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A five year study of Atlantic salmon in two Russian and two Norwegian rivers

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Abstract

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This report presents results from a joint research program between the Polar Institute of Marine Fisheries and Oceanography (PINRO) and The Norwegian Institute for Nature Research (NINA). The main goal of this program has been a comparative study of life histories of Atlantic salmon in four rivers, two Russian (the Rivers Varzuga and Kola) and two Norwegian (the Rivers Alta and Orkla). In this report growth and density analyses of parr, and growth and age structure of adult salmon have been included. Results from 1993-1997, and in some cases also older data, are presented.

The four rivers are among the most important salmon rivers in Norway and northern Russia. Annual average catches of 9, 13, 25 and 72 tonnes have been reported in the Rivers Orkla, Alta, Kola and Varzuga, respectively. However, spawning runs and catches have been influenced by several factors, like hydropower development, mining industry, variable exploitation rates in the sea, and temperature conditions at sea. Illegal fishing (poaching) impacts appreciably on the abundance of Atlantic salmon in Russian rivers.

The estimated densities of Atlantic salmon parr were higher in the two Norwegian than the two Russian rivers, while annual growth rate seemed to be highest in one of the Russian rivers (the River Kola). However, variations in density estimates were large among years in all rivers.

The mean smolt age of Atlantic salmon was approximately three years in the River Varzuga, 3.5 years in the Rivers Kola and Orkla, and slightly less than four years in the River Alta. The mean size of smolts was about 10 cm in the River Varzuga, 13 cm in the Rivers Alta and Orkla, and 15 cm in the River Kola. The smolt age reflects a combination of annual growth rate and smolt size. The low smolt age in the River Varzuga is probably mainly a result of smaller smolt size than in the other rivers. Similarly, the annual growth rate of salmon parr in the River Kola is higher than in the two Norwegian rivers. However, because of the large smolt size, the mean smolt age is similar to that in the River Orkla.

The River Varzuga is mainly a grilse river. Most fish, i.e. more than 90 % of both males and females, returned to the river after only one winter at sea. Also in the other rivers most males were grilse. However, in the other rivers females were usually 2SW or 3SW fish. The River Varzuga is the most abounding of the four rivers in water, and hence, river discharge can hardly explain the large proportion of grilse in the river. The sea-age composition of the River Alta salmon is different. In this river most males are grilse, while most females are 3SW fish.

The seasonal run dynamics in the River Varzuga differ from the other rivers. There are two peaks in migration of Atlantic salmon, one during summer and one during autumn. Almost all fish entering the river later than 20 August are immature. The autumn run usually contributes to about 70 % of the total annual run. It is supposed that immature Atlantic salmon migrating during autumn stay in the river during the whole winter and also the next summer without feeding, and then spawn during September.

We observed significant positive correlation between the catch of Atlantic salmon in the River Alta and ascent of salmon in the River Kola. Both the catch of salmon in the River Alta and the number of salmon ascending the River Kola were significantly correlated to sea water temperatures measured at the Kola Meridian section. These results indicate that similar environmental conditions at sea affect both salmon stocks.

Key words: Atlantic salmon - Norway-Russia - population, structure - catch - growth.

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Preface

The Norwegian Directorate For Nature Management (DN), with reference to the Russian-Norwegian Environmental Commission, invited the Polar Institute of Marine Fisheries and Oceanography (PINRO) to participate in a joint Russian-Norwegian research program on anadromous fish on 25 June 1992. The Norwegian Institute for Nature Research (NINA) was proposed as the Norwegian institution to participate in the joint project.

One main goal of this program has been a comparative study of life histories of Atlantic salmon in four rivers, two Russian and two Norwegian. Due to existing large survey programs, the Rivers Orkla, Alta, Kola and Varzuga were chosen as study rivers. Hence, extra costs to carry out field sampling have been considerably reduced. We are grateful for the permission to use the comprehensive data from these four rivers in this report, and we thank all those persons who have participated in the field work and preparation of data.

Alexander Zubchenko and Arne J. Jensen have been the Russian and Norwegian project leaders, respectively, while Evgeni Kashin (PINRO) and Nils Arne Hvidsten, Bjørn Ove Johnsen and Tor Næsje (NINA) have taken part in sampling of data. During project meetings, Elena Samoilova (PINRO) has played an important role as an interpreter.

We are grateful for the financial support from DN during these years.

Trondheim and Murmansk, January 1998

Arne J. Jensen   Alexander Zubchenko

Contents

1 Introduction

Concern over the future of the Atlantic salmon, *Salmo salar*, was expressed more than 100 years ago (see MacCrimmon & Gots 1979), and the nominal catches of Atlantic salmon throughout its distribution area on both sides of the Atlantic ocean have continued to decline during the last 25 years (Anon. 1996). Reductions in populations may be closely linked with changes within home rivers, especially the loss of spawning and nursery grounds, resulting from a variety of human activities. Most evident among the human impacts are the presence of dams and chemical pollutants that have prevented access of adult fish to former breeding and smolt production areas (MacCrimmon & Gots 1979). Also atmospheric pollution (Watt et al. 1983, Hesthagen & Hansen 1991), deforestation, mining (Sorensen 1991), and in later years the aquaculture industry (Hansen et al. 1991, Heggberget et al. 1993, Heggberget 1996) have been a threat to the wild salmon.

While several Atlantic salmon populations in southern Europe have declined during this century, some of the richest populations are still found in Norway and northern Russia. In Norway, salmon is still present in 594 rivers (Anon. 1995), and 127 rivers with salmon are found in northern Russia (Kazakov et al. 1993). Therefore, Norway and Russia have a special responsibility to the international community to care for their salmon resources.

Because of the several threats to salmon populations, it is important to carry out survey programs in the most significant rivers. Such programs are in progress in both countries. However, some of the methods and equipment in use differ. Therefore, it was most useful both for NINA and PINRO to exchange knowledge and technology about the respective countries salmon surveys, in addition to treatment of material and data. The aims of the joint program have been: 1) to exchange knowledge and technology about surveys in Atlantic salmon rivers, and handling of material, including harmonising of methods and equipment, 2) to survey selected Atlantic salmon populations to get information about changes in population size and composition, which may indicate changes in the environment, 3) to obtain information about parasites on Atlantic salmon, especially *Gyrodactylus salaris* and salmon lice. Since 1995 the Russian Academy of Science, Karelian Research Centre, Petrozavodsk, has also been included in the joint research on *G. salaris*.

The main goal with this report has been to compare the life history of Atlantic salmon in four rivers, two Russian (the Rivers Varzuga and Kola) and two Norwegian (the Rivers Alta and Orkla). Growth and density analyses of parr, and growth and age structure of adult salmon have been included. Results mainly from 1993-1997 are presented in this report, but also some older material have been included. The data from the River Alta are mainly from Næsje et al. (1998), while those from the other rivers are unpublished material.

2 Study areas

The present study was carried out in four rivers with Atlantic salmon: the Rivers Varzuga and Kola in Russia and the Rivers Alta and Orkla in Norway **(Figure 1).** These rivers were chosen due to their existing large surveying programs. In this way sampling costs were kept to a minimum. During this study, we harmonised methods and equipment both during field studies and in handling of material and data.

2.1 River Varzuga

The River Varzuga is the second largest salmon river (next to the River Ponoy) on the Kola Peninsula. It originates in Varzugskoe lake located in the south-eastern part of the peninsula and drains into the White Sea in the vicinity of the village of Kuzomen **(Figure 2).** The mean water discharge near the village of Varzuga is 76.5 m^3s^{-1}. The river is usually covered by ice from December to April. The water temperature rises rapidly during May, and increases to a maximum of about 17 °C in July **(Figure 3)**. A thorough description of the river is given by Jensen et al. (1997).

A total of 17 different fish species are found in the River Varzuga (Jensen et al. 1997). In addition, introduced pink salmon enter the river occasionally. The predominant anadromous species is Atlantic salmon. The Atlantic salmon may migrate 160 km up the river to an altitude of 127 m. Before 1958, nets were used to fish for salmon in the River Varzuga. They were operated in the lower areas and partitioned not less than 2/3 of the river width. From 1958, a counting fence has been used. It is installed annually at a site located 12 km upstream from the river outlet. According to fish regulations, at least 50 % of the spawners must be let through the fence to the spawning grounds.

2.2 River Kola

The River Kola is one of the most important salmon rivers in Russia. It begins at the Kolozero Lake, situated almost in the central part of the Kola Peninsula, and drains into the Kola fjord of the Barents Sea **(Figure 4)**. The river is 83 km long. The drainage area is 3846 km^2 and the annual mean discharge is 41.2 m^3/s. The river is usually covered by ice from November to April. The water temperature increases rapidly during May-June and reaches a maximum of 16-17 °C in July-August **(Figure 3)**. There are several communities located on the river banks. The largest is the town of Kola (about 50 000 people) situated at the river mouth. The railway connecting Murmansk and St. Petersburg runs along most of the entire river length. A thorough description of the river is given by Jensen et al. (1997).

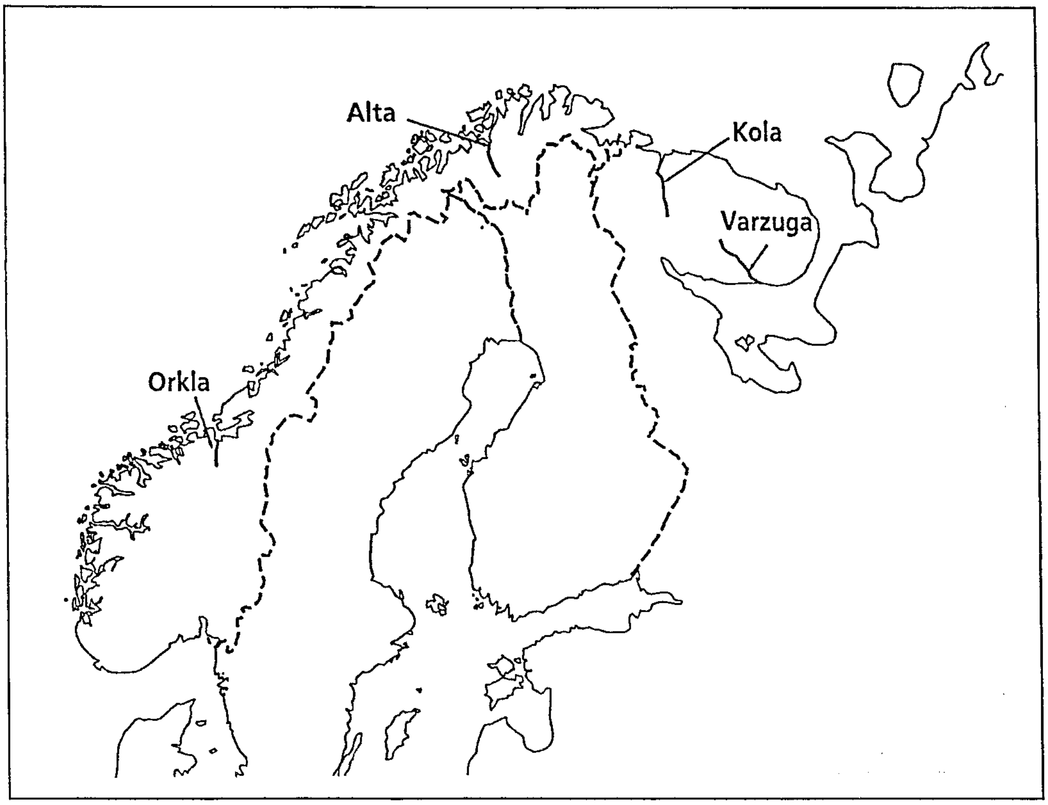


Figure 1. Map of Norway and northern Russia, with the locations of the four rivers.

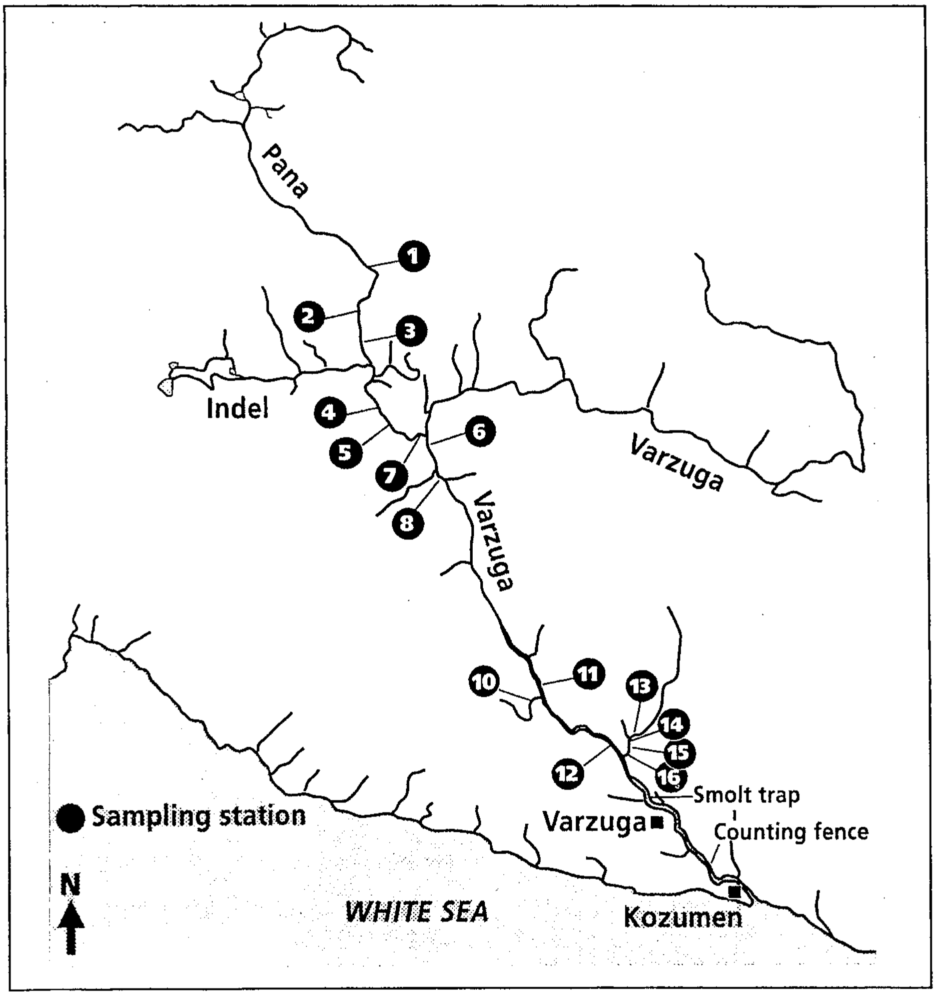
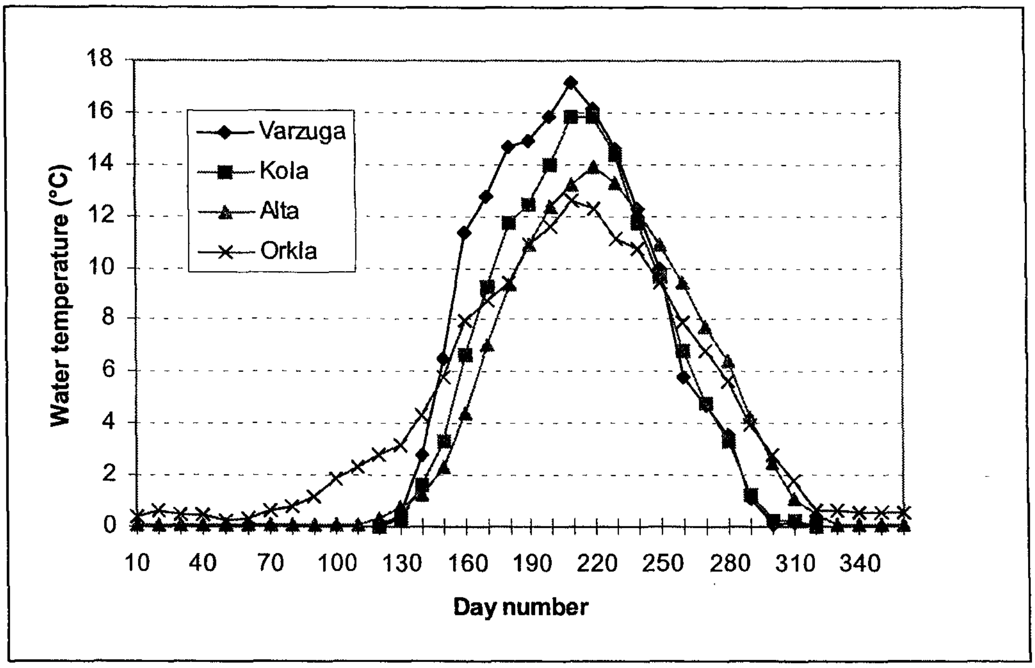


Figure 2. Map of the River Varzuga, with locations of the counting fence and sampling stations for presmolt Atlantic salmon.

