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SALMON PARR (Salmo salar L.) PRODUCTION AND SPAWNING STOCKS IN BALTIC SALMON RIVERS IN NORTHERN SWEDEN 1976-94

by

Östen Karlström, National Board of Fisheries, Research Office,
Skeppsbrogatan 9, S-97238 Luleå, Sweden

ABSTRACT.

The abundance of salmon parr in eight salmon rivers in northern Sweden was investigated during 1976-94 by electrofishing surveys. Salmon parr densities were low during the 1970s' and 1980s', because of the low level of spawning escapement. The number of spawners increased from the end of the 1980s', leading to higher parr densities. In 1992 and 1993 however, densities of 0+ parr were very low, in spite of increased abundance of spawners, indicating an increased mortality at the alevin-fry stage. High mortality at the alevin stage was also observed in these years in all Swedish Baltic salmon hatcheries and was attributed to the M 74 syndrome. It seems likely that the mortality in the wild salmon rivers was also due to the M 74 syndrome. The decline in the wild salmon parr density was 75 %. There was a good correlation between parr densities and the smolt run estimated at a smolt trap in the river Torne älv. This correlation can be used to estimate smolt output from parr densities.
For rivers in the Bothnian Bay area (subdiv. 31) predicted smolt production is about 200 000 in 1995 and about 120 000 in 1996 or 15-20 % and 10-15 % respectively of the estimated potential production of about 1,1 million smolts. This situation requires urgent action to protect the wild salmon stocks in the northern rivers, especially in the smaller most vulnerable populations in the smaller rivers.

INTRODUCTION.

Salmon stocks in the remaining wild salmon rivers in the northern part of Sweden have decreased gradually since the 1980 s', falling to very low levels in the 1970 s' and 1980 s', as a result of high fishing mortality. (Karlström 1977 b, 1983,1989). Because the fishing principally exploit reared fish (90 %) it has been difficult to reach agreement on regulations, designed to protect the wild salmon stocks.
Electrofishing surveys have been conducted in the northern Swedish rivers since 1976 by the Swedish National Board of Fisheries, Research Office in Luleå. In this paper the density of parr, estimated during these surveys, is analysed and is compared to the situation observed in Swedish salmon hatcheries, where high alevin mortalities have been observed in the last four

years, as a result of "M-74 syndrome". (Börjesson et al 1993). These results will be useful developing guidelines for the management of the wild salmon stocks in the Baltic.

II. MATERIAL AND METHODS.

Electrofishing surveys were carried out in the following salmon rivers:
Large salmon rivers, rising in the mountain region (mountain rivers):
Torne älv, Kalix älv and Vindelälven.
Smaller salmon rivers, rising in inland region (inland or forest rivers):
Råne älv, Åby älv, Byske älv, Öre älv and Lögde älv.
The rivers are shown in Figure 1.

All sampling was standardized with regard to area sampled, time of year (from August to the beginning of October, with favorable water discharge), gear (direct current generators) and was conducted by the same exprienced operators.

The method used to estimate the number of fish has been described earlier (Karlström 1977 a) and is widely used in studies in northern Swedish rivers. From successive removal fishings, catchability (efficiency of fishing, p) was calculated and used to estimate the total number of fish at the sampling sites following only one fishing run. This method makes it possible to investigate a larger number of sampling sites, which is important in large rivers and when many rivers are being sampled.
The size of the sampling sites was usually between 1000-1500 m^2.

In the period 1976-93 a total of 67 successive removal fishings were carried out. The mean catchability of one summer old parr was 0,43 (range 0,17 - 0,65) and of older parr 0,49 (range 0,29 - 0,67). There was a wide range in the catchability depending on water discharge and the type of biotope. Catchability has been calculated from successive fishings in relation to these factors (Table 1).

Table 1. Estimated catchabilities (p) of salmon parr in relation to water discharge and type of biotope.

	Biotopes difficult to fish *		Normal biotopes		Biotopes easy to fish	
	0+ *	1+/older	0+	1+/older	0+	1+/older
High water discharge	0,22	0,28	0,30	0,40	0,38	0,48
Normal water discharge	0,28	0,35	0,40	0,50	0,48	0,60
Low water discharge	0,34	0,42	0,50	0,60	0,58	0,72

* 0+ : one summer old; 1+ : two summer old; 2+ : three summer old
* biotopes difficult to fish: high water discharge and (or) coarse bottom substrate
biotopes easy to fish: low water discharge and (or) fine bottom substrate.

The number of parr was calculated per 100 m^2 (parr unit).
Older parr are more dispersed in the river compared to one summer old parr, which tend to be located close to the area of spawning. In the upper parts of the mountain rivers and early in the season one-summer old parr are too small for effective electrofishing. Parr production in the river is therefore more accurately estimated from the number of two summer old and older parr. The sampling sites selected were in habitats suitable for older parr and this accounts for the predominance of older parr at most sites.

Parr were aged by scale reading in combination with analysis of length distribution. Smolt age in the rivers is normally 3 years, but 2 and 4 year old smolts occur. (Karlström and Byström 1994).

Some characteristics of the rivers and details of sampling are shown in table 2.

Table 2. Characteristics of the rivers and details of sampling.

Rivers	Type	Mean discharge m^3/s	Reproduction area, Ha	Fishing years	N sampling sites/year	Operator
Torne älv	mountain	340	5000	1976-94	12-40	FILU
Kalix älv	mountain	250	2500	1976-94	7-29	FILU
Råne älv	inland	37	100	1993-94	9-12	FILU
Åby älv	inland	8	20	1986-94	3-5	FILU
Byske älv	inland	30	270	1980-94	4-6	FILU
Vindelälven	mountain	180	1000	1980-94	5-14	AC
Öre älv	inland	32	50	1980-94	6-14	AC, (FILU)
Lögde älv	inland	16	45	1980-94	4-11	AC, (FILU)

Fishing years: Fishings were not carried out every year in the time period in all rivers, but in almost all rivers from 1989.
Sampling sites: The higher numbers of sampling sites were carried out from the end of 1980-s'.
Operator : FILU : Swedish National Board of Fisheries, Research Office Luleå.
AC : County of Västerbotten, regional fishery authority. Data from Carlsson 1995.

