September. Salmon are exploited in the offshore fishery from the autumn at the age of A1+.

The coastal fishery normally catch spawning migrators; thus the size of catches in the coastal fishery depends on both the effectiveness and the number of coastal fishing gears as well as the number of spawning migrators leaving the feeding areas. Coastal fisheries employ a number of different gears with trap-nets and pound-nets being used the most.

River catches have decreased almost continuously since 1945 owing mainly to the decreased abundance of salmon in the rivers. The fewer opportunities to catch salmon in the rivers used for hydroelectric power production have also contributed to this decline. As a result, even after the slight increase in 1990-92, river catches still make up only about 3% of the total catch. At present, most of the river catch is taken by Finland and Sweden, primarily in the Gulf of Bothnia. Most of these fish are caught with gill-nets and rod and line by recreational fishermen. In Sweden, a considerable portion of the catch in dammed rivers is also used for breeding purposes.

For many years Denmark was the leading salmon fishing nation owing to the high Danish catch in offshore fisheries. However, since 1986 Sweden and Finland have dominated. This development coincided with the slight increase in the coastal and river fisheries and the corresponding decrease in offshore fishery (Figure 4A & B).

International and national regulation of the salmon fishery

'The Baltic Salmon Fisheries Convention of 1962' took effect in 1966 after ratification by Denmark, Federal Republic of Germany, Finland and Sweden. In 1976 the articles of the 1962 Convention were adopted by the newly established 'International Baltic Sea Fishery Commission' (IBFSC). The convention area includes the entire Baltic Sea to the coasts. The Commission has accepted a number of regulating measures of the salmon fishery within the Convention area. Salmon-producing nations have also taken a number of steps to gradually strengthen their national regulations. However, it can be concluded that the regulations have been insufficient as the wild stocks, particularly in the Gulf of Bothnia, decreased more or less continuously up until the end of the 1980s. Around that time there was a gradual strengthening in the effectiveness of the measures undertaken. One of the most important changes was the division of the disputed White Zone east of Gotland between Sweden and former Soviet Union in 1988. This stopped large-scale offshore fishing activities outside national fishing zones. Furthermore, commercial prices of Baltic salmon have decreased considerably over the past decade or so owing to competition from farmed salmon. At the end of the 1970s fishermen received 40-50 SEK/kg, whereas by the end of the 1980s the price had dropped to 15-25 SEK/kg. This made the salmon fishery less attractive to fishermen and decreased incentives to fish salmon commercially.

A considerable shift in attitude of the IBFSC became evident at their meeting in 1989 when, for the first time, they decided to base future decisions on 'safe biological limits defined to safeguard wild Baltic salmon stocks' (Anon. 1990) instead of

only 'safe biological limits for Baltic salmon' (Anon. 1989). It seems unlikely that many of the delegates at IBFSC understood the full implications of this change. Since some wild stocks were on the verge of extinction, the only biologically meaningful action would have been to largely decrease exploitation of these stocks. This would require a ban on both the offshore fishery in the Main Basin and most of the coastal fishery in the Gulf of Bothnia. Although changes in regulatory measures of this magnitude have not been implemented, in 1991 a Total Allowable Catch (TAC) for Baltic salmon was established for the first time. TACs were also established in 1992 (expressed in weight) and 1993 (expressed in numbers). There has been considerable resistance to the agreements, and it has, for several reasons, been difficult for Sweden and Finland to keep within the agreed catch quota.

Current problems in assessment

The situation in the Baltic is complicated by the fact that reared salmon nowadays constitute 80 to 90% of the entire recruitment. Reared salmon and wild salmon differ in the level of exploitation that they can withstand. If brood stocks for rearing are kept in a hatchery as in Finland, reared stocks may even be able to withstand exploitation rates approaching 100%. Since 1980, the ICES group 'Baltic Salmon and Trout Assessment Working Group' has carried out assessments and suggested catch options based on conditions for wild stocks. Due to a lack of appropriate data many assumptions were made and tagging data or catch data for reared stocks were used for calculations of levels of fishery exploitation. In 1989, the IBFSC endorsed the principle of safeguarding wild stocks, and it became even more important to base calculations on quantitative data from important wild stocks. Since fishing is the major factor leading to the depletion of wild stocks in the Gulf of Bothnia, these stocks have been the basis for assessments. There are, however, some major difficulties in carrying out such evaluations.

Firstly, since wild salmon make up only about 10-20% of the entire recruitment, and both reared and wild salmon are caught mainly in a mixed-stock fishery, reliable methods are needed to distinguish between the two components. For several years, identification has been carried out mainly by scale-reading analysis. Wild fish and reared fish differ in the structure of the 'freshwater zone' of the scale, with wild fish having more pronounced winter zones (Antere & Ikonen 1983). The rate of misclassification of reared fish as wild fish may be more than 10% of the examined reared fish (Anon. 1993a). It is therefore not possible to get any reliable estimates of the proportion of wild fish when the true proportion is on the order of 0-15% (Anon. 1993a). The method is better suited to areas where wild fish constitute more than 30% of the catch as is usually only the case in parts of the Gulf of Bothnia. The tagging of wild fish has been carried out on a rather small scale. Such data can be useful in charting feeding areas and migration routes, but are not sufficient for any type of continuous quantitative assessments. At present it seems unlikely that new methods will be found with which wild and reared fish can be distinguished on a scale sufficient to allow a separate assessment of wild stocks although it would be straightforward to cut the adipose fin on all reared fish. In a Swedish hatchery the cost of adipose fin cutting is about 0.18 SEK per parr. Thus, to cut the fins of all

5.25 million reared smolts would cost 0.94 million SEK. This cost may seem high, but the cost of producing one reared smolt is 15-20 SEK, and fin-cutting would only add about 1% to the production cost. Until an easy and cheap way of distinguishing between wild and reared fish is found, assessments will have to be made on the entire stock, including both wild and reared fish. An alternative is to base models on tagging data from selected reared stocks, which resemble wild stocks in terms of life histories and exploitation patterns.