Figure 3. Water temperature (°C) in the rivers Varzuga, Kola, Alta and Orkla. The data are mean values for ten day intervals during 1993-1997 in River Varzuga at Varzuga village and River Kola at the site «1429 km», 1981-1997 in River Alta at Gargia and 1990-1997 in River Orkla at Meldal.



Twelve fish species are found in the river. In addition introduced pink salmon occurs occasionally (Jensen et al. 1997). Atlantic salmon is the most predominant species. The part of the river accessible for salmon is 60 km.

To reduce illegal fishing and to improve the system to safeguard the spawning grounds, a counting fence has been installed annually since 1959. The counting fence is placed 25 km upstream from the river mouth and consists of a net which completely closes the river. A trap, rectangular form, is mounted in the centre of the fence. The counting fence is installed after the spring flood (late May-early June) and is operated until steady frosts (September-October). Until 1996, during operation, the counting fence retained all spawners. Therefore, only those salmon which had passed the site during the spring flood before the fence was installed could migrate further upstream in the River Kola. Between 110 000 and 370 000 juvenile Atlantic salmon of differing ages were released annually into the river since 1934. These juveniles have been produced by the Taibola hatchery, located about 70 km upstream from the river mouth. In 1996, 500 spawners were let through to pass the counting fence (300 males, 200 females) to ascend to upper reaches of the river. In 1997, 50 % of the spawners were retained at the fence, while the other half ascended further upstream.

2.3 River Alta

The River Alta is situated in northern Norway in the County of Finnmark at 70°N, 23°E. The river has its origin on Finnmarksvidda at Kautokeino and then runs to the north, emptying into the sea at Alta, in the innermost part of the Alta fjord **(Figure 5)**. The catchment area is 7 400 km², and consists of birch forests, mountains or other areas with low productivity, and some farm land in the lower parts. About 17 000 people live in the catchment area. Most of them live in Alta (9 000 people) at the river mouth, and in Kautokeino (2 900 people) 130 km from the outlet.

The River Alta has been utilised for hydroelectric purposes since 1987. A 110 m high dam was constructed across the main river 5 km downstream from the outlet of the Lake Virdnejavre, 46 km from the outlet. This lake is used as a reservoir, and its surface has been elevated by 15 m. The power station is located close to the dam. The outlet of the power station is located at the end of the salmon producing area. The annual flow regime has changed due to the hydropower development, with higher water discharge during winter and slightly lower water discharge during the spring flood. The average annual water discharge is 74.5 m^3s^{-1}. The river is covered by ice from November to May. However, 5-7 km of the river just below the outlet of the power station is usually without ice during most of the winter. The water temperature increases during June, and reaches a maximum of about 14 °C in August **(Figure 3)**. After the hydropower regulation, the water temperature has decreased 1-2 °C during June and July, and increased correspondingly in late summer. Beneath the power station the water temperature has increased 1-2 °C during winter.

Anadromous fishes can migrate 46 km upstream from the sea to about 85 m above sea level. A thorough description of the river is given by Berg (1964). Atlantic salmon is the dominant fish species. The mean annual catch during the last ten years has been approximately 13 tons, with a mean weight of 8 kg for individual salmon. Only sport fishing is allowed in this river. Twelve other fish species exist in the river, but together they constitute only about 2 % of the total catch by electrofishing (Heggberget et al. 1984).

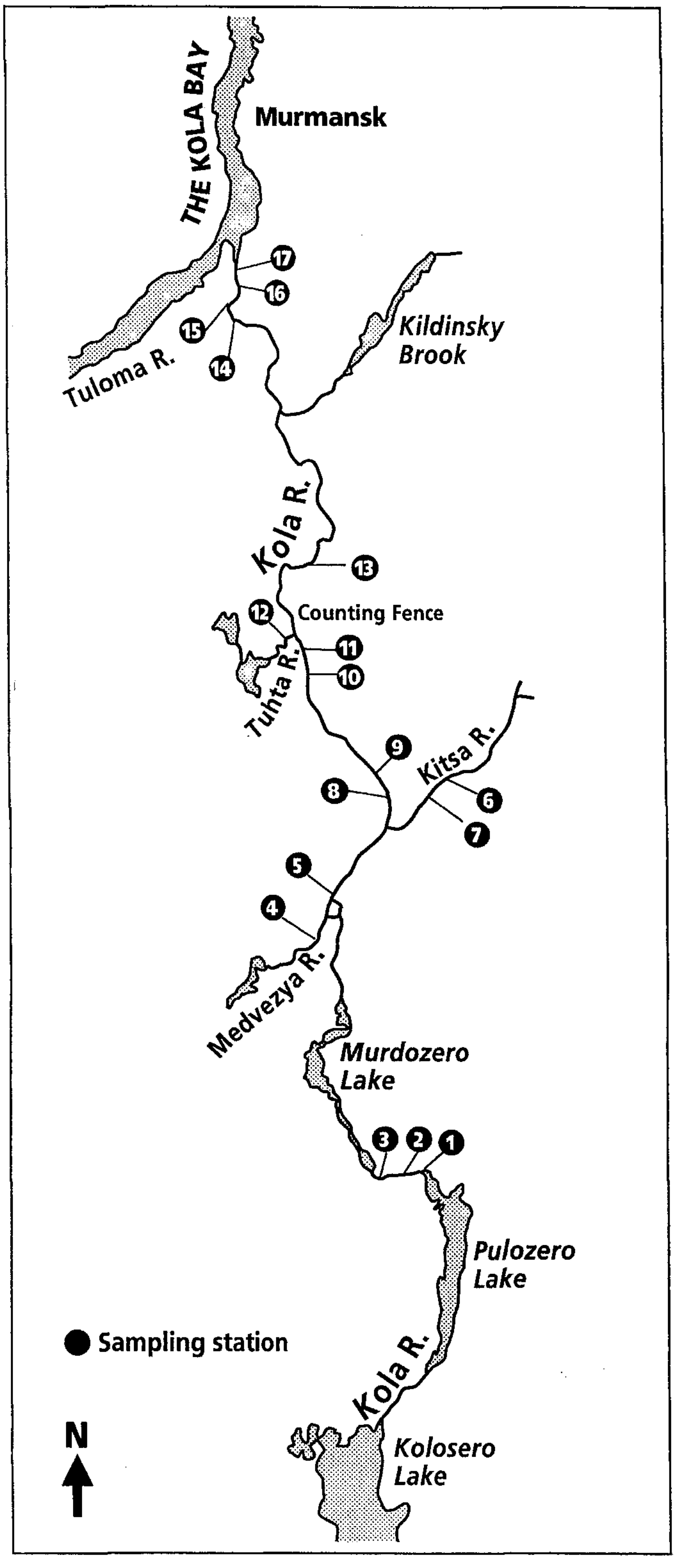


Figure 4. Map of the River Kola, with the locations of the counting fence and sampling stations for presmolt Atlantic salmon.

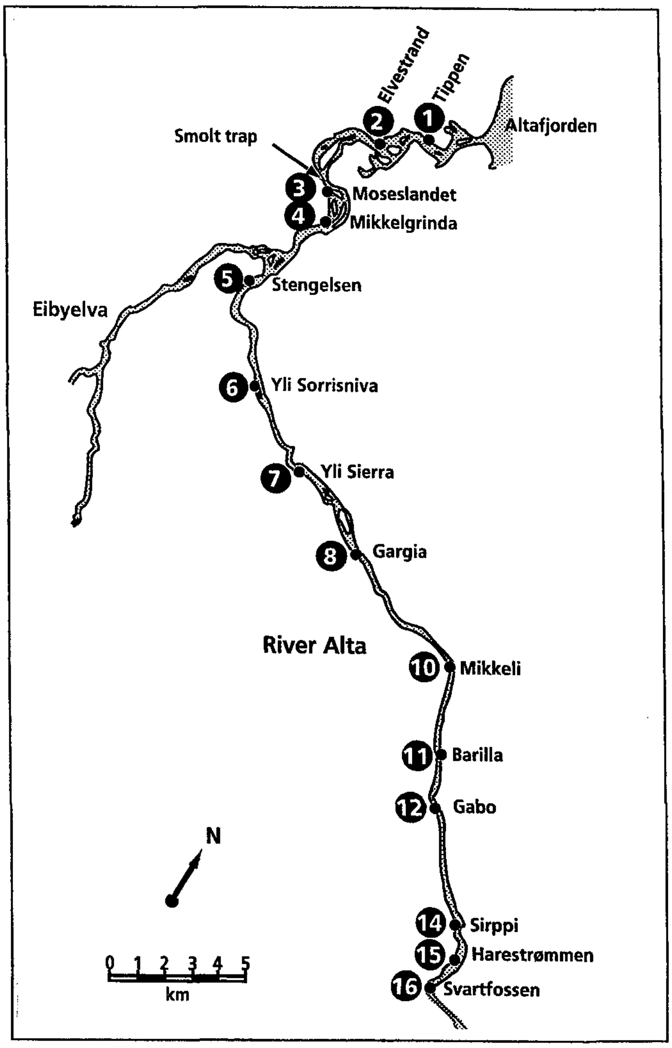


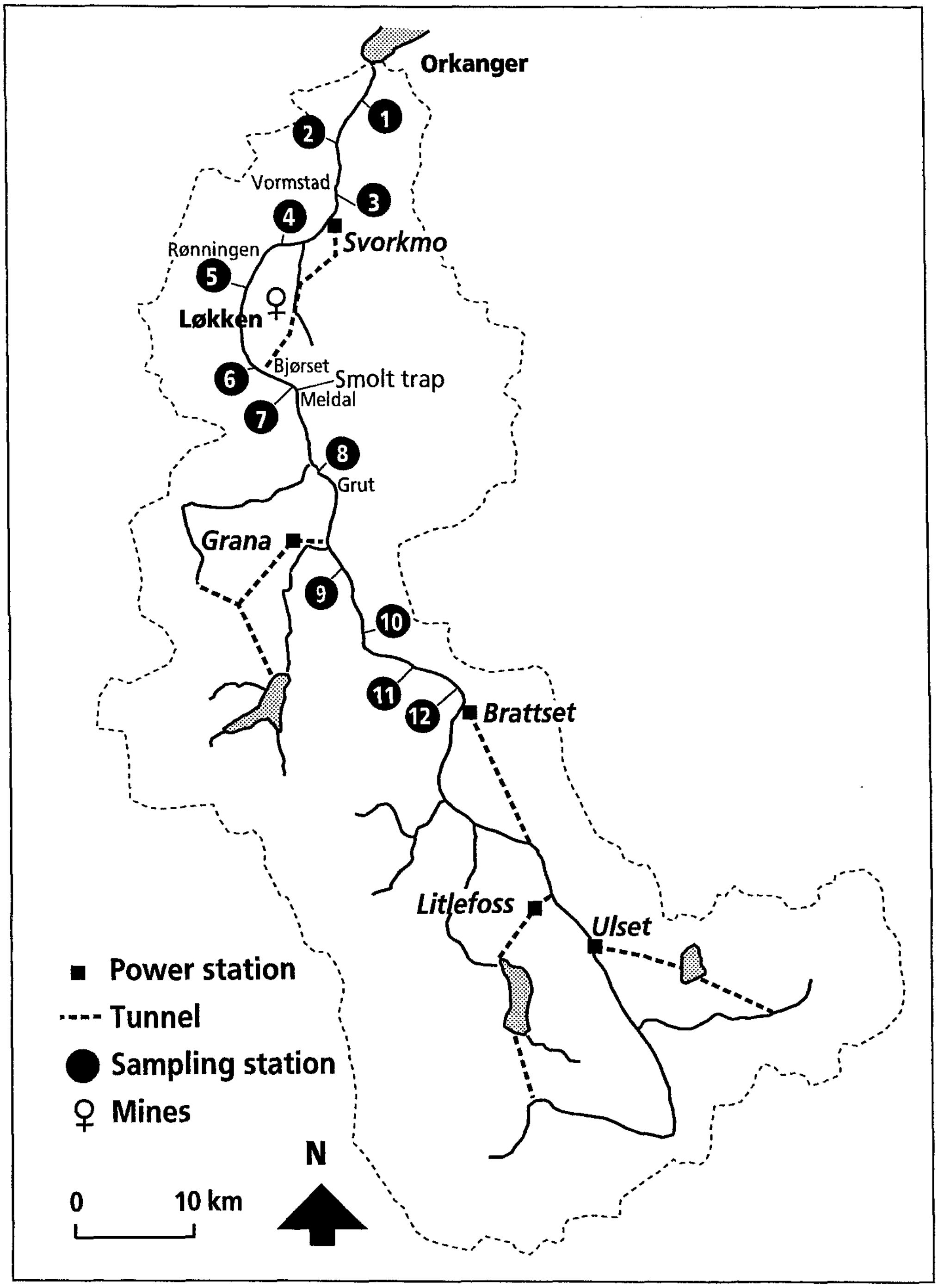
Figure 5. Map of the River Alta, with locations of the sampling stations for presmolt Atlantic salmon.

2.4 River Orkla

The River Orkla is situated in central Norway in the County of Sør-Trøndelag **(Figure 6)** and empties into the sea at Orkanger (63°17' N, 9°50' E). The drainage area is about 2 700 km², and consists of birch and spruce forests (44 %), mountains or other areas with low productivity (51 %), and some farm land in the lower parts (4 %). About 12 000 people are living in the catchment area, of which about 4 000 resides in Orkanger at the river mouth.

Eighty-eight km of the river is accessible for anadromous fishes. Atlantic salmon is the predominating fish species. Brown trout (both anadromous and resident), eel, three-spined stickleback, and flounder are also present. In the river the fish are harvested by sport fishermen using rod and line. The river is one of the most important salmon rivers in Norway. The mean annual catches the last ten years have been 15 tons and 1.1 tons for Atlantic salmon and anadromous brown trout, respectively.

Figure 6. Map of the River Orkla, with locations of the sampling stations for presmolt Atlantic salmon.



Since 1983, the River Orkla has been utilised for hydroelectric purposes. Several reservoirs were built in the mountains in tributaries to the River Orkla. The Ulset, Litlefossen, Brattset and Grana power plants utilise the elevation difference from these reservoirs to the main river **(Figure 6)**. In addition, the Svorkmo power plant utilises a drop of 99 m on a 15 km stretch of the main river between Bjørset and Svorkmo.

Mean annual water discharge at Meldal is 48.4 m^3/s. Before hydropower development, the water flow was very low during winter, with a median lowest flow of 3.7 m^3/s, and flows below 1.0 m^3/s were observed. Highest flows occurred during melting of snow in spring, with a median highest flow of about 270 m^3/s in June. After hydropower development, the minimum water flow is 10 m^3/s between Berkåk and Meldal, while the discharge during spring flow is reduced.

The River Orkla is completely covered by ice during cold winters only. The ice cover has been reduced after hydropower regulation, especially downstream of the outlet of the power stations. The water temperature increases during March-April from close to zero to about 3 °C, and continues to increase until a maximum of about 13 °C in late July or early August **(Figure 3)**.

3 Material and methods

3.1 Density estimates of juvenile salmon

Densities of juvenile salmonids were analysed each year during August/September in 1993-97 by successive removal (Zippin 1956) using electrical fishing gear (model FA2, Ing. Steinar Paulsen, Trondheim) at 17 (15 in 1993), 14, and 12 sites in the Rivers Kola, Alta and Orkla, respectively. In the River Varzuga density estimates were carried out at 12 sites during July in 1994 and 1995, at 6 sites during September 1996 and at 10 sites during August 1997, respectively. The area of each sampling site was usually 60-200 m² (25-50 m² in the River Varzuga in 1994), and the total area examined each year was 400-1 150, 1 160-1 275, 2 200-2 800, and 1200 m² in the Rivers Varzuga, Kola, Alta and Orkla, respectively. The same localities were sampled each year. Three successive removals at about half-hourly intervals were carried out as standard procedure. Young-of-the-year were not included in the density estimates because of their small size, low catchability, and high mortality during the first year of life.