Mountain rivers are larger and the water discharge is more stable. High water lasts longer in the summer and water temperatures are lower in the summer compared with the inland rivers. The sampling sites were distributed throughout the river systems.
Because of very high water discharge electo-fishings were not carried out in the years 1978, 1985 and 1992 (except in some parts of some rivers).

The size of the spawning stocks was estimated from salmon catches in the rivers. The fishing method and effort and the method of collection of catch statistics, i.e. through interviews, did not change significantly during the period of study. This method does not provide an estimate of the total stock but the relative size of the spawning stock and can be compared in the different years and rivers.

The data were analysed using Excel 5.0 and Win.stat 3.0.

III. RESULTS.

Parr densities and parr year classes.

The quality of salmon parr habitat areas varies within and between rivers; for instance the river Kalix älv has a higher quality of rearing habitat in general than the other rivers. Normal densities during the 1960 s'were approximately 5-6 older parr per parr unit (100 m^2) in northern salmon rivers (Karlström 1977 a).
Parr densities in the rivers are shown in Figure 2. They were low in all salmon rivers in the period 1976(80)-87. Densities in most rivers increased from 1989, to high levels of 0+ parr in 1991. This led to abundant numbers of 1+ parr in 1992, 2+ parr in 1993 and even 4+ parr in 1994.

But in 1992 and 1993 densities of 0+ parr decreased to very low levels in all rivers, resulting in low densities of older agegroups of parr in 1993 and 1994. In 1994 the density of 0+ parr increased in most rivers (Figure 2).

The variation in parr densities in the river Torne älv during the period of study is shown in Figure 3. In 1976-84 no 0+ salmon parr were observed in 76 % of the sampling sites; corresponding frequencies for the years 1986-90, 1991, 1992-93 and 1994 were 40, 17, 68 and 35 % respectivly. This indicates a very sparce spawning in some periods.

The size of each year class of parr was calculated as the mean density of all agegroups (0+ to 4+). For 1994 the estimate was only available for 0+ parr, but this was corrected from the relationship between 0+ and older parr in previous years. For the rivers Vindelälven and Lögde älv the estimate was made from 0+ parr, since older parr were not aged. The estimates based on 0+ parr are less accurate than those from older parr.
The results of this analysis are shown in Table 3 and in Figure 4.
There was an increase in the size of the yearclasses in all rivers from 1988 to 1991, but for 1992 and 1993 yearclasses, the density of parr fell to very low levels. Similar temporal trends in yearclass strength were evident in all rivers sampled. The yearclass of 1994 was slightly higher in most rivers, except in the rivers Vindelälven and Lögde älv.

Spawning stocks and reproduction.

Salmon catches in the rivers are shown in Table 4 and graphically in Figure 5. In the river Vindelälven the data are from a fishladder and indicate the size of the spawning run. These show the same overall trend as the catches in the other rivers and indicate that the salmon catches in these rivers give a general indication of the size of the spawning run. The graphs show an increasing trend in catches since1988 with a peak in 1990. Similar trends are evident in the different rivers.

There was a strong positive correlation between spawning stock and parr yearclass the following year for 1988-91 in all rivers (Figure 6, r^2: Torne älv 0,93; Kalix älv 0,81; Byske älv 0,96; Vindelälven 0,94). However the small yearclasses from 1992 were not explained by small spawning stocks. The years 1992 and 1993 fall outside the general regression line, but the hatching year 1994 is closer to the line for the rivers Torne älv, Kalix älv and Byske älv.

Parr density and M 74-syndrome.

The relationship between parr density and M 74 syndrome was examined. The quotient between spawning stock and the corresponding yearclass was calculated for each river and year, and allows the parr to be density adjusted for the size of spawning stock. In order to correct for the variable spawning size of the rivers relative values were used. The results are shown in Table 5.

Data on mortality, attributed to M 74 syndrome for Swedish salmon hatcheries in the Gulf of Bothnia, are shown in Table 5 (mean, minimum and maximum mortality for the years 1988-94).
The parr density data (yearclasses) and the M 74 data are shown graphically in Figure 7. It is clear that when high levels of mortality were observed in hatcheries the production of wild salmon was low. In Figure 8 the relationship is analysed and there was a clear negative correlation between salmon parr density in the rivers and M 74 mortality in the hatcheries. (r^2: 0,78).

The "adjusted reproduction mean value" (quotient parr density/salmon catch) for all rivers is 1,12 for the years 1988-91 ("without M 74") and 0,28 for the years 1992-94 ("with M 74"), or a decrease of 75 %, similar to the level of mortality attributed to M 74 in the hatcheries.

Smolt production and wild salmon stocks in the future.

Estimates of the smolt run, derived from a smolt trap in the river Torne älv for 1988-94 are shown in Table 6 (data from Karlström and Byström 1994 and Karlström and Perä 1995). There is an increase in the smolt run from about 65000 in 1988-90 to 200000 in 1994. The corresponding parr yearclass three years earlier (3 year old smolt) are shown in the same table. Figure 9 shows that there is a strong positive correlation between the size of the salmon parr yearclass and the corresponding smolt run three years later (r^2 : 0,95 linear regr. and 0,90 log. regr.).
The data from electrofishing surveys can therefore be used to indicate the extent of salmon production for the whole river. This is likely to be the case in the other rivers, since the sampling sites in these rivers are selected in the same way as in the river Torne älv.

Data on the smolt run in the river Torne älv are presented in Table 7 and in Figure 10. The estimate of the potential smolt production has been derived from Karlström (1989) and has also been used by ICES Baltic Salmon and Trout Working Group. The prognosis for 1995 and 1996 based on the log. regression line is about 70000 smolts. But 3+ parr were abundant in 1994, and these will migrate as smolt in 1995, increasing the smolt run to approximatly 100000 smolt. The smolt run in 1997 may be somewhat higher than in 1996, but a more precise estimate will be available when this years electrofishing survey has been conducted.