Most wild salmon stocks in the Gulf of Bothnia are in a poor state and occur in large rivers having mean water flows at the river mouth in the range of 30-400 $\text{m}^3 \cdot \text{s}^{-1}$. These factors contribute to a lack of reliable estimates of spawner numbers, age-specific survival rates and size of smolt production. Present figures are mainly based on catch statistics, data from electrofishing surveys and smolt traps (Karlström 1989). Estimates made in the 1960s or earlier, when stocks were greater have often been used for assessment purposes. For instance, it has often been assumed that for wild salmon stocks in the Gulf of Bothnia a survival from egg to smolt is about 2% (Lindroth 1965, Anon. 1988). If an average female spawner weighs 5 kg and contributes 1100 eggs $\cdot \text{kg}^{-1}$, each female would produce 110 smolts. To maintain the stock, only one male and one female of these 110 smolts would have to return to the river. The needed escapement would thus be 2/110 smolts = 0.018 or 1.8% of the smolts. Another figure proposed in the 1960s is the so called 'artificial smolt unit' (ASU), which was used to calculate the value of reared smolts compared to wild ones. In setting the value of the ASU, it was assumed that one reared smolt is, on average, worth half a wild smolt owing to lower survival during the post-smolt period. In population models of Baltic salmon, reared smolts are normally assumed to have a mortality of, on average, 75-85% during their first year at sea (Larsson 1983). Only fish surviving the post-smolt period are available to the fishery. According to the ASU unit, wild smolts would then have corresponding mortalities of only 50-70%. These values of relative survival of wild and reared smolts also originate from the 1960s when comparative taggings of wild and reared smolts were made in Sweden (Österdahl 1969) and Finland (Toivonen 1977). In later investigations it was found that the survival of reared smolts was higher than assumed by the ASU (Larsson *et al.* 1979). These findings support the fact that reared smolts have increased in size since the 1960s. Thus, since survival is positively correlated with length, an increase in the survival of reared smolts compared with wild ones may be expected.

Unfortunately, there is no Baltic river with a wild salmon stock where the entire smolt run can be trapped and also the ascending spawners monitored to provide suitable data. The Swedish River Ume älv (Figure 1) where ascending fish can be monitored has both reared and wild salmon stocks. The wild stock breeds in the tributary Vindelälven. The two populations can be distinguished because all reared smolts released in the river since 1970 have had their adipose fin cut. Spawners of both stock components are caught in a trap situated at the lowest dam in Stornorrfors, about 20 km from the river mouth. Wild spawners are released above the dam, allowing them to migrate to their natural spawning areas in the Vindelälven. Catch statistics from the trap, the remainder of the river fishery and the coastal fishery close to the river mouth were gathered in 1973-84. Together with data on the

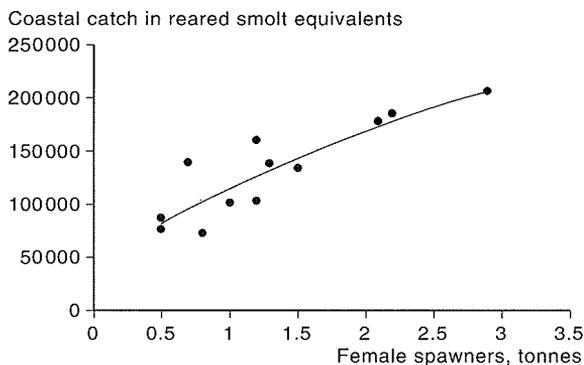


Figure 5. Stock-recruitment curve for the wild river Vindelälven salmon stock from 1973 to 1984. Dots show values in individual years, and the line is a Ricker curve fitted to the data.

catch of spawners in the trap, this information was used to formulate a stock recruitment relationship (Figure 5, adapted from Andersson 1988). All wild smolts were assumed to be three years old and the entire catch was divided into age classes based on weights in order to determine their smolt year-class affiliation. The number of reared smolts released each year is known, whereas the number of wild smolts is not known. By comparing the catch of adipose fin-cut fish with the catch of wild fish (still having an adipose fin) it is possible to express the recruitment in terms of the catch derived from reared smolts. A Ricker curve was then fitted to the individual points from different years (Ricker 1954, Hilborn & Walters 1992):

$$\begin{aligned} & \text{(Catch in reared smolt equivalents)} = \\ & \text{(Female spawners kg)} \times e^{4.54(1 - (\text{Female spawners kg})/35748)}, \quad r^2 = 0.208. \end{aligned}$$