From all 12 sites in the River Orkla and from four sites in the River Alta (sites no. 4, 8, 12, 16) each year all fish were conserved in alcohol, and brought to the laboratory for determination of age, length (natural tip), sex and gonadal development. In the River Kola, fresh fish were brought to the laboratory and analysed. In 1993, fish from eight sites (2, 4, 6, 8, 10, 12, 14 and 16) were analysed, while in later years all fish from all stations were analysed. Age was determined from scale analyses, but in cases of doubt otoliths were also analysed. At the remaining sites all fish were returned alive to the river after the third successive removal. The age of these fish was estimated according to the length frequency distribution of the fish. In the River Varzuga, growth data exist for a subsample of fish during 1994-1997. The total number of Atlantic salmon parr sampled during density estimates is given in **Table 1**.

3.2 Growth of parr

In order to compare growth of fish in the Norwegian and Russian rivers, a model for fish growth of fish in relation to water temperature and ration size was used. When the yolk sac is absorbed, growth is mainly dependent on nutrient conditions, water temperature, and fish weight (Donaldson & Foster 1940, Brett et al. 1969, Elliott 1975a, b, Spigarelli et al. 1982). When food is present in abundance, estimated optimum temperatures for growth vary among species (Brett et al. 1969, Elliott 1975a, b, Hokanson et al. 1977). In sockeye salmon (*Oncorhynchus nerka*) optimum growth at excess rations occurrs at 15°C, and progressively shifts to a lower temperature at reduced rations (Brett et al. 1969). A corresponding model for brown trout has been developed by Elliott (1975a, b), and was later improved (Elliott et al. 1995). For brown trout, the optimum temperature for growth at excess rations was found to be 13.1°C, while growth commences at 4°C and 19.5°C.

Table 1. *Total number of Atlantic salmon parr sampled for density estimates in the Rivers Varzuga, Kola, Alta and Orkla during 1993-1997. The number of fish from which age estimates and growth analyses have been performed are also given.*

Year	Density estimates	Age analyses
Varzuga		
1994	801	485
1995	688	346
1996	145	95
1997	309	138
Kola		
1993	374	280
1994	293	301
1995	83	139
1996	72	171
1997	143	227
Alta		
1993	1003	344
1994	1914	808
1995	961	451
1996	1079	435
1997	1225	475
Orkla		
1993	533	533
1994	750	750
1995	693	693
1996	841	841
1997	243	243

A similar model for growth of Atlantic salmon has been published recently by Elliott & Hurley (1997):

$$W_t = [W_0^b + bc(T - T_{LIM})\, t/\{100(T_M - T_{LIM})\}]^{1/b}$$

where W_0 is the initial weight of the salmon, W_t is the final weight of the fish after t days at T °C, and $T_{LIM} = T_L$ if $T < T_M$ or $T_{LIM} = T_U$ if $T > T_M$. They found the optimum temperature for growth of Atlantic salmon to be T_M = 15.94 °C, while lower and upper limits for growth is T_L = 5.99 °C and T_U = 22.51 °C, respectively. The other parameters were: b = 0.31 and c = 3.53.

Mean instantaneous growth rate per year (G_{wa}) was computed according to the following equation:

$$G_{wa} = \ln W_t - \ln W_0$$

where W_0 (g) is the mean wet weight of fish caught in July (the River Varzuga), August (the River Alta) or September (the Rivers Kola and Orkla) one year, and W_t (g) the mean weight of fish of the same cohort collected one year later. The mean weight W (g) of the fish is computed from mean length L (mm) using the equation:

$$W = k*L^3$$

We used k = $9.27* 10^{-6}$, which was the mean value for 225 fresh Atlantic salmon parr collected in August in three Norwegian rivers (Orkla, Nidelva and Saltdalselva). Data for growth analysis were collected five times at one year intervals in the Rivers Kola, Alta and Orkla, and four times in the River Varzuga **(Table 1).**

3.3 Adult fish

Scale samples of adult Atlantic salmon were collected in all four rivers **(Table 2)**. In the Norwegian rivers, scale samples were collected by sport fishermen. In the Russian rivers they were taken from the commercial catch in counting fences located in the lower part of the rivers. Weight, length and sex were analysed from each fish.

All ascending salmon were kept as commercial catch each day in the River Kola, except in 1996 when 500 spawners were let through to pass the counting fence, and in 1997, when all salmon each second day were kept. The ascent the next day was assumed to be similar to the day before. In the River Varzuga, all salmon were kept as commercial catch each second or third day during the migration period. The ascent the next day(s) in the River Varzuga was assumed to be similar to the day before. Hence, estimates of total migration are present from the Russian populations.

In the Norwegian rivers total annual catches of Atlantic salmon are according to Official Statistics.

We have compared annual ascent of Atlantic salmon in the two Russian rivers and annual catches of salmon in the two Norwegian rivers with sea temperatures measured by PINRO along the Kola Meridian transect in the layer 0-50 m (Tereshchenko 1996). Atlantic salmon smolts migrate to sea during June in the River Orkla and in July in the other three rivers (Jensen et al. 1997). Also, it is reason to believe that highest mortality during the stay at sea occurs the first months after migration to the sea. Therefore, in this report we compared the ascent/catches of Atlantic salmon with the mean sea temperature measured in the Kola section during periods of one year from July one year to June the next year. Atlantic salmon ascent/catch in year n was compared with mean temperatures of year n-1, year n-2 and year n-3.

Table 2*. Number of scale samples of adult Atlantic salmon from the Rivers Varzuga, Kola, Alta and Orkla in the period 1993-1997.*

Year/Locality	River Varzuga	River Kola	River Alta	River Orkla
1993	1658	499	646	479
1994	2278	920	347	611
1995	1385	876	630	599
1996	1481	941	324	367
1997	1751	625	302	131

4 Results

4.1 River Varzuga

4.1.1 Growth and density of parr

In early July 1994, young-of-the-year (0+) Atlantic salmon in the River Varzuga were on the average 26.4 mm long (**Table 3**). The mean length of 1+ salmon was 52.2 mm, and that of 2+ salmon was 69.3 mm. Similarly, in late June 1995, 1+ and 2+ salmon were on average 57.1 and 86.9 mm, respectively. In 1996 and 1997 sampling took place later in summer, and 0+ salmon were larger than in June/July. Also 1+ salmon were larger than during sampling in 1994-95 **(Table 3).**

The annual growth rate of Atlantic salmon parr from early July 1994 to late June 1995 was 85-88 % of the corresponding growth estimated by the growth model for Atlantic salmon parr fed on maximum rations at the same temperature regime (Elliott & Hurley 1997, **Table 4**). In the period from June 1995 to September 1996 the corresponding growth rate for 1+ salmon was 41 % of the estimated values. Also from September 1996 to August 1997 observed growth rates were rather low (53-60 %) compared to the estimated ones **(Table 4).**

Estimated densities of Atlantic salmon parr (excluding fry) in the River Varzuga were 28.8 ± 12.0 and 19.3 ± 5.9 individuals per 100 m^2 in 1994 and 1995, respectively (Jensen et al. 1997). Similarly, estimated densities of Atlantic salmon parr in 1996 and 1997 were 15.6 ± 4.8 and 12.9 ± 6.4 individuals per 100 m^2, respectively **(Table 5).** The values for the four years are not quite comparable, because the sites differed. The highest densities were found at sites number 1, 10 and 15, but densities were also high at sites 2, 3, 6, 7, 9 and 16 **(Figure 7)**. The lowest densities were recorded at sites number 8 and 14. In all years fish of age 1+ were most frequent in the catches **(Figure 8).**

4.1.2 Status of adult stock

During 1961-1997, the number of Atlantic salmon ascending the River Varzuga varied between 18 482 (1978) and 137 419 (1987), with an average of 49 048 fish **(Figure 9)**. Until 1987, all ascending fish were caught for commercial purposes in the counting fence which operated every second day, while on alternate days they were allowed to migrate freely to the spawning grounds. Therefore, the annual catch of salmon was usually about 50 % of the total spawning run **(Figure 9)**. From 1987 onwards, the counting fence has been operated each third day or less frequently, and a larger proportion of the fish have been allowed to migrate to the spawning areas. The last few years a recreational sport fishery has been permitted at three sites on the river. This is a catch and release fishery, but each person with a licence may keep one salmon weekly. The harvest of salmon in the fishing camps is not included in the catch data in **Figure 9**. During 1961-1989, the catch varied between 9 241 salmon (1978) and 50 666 salmon (1987). The annual average catch during this period was 22 169 fish, corresponding to 72.5 tonnes (33.4-161.2 tonnes). The last years the catches in the counting fence have been considerably reduced in favour of the recreational sport fishery **(Figure 9)**.

We found no significant correlation between the annual number of Atlantic salmon ascending the River Varzuga and corresponding data from the River Kola, or with annual catches in the two Norwegian rivers ($p > 0.05$). Either, we did not find any significant correlation between the annual number of Atlantic salmon ascending the River Varzuga and sea temperatures measured along the Kola Meridian section ($p > 0.05$).

Table 3*. Mean natural tip length (l, mm ± 95% confidence limits) of different age groups of Atlantic salmon parr collected by electrofishing in the River Varzuga in 1994-1997. Sample sizes are given in parentheses.*

Age/year	05-13.07.94	25.06-1.07.95	13-20.09.96	14-21.08.97
0+	26.4 ± 0.5(397)	-	39.1 ± 0.7 (37)	38.9 ± 0.5 (86)
1+	52.2 ± 0.5 (70)	57.1 ± 0.5 (300)	60.6 ± 0.9 (37)	58.1 ± 1.2 (24)
2+	69.3 ± 1.5 (16)	86.9 ± 2.2 (46)	80.3 ± 2.4 (18)	78.9 ± 2.1 (20)
3+	99.5 (2)	-	95.6 (2)	90.1 ± 2.2 (7)

Table 4. *Mean weight (W_0, g) of 0+, 1+ and 2+ Atlantic salmon sampled in 1994-1996 in the River Varzuga, mean weight (W_t, g) of the same year-class one year later, and the corresponding final weight estimated from the model for growth of Atlantic salmon fed on maximum rations (Elliott & Hurley 1997) at the same temperature regimes. Mean instantaneous growth rate per year (G_{WA} year^{-1}) of Atlantic salmon recorded in the river, and the corresponding estimated growth rate. The ratio (%) between observed and estimated growth rate is also given.*

Age	Initial weight (W_0 g)	Final weight (W_t g) Observed	Final weight (W_t g) Estimated	Mean instantaneous growth rate per year (G_{WA} year^{-1}) Observed	Mean instantaneous growth rate per year (G_{WA} year^{-1}) Estimated	Ratio observed/ estimated (%)
July 1994 - June 1995						
0+	0.17	1.73	2.64	2.32	2.74	85
1+	1.32	6.08	7.45	1.53	1.73	88
June 1995 - September 1996						
1+	1.73	4.80	20.88	1.02	2.49	41
September 1996 - August 1997						
0+	0.55	1.82	4.08	1.20	2.00	60
1+	2.06	4.55	8.86	0.79	1.46	53

Table 5. *Number of Atlantic salmon parr of different age groups caught at six and ten stations, respectively, in the River Varzuga, and densitiy estimates (Zippin method, number per 100 m^2) during electrofishing with three successive removals in September 1996 and August 1997. The area (m^2) of each station is also given. Brown trout were not caught during this survey.*

Site	Date	Area (m^2)	Atlantic salmon 0+	1+	older	Sum	Density estimates of fish (except 0+) 1. fishing	2. fishing	3. fishing	Zippin estimate
1996										
3	13.09.96	100	27	14	6	47	13	5	2	21.3
4	14.09.96	90	9	4	1	14	3	2	0	5.8
6	14.09.96	98	33	9	4	46	7	2	4	20.7
9	17.09.96	50	9	3	3	15	4	2	0	12.4
11	19.09.96	40	6	4	2	12	4	2	0	15.5
12	20.09.96	45	4	3	4	11	4	2	1	18.0
Mean (numbers per 100 m^2):										15.6 ± 4.8
1997										
4	14.08.97	112	35	2	0	37	1	1	0	2.0
5	15.08.97	77	30	6	1	37	2	3	2	> 9.1
6	15.08.97	46	13	3	3	19	1	5	0	24.8
7	15.08.97	42	21	6	3	30	6	2	1	22.8
8	16.08.97	39	8	1	0	9	1	0	0	2.6
9	17.08.97	55	18	2	6	26	8	0	0	14.5
10	19.08.97	121	38	6	13	57	8	7	4	25.7
11	19.08.97	45	47	3	5	55	3	5	0	21.6
12	20.08.97	64	28	1	0	29	0	0	1	> 1.6
16	21.08.97	48	8	2	0	10	0	2	0	> 4.2
Mean (numbers per 100 m^2):										12.9 ± 6.4

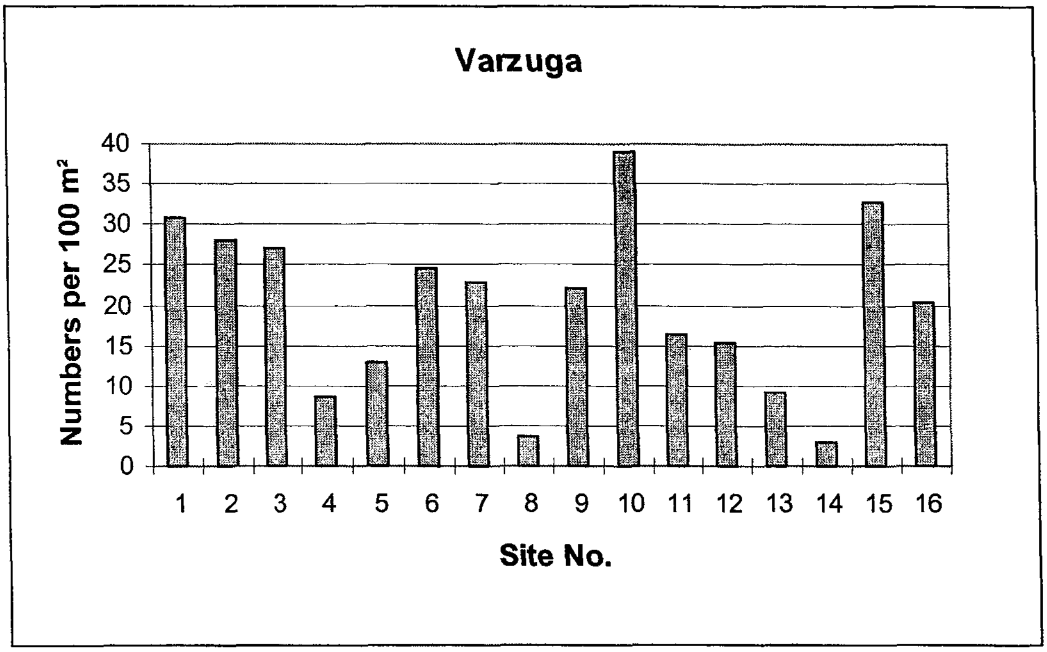


Figure 7. Average density estimates (numbers per 100 m², Zippin method) of Atlantic salmon parr (excluding fry) at each of the 16 sites in the River Varzuga 1994-1997. Only some of the sites (between 6 and 12) were estimated each year.

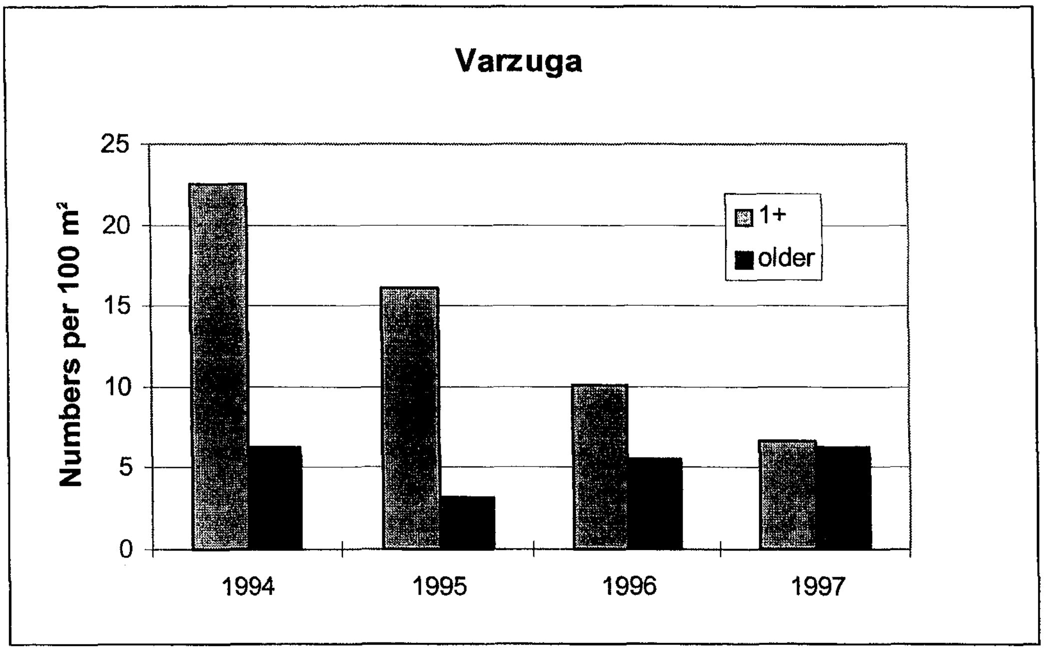


Figure 8. Average density estimates of Atlantic salmon parr of age 1+ and older in the River Varzuga in the period 1994-1997 (numbers per 100 m²).