No estimates of the smolt run are available for the other rivers. The potential smolt production in the rivers has been estimated from the size of the reproduction areas, with an estimated smolt production of 1-2 smolt per parr unit area; with the highest smolt production in the southern rivers. The original estimates are from Karlström (1977 a, 1989) with later corrections a.o. by the ICES Baltic STWG. The actual yearly smolt production is estimated from the size of the parr yearclasses.

The smolt production in the wild salmon rivers in the Bothnian Bay area is shown in Table 7 and in Figure 10. The production increased from about 150000- 200000 smolts in the 1980's to over 400000 in 1994, falling below 200000 in 1995 and to slightly over 100000 smolts in 1996, only 10-15 % of the estimated potential. In some smaller rivers, paricularly in the rivers Råne älv, Öre älv and Lögde älv the smolt production is below 1000 smolts.

IV. DISCUSSION.

There is a problem of how to select sampling sites and how many sites to fish, especially in large rivers, in order to get an accurate indication of the parr production in the whole river. In this investigation the rivers were surveyed and the most of the sampling sites were distributed in good to moderately good areas throughout the whole river system. This stratification was thought to give the best indication of the production of the river, from a restricted number of sampling sites, since the good areas have the greatest effect on the smolt production.

The parr density:smolt run data analysis gave a high positive correlation (Figure 9). Because there is only one point at the upper end (smolt year 1994) the slope (gradient) of the line is uncertain. More data are needed at this upper level. The high positive correlation between the electrofishing data and the smolt run data in the river Torne älv still confirms that the choice of sampling sites was "appropriate" and also that the method of one fishing run, combined with catch efficiency data and careful standardization, is acceptable. The same temporal trend in parr yearclasses between the rivers also supports the use of this method, which provides acceptable estimates of longterm production, even for large rivers. Long term electrofishing data thus give a good indication of the salmon production between years and rivers.

There was a positive correlation between the spawning stock and the parr densities in all rivers to 1991. The increasing trend in the salmon catches from 1988 onwards, with a peak in 1990 is probably a result of fishery regulations. The most important of these were: Cessation of early summer fishing of ascending spawning salmon in Swedish wild salmon rivers and river mouth areas from 1983 onwards (the same measure in the Finnish coastal fishery was introduced from 1986); Regulation of the salmon fishery in the "white zone" in the Baltic from 1988; Introduction of a TAC in the Baltic from 1991. In addition variation in postsmolt survival and of fishing intensity may have influenced the catches.

It seems that the most important factors occurred in the late 1980 s'. The increasing spawning stocks, resulting from regulation of the fishery, gave, in all rivers and river sections, an immediate increase in the production, both in parr density and distribution in the river.

The very low parr densities in 1992-94 cannot be explained by small spawning stocks, but there was a clear negative correlation with M 74 mortality in salmon hatcheries in these years. This is also true for brood stocks from the wild rivers Torne älv, Byske älv and Vindelälven, which had the same high level of alevin mortality as the reared stocks. Other circumstances (water and temperature regime etc) were not analysed but no significant differences were observed except in 1994, when there was very low water discharge in the rivers in late summer. However this did not result in very low parr densities compared with the years 1992-93. Planting of 0+ salmon parr in some rivers resulted in normal survival over the years (Karlström, unpublished). It is clear that "external circumstances" observed in these years could not explain the low and abrupt fall in the production in any river. The reduction in parr densities was approximatly 75 %, which is the same level as observed in the hatcheries and attributed to M 74. Although there are no direct observations of alevin mortality in the rivers, it seems likely that M 74 mortality has influenced wild salmon stocks too.

Smolt production in the northern rivers increased in 1994 to 40 % of the potential, but it is anticipated that there will be a reduction to 10-15 % of the potential in 1996. This means that the situation may be worse than during the low production period in 1970-80 s', especially in the small salmon rivers, where the smolt production may fall to below 1000 smolts, and where there will be a real risk of extinction . Fortunately there will be good runs in 1996-97 and it is important to safeguard these fish and maximize the number allowed to spawn. In 1997-98 and onwards the wild spawning stocks will be small and if there is still a problem with M 74, many salmon stocks will be at risk of extinction.

V. SUMMARY.

There was a good correlation between parr density derived from electrofishings and smolt run data, indicating that the method used, gives acceptable production data for the whole rivers and can be used for longterm analyses of salmon reproduction.

There was an increasing trend in the spawning stocks in all rivers from the end of the 1980 s' at least partly because of salmon fishing regulations introduced from the end of the 1980 s'.

The increased spawning stocks gave increased production up to the 1991 yearclass.

Very low production in 1992 - 1994 in the wild stocks coincided with high M 74 mortality in the hatcheries and it seems likely that the abrupt and simultanous fall in the wild salmon production is due to M 74.

There will be a drop in the smolt production in coming years, at least in 1995-97, leading to small number of spawners 1997-2000 and many salmon stocks will be at risk of extinction. This calls for urgent and effective regulation of the salmon fishery in coming years.

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Table 3. Size of year classes (N parr per 100 m²) in Torne-, Kalix-, Åby- and Byske älv, 1988-94.

Year	N parr/100 m²				
	Torne älv	Kalix älv	Byske älv	Åby älv	Mean
1976(80)-87	0,36	1,6	1	0,94	1
1988	0,84	1,8	0,87	0,82	1,1
1989	1,3	4,4	2,1	2,9	2,7
1990	1,1	3,8	3,1	1,9	2,7
1991	3,8	5,6	6,7	4,4	5,2
1992	0,36	0,6	1,7	0,35	0,75
1993	0,37	0,85	0,85	0,78	0,71
1994	1,6	1,7	2,9	1,4	1,9

Table 4. Salmon catches (kilo) in Torne, Kalix, Byske and Vindelälven Years 1987-93.