The potential smolt production capacity of the river Vindelälven has been estimated to be about 200 000 smolts (Table 1). If a wild smolt is equal to two reared smolts, a catch of 115 000 smolt equivalents is equal to a production of 57 500 wild smolts which would be equal to $57\,500/200\,000 = 0.288$ or 28.8% of full production. This was rather close to the estimated average smolt production level of salmon rivers in the Gulf of Bothnia according to Table 1. Thus the river Vindelälven may be representative for other rivers in the Gulf of Bothnia. According to the Ricker curve, 1500 kg females produce a catch of 115266 reared smolt equivalents. The average weight of wild female spawners in River Ume älv was 5.02 kg (Andersson 1988), thus each of the 299 females gave a recruitment comparable to that of $115266/299 = 386$ reared smolts. If a wild smolt was equal to two reared smolts owing to differences in survival, 386 reared smolts equal 193 wild smolts. The discrepancy between this value and the 'average' value mentioned above of 110 smolts per 5 kg female may have arisen any time during the life cycle. There may be an egg-to-smolt survival of more than 2% in wild salmon, or the survival of wild smolts is even more than twice as high as that of reared smolts. A third factor is the possibility of differential mixed-stock exploitation rates for wild and reared components of the stock. This example illustrates that it may be of little use only to concentrate on fishery exploitation. Instead, it may be more worthwhile to try to cover the entire salmon life cycle in the assessment of wild Baltic salmon. This would also contribute to a more long-term view of the management of salmon.

Although TAC has been the international way to regulate the salmon fishery in 1991-93, several concerns have been raised regarding use of a TAC as the main instrument for regulating the fishery on Baltic salmon. Most importantly, salmon have rapidly growing individuals, where each year class is exploited by man for about two years. The IBFSC normally meets in September of year N to decide on the TAC for the following year, $N+1$. On that occasion there must be a scientifically based estimate of the number of smolts in the year class leaving the river in year N and the survival of these post-smolts. To date, no method for providing this type of data has been developed (Anon. 1992). It is therefore necessary that the TAC be low enough to allow the required number of wild salmon to survive the fishery and start their spawning migration, even when post-smolt survival is low.

A reduction in the mixed-stock fisheries in the Main Basin aimed at protecting wild salmon would result in large numbers of reared spawners returning to the Gulf of Bothnia. If these are not caught in coastal fisheries, they will enter rivers in large numbers but in many rivers there are limited possibilities to fish thus leading to an under-utilization of a valuable resource. Furthermore reared salmon may stray to neighbouring rivers having wild salmon stocks. Since reared and wild salmon may tolerate different exploitation levels, it is important to try to find selective means for protecting wild stocks. The coastal fishery in the Gulf of Bothnia provide such means as wild spawners start migrating earlier than reared fish. Scale-sampling results indicate that wild salmon are, on average, caught a few days earlier than reared salmon in the coastal fishery on spawners of mixed origin (Anon. 1992). Swedish data also show that catches outside rivers carrying wild salmon stocks in the northern Gulf of Bothnia were on average about 10 days earlier than catches outside rivers carrying reared stocks (Anon. 1993a). Similarly for the River Ume älv, the mean coastal catch date was earlier for wild salmon than for reared salmon, i.e. 2 days for grilse, 3 days for 2+ fish and 5 days for 3+ salmon (Figure 6). For

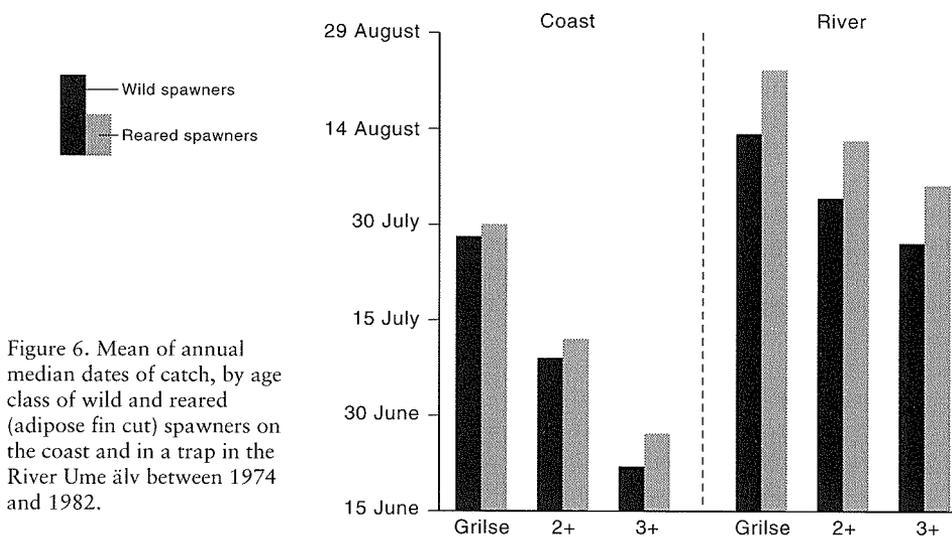


Figure 6. Mean of annual median dates of catch, by age class of wild and reared (adipose fin cut) spawners on the coast and in a trap in the River Ume älv between 1974 and 1982.

river catches in the trap, the mean time lag was larger between wild and reared salmon. Since wild salmon are caught earlier than reared salmon and large salmon are caught earlier than smaller ones, a closed spring fishery would selectively save the most valuable part of the spawning migrators. Regulations of this type are now in force in Sweden for the trap-net fishery in the Gulf of Bothnia. Finland used a similar management system in 1986-91 and has plans to re-establish it in 1994. In both cases there is a fixed opening date of the fishery, and the annual variability in run-timing has not been considered.