4.1.3 Population structure

The smolt age of Atlantic salmon from the River Varzuga varied between two and five years, with 64-81 % of the fish being three years old when they migrated to sea. The mean smolt age varied between 2.89 ± 0.03 and 3.10 ± 0.04 years **(Table 6)**. The smolts were unusually small at descent, with the mean length varying between 93 and 106 mm **(Table 6).**

The River Varzuga is mainly a grilse (one-sea-winter fish, 1SW) river. Most fish, more than 90 % of both males and females, returned to the river after only one winter at sea **(Figure 10).** The mean weight of grilse varied between 2 123 ± 42 g and 2 532 ± 21 g, and 2SW fish between 4 200 ± 118 g and 5 196 ± 318 g **(Table 7).**

There were two peaks in the migration of Atlantic salmon to the River Varzuga, one during summer and one during autumn. Almost all fish entering the river later than 20 August are immature. Usually the autumn migration is most intense during the middle of October, but a significant part of the stock migrates as late as November. The autumn run usually comprises about 70 % of the total annual run. It is believed that immature Atlantic salmon migrating during autumn stay in the river during the winter and into the next summer without feeding, and then spawn during September.

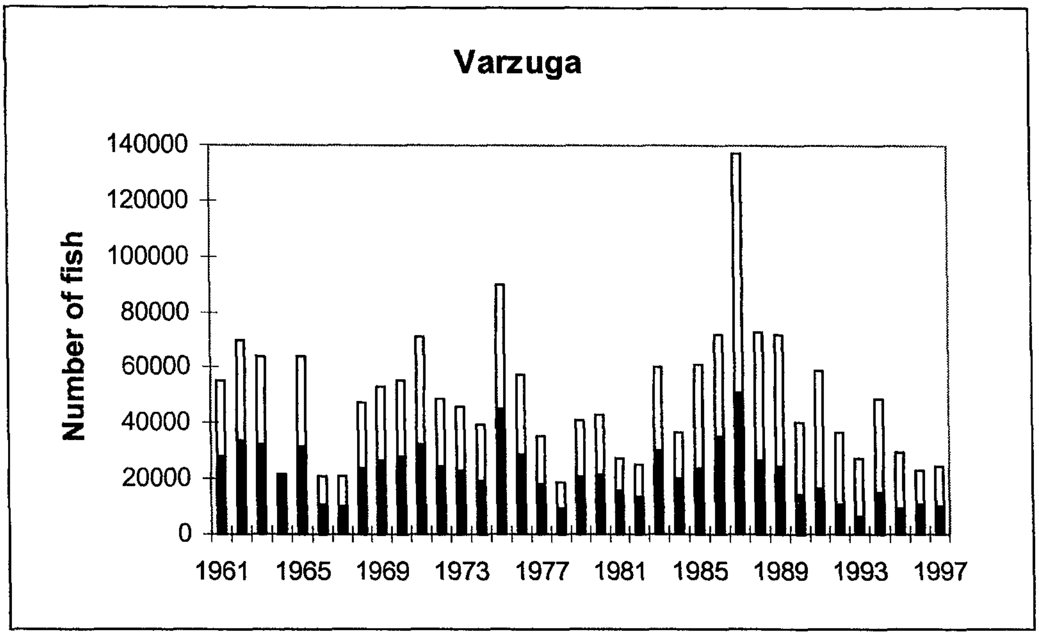


Figure 9. Total ascent (numbers) of adult Atlantic salmon in River Varzuga in the period 1961-1997. The lower, black part of the bars indicate fish which were kept, and the upper, white part indicates fish which were released.

Table 6. *Age and size (± 95 % confidence limits) of Atlantic salmon at smolt migration from the River Varzuga in the period 1993-1997, analysed from scale samples. Distribution of smolt ages are given as percentages.*

Year	Sample size	Smolt age (years) 2	3	4	5	6	Mean smolt age (yr)	Mean smolt size (mm)
1993	293	24	64	12	< 1		2.89 ± 0.03	93 ± 0.8
1994	297	7	81	11	< 1		3.03 ± 0.03	102 ± 1.0
1995	302	9	72	19	< 1		3.01 ± 0.04	106 ± 0.8
1996	232	12	70	18	< 1		3.06 ± 0.05	104 ± 1.4
1997	249	9	68	22	< 1		3.10 ± 0.04	102 ± 1.2

Table 7. *Mean weight (g ± 95 % confidence limits) of 1SW, 2SW, 3SW and 4SW Atlantic salmon from the River Varzuga. Sample sizes are given in parentheses.*

Year/age	1SW	2SW	3SW	4SW
1993	2404 ± 50 (1502)	4563 ± 257 (125)	-	-
1994	2382 ± 42 (2136)	5196 ± 318 (94)	-	-
1995	2123 ± 42 (1273)	4939 ± 440 (94)	-	-
1996	2532 ± 21 (1426)	4505 ± 131 (51)	-	-
1997	2283 ± 19 (1706)	4200 ± 118 (43)	9600 (1)	-

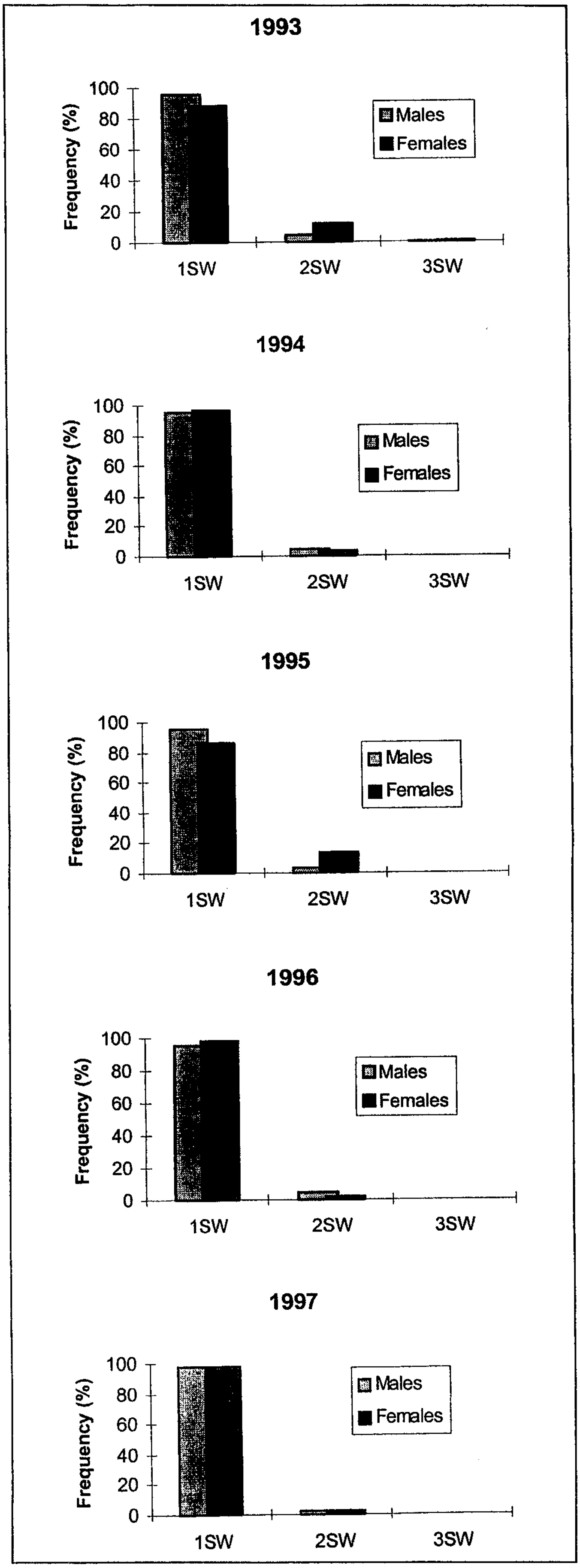


Figure 10. Sea age distribution of male and female Atlantic salmon in the River Varzuga during 1993-1997.

4.2 River Kola

4.2.1 Growth and density of parr

In early September, young-of-the-year Atlantic salmon in the River Kola were on average 46-51 mm long **(Table 8).** The mean annual growth increments the next three years were 22-44 mm, 18-38 mm and 10-32 mm, respectively. Compared to the model for growth of Atlantic salmon parr fed on maximum rations at the same temperature regime (Elliott & Hurley 1997), the growth was in usually rather high, and exceeded 100 % in two cases **(Table 9)**. However, in the period from September 1996 to September 1997, the observed growth of both 0+, 1+ and 2+ salmon was considerably lower than the estimated values (28-63 % of the estimated ones).

Atlantic salmon is the predominant species in the River Kola. In 1993, no other species was observed, while a few brown trout were caught the other years (Jensen et al. 1997). They were all found at the three uppermost sites (no. 1, 2 and 3), upstream of Murdozero Lake **(Table 10).**

The mean densities of Atlantic salmon parr (excluding fry) were 32.6 ± 10.3, 33.3 ± 19.8, and 8.2 ± 5.4 individuals per 100 m^2 in 1993, 1994 and 1995, respectively (Jensen et al. 1997). In 1996 and 1997, densities were 4.7 ± 3.8 and 6.6 ± 4.0 fish per 100 m^2, respectively **(Table 11).** The highest densities of salmon parr were observed at site 4, 5, 8 and 11, and densities were also high at sites 9, 12 and 13. In the upper part of the river (sites no. 1, 2 and 3) densities were very low **(Figure 11).** Densities of 1+ and 2+ fish were considerably higher in 1993 and 1994 than in the next three years **(Figure 12).**

4.2.2 Status of adult stock

In the period 1959-1997, the catch of salmon in the River Kola varied from 9.1 tonnes (1965) to 57.5 tonnes (1984), with an average of 24.8 tonnes. Numbers of salmon varied between 1 558 fish in 1964 and 14 225 fish in 1974, with an average of 6 382 fish **(Figure 13).** These data indicate that the initiation of concentrated fishing for salmon at the counting fence in 1959, and the introduction of more stringent measures to safeguard the river had a favourable influence on the salmon population in the River Kola. Hence, the population increased noticeably in the 1970's, and was at a high level for several years. However, the last few years there has been a declining trend.

The annual number of Atlantic salmon ascending the River Kola was significantly correlated to the annual catch of salmon in the River Alta ($r = 0.417$, $p < 0.05$). However, there was no significant correlation to the annual number of salmon ascending the River Varzuga, or the annual catch of salmon in the River Orkla ($p > 0.05$).

Table 8. Mean natural tip length (l, mm ± 95 % confidence limits) of different age groups of Atlantic salmon parr collected by electrofishing in the River Kola in August/September 1993-1997. Sample sizes are given in parentheses.

Age/year	1-10.09.1993	23.08-6.09.1994	16.08-4.09.1995	29.08-16.09.1996	26.08-2.09.1997
0+	45.7 ± 1.0 (64)	45.8 ± 1.6 (24)	47.0 ± 3.0 (8)	50.5 ± 4.0 (6)	45.8 ± 0.6 (152)
1+	73.4 ± 2.0 (96)	77.7 ± 2.0 (86)	80.0 ± 3.3 (18)	90.7 ± 2.9 (60)	72.4 ± 7.6 (22)
2+	93.9 ± 3.8 (78)	105.8 ± 3.0 (152)	115.9 ± 4.0 (59)	107.7 ± 4.6 (48)	108.2 ± 6.8 (23)
3+	118.1 ± 6.2 (31)	125.5 ± 6.6 (34)	134.5 ± 3.0 (48)	135.1 ± 4.1 (47)	118.0 ± 7.0 (23)
4+	129.2 ± 9.1 (11)	132.2 ± 4.0 (5)	144.5 ±12.8 (6)	139.5 ± 12.1 (4)	123.9 ± 12.4 (7)

***Table 9.** Mean weight (W_0, g) of 0+, 1+ and 2+ Atlantic salmon sampled in September 1993-1996 in the River Kola, mean weight (W_t, g) of the same year-class one year later, and the corresponding final weight estimated from the model for growth of Atlantic salmon fed on maximum rations (Elliott & Hurley 1997) at the same temperature regimes. Mean instantaneous growth rate per year (G_{WA} year^{-1}) of Atlantic salmon recorded in the river, and the corresponding estimated growth rate. The ratio (%) between observed and estimated growth rate is also given.*

Age	Initial weight (W_0 g)	Final weight (W_t g) Observed	Final weight (W_t g) Estimated	Mean instantaneous growth rate per year (G_{WA} year^{-1}) Observed	Mean instantaneous growth rate per year (G_{WA} year^{-1}) Estimated	Ratio observed/ estimated (%)
September 1993 - September 1994						
0+	0.89	4.35	5.02	1.59	1.73	92
1+	3.67	10.98	12.31	1.10	1.21	91
2+	7.67	18.32	20.85	0.87	1.00	87
September 1994 - September 1995						
0+	0.89	4.75	4.73	1.67	1.67	100
1+	4.35	14.43	13.33	1.20	1.12	107
2+	10.98	22.56	26.21	0.72	0.87	83
September 1995 - September 1996						
0+	0.96	6.92	5.08	1.98	1.67	119
1+	4.75	11.58	14.44	0.89	1.11	80
2+	14.43	22.86	32.95	0.46	0.83	55
September 1996 - September 1997						
0+	1.19	3.52	6.62	1.08	1.72	63
1+	6.92	11.74	20.82	0.53	1.10	48
2+	11.58	15.23	30.26	0.27	0.96	28

Table 10. Number of Atlantic salmon and brown trout parr caught at seventeen stations in the River Kola in August/September 1996-1997. The area (m²) of each station is also given.

		Area			Atlantic salmon						Brown trout			
Site	Date	(m²)	0+	1+	2+	3+	older	Sum	0+	1+	2+	3+	older	Sum
1996														
1	29.08.96	100	1		3			4			2	1	1	4
2	29.08.96	100			1			1			1			1
3	29.08.96	100						0	1	7	1	2		11
4	30.08.96	100	1		7	6		14						0
5	10.09.96	80			1	2	1	4						0
6	30.08.96	30			1			1						0
7	30.08.96	80						0						0
8	30.08.96	100		14	10	4		28						0
9	30.08.96	30						0						0
10	13.09.96	100						0						0
11	13.09.96	30						0						0
12	13.09.96	75	1		1	3		5						0
13	13.09.96	80	1	8	3			12						0
14	11.09.96	60		2				2						0
15	11.09.96	60					1	1						0
16	11.09.96	75	1					1						0
17	11.09.96	100						0						0
1997														
1	28.08.97	100		6		1	1	8	5					5
2	28.08.97	100						0						0
3	28.08.97	100			1			1	1	3				4
4	29.08.97	65	2	4		2	1	9						0
5	29.08.97	100	20	3	4	2	1	30						0
6	26.08.97	45	15	1				16						0
7	26.08.97	75	55	1				56						0
8	26.08.97	75		1	1	3		5						0
9	26.08.97	50	1		4	6	3	14						0
10	02.09.97	100	7	1	2			10						0
11	02.09.97	45			5	5		10						0
12	02.09.97	75	19	2	3	2	2	28						0
13	27.08.97	100		3	2	1		6						0
14	27.08.97	60						0						0
15	27.08.97	60		2				2						0
16	01.09.97	100				1		1						0
17	01.09.97	100						0						0

There was a significant positive correlation between the annual number of Atlantic salmon ascending the River Kola and sea temperatures the previous year ($r = 0.342$, $p < 0.05$), but not to similar temperatures two or three years earlier ($p > 0.05$). There was also a significant correlation to mean monthly sea temperatures in each of the months May, June, July, August, September and October the same year, with the highest correlation to the August temperatures ($r = 0.443$, $p < 0.01$).

4.2.3 Population structure

The smolt age of Atlantic salmon in the River Kola varied between 2 and 5 years, with three and four year old smolts being most common. The mean smolt age varied between 3.12 ± 0.03 and 3.60 ± 0.04 years during 1993-1997 **(Table 12)**. The smolts were unusually large at descent, having a mean length between 146 and 161 mm **(Table 12)**.