Year	Torne älv	Kalix älv	Byske älv	Vindel-älven
1987	870	860	420	930
1988	860	1210	310	2340
1989	1480	1660	760	1560
1990	3500	3780	2970	5040
1991	1940	2280	2420	1540
1992	2590	2880	1090	2480
1993	2170	2970	1750	5440

Table 5. The relation salmon catch/parr year class in northern rivers. Year class 1988-94. M 74 related salmon fry mortality in rearing plants in the Gulf of Bothnia.

Year	Torne älv	Kalix älv	Byske älv	Vindel älven	Lögde älv	Mean	*% M 74*	
							mean	*min-max*
1988	0,88	1,45	0,93			1,09	*15*	*5 to 20*
1989	1,36	2,43	3,1	1,28	1,5	1,93	*10*	*5 to 15*
1990	0,69	1,55	1,77	0,77	2,59	1,47	*13*	*5 to 25*
1991	1	1	1	1	1	1	*20*	*5 to 40*
1992	0,16	0,18	0,19		0,06	0,14	*52*	*42 to 80*
1993	0,01	0,2	0,35	0,18	0,68	0,28	*75*	*55 to 97*
1994	0,67	0,38	0,73	0,09	0,2	0,41	*63*	*50 to 90*

Data of M 74 mortality from H. Börjesson (pers.com.)

Table 6. Smolt run in the river Torne älv 1988-94 and corresponding parr yearclasses.

Parr yearclass		Smolt migration	
Year	N/100 m²	Year	N smolt
1985	0,21	1988	65650
1986	0,22	1989	
1987	0,31	1990	63180
1988	0,84	1991	86730
1989	1,3	1992	
1990	1,1	1993	123330
1991	3,8	1994	198910

Tabell 7. Estimated smolt production in wild salmon rivers in Bothnian Bay area (subdiv 31)

Rivers	Reprod.- area, ha	N smolt, thousends 1980-s	1992	1993	1994	1995 prognosis	1996 prognosis	Potential
Torne älv	5000	65	100	123	199	100	65	500
Kalix älv	2500	50	90	90	130	60	30	250
Råne älv +	100					< 1	< 1	
Pite älv +	435					5	< 5	
Åby älv +	20					< 1	< 1	
Byske älv	270	10	15	20	35	10	5	60
Sävarån +						< 1	< 1	
Rickleån +						< 1	< 1	
Vindelälven	1000	25	25	20	35	15	10	200
Öre älv +	50					< 1	< 1	
Lögde älv +	45					< 1	< 1	
Sum of +		10	15	20	30	5	5	100
All rivers	**9500**	**160**	**240**	**280**	**430**	**200**	**120**	**1100**
% of pot.		*15*	*22*	*25*	*39*	*18*	*11*	