Tagging data for reared fish from the Swedish rivers Lule älv, Ångermanälven and Indalsälven have been used to investigate the long-term variation in run-timing. Coastal tag recoveries in the Gulf of Bothnia in 1957-92, excluding grilse recoveries, were included in the analysis in cases where the catch date was known. An annual mean catch date, weighted by individual fish weights, was calculated for each river stock. Finally, a single annual arithmetic mean catch date was calculated from the mean catch dates for the three individual stocks. This estimate was based on annual catches varying in the range of 52-719 salmon. Figure 7 shows a considerable variation in mean catch date where maximum and minimum values differed by 27 days. Within each year most of the catch takes place within a short period. The mean annual s.d. of catch date was 16.0, 16.6 and 18.2 days in the three river stocks Lule älv, Ångermanälven and Indalsälven, respectively. If we assume that the catch in each year is normally distributed, then 68.2% of the entire catch is taken within mean \pm s.d. or 32, 33 and 36 days, respectively. Considering the annual variation in run-timing and the small s.d., it may be expected that large variations in fishery exploitations would occur with a fixed opening date in the fishery.

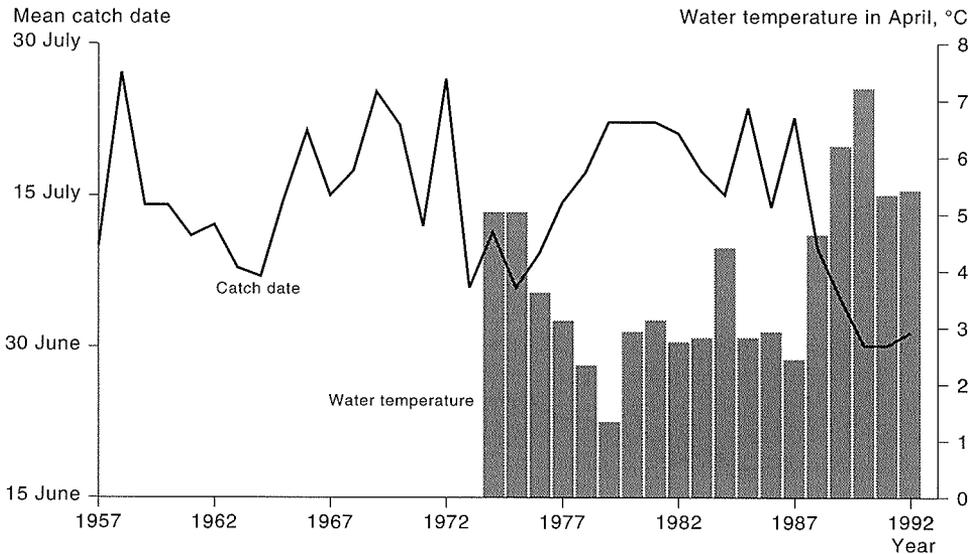


Figure 7. Mean annual coastal catch date of three Swedish Gulf of Bothnia stocks from 1957 to 1992. The bars show mean April seawater temperature along the Trelleborg-Sassnitz ferry route from 1974 to 1992.

To study the possible connection between run-timing and the size of the escapement without spring closures of the fisheries, data were used on catches of spawners in the rivers. The three rivers above have fixed traps to catch spawners close to the lowest dam in the river. Normally the traps are operated throughout the season; thus the catch level of this fishery can be used as an index of escapement. First, the annual deviation from the mean level of female spawners caught in each river in 1974-92 was calculated. Then a single annual catch level was calculated as an arithmetic mean from the three series of deviations from the mean for the individual stocks. The correlation coefficient between the average annual coastal catch date and the index of escapement was -0.826 although cause and effect have not been demonstrated. Irrespective of this, early salmon runs produced high escapement and *vice versa*. If the opening date of the coastal fishery is fixed, the annual variation in escapement should increase further.

One way of avoiding this might be to change the opening date in response to the expected run-timing, to ensure that the spawning run is exploited in a more stable manner from year to year. To investigate this possibility, the relationship between seawater temperature in the Main Basin and run-timing was studied (Table 2). The correlation increased gradually from January to April and then decreased in May. Data for the April temperature (Figure 7) and a scatterplot (Figure 8) produce the linear regression:

$$\begin{aligned} (\text{Annual mean catch date}) &= 212 - 4.6 \times (\text{water temperature in April}); \\ r^2 &= 0.769, p < 0.001. \end{aligned}$$

Table 2. Correlation between monthly mean seawater temperatures measured from the ferry on the Trelleborg-Sassnitz route, in the south of the Baltic, and mean day of coastal catch of three salmon stocks in the Gulf of Bothnia, 1974-1992.