***Table 11.** Catch of Atlantic salmon and brown trout parr (excluding fry) in the River Kola in the first, second and third successive fishing, and density estimates (Zippin method, number per 100 m²) in August/September 1996-1997. The area of each site is given in Table 10.*

Site	Atlantic salmon				Brown trout			
	1. fishing	2. fishing	3. fishing	Zippin estimate	1. fishing	2. fishing	3. fishing	Zippin estimate
1996								
1	3	0	0	3.0	4	0	0	4.0
2	1	0	0	1.0	1	0	0	1.0
3	0	0	0	0	6	3	0	9.2
4	9	4	0	13.3	0	0	0	0
5	4	0	0	5.0	0	0	0	0
6	1	0	0	3.3	0	0	0	0
7	0	0	0	0	0	0	0	0
8	20	4	4	29.6	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	4	0	0	5.3	0	0	0	0
13	7	4	0	14.2	0	0	0	0
14	2	0	0	3.3	0	0	0	0
15	1	0	0	1.7	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
Mean (numbers per 100 m²):				4.7 ± 3.8				0.8 ± 1.1
1997								
1	0	2	0	> 2.0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	1	0	> 1.0	3	0	0	3.0
4	6	1	0	10.8	0	0	0	0
5	3	3	4	> 10.0	0	0	0	0
6	1	0	0	2.2	0	0	0	0
7	1	0	0	1.3	0	0	0	0
8	3	2	0	6.9	0	0	0	0
9	8	4	1	28.0	0	0	0	0
10	3	0	0	3.0	0	0	0	0
11	6	4	0	23.1	0	0	0	0
12	5	3	1	13.6	0	0	0	0
13	5	1	0	6.0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	2	0	0	3.3	0	0	0	0
16	1	0	0	1.0	0	0	0	0
17	0	0	0	0	0	0	0	0
Mean (numbers per 100 m²):				6.6 ± 4.0				0.2 ± 0.4

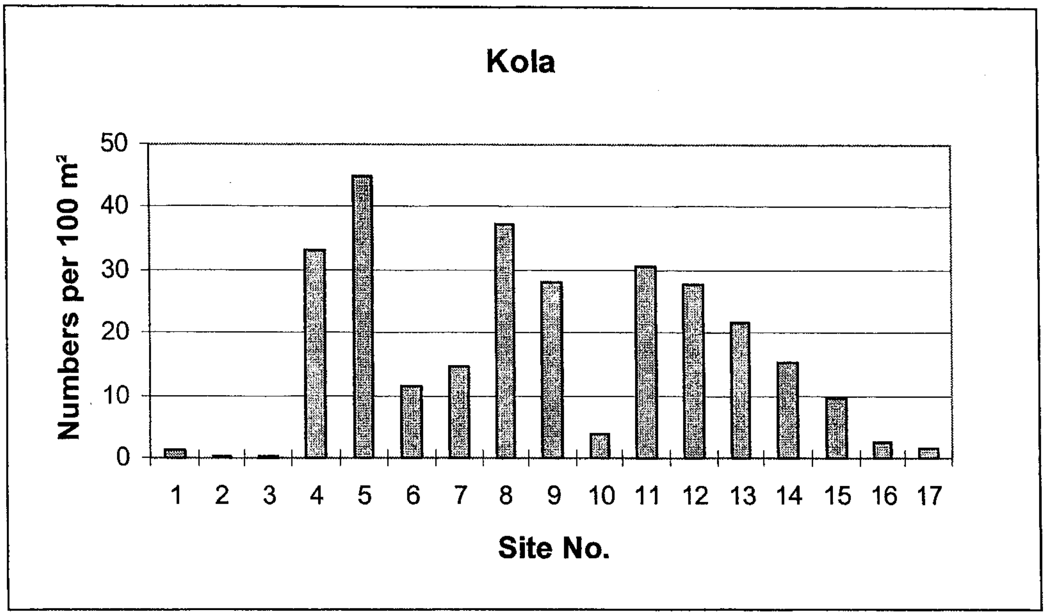


***Figure 11**. Density estimates (numbers per 100 m², Zippin method) of Atlantic salmon parr (excluding fry) at each of the 17 sites in River Kola 1993-1997.*

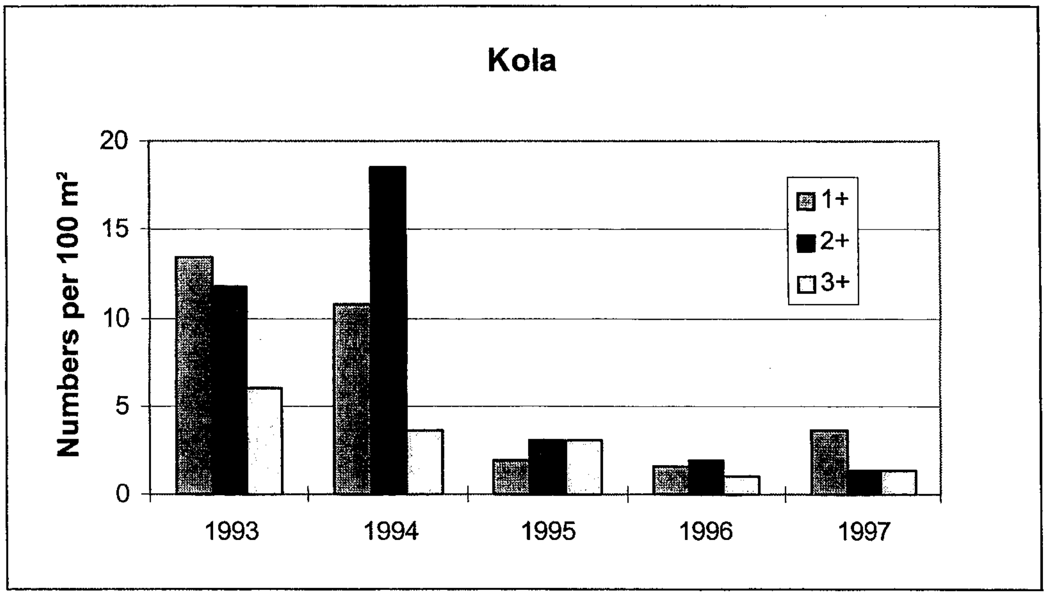


***Figure 12**. Average density estimates of Atlantic salmon parr of age 1+, 2+ and 3+ in the River Kola in the period 1993-1997 (numbers per 100 m²).*

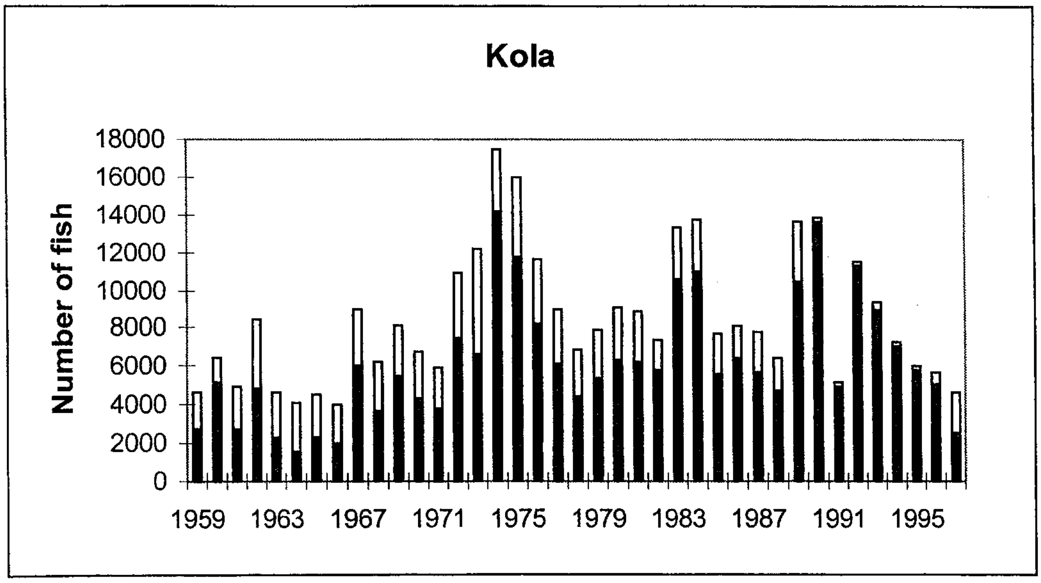


***Figure 13**. Total ascent (numbers) of adult Atlantic salmon in the River Kola in the period 1959-1997. The lower, black part of the bars indicates fish which were kept, and the upper, white part indicates fish which were left for spawning.*

Table 12*. Age and size (± 95 % confidence limits) of Atlantic salmon at smolt migration from the River Kola in the period 1993-1997, analysed from scale samples. Distribution of smolt ages are given as percentages.*

Year	Sample size	Smolt age (years) 2	3	4	5	6	Mean smolt age (yr)	Mean smolt size (mm)
1993	245	7	50	36	1		3.41 ± 0.05	160.9 ± 1.5
1994	239	5	53	35	8		3.45 ± 0.05	146.0 ± 1.3
1995	343	5	39	48	9		3.60 ± 0.04	146.0 ± 1.1
1996	267	6	77	17	< 1		3.12 ± 0.03	152.3 ± 1.2
1997	192	3	45	48	4		3.54 ± 0.05	155.9 ± 1.8

Both 1SW, 2SW and 3SW salmon were frequent in the river, and some 4SW were also observed. Among males, 1SW predominated, with more than 70 % of the fish in all years **(Figure 14).** Most of the females were usually 2SW or 3SW fish, while only a few female 1SW were observed **(Figure 14).**

The mean weight of 1SW fish varied between 2 071 ± 38 g and 2 374 ± 49 g **(Table 13).** Similarly, the mean weight of 2SW fish varied between 4 981 ± 235 g and 5 769 ± 203 g, and 3SW salmon were between 8 983 ± 360 g and 9 722 ± 1 302 g. Some 4SW salmon were also included in the catches, and the average weight of them was more than 13 kg **(Table 13).**

4.3 River Alta

4.3.1 Growth and density of parr

In the middle of August, young-of-the-year Atlantic salmon in the River Alta were on average 34-38 mm long **(Table 14).** The mean annual growth increment of 0+, 1+ and 2+ salmon from August 1993 to August 1994 was 27-29 mm, while that from August 1994 to August 1995 was only 19-23 mm. Compared with the model for growth of Atlantic salmon parr fed on maximum rations at the same temperature regime (Elliott & Hurley 1997), the growth was 92 % of the model from August 1993 to August 1994, but only 61-79 % of the model from August 1994 to August 1995 **(Table 15).** From August 1995 to August 1996 the observed growth increment was 18-22 mm. This was also low compared to the estimated ones (71-87 %). During the period from August 1996 to August 1997, the growth increment of 0+ salmon was as high as 31 mm, representing a growth rate nearly similar to the estimated one (95 %). Also the growth of 1+ fish was higher than the previous years (29 mm, **Table 14**). The last year was the warmest one during the period studied. Hence, in spite of this high growth rate, the growth of 1+ salmon represented only 86 % of that estimated from the model for growth of Atlantic salmon parr fed on maximum rations at the same temperature regime **(Table 15).**

Atlantic salmon was the predominant species in the River Alta. Brown trout constituted 1-2 % of the electrofishing catches **(Table 16, Table 17,** Jensen et al. 1997). Other fish species were seldom observed.

Estimated densities of Atlantic salmon parr (excluding fry) in the River Alta were to 32.1 ± 19.7, 60.2 ± 28.6, and 61.4 ± 31.6 individuals per 100 m^2 in 1993, 1994 and 1995, respectively (Jensen et al. 1997). The corresponding densities of brown trout were less than 1 per 100 m^2 in all years studied. In 1996 and 1997, densities of Atlantic salmon parr were 53.1 ± 25.5 and 83.8 ± 32.0, respectively **(Table 17).**

The highest densities of Atlantic salmon parr were observed at sites 5-8, in the middle part of the river **(Figure 15).** At site 6 densities were extremely high, with 1,4 salmon parr per m^2 as an average for the five years studied. At sites 1-3, which are closest to the river mouth, densities of salmon were considerably lower than further upstream. In that part of the river the bottom is more silty, with habitats which are less favourable for salmon than elsewhere in the river. Also at sites 14-16 densities were lower than in the middle part of the river. These sites are located closest to the outlet of the hydropower station, and is negatively influenced by it. Densities of fish in this part of the river have decreased since the power station was brought into service in 1987 (Forseth et al. 1996).

The estimated densities of 1+ salmon were lowest in 1993 and 1996, and highest in 1994 and 1997 **(Figure 16).** The densities of fish older than 1+ increased steadily during the study period, and were highest in 1997.

4.3.2 Status of adult stock

Reported catches of adult Atlantic salmon from the sport fishery varied between 2.3 (1970) and 32.5 tons (1975) in the River Alta, with an average of 13.0 tons for the period 1966-1997 **(Figure 17).** The average catch of brown trout during the same period was 0.9 tons, varying between 0.1 and 2.0 tons. Since 1974, the sport fishermen have had to pay a deposit for their licence to fish. This deposit is re-

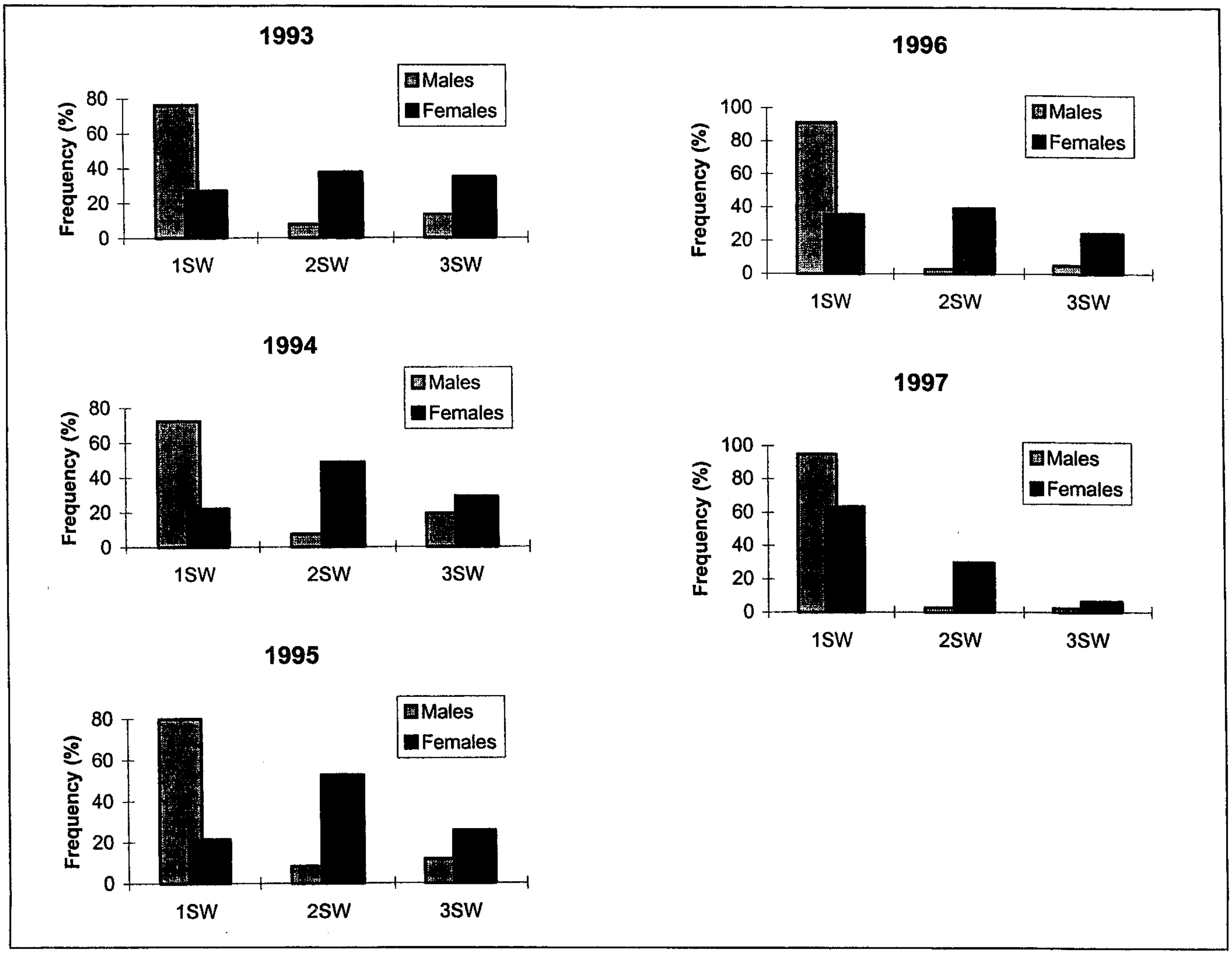


Figure 14. *Sea age distribution of male and female Atlantic salmon in the River Kola during 1993-1997.*

Table 13. Mean weight (g ± 95 % confidence limits) of 1SW, 2SW, 3SW and 4SW Atlantic salmon from the River Kola. Sample sizes are given in parentheses.