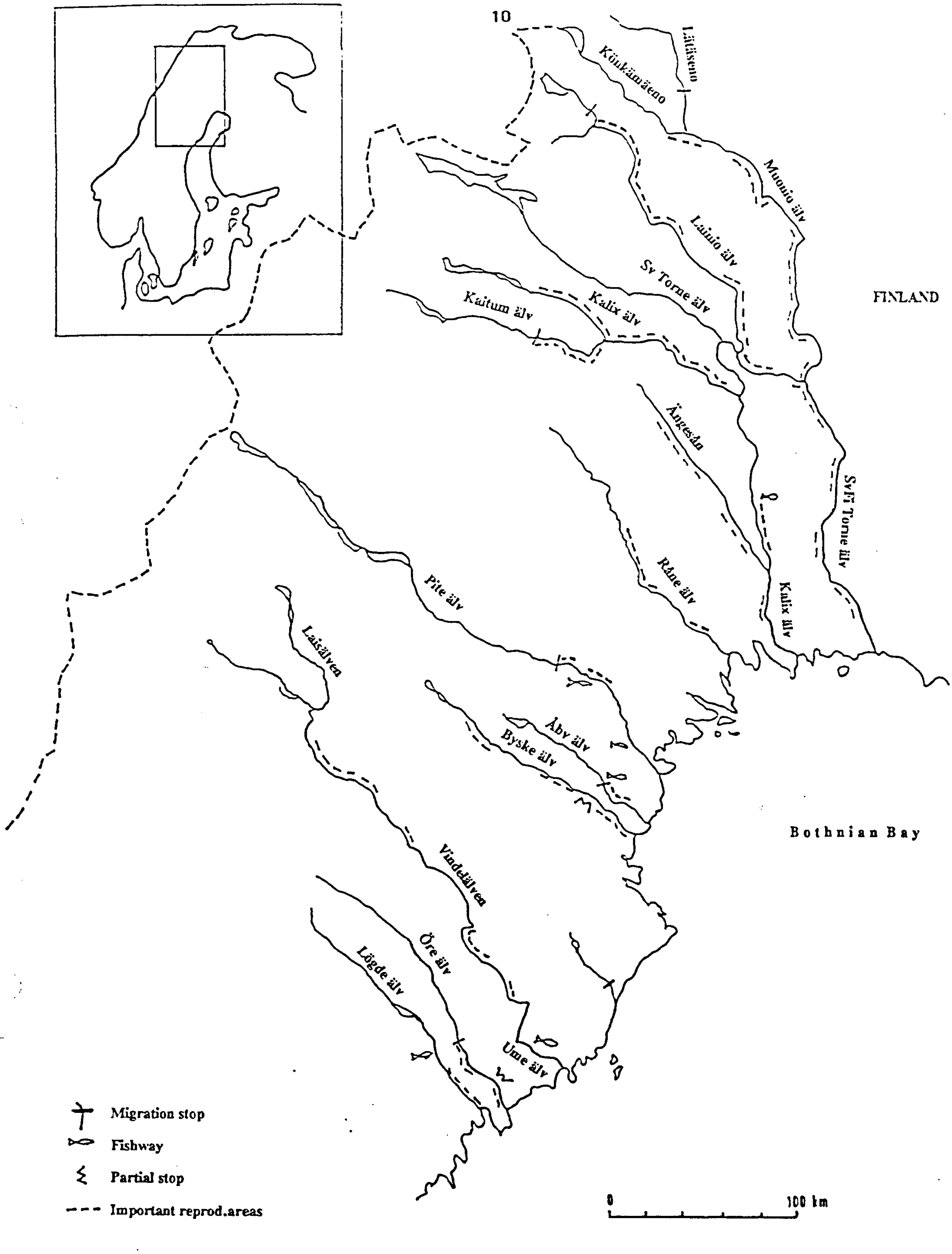

Fig. 1. Wild salmon rivers in the Bothnian Bay area

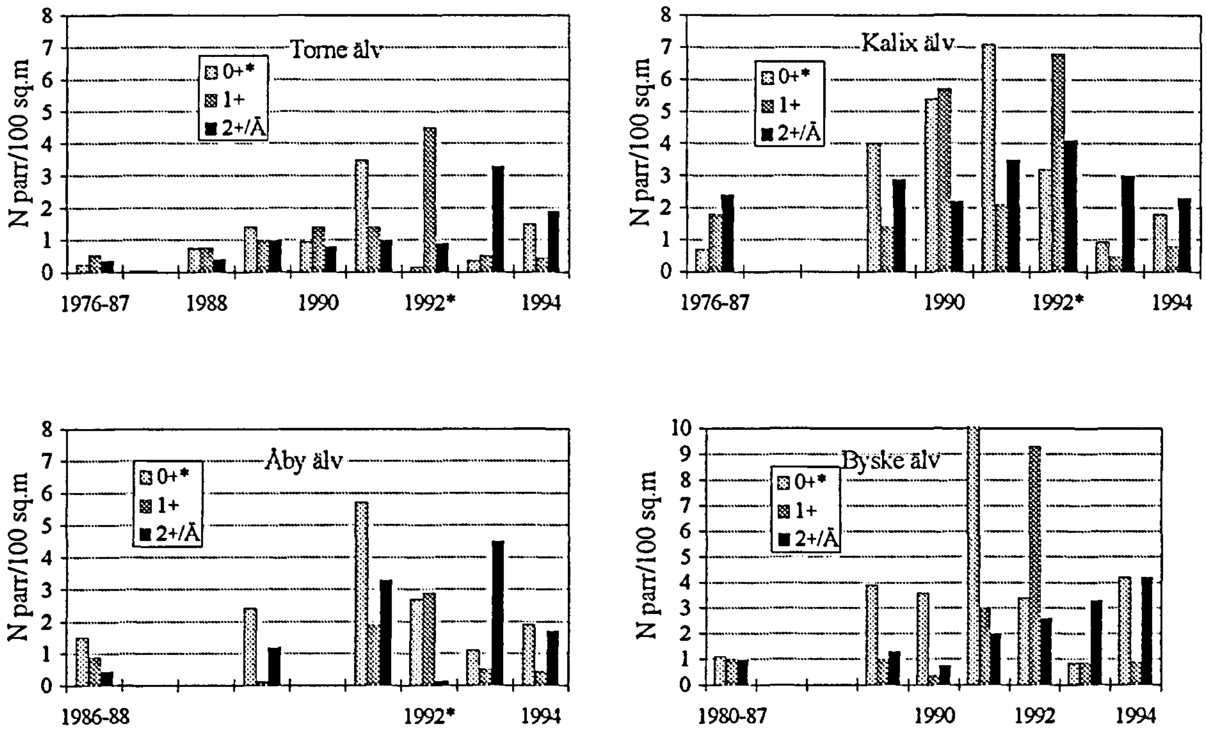

Figure 2. Number of salmon parr in sampling sites in wild salmon rivers in the Bothnian Bay area, 1976-94.

Explanations: 0+: one summer old, 1+: two summer old, 2+/O: three summer and older.

* Torne älv and Kalix älv 1992 only a part of the river. Åby älv 1992 only one sampling site.

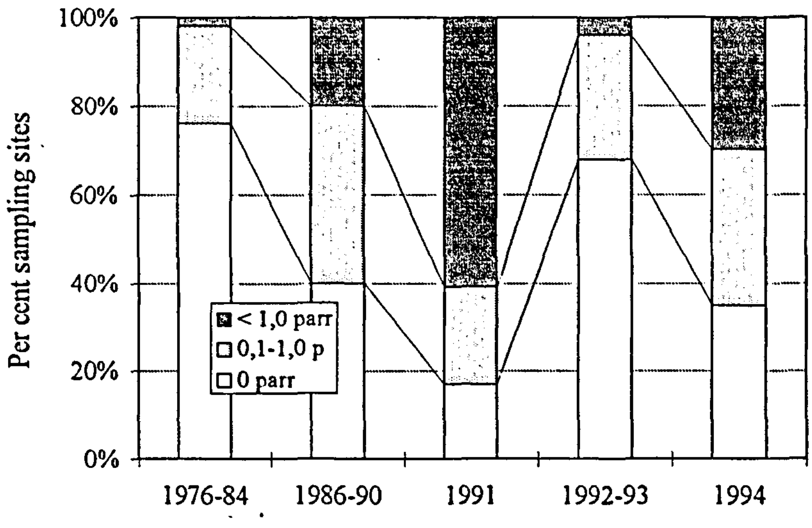

Figure 3. Per cent sampling sites with different parr densities (N/100 m²) in the river Torne älv in 1976-94.