	Temperature measurements in							
	January	February	March	April	May	February- April	March- May	April- May
Correlation coefficient	-0.672	-0.772	-0.826	-0.877	-0.711	-0.851	-0.867	-0.855

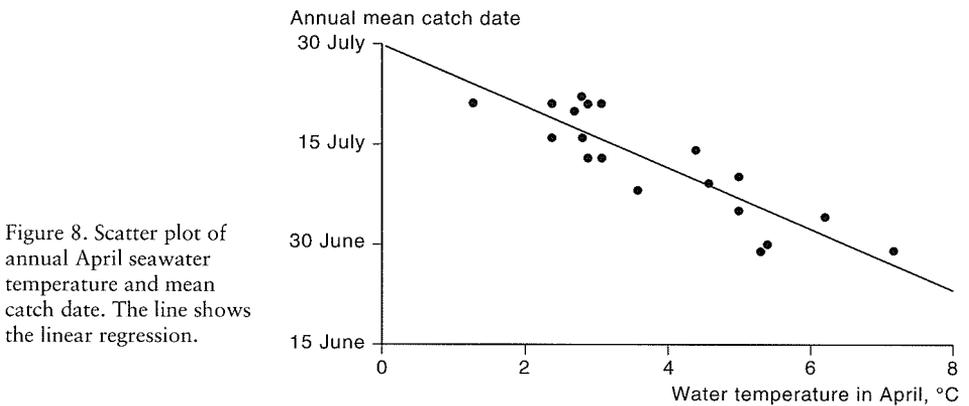


Figure 8. Scatter plot of annual April seawater temperature and mean catch date. The line shows the linear regression.

If water temperature in April is used as an indicator to annually change opening dates of the fisheries in response to expected run-timing, the variation in escapement may be decreased. The simplest way to use the data would be to change the opening date by approximately 14 days, depending on whether the water temperature in April was below or above 4.0°C.

If the opening date is sufficiently late, a regulation of the type proposed may very well be the main measure for the coastal salmon fishery in the Gulf of Bothnia. A TAC is not suitable for the coastal fishery as the fishery will be intensive at the start of the season when wild salmon migrate and it may be stopped when only reared grilse remain to be caught.

Reproductive disturbance in Baltic salmon

The syndrome M74

In 1974, the Swedish Salmon Research Institute detected increased mortality among salmon alevins in some Swedish hatcheries. The first visible symptoms occurred during the resorption of the yolk sac which was followed by rapidly accelerating mortality. The disease was given the name 'M74' by Jonas Sahlin, manager of Bergeforsen Hatchery on the river Indalsälven. The letter 'M' suggests that the cause is some factor in the environment ('miljö' in Swedish), while '74' refers to the year when the problem was detected.

M74 has only been found in Baltic salmon females that have returned to the rivers to spawn. For these females mortality among their offspring is close to 100%. It has not been observed among salmon on the Swedish west coast which feed in the Atlantic. The survival of alevins produced by farmed females kept in the Baltic is normal and the syndrome has not been confirmed from fish produced in the Finnish compensatory programme, which is based on keeping broodstocks of salmon in hatcheries.

The cause of the syndrome is still unknown although microorganisms are probably not involved (Johansson *et al.* 1993). Similar symptoms were described from Lake Michigan (Johnson & Pecor 1969) where high mortality among coho salmon alevins occurred in connection with the transition from endogenous to exogenous feed. This mortality was related to increased concentrations of DDT in the egg. Investigations to date in the Baltic have not detected increased levels of any environmental poisons (PCDD/F, sDDT, sPCB, PCN and HCB) in M74-alevins compared with healthy ones (Johansson *et al.* 1993). During 1989-91 biological and chemical investigations were carried out on spawners whose progeny (alevins) were affected by M74 (Norrgren *et al.* 1993). Biochemical investigations showed that the detoxification system EROD-activity (cytochrome P450-dependent etoxyresorufin-O-deethylase) in the livers of sick alevins was elevated compared with levels in healthy individuals. This suggests that the problems are caused by environmental poisons. It was recently found that females, whose offspring show signs of M74, exhibit a number of behavioural abnormalities such as sluggishness. New data also indicate that there is a close connection between disturbed balance in females and the occurrence of M74 (H. Börjeson, Swedish Salmon Res. Inst., pers. comm.).

Table 3. M74-related mortality in Swedish stocks of Baltic salmon in 1992 and 1993. All data are from hatcheries where spawners of wild or reared origin were caught for stripping. The mortality occurs from hatching to the start of feeding. (All data supplied by H. Börjeson, Swedish Salmon Research Institute, Älvkarleby, Sweden.)

River	Reared/Wild origin, R/W	M74-mortality, %	
		1992	1993
Torne älv	W	80-90	> 90
Lule älv	R	60	76
Skellefte älv	R	45	≈ 55
Byske älv	W	75	95
Ume älv/Vindelälven	R/W	75/50	96
Lögde älv	W	60	> 90
Ångermanälven	R	50	85
Indalsälven	R	55	> 82
Ljungan	R/W	60	97
Ljusnan	R	42	87
Dalälven	R	80	83
Mörrumsån	R/W	55	95

The incidence of M74 has varied from year to year, and for many years it did not give rise to any major problems in Swedish hatcheries. However, in 1992 the frequency of M74 increased dramatically, and the figures in 1993 were even higher when losses varied from 60 to 95% in most of the hatcheries (Table 3). Since losses of such magnitude cannot be compensated in normal hatchery routines, the release of smolts produced in Swedish hatcheries will be lower in 1994 and 1995. Although Finnish salmon rearing with broodstocks in hatcheries have not been affected, mortality among River Neva stock spawners in the Gulf of Finland and the Gulf of Bothnia were high for the first time in 1993 (E. Ikonen, Finnish Game & Fish. Res. Inst., Helsinki, pers. comm). This is an important point because River Neva fish do not leave their area of release. Thus it can be concluded that the agents causing M74 occur in both the Gulf of Finland and the southern part of the Gulf of Bothnia, the Bothnian Sea.