Year/age	1SW	2SW	3SW	4SW
1993	2131 ± 52 (286)	4981 ± 235 (95)	9694 ± 352 (108)	14720 ± 1590 (10)
1994	2288 ± 51 (493)	5257 ± 171 (210)	9694 ± 257 (211)	13383 ± 3166 (6)
1995	2374 ± 49 (521)	5769 ± 203 (207)	9508 ± 332 (145)	-
1996	2238 ± 44 (575)	5528 ± 222 (108)	8983 ± 360 (86)	13416 ± 2076 (6)
1997	2071 ± 38 (535)	5357 ± 298 (68)	9722 ± 1302 (22)	-

Table 14. Mean natural tip length (l, mm ± 95 % confidence limits) of different age groups of Atlantic salmon parr collected by electrofishing in the River Alta in August 1993-1997. Sample sizes are given in parentheses.

Age/year	13-15.08.93	15-18.08.94	14-18.08.95	12-15.08.96	11-14.08.97
0+	36.1 ± 0.4 (183)	36.5 ± 0.3 (363)	34.3 ± 0.6 (79)	33.8 ± 0.6 (103)	37.7 ± 0.6 (139)
1+	61.0 ± 0.1 (71)	63.0 ± 0.8 (250)	59.3 ± 1.1 (179)	56.0 ± 0.9 (138)	65.0 ± 1.1 (210)
2+	85.2 ± 1.8 (75)	89.5 ± 1.4 (118)	84.6 ± 1.4 (128)	81.4 ± 1.8 (133)	84.8 ± 3.1 (47)
3+	104.1 ± 0.7 (15)	114.1 ± 1.9 (73)	108.1 ± 2.1 (63)	103.4 ± 3.1 (51)	99.4 ± 3.9 (58)

Table 15. *Mean weight (W_0, g) of 0+, 1+ and 2+ Atlantic salmon sampled in August 1993-1996 in the River Alta, mean weight (W_t, g) of the same year-class one year later, and the corresponding final weight estimated from the model for growth of Atlantic salmon fed on maximum rations (Elliott & Hurley 1997) at the same temperature regimes. Mean instantaneous growth rate per year (G_{WA} year^{-1}) of Atlantic salmon recorded in the river, and the corresponding estimated growth rate. The ratio (%) between observed and estimated growth rate is also given.*

Age	Initial weight (W_0 g)	Final weight (W_t g) Observed	Final weight (W_t g) Estimated	Mean instantaneous growth rate per year (G_{WA} year^{-1}) Observed	Mean instantaneous growth rate per year (G_{WA} year^{-1}) Estimated	Ratio observed/ estimated (%)
August 1993 - August 1994						
0+	0.43	2.32	2.72	1.69	1.84	92
1+	2.10	6.65	7.30	1.15	1.25	92
2+	5.73	13.77	14.93	0.88	0.96	92
August 1994 - August 1995						
0+	0.45	1.93	2.82	1.46	1.84	79
1+	2.32	5.61	7.88	0.88	1.22	72
2+	6.65	11.71	16.78	0.57	0.93	61
August 1995 - August 1996						
0+	0.37	1.63	2.02	1.48	1.70	87
1+	1.93	5.00	5.92	0.95	1.12	85
2+	5.61	10.25	13.03	0.60	0.84	71
August 1996 - August 1997						
0+	0.36	2.55	2.86	1.96	2.07	95
1+	1.63	5.65	6.89	1.24	1.44	86
2+	5.00	9.10	14.74	0.60	1.08	56

funded when they return their licence, including a detailed catch report. Therefore, the catch statistics for the River Alta since 1974 are considered the most reliable.

After the building of the hydropower station in 1987, densities of juvenile salmon have decreased significantly (ca 85 %) in the upper 15 % of the salmon producing part of the River Alta (the Sautso area). In lower parts of the river, densities of presmolt salmon remain unchanged or have increased. Another effect of the power plant is reduced catches of salmon in the sport fisheries in the Sautso area. Catches of 1SW have declined relative to catches in lower regions of the river, while catches of 3SW fish have declined in absolute numbers. The negative development in catches are probably caused by increased mortality in juvenile stages (Forseth et al. 1996).

The annual catch of Atlantic salmon in the River Alta was significantly correlated to the annual ascent of salmon in the River Kola ($r = 0.417$, $p < 0.05$), but not to similar data from the Rivers Varzuga and Orkla ($p > 0.05$).

There was no significant correlation between the annual catch of Atlantic salmon in the River Alta and sea temperatures the previous year ($p > 0.05$). However, sea temperatures both two and three years earlier were significantly correlated to the catch ($r = 0.415$, $p < 0.05$ and $r = 0.554$, $p < 0.01$, respectively).

4.3.3 Population structure

Smolt ages between two and six years have been observed in the River Alta. However, most fish (60-77 %) had a stay of four years in the river before they migrated to sea. The average smolt age varied between 3.83 ± 0.05 (1993) and 4.06 ± 0.08 years (1997) **(Table 18).** The mean smolt lengths have been 131-138 mm **(Table 18).**

In the period 1993-97 more males (52 %) than females (48 %) were caught during the sport fishery. Among males, 1SW fish were most frequent (60-86 %), but 3SW fish also made a significant contribution (5-22 %) to the male population. Among females, 3SW fish predominated (51-92 %). Some 4SW fish of both sexes also occurred, while 2SW fish were scarce **(Figure 18).** Mean weight of the different age groups is given in **Table 19.**

***Table 16**. Number of Atlantic salmon and brown trout parr caught at fourteen stations in the River Alta in August 1996-1997. The area (m²) of each station is also given. * indicates that 2+ and older fish are pooled.*

		Area	Atlantic salmon						Brown trout					
Site	Date	(m²)	0+	1+	2+	3+	older	Sum	0+	1+	2+	3+	older	Sum
1996														
1	12.08.96	147	8					8						0
2	12.08.96	156	11	5			3*	19						0
3	12.08.96	210						0						0
4	12.08.96	128	3	96			24*	123	10	5			1*	16
5	15.08.96	106	72	29			31*	132						0
6	15.08.96	204	16	33			108*	157						0
7	15.08.96	128	3	20			57*	80						0
8	15.08.96	109	50	22			83*	155		1			2*	3
10	14.08.96	176	21	47			33*	101						0
11	14.08.96	166	28	6			25*	59						0
12	14.08.96	200	21	9			61*	91					1*	1
14	13.08.96	56	42	5				47	1	1				2
15	13.08.96	110	20	11			12*	43	1					1
16	13.08.96	312	28	9			27*	64						0
1997														
1	11.08.97	100	1	6			19*	26						0
2	11.08.97	100	1				2*	3		1				1
3	11.08.97	100	2	2			7*	11		2				2
4	14.08.97	100		54	7	4		65						0
5	11.08.97	125	15	46			59*	120	1					1
6	12.08.97	108	1	100			114*	215	1				2*	3
7	12.08.97	108		39			66*	105		2				2
8	14.08.97	88	41	29	12	34	18	134					1*	1
10	12.08.97	108	14	52			50*	116					1*	1
11	12.08.97	108	19	23			39*	81						0
12	12.08.97	108	5	29	16	8	1	58						0
14	13.08.97	40	26	1			29*	56						0
15	13.08.97	100	78	30	2			110	22	2				24
16	13.08.97	108	15	68	10	12	2	107						0

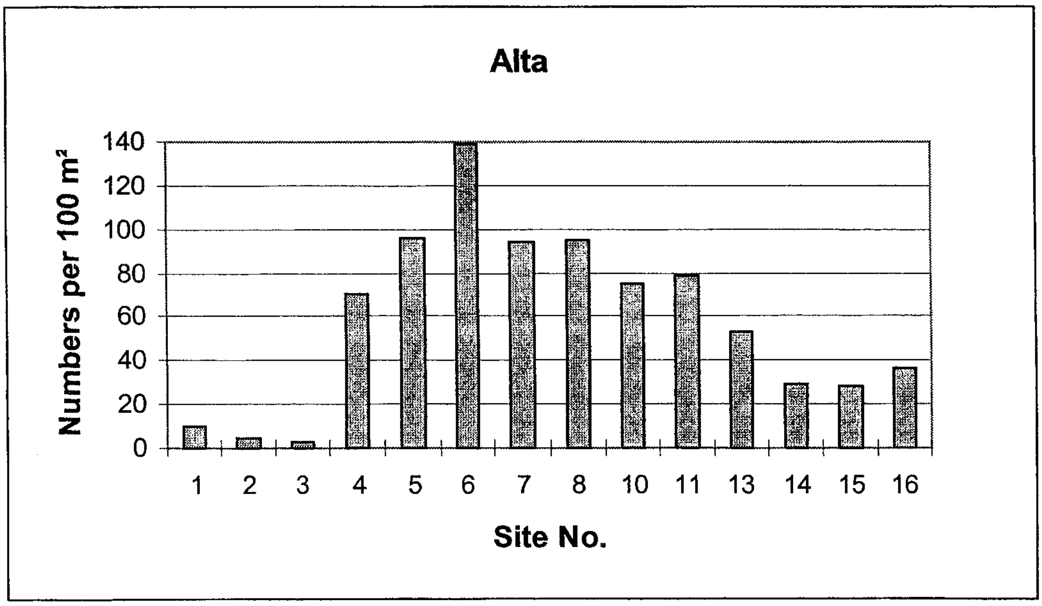


***Figure 15**. Density estimates (numbers per 100 m², Zippin method) of Atlantic salmon parr (excluding fry) at each of the 14 sites in the River Alta 1993-1997.*

***Table 17**. Catch of Atlantic salmon and brown trout parr (excluding fry) in the River Alta in the first, second and third successive fishing, and density estimates (Zippin method, number per 100 m²) in August 1996-1997. The area of each site is given in **Table 15**.*

Site	Atlantic salmon				Brown trout			
	1. fishing	2. fishing	3. fishing	Zippin estimate	1. fishing	2. fishing	3. fishing	Zippin estimate
1996								
1	0	0	0	0	0	0	0	0
2	5	3	0	5.3	0	0	0	0
3	0	0	0	0	0	0	0	0
4	55	36	29	149.6	5	1	0	4.7
5	25	21	14	100.9	0	0	0	0
6	88	30	23	77.1	0	0	0	0
7	44	21	12	70.0	0	0	0	0
8	55	36	14	112.4	3	0	0	2.8
10	37	26	17	69.0	0	0	0	0
11	11	11	9	75.8	0	0	0	0
12	40	18	12	41.3	0	1	0	> 0.5
14	4	1	0	9.0	1	0	0	2.0
15	16	3	4	22.6	0	0	0	0
16	14	8	4	10.0	0	0	0	0
Mean (numbers per 100 m²):				53.1 ± 25.5				0.7 ± 0.8
1997								
1	21	3	1	25.2	0	0	0	0
2	2	0	0	2.0	1	0	0	1.0
3	6	1	2	10.2	1	1	0	2.2
4	45	10	10	69.8	0	0	0	0
5	55	26	24	113.8	0	0	0	0
6	119	64	31	230.6	2	0	0	2.0
7	60	24	21	117.9	1	0	1	> 1.9
8	60	25	8	112.4	1	0	0	1.1
10	63	23	16	110.2	1	0	0	0.9
11	40	16	6	61.3	0	0	0	0
12	26	23	5	59.3	0	0	0	0
14	16	4	10	126.1	0	0	0	0
15	21	7	4	34.4	2	0	0	2.0
16	52	25	15	100.1	0	0	0	0
Mean (numbers per 100 m²):				83.8 ± 32.0				0.8 ± 0.5

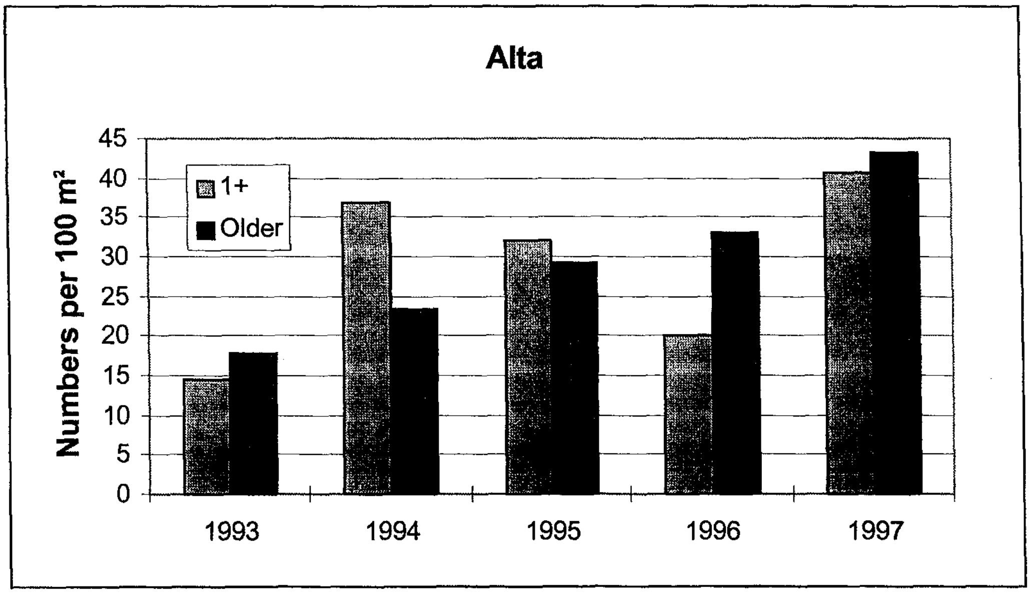


***Figure 16**. Average density estimates of Atlantic salmon parr of age 1+ and older in the River Alta in the period 1993-1997 (numbers per 100 m²).*

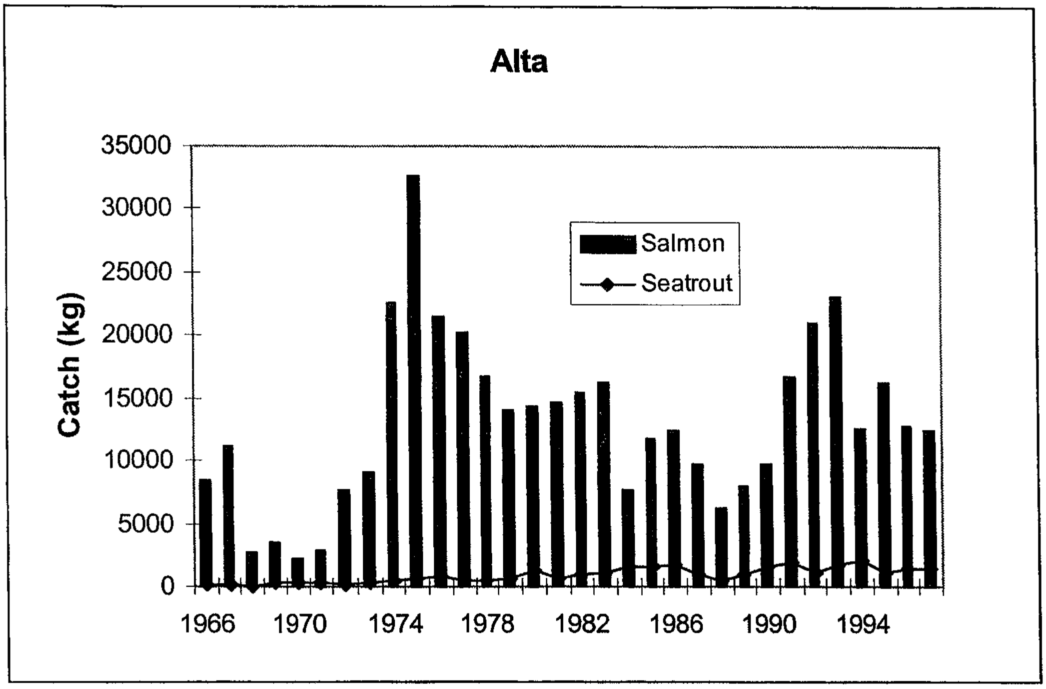


Figure 17. Catches (kg) of adult Atlantic salmon (bars) and sea trout (line) in the River Alta during 1966-1997.