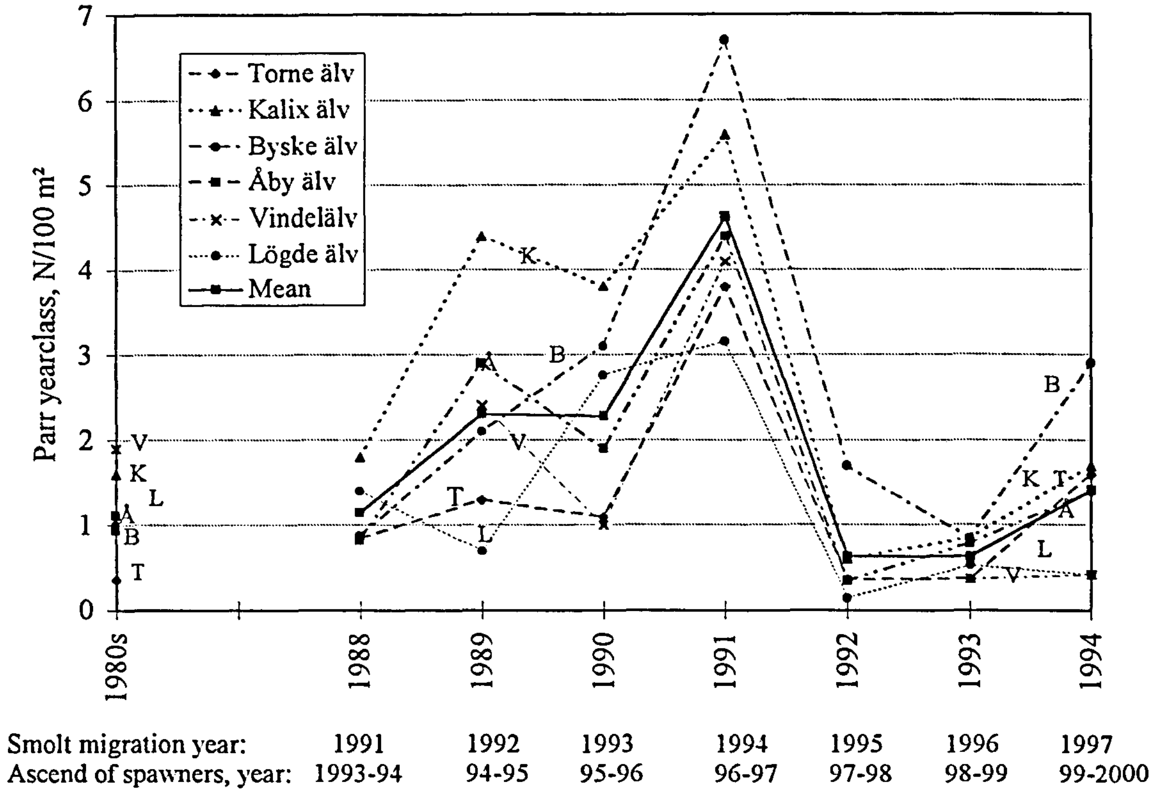

Figure 4. Size of salmon parr year classes (N parr/100 m²) in 1980s' and in1988-1994 in wild salmon rivers: Torne älv(T), Kalix älv(K), Åby älv(Å), Byske älv(B), Vindelälven(V) and Lögde älv(L). The first row below the figure shows the year of smolt migration of the parr year class (3 year old smolt) and the second row shows the year of ascending spawners after 2-3 sea years

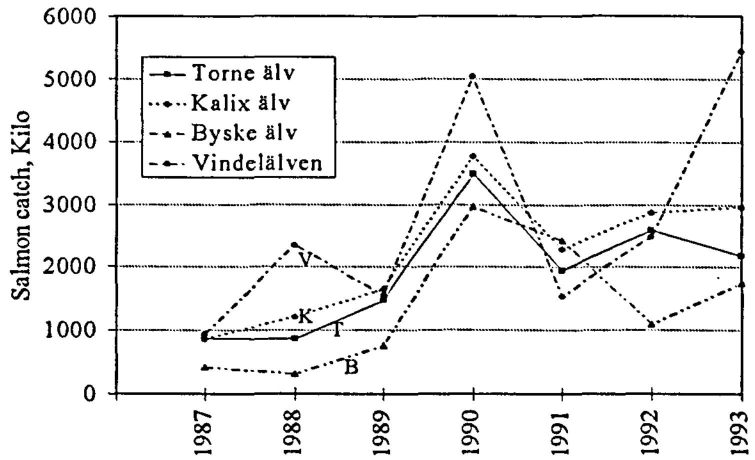

Figure 5. Salmon catches (kilo) in wild salmon rivers, Torne-, Kalix-, Byske- and Vindelälven 1987-93.

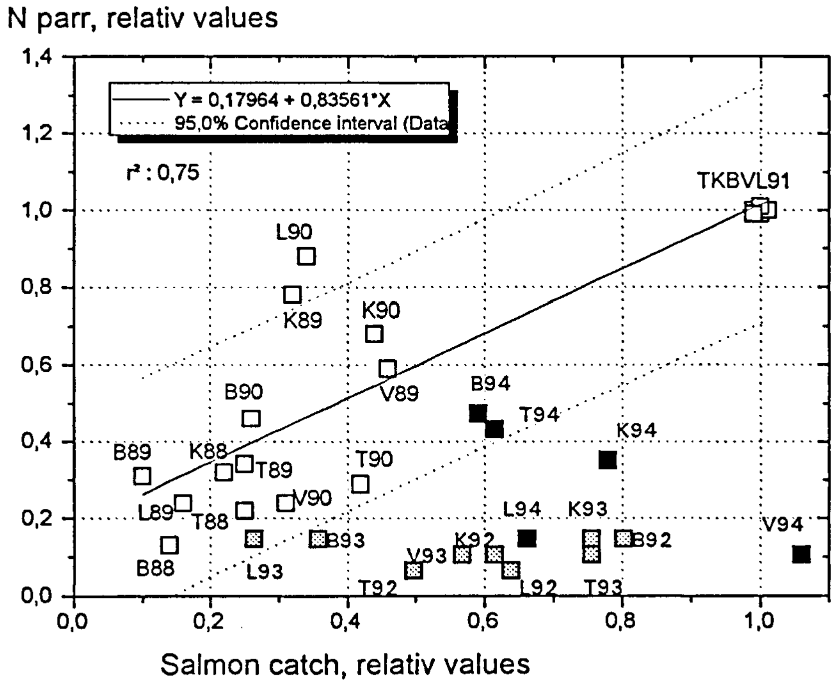

Figure 6. Parr year classes (reproduction) 1988-94 and the salmon catches the year before (spawning stock) in northern salmon rivers. Explanation: T88:Torne älv hatching year 1988, K:Kalix älv, Å:Åby älv, B:Byske älv, V:Vindelälven, L:Lögde älv.
r^2: the percentage of variance in the dependent variable which can be explained by the given equation.