In Sweden, plans are now being considered for keeping broodstocks in hatcheries, as in the Finnish compensatory programme. The Swedish compensatory programme has worked rather well for many years so it is understandable that many persons consider it unreasonable to give up one of the key elements in the programme. A further reason for proceeding cautiously is, of course, that no one knows whether the current outbreak of M74 is temporary or permanent. The hesitance of key people is further increased by the fact that for some hatcheries it would cost several million SEK to make the changes required for keeping a brood stock in a suitable manner.

Though M74 affects reared stocks seriously, the influence of M74 on wild stocks is of greater concern. In cases where offspring from wild spawners were brought into a hatchery, their mortality rates were found to be similar to those of reared-spawner offspring (Table 3). These findings suggest that wild stocks are also affected by the syndrome. However, electrofishing surveys of salmon parr in rivers in the Gulf of Bothnia in 1992 gave somewhat conflicting results: densities of 0+ parr in the River Lögde älv were only $0.1 \text{ parr} \cdot 100 \text{ m}^{-2}$ compared with $3.0 \text{ parr} \cdot 100 \text{ m}^{-2}$,

in 1990-91 (Anon. 1993a). Densities in the River Torne älv were also low, but densities in the Byske älv and Kalix älv were rather similar to the levels measured in 1990-91. Because the locations of spawning sites change in a random manner and 0+ parr tend to remain close to their place of birth, the number of such parr is a rather uncertain indicator of year-class strength. There was therefore no strong evidence that wild stocks in all rivers had been seriously affected by M74 in 1992. Instead, it was decided to wait for data from surveys in 1993 which are considered more reliable, because they sample 1+ parr which disperse more. Once it became apparent that reared salmon suffered even higher mortality in 1993 than in 1992, the planned surveys in autumn 1993 took on even more importance. They will not only give clear indications of what happened to the year class hatching in 1992 but will also provide the first information about the fate on the 1993 year class.

In 1993 the northern part of Sweden received an unusually large amount of snow, and melting started late. Later in the summer, rains were unusually heavy and all larger rivers reached flood stage. Consequently, almost all electrofishing had to be postponed until water levels had decreased and serious electrofishing work in rivers emptying into the Gulf of Bothnia did not begin until late August, or two weeks later than normally. The surveys were made in a standardized manner (Karlström 1994), and several sites were monitored from 1976 onwards (Table 4). The low parr

Table 4. Densities of salmon parr (no · 100 m⁻²) measured by electrofishing surveys in the River Lainio älv (a tributary to the Torne älv), the middle part of river Torne älv and in the lower part of the River Byske älv in 1976 to 1993. Catch figures represent the total catch in the River Torne system and the River Byske älv.

Year		0+	Age 1+	2+/older	Sampling sites, N	Salmon catch, tonnes
River Lainio älv	1976-89	0.15	0.16	0.14	4.7 · year ⁻¹	3.7
	1986					3.3
	1987					2.8
	1988					2.7
	1989					7.7
	1990	0.70	0.72	0.48	14	13.9
	1991	3.3	1.1	0.68	18	15.9
	1992	0.05	4.70	1.1	12	22.6
	1993	0.26	0.29	2.0	12	
River Torne älv (middle)	1976-89	0.37	0.25	0.21	2.4 · year ⁻¹	
	1990	0.72	1.1	0.17	4	
	1991	5.7	1.4	0.72	4	
	1992	0.21	4.3	0.70	4	
	1993	0.29	0.09	2.4	4	
River Byske älv	1980-88	1.1	1.0	0.94	17 in total	0.3-0.9
	1986					0.373
	1987					0.416
	1988					0.307
	1989	3.9	1.0	1.3	4	0.760
	1990	3.6	0.35	0.73	6	2.968
	1991	10.6	3.0	2.0	4	2.421
	1992	3.4	9.3	2.6	6	1.089
	1993	0.84	0.85	3.3	4	