Table 18. Age and size (± 95 % confidence limits) of Atlantic salmon at smolt migration from the River Alta in the period 1993-1997, analysed from scale samples. Distribution of smolt ages are given as percentages.

Year	Sample size	Smolt age (years) 2	3	4	5	6	Mean smolt age (yr)	Mean smolt size (mm)
1993	625	< 1	25	67	7	< 1	3.83 ± 0.05	131.4 ± 1.5
1994	340		18	70	12		3.94 ± 0.06	138.3 ± 2.3
1995	607	< 1	24	61	15	< 1	3.92 ± 0.07	136.5 ± 1.0
1996	297		12	77	11		3.99 ± 0.06	133.4 ± 2.2
1997	273		17	60	22	< 1	4.06 ± 0.08	133.6 ± 2.6

Table 19. Mean weight (g ± 95 % confidence limits) of 1SW, 2SW, 3SW and 4SW Atlantic salmon from the River Alta. Sample sizes are given in parentheses.

Year/age	1SW	2SW	3SW	4SW
1993	2203 ± 60 (220)	6486 ± 670 (14)	10959 ± 205 (354)	14868 ± 1496 (31)
1994	1914 ± 103 (88)	6565 ± 595 (26)	10330 ± 258 (177)	15058 ± 1048 (38)
1995	1967 ± 40 (189)	6491 ± 904 (11)	10664 ± 195 (337)	15028 ± 1198 (29)
1996	2029 ± 54 (225)	5803 ± 887 (19)	10044 ± 627 (45)	13378 ± 896 (24)
1997	1952 ± 64 (164)	6868 ± 558 (37)	10525 ± 405 (79)	14054 ± 1528 (13)

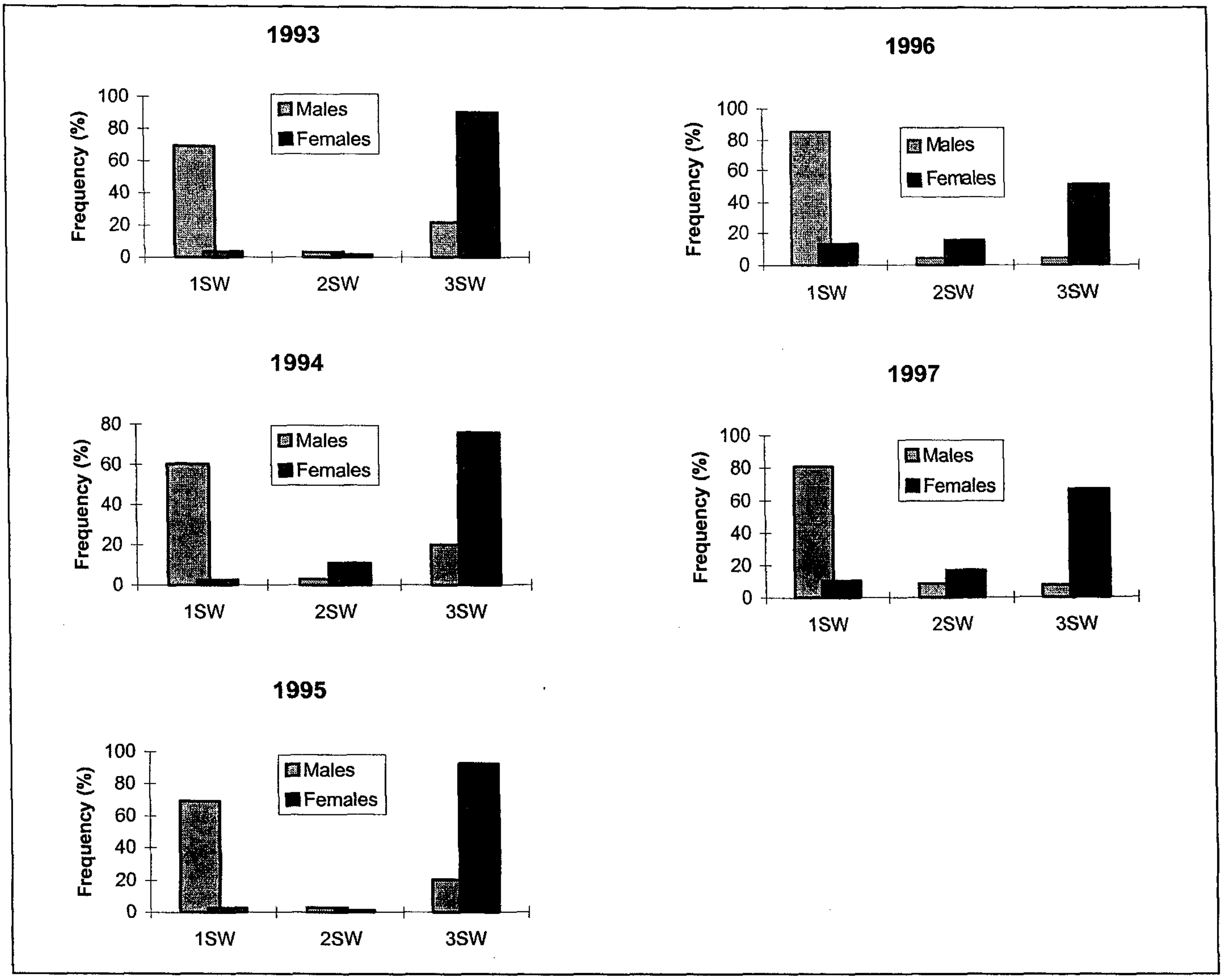


Figure 18. Sea age distribution of male and female Atlantic salmon in the River Alta during 1993-1997.

4.4 River Orkla

4.4.1 Growth and density of parr

Mean lengths of 0+ Atlantic salmon parr collected in the River Orkla in September 1993-1997 were 42.4 45.1 mm **(Table 20)**. At the same time, one year old fish were 69.3-73.6 mm, and two year old fish were 94.9 102.0 mm. The average annual growth increment of 0+ salmon from September one year to September the subsequent year was 27.2 mm (variation 25.9-28.2 mm), while the similar growth increment for 1+ salmon was 26.6 (23.6-29.8) mm.

The annual growth rate of salmon parr during the period from September 1993 to September 1994 was 79-83 % of the corresponding growth estimated by the growth model for Atlantic salmon parr fed on maximum rations at the same temperature regime (Elliott & Hurley 1997, **Table 21**). In the period from September 1994 to September 1995 the corresponding growth rates were 99-109 % of the estimated values. Similar growth rates (98-103 %) were also observed from September 1995 to September 1996, while the subsequent year the observed growth rates were 108-114 % of the estimated ones.

In the period 1993-1997, mean densities of Atlantic salmon parr (excluding fry) varied between 21.4 ± 6.9 and 61.6 ± 27.8 fish per 100 m^2 (Jensen et al. 1997, **Table 22, Table 23**). with highest densities in 1994 and lowest in 1997. Similar estimates for juvenile brown trout varied between 8.1 ± 3.5 and 16.0 ± 8.5 fish per 100 m^2 (**Table 23,** Jensen et al. 1997). The highest densities of salmon were observed on site number 8 **(Figure 19)**. Sites number 1, 5 and 9 also had high densities.

Densities of Atlantic salmon parr were higher in 1994, 1995 and 1996 than in 1993 and 1997. This is partly because of the strong 1993 year-class **(Figure 20)**, which was included in the 1994-1996 estimates, but not in the 1993 and 1997 estimates. However, densities of both Atlantic salmon and brown trout were highest in 1994 and lowest in 1997. In

Table 20. Mean natural tip length (l, mm ± 95% confidence limits) of different age groups of Atlantic salmon parr collected by electrofishing in the River Orkla in September 1993-1996, and October/November 1997. Sample sizes are given in parentheses.

Age/year	10-13.09.93	12-14.09.94	19-22.09.95	3-5.09.96	10.10-4.11.97
0+	43.1 ± 0.6 (175)	43.4 ± 0.8 (173)	42.4 ± 0.9 (98)	44.2 ± 0.5 (305)	45.1 ± 1.8 (27)
1+	73.6 ± 1.0 (167)	71.3 ± 0.7 (359)	69.3 ± 1.0 (241)	69.5 ± 1.5 (198)	71.6 ± 1.3 (132)
2+	102.0 ± 2.1 (125)	100.5 ± 1.7 (173)	94.9 ± 1.3 (309)	95.5 ± 1.4 (236)	99.3 ± 3.5 (52)
3+	117.5 ± 2.6 (66)	121.6 ± 2.7 (43)	117.6 ± 2.7 (45)	119.5 ± 2.0 (106)	115.3 ± 3.3 (31)

Table 21. Mean weight (W_0, g) of 0+, 1+ and 2+ Atlantic salmon sampled in September 1993-1996 in the River Orkla, mean weight (W_t, g) of the same year-class one year later, and the corresponding final weight estimated from the model for growth of Atlantic salmon fed on maximum rations (Elliott & Hurley 1997) at the same temperature regimes. Mean instantaneous growth rate per year (G_{WA} year^{-1}) of Atlantic salmon recorded in the river, and the corresponding estimated growth rate. The ratio (%) between observed and estimated growth rate is also given.

Age	Initial weight (W_0 g)	Final weight (W_t g)		Mean instantaneous growth rate per year (G_{WA} year^{-1})		Ratio observed/ estimated (%)
		Observed	Estimated	Observed	Estimated	
September 1993 - September 1994						
0+	0.74	3.36	4.58	1.51	1.82	83
1+	3.70	9.41	2.04	0.93	1.18	79
September 1994 - September 1995						
0+	0.76	3.09	.77	1.40	1.29	109
1+	3.36	7.92	.05	0.86	0.87	99
September 1995 - September 1996						
0+	0.71	3.11	.98	1.48	1.43	103
1+	3.09	8.07	.23	0.96	0.98	98
September 1996 - October 1997						
0+	0.80	3.40	.04	1.45	1.34	108
1+	3.11	9.08	.93	1.07	0.94	114

1997 the field work had to be postponed to October because of unfavourably high water flow during September, and also in October the flow conditions were unfavourable. High water flow during electrofishing is known to hinder the catch of both Atlantic salmon and brown trout parr (Jensen & Johnsen 1988).

4.4.2 Status of adult stock

Reported catches of adult Atlantic salmon from the sport fishery varied between 0.9 (1969) and 26.9 tons (1987) in the River Orkla, with an average of 9 tons for the period 1966-1997 **(Figure 21)**. The average catch of brown trout during the same period was 1.1 tons, varying between 0.3 and 2.2 tons.

The River Orkla was developed for hydroelectric purposes in the early 1980's. After the hydropower development, minimum water flows as high as 10 m^3/s between Berkåk and Meldal have been provided, and Atlantic salmon smolt production in this part of the river has increased (Hvidsten & Ugedal 1991).

In the lower 15 km of the River Orkla, juvenile salmonid populations have been considerably reduced because of heavy metal pollution from the Løkken copper mine. A small tributary, the River Raubekken, drains the catchment near the copper mine. This tributary transported high concentrations of heavy metals, mainly copper, zinc, iron and cadmium, into the main river. When the river was utilised for hydroelectric purposes in the early 1980's, the opportunity was taken to mix water from the tributary with discharge

Table 22. Number of Atlantic salmon and brown trout parr caught at twelve stations in the River Orkla in September 1996 and October/November 1997. The area (m^2) of each station is also given.

Site	Date	Area m²)	Atlantic salmon 0+	1+	2+	3+	older	Sum	Brown trout 0+	1+	2+	3+	older	Sum
1996														
1	04.09.96	100	7	9	13	2		31	16	2				18
2	04.09.96	100	5	6	1			12	38	24	1			63
3	03.09.96	100	18	19	13			50	2	4				6
4	04.09.96	100	23	5	19	14		61		1				1
5	04.09.96	100	67	28	26	7	1	129	11	5	1			17
6	04.09.96	100	37	22	16	2		77	15	1				16
7	03.09.96	100	48	23	7	1		79	59	4				63
8	03.09.96	100	38	49	71	30	2	190	87	16	8	1		112
9	05.09.96	100	14	14	22	20		70	17	15	5	1		38
10	05.09.96	100	28	11	18	8		65	25	8				33
11	05.09.96	100	3	5	11	14		33	2	4	3	1		10
12	05.09.96	100	9	8	17	10		44	11	9	2	1		23
1997														
1	12.10.97	100	18	10				28	2	10	3			15
2	12.10.97	100	4	24	6	1		35	5	5				10
3	12.10.97	100	5	21	6	3		35		2				2
4	04.11.97	100	1	16		5		22		5				5
5	04.11.97	100	14	24	12	2		52	21	9	1			31
6	04.11.97	100		7	3	2		12	4	2				6
7	12.10.97	100		13	1	4		18	40	5				45
8	11.10.97	100	1	7	5	1		14	15	10	3			28
9	11.10.97	100		1	2	5		8	2	6	5			13
10	10.10.97	100	2	1	1	1		5	8					8
11	10.10.97	100			2	4		6	5	2				7
12	10.10.97	100	1		4	3	1	9	11	10	1	1		23

Figure 19. Average density estimates (numbers per 100 m², Zippin method) of Atlantic salmon parr (excluding fry) at each of the 12 sites in the River Orkla 1993-1997.

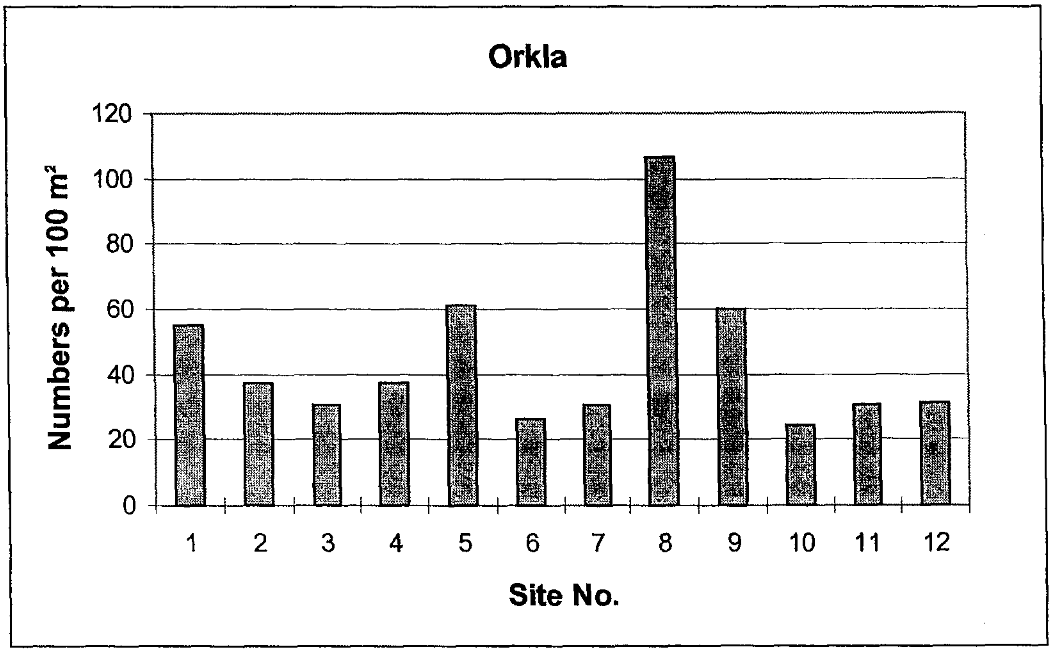


Table 23. Catch of Atlantic salmon and brown trout parr (excluding fry) in the River Orkla in the first, second and third successive fishing, and density estimates (Zippin method, number per 100 m²) in September 1996 and October/November 1997. The area of each site is given in Table 18.