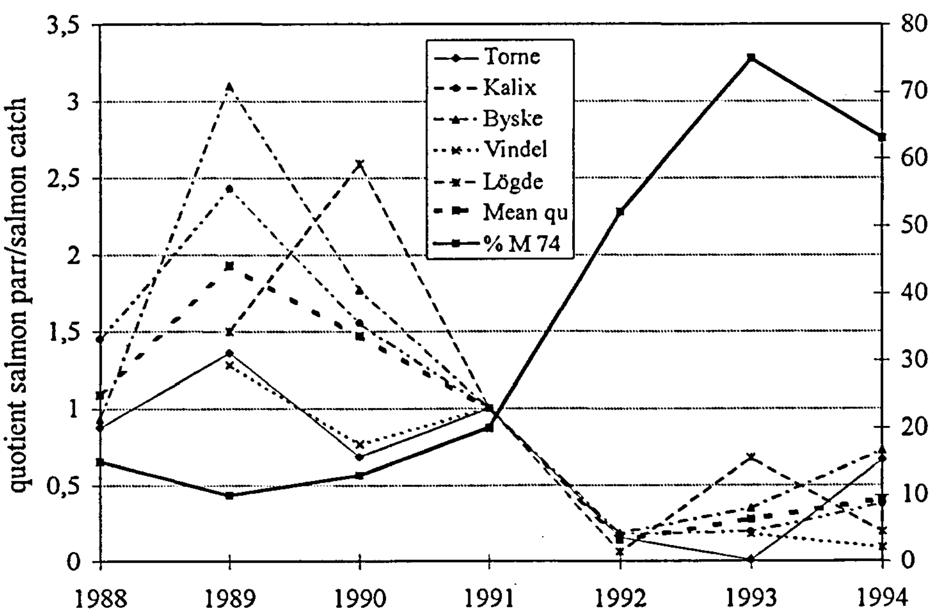

Figure 7. Salmon reproduction in wild salmon rivers in the Bothnian Bay area and M 74 related mortality in salmon rearing plants in the Gulf of Bothnia area in 1988-94.

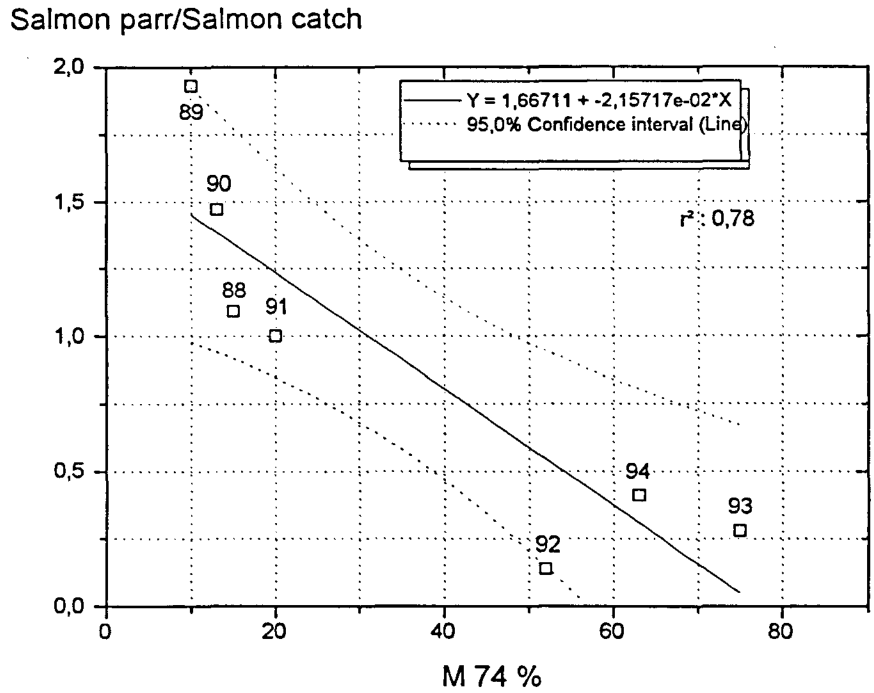

Figure 8. Regression line (linear) of salmon reproduction in wild northern salmon rivers (Torne älv, Kalix älv, Byske älv, Vindelälven and Lögde älv) and M-74 related mortality in salmon rearing plants in the Gulf of Bothnia, hatching years 1988-94.

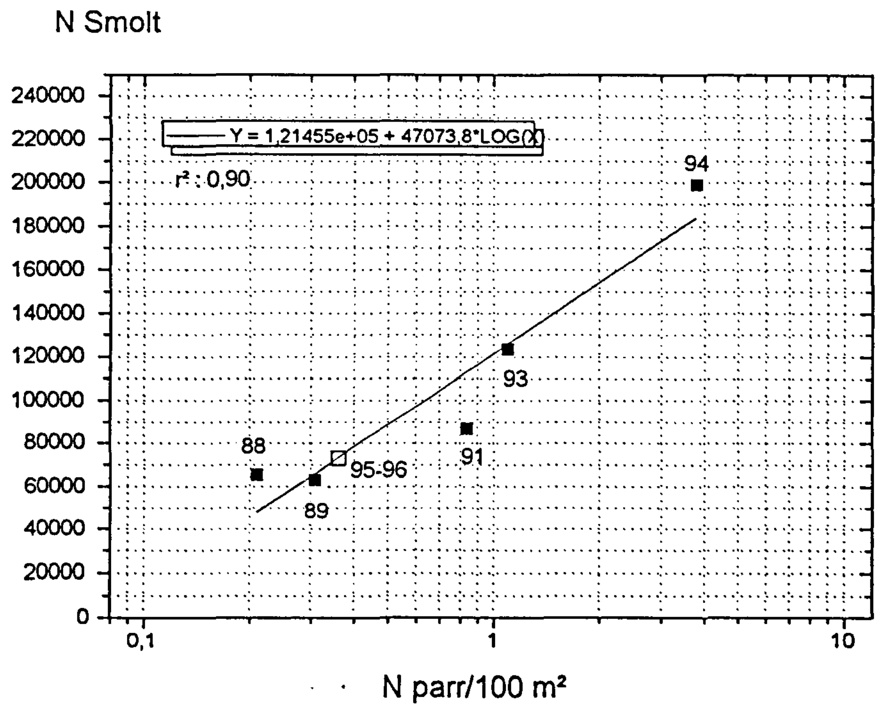

Figure 9. Salmon parr yearclasses (N/100 m²) from electrofishings and corresponding smolt run in smolttrap in the river Torne älv in the smolt years 1988-94. log.regr.
Smoltproduction for 1995-96 is indicated in the figure.