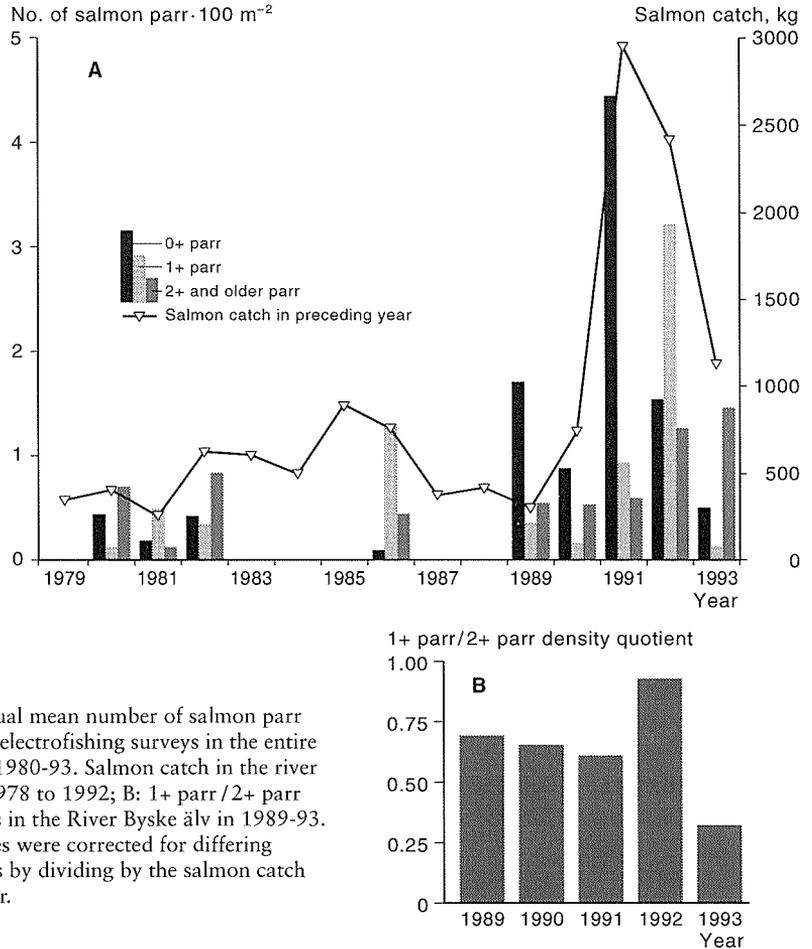


Figure 9. A: annual mean number of salmon parr (no · 100 m⁻²) in electrofishing surveys in the entire River Byske älv 1980-93. Salmon catch in the river is shown from 1978 to 1992; B: 1+ parr / 2+ parr density quotients in the River Byske älv in 1989-93. The parr densities were corrected for differing spawner biomass by dividing by the salmon catch in the parent year.

densities in the 1980s can be explained by the small spawning stocks during that period. The number of ascending spawners has been increasing since 1990 as indicated by the increased salmon catch in the rivers. This has resulted in a considerable increase in parr densities (Table 4, Figure 9A). In 1993 the overall parr densities were low; the 0+ and 1+ groups were smaller than had been expected based on the size of the spawning stocks in 1991 and 1992. It is necessary to know the escapement in each year to correctly analyse these data. If catch is assumed to be directly proportional to escapement, then catch can be used to correct for differences in spawner biomass between year classes. Parr densities were divided by the salmon catch in the parent year, whereupon the quotient between the numbers of 1+ and 2+ parr was calculated (Figure 9B). The quotient remained fairly constant from 1989 to 1992, averaging 0.72, but it decreased to 0.31 in 1993, or 43% of the average level in 1989-92. This strongly suggests that the stock suffered from M74 in 1992.

Implications of M74 for the future of wild stocks

Since most wild stocks suffer from a considerable lack of spawners, they will probably react linearly to changes in mortality at the alevin stage. M74 in reared Swedish stocks increase mortality by about 70%. If wild stocks are affected by M74 in the same manner and this mortality continues in the future, wild stocks would decrease rapidly. Within two generations, or approximately 12 years, smolt production would decrease from the present 15-20% of the potential level to less than 5%. Long before this point, however, several of the weakest stocks would disappear. Furthermore, the smolt year classes in 1993 and 1994 would be the last large ones, and, consequently, the last buffer against disappearance of several minor river stocks. It will therefore be important to ensure that high proportions of these year classes return as spawners.

The selective pressure on a stock where almost all offspring from one female die while offspring from other females remain unaffected must be very strong. Therefore the chance of developing eventual resistance to the disease should be high with a surplus of spawners. From this point of view a large number of spawners would also be the best method of counteracting M74.

The fishery regulations needed to counteract M74 will have to be extensive and must decrease exploitation so that the number of spawners increases by at least 3.3 times the present level to counteract a 70% mortality rate. This would bring the stock up to the present level for 1-3 years before the weak smolt year classes 1995-97 come back to the river to spawn two-three years later. The exploitation of these year classes will have to decrease so that 10.9 (3.3×3.3) times as many spawners escape the fisheries. At present, the level of fishery exploitation may be on the order of 90-94% of all fish surviving the post-smolt stage (Anon. 1988, Anon. 1992). A 3.3-fold increase in the number of returning spawners would require a decrease in exploitation to 60-70% of salmon surviving the post-smolt stage. The coastal exploitation rate close to the river mouth is often about 50%, and the river exploitation rate may be about 30%. If all fishing on the discrete stock is prohibited the exploitation rate would probably decrease to about 75%. This type of measure is therefore insufficient, implying that a reduction in the mixed-stock fishery is also necessary. The only reliable way to achieve a 10.9-fold increase in escapement would be to stop all fishery exploitation on wild stocks.

Even the banning of all fishery exploitation may not be enough to save all wild stocks if M74 becomes prevalent. As a precaution for such an eventuality, other measures ought to be undertaken. If M74 occurs in all parts of the Baltic an international programme will be needed to establish a gene bank to protect both reared and wild stocks. Fish from endangered stocks would be collected and brought into hatcheries where they would be kept isolated from other stocks. These fish may later be used as broodstock to produce fish to be released in nature. As a complement, milt samples would be collected from a number of males from each stock. These samples are kept deep frozen. A gene bank has been established in Norway where both of the methods mentioned above currently are used to preserve 161 of the country's salmon stocks (Lillehammer & Gausen 1992).

Conclusions

Many wild salmon stocks in the Baltic have disappeared, and others are approaching extinction. Since 1989, the level of the fishery exploitation has decreased and as a result some wild stocks have undergone a minor increase. In other parts of the distribution area of Atlantic salmon the exploitation pattern has changed considerably more in the last ten years. In the middle of the 1980s, a significant fishing exploitation on mixed stocks still occurred in several areas. Most of these fisheries have, however, disappeared in the last few years. In 1989 the salmon drift-net fishery in the Norwegian Sea was forbidden. This fishery exploited both Norwegian, Swedish, Finnish and Russian salmon stocks (Anon. 1993b). In 1991 the salmon quota at the Faroes was bought by a private organization, the North Atlantic Salmon Fund, and now only a research fishery is allowed there. Last summer (1993) the same organization purchased the quota at West Greenland. In Canada, the government has recently bought out the Newfoundland coastal salmon fishery, which exploited both Canadian and USA salmon.

Of course fisheries on mixed salmon stocks still exist in several areas, but it is only in the Baltic that the major part of the fisheries is based completely on mixed stocks. Part of the explanation for this is that a large number of countries must act jointly to implement major changes in Baltic fishery politics. Profits made by the commercial salmon fishery have decreased considerably in the last few years, so it should be easier to make unpopular decisions. Perhaps the threat from M74 can act as a catalyst to bring the countries together in a cooperative effort to take some large steps forward in the management of Baltic salmon. Let us hope that M74 is only a temporary phenomenon, but that changes in the management system will survive longer.

Addendum

In the year that passed since this paper was written, in late 1993, a number of significant developments have occurred with regard to Baltic salmon. This addendum brings the situation up-to-date, reflecting the situation in late 1994.

M74 continued to cause high mortality in reared salmon alevins in 1994. In Swedish hatcheries, mortality averaged 70% (range 50-90% in different stocks). Results of electrofishings made in a few northern rivers up until 1993 were shown in Table 4, and results from surveys in 1994 are added in Table 5.

Densities of 0+ parr in the river sections were higher in 1994 than in 1992-93. This was generally also true in other river sections and other rivers (Karlström 1995), the exceptions being the rivers in the southern part of the county of Västerbotten, i.e. the Vindelälven, Öre älv and Lögde älv. In these rivers densities were as low in 1994 as they had been during preceding years (Carlsson 1995).

Small numbers of 1+ parr in 1994 in all rivers suggest that the 1993 year class was poor as indicated by 0+ densities in 1993. This resembles the situation in 1993, when 1+ parr densities were also very low in all rivers examined.

The main part of the group 2+/older in 1994 was four-summer olds and had originated from the strong year class 1991 (Karlström 1995). The normal smolt-age in

Table 5.

Densities of salmon parr (no. ·100 m⁻²) in the River Lainio älv, in the middle part of the River Torne and in the lower part of the River Byske in 1994.

River	Age			Sampling sites (N)
	0+	1+	2+/older	
Lainio älv	1.2	0.14	1.3	14
Torne älv (middle)	1.3	0.55	1.8	5
Byske älv (lower)	4.2	0.86	4.2	6

the rivers is three years, but evidently the proportion of parr delaying their smoltification beyond three years of age was sufficient to increase parr densities in 1994 substantially.

The salmon catch (and probably spawning stock) in 1993 was at about the same level as the catch in 1992 in all rivers, except the river Vindelälven, where the number of spawners was higher (Carlsson 1995, Karlström 1995).

Table 1 gave estimates of the natural smolt production in 1992. Estimates and predictions of the smolt production in the years 1993-95 indicated that large fluctuations occurred during this period (Anon. 1994). In the Gulf of Bothnia, smolt production was estimated to be 290 000 in 1993, 440 000 in 1994 and 105 000 in 1995. These figures were 24, 37 and 9% of the estimated potential production (1200 000 smolts). The high smolt production in 1994 was a result of the very strong 1991 year class, and the low production for 1995 can be ascribed to the poor year class in 1992. Similarly the smolt production in 1996-97 will be low. Thus the situation looks bleak for salmon stocks in coming years. These additional data support the earlier statement, given in this paper, about the serious effects of the M74-syndrome on wild stocks.

As a result of the impact of M74 on wild stocks, the biologically based advice given to the Baltic Sea Fishery Commission in autumn 1994 was that all fishery exploitation of wild salmon be prohibited. IBSFC responded by lowering the total TAC of Baltic salmon from 600 000 individuals in 1994 to 500 000 in 1995. In addition, IBSFC changed their management policy, i.e. their main goal of assigning 'safe biological limits defined to safeguard wild Baltic salmon stocks' was downgraded in priority and became only one of three equally important goals.

Sweden unilaterally imposed a number of restrictions on the salmon fishery. Fisheries in river mouths and within rivers having wild salmon stocks were closed in 1994, and will be closed in 1995. The exception will be angling in rivers for a short period. A unilateral closure of the Swedish offshore fishery for salmon was also imposed for the winter 1994-95.

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