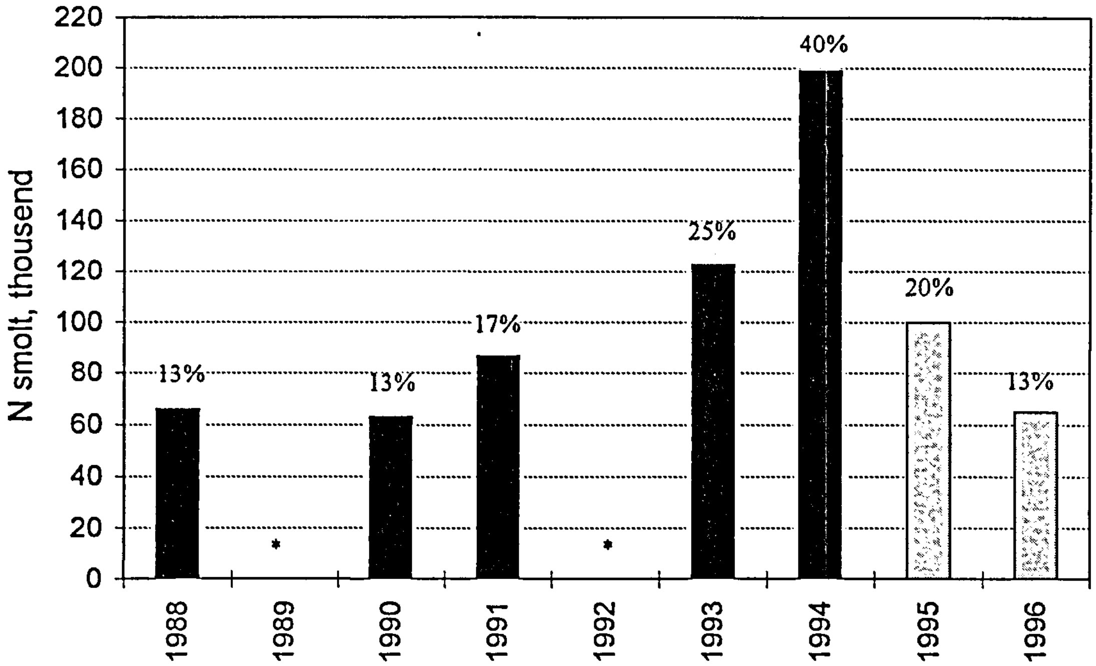

Figure 10. Smolt run in the river Torne älv 1988-94. Prognosis for 1995 and 1996.
Per cent indicate the smolt run of the estimated potential. * no fishings these years.

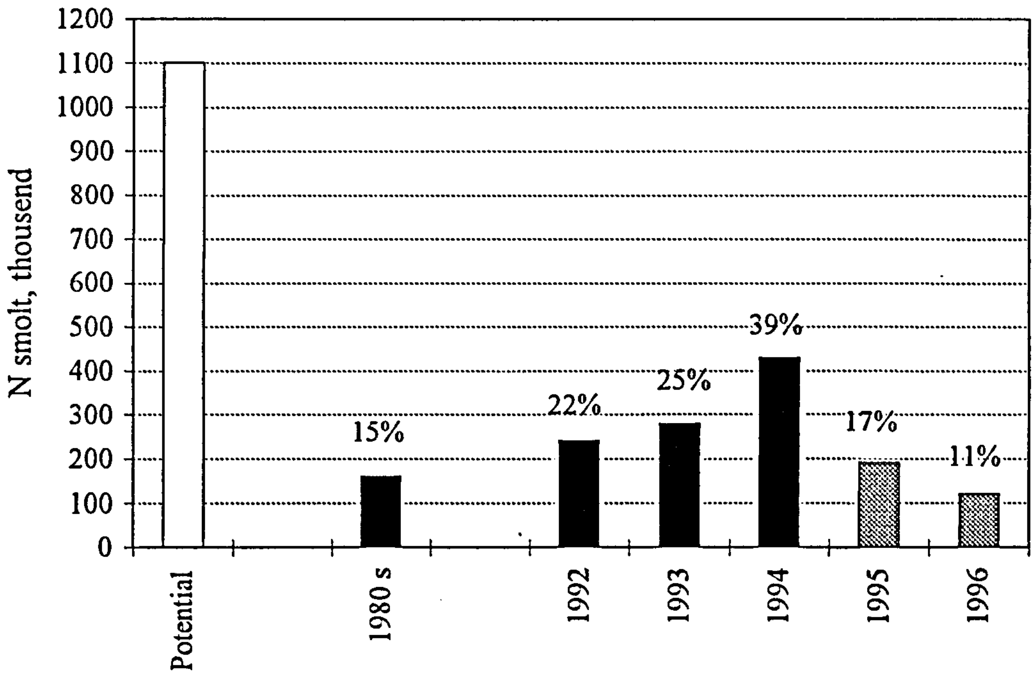

Figure 11. Calculated smolt production in wild salmon rivers in northern Sweden (subdiv 31) in 1980s'and in 1992-94 and prognosis for 1995-96. Estimated potential.
Per cent indicate the estimated actual smolt production of the potential.