Site	Atlantic salmon				Brown trout			
	1. fishing	2. fishing	3. fishing	Zippin estimate	1. fishing	2. fishing	3. fishing	Zippin estimate
1996								
1	19	5	0	24.2	1	1	0	2.2
2	6	1	0	7.0	19	4	2	25.6
3	22	8	2	33.2	4	0	0	4.0
4	31	5	2	38.4	1	0	0	1.0
5	35	19	8	70,.4	3	3	0	6.6
6	36	3	1	40.1	1	0	0	1.0
7	22	8	1	31.8	4	0	0	4.0
8	101	38	13	160.1	16	7	2	26.6
9	32	14	10	66.5	8	12	1	26.8
10	25	10	2	38.4	4	2	2	11.9
11	13	12	5	42.9	4	2	2	11.9
12	22	7	6	39.4	5	4	2	15.4
Mean (numbers per 100 m²):				49.4 ± 22.4				11.4 ± 5.8
1997								
1	22	4	2	28.4	12	1	0	13.0
2	18	9	4	34.9	3	0	2	8.4
3	23	5	2	30.6	2	0	0	2.0
4	10	7	4	29.0	3	1	1	5.9
5	19	17	2	43.1	4	4	2	16.8
6	10	2	0	12.0	2	0	0	2.0
7	16	1	1	18.1	5	0	0	5.0
8	10	1	2	13.5	10	3	0	13.1
9	3	3	2	18.7	6	3	2	13.5
10	2	1	0	3.1	0	0	0	0
11	6	1	0	7.0	1	1	0	2.2
12	4	1	3	18.7	6	4	2	15.3
Mean (numbers per 100 m²):				21.4 ± 6.9				8.1 ± 3.5

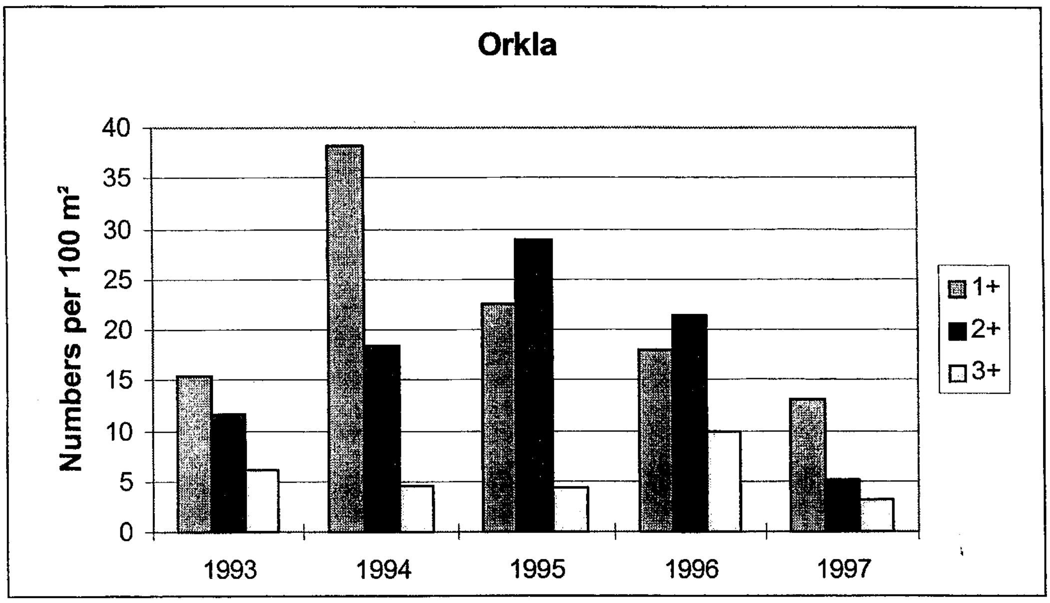


***Figure 20**. Average density estimates of Atlantic salmon parr of age 1+, 2+ and 3+ in the River Orkla in the period 1993-1997 (numbers per 100 m²).*

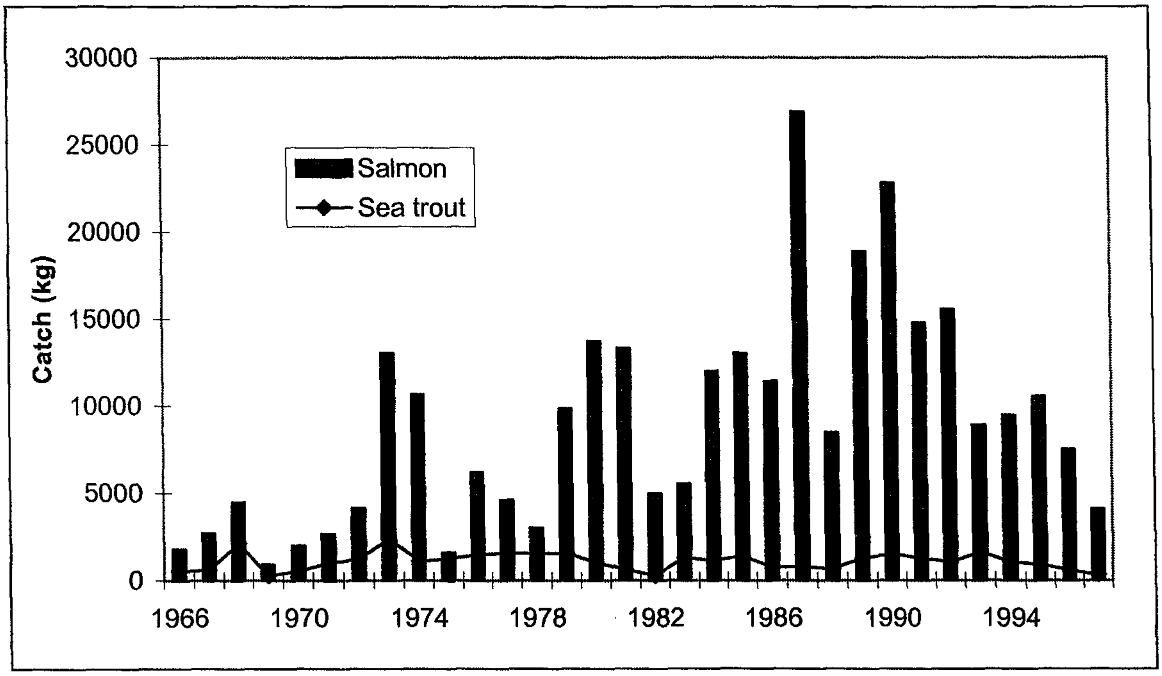


Figure 21. Catches (kg) of adult Atlantic salmon (bars) and sea trout (line) in the River Orkla in the period 1966-1995.

water from the Svorkmo power plant before it reached the main river. At the same time measures were taken in the mining area, which partially prevented polluted water from seeping into the Raubekken. In addition, the hydropower company maintains a rather high minimum flow in the river. As a consequence, the concentrations of copper, zinc, iron, lead and cadmium have declined in the lower part of the main river since 1982. During the same period, densities of juvenile Atlantic salmon in the lower part of the river have increased to levels almost similar to those upstream from the tributary. Heavy metal analyses of juvenile Atlantic salmon have shown that concentrations of cadmium, copper and selenium are still higher in fish downstream than those upstream of the tributary. Hence, living conditions for salmonids in the lower 15 km of the River Orkla are now greatly improved (Jensen et al. 1995, 1998a).

There was a significant increase in catch of Atlantic salmon in the River Orkla during the period 1966-97 ($r = 0.525$, $p < 0.01$). Partial correlation analysis, controlling for year, revealed that there was no significant correlation between the catch of Atlantic salmon in the Rivers Orkla and Alta ($p > 0.05$). Either, there was no correlation between the catch of salmon in the River Orkla and the ascent of salmon in the two Russian rivers ($p > 0.05$) or between the catch in the River Orkla and sea temperatures in the Kola Meridian section ($p > 0.05$).

4.4.3 Population structure

The smolt age of Atlantic salmon from the river Orkla varied between two and five years. Most fish were three or four years at smoltification. The mean smolt age varied between 3.40 ± 0.04 and 3.61 ± 0.10 years, and the mean length of smolts was 132-139 mm **(Table 24)**.

Both 1SW, 2SW and 3SW fish were frequent in the river, and also some 4SW were observed. The proportion of males was 56 % as a mean for the 1993-97 runs. Among males, 1SW predominated in 1993, 1994 and 1997. However, because of unusually high return rate of fish which smoltified in 1993, 2SW fish of both sexes predominated the catches in 1995, and similarly, 3SW fish dominated in 1996 **(Figure 22)**. Most of the females were 2SW or 3SW fish, while usually only a few female grilse were observed. The mean weight of grilse, 2SW, 3SW and 4SW fish are given in **Table 25.**

***Table 24**. Age and size (± 95 % confidence limits) of Atlantic salmon at smolt migration from the River Orkla in the period 1993-1997, analysed from scale samples. Distribution of smolt ages are given as percentages.*

Year	Sample size	Smolt age (years) 2	3	4	5	6	Mean smolt age (yr)	Mean smolt size (mm)
1993	417	1	52	45	2		3.48 ± 0.06	133.6 ± 2.0
1994	602	2	54	42	2		3.45 ± 0.05	132.4 ± 1.7
1995	593	1	54	44	1		3.40 ± 0.04	137.6 ± 1.7
1996	349	1	51	47	1		3.50 ± 0.06	138.7 ± 2.2
1997	125	2	38	58	2		3.61 ± 0.10	138.9 ± 4.0

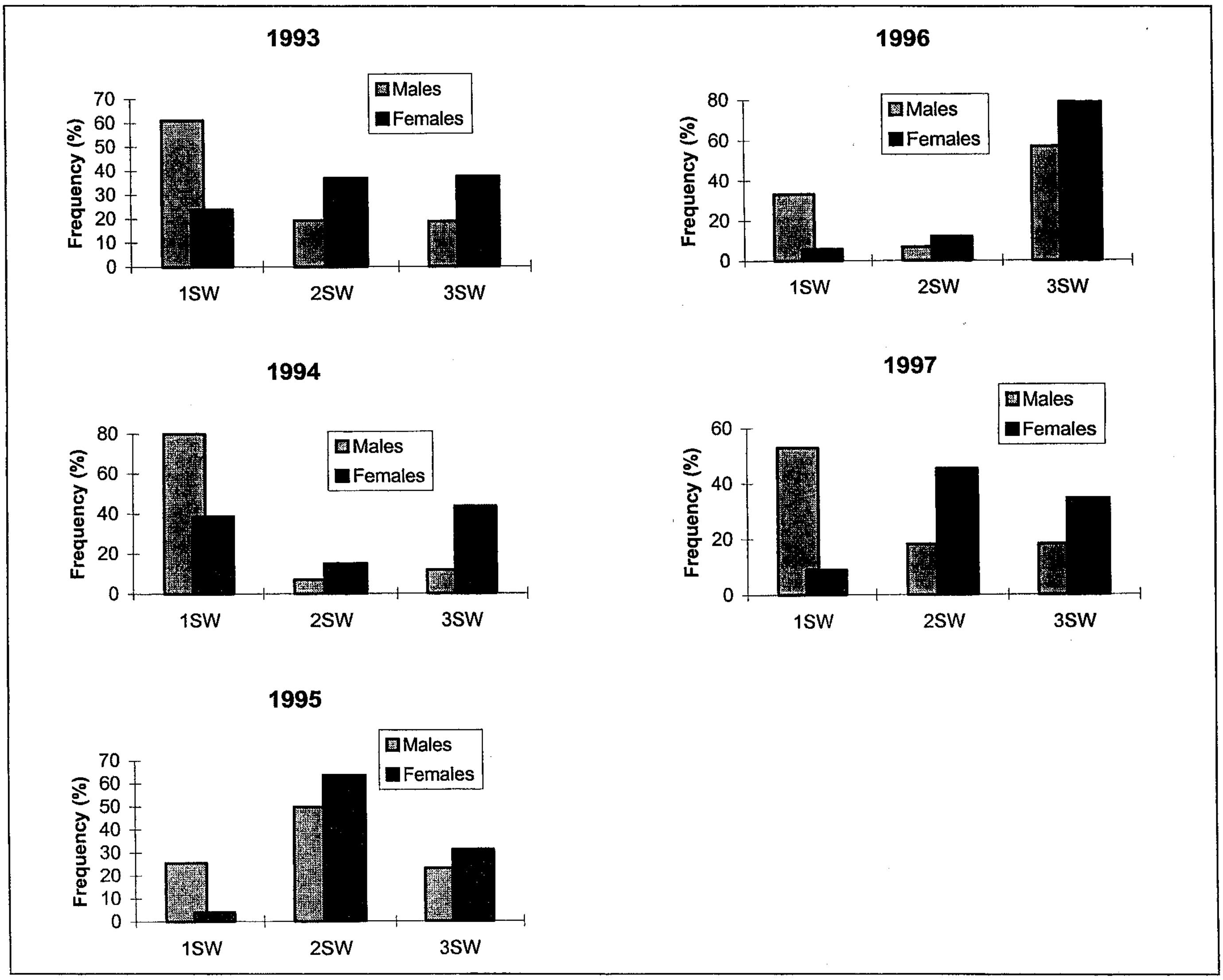


***Figure 22**. Sea age distribution of male and female Atlantic salmon in the River Orkla during 1993-1997.*

Table 25. Mean weight (g ± 95 % confidence limits) of 1SW, 2SW, 3SW and 4SW Atlantic salmon from the River Orkla. Sample sizes are given in parentheses.

Year/age	1SW	2SW	3SW	4SW
1993	1979 ± 101 (188)	5475 ± 236 (107)	9236 ± 365 (105)	10200 ± 1568 (50)
1994	2255 ± 51 (389)	5501 ± 331 (52)	8994 ± 349 (105)	13162 ± 3402 (8)
1995	1982 ± 126 (77)	6047 ± 110 (335)	8862 ± 280 (157)	10414 ± 2704 (7)
1996	1780 ± 85 (71)	5939 ± 418 (33)	9280 ± 209 (240)	11645 ± 1840 (11)
1997	1951 ± 221 (41)	5837 ± 286 (38)	9310 ± 587 (30)	12525 ± 2001 (12)

5 Discussion

5.1 Growth of parr

Once the yolk sac has been absorbed, growth is mainly dependent on nutrient conditions, water temperature, and fish weight (Donaldson & Foster 1940, Brett et al. 1969, Elliott 1975a, b, Spigarelli et al. 1982). For Atlantic salmon, the optimum temperature for growth at excess rations has been found to be 15.9 °C, while growth commences at 6.0 °C and 22.5 °C (Elliott & Hurley 1997). Therefore, the annual river temperature regime is important for the scope for growth. The length of the growth season, i.e. the number of days above 6 °C, is shortest in the River Kola (about 100 days), a few days longer in the Rivers Alta (about 105 days) and Varzuga (about 110 days), and of longest duration in the River Orkla (130 days).

During most of the summer, temperatures are higher and closer to the optimum for growth in the two Russian rivers than in the two Norwegian rivers (**Figure 3**). We incorporated the temperature regime of the four rivers into the growth model for Atlantic salmon fed on excess rations (Elliott & Hurley 1997), starting with a 50 mm (1.16 g) salmon parr. According to the model, one year later this fish would have increased to 92.2, 86.6, 81.2 and 79.7 mm (7.26, 6.02, 4.97 and 4.70 g) respectively, in the Rivers Varzuga, Kola, Alta and Orkla. Slower growth than this indicates unfavourable food conditions.

The annual growth increment of salmon parr was higher in the River Kola than in the three other rivers (**Figure 23**). Compared to the growth model for Atlantic salmon fed on excess rations (Elliott & Hurley 1997), the Orkla salmon had the highest growth, given the local temperature regime in that river, with growth rates very similar to the estimated ones (**Figure 24**). The observed growth rates of the Kola and Alta salmon were 80-90 % of the estimated ones, while the Varzuga salmon grew 60-70 % of the estimated ones (**Figure 24**).

5.2 Densities of parr

The estimated densities of Atlantic salmon parr were higher in the Norwegian than the Russian rivers **(Figure 25)**. However, for several reasons the results are not quite comparable. Habitat, i.e. bottom conditions, depth and water velocity, influences the catch of fish during electrofishing, and parr densities, therefore, can vary considerably among sites **(Figure 7, Figure 11, Figure 15, Figure 19)**. Hence, mean density estimates for a river may change according to the location of each site and the time of sampling. Moreover, water discharge during the field work may affect the results, particularly at high water flows (Jensen & Johnsen 1988). Kazakov (1994) have also estimated densities of Atlantic salmon in the River Varzuga, and he reported considerably higher numbers than those given in this report. However, he sampled other sites in the river, and moreover, he included fry in his density estimates, while we excluded fry. In most cases 60-90 % of the salmon in the study of Kazakov (1994) were fry, and this explains much of the discrepancy from our results.

The low density estimates of fish in the River Kola the last three years could be a consequence of unfavourably high water flow when the field work was done, since the level of water may affect density estimates (Jensen & Johnsen 1988). However, the size of the spawning population may significantly influence the densities of juveniles if the population is below carrying capacity. Until 1996, all spawners were retained at the counting fence in the River Kola. Some of these fish were kept alive until the autumn, and then stripped. The eggs were transported to the Taibola hatchery, located about 70 km upstream from the river mouth, and between 110 000 and 370 000 juvenile Atlantic salmon of different age were released annually into the river. In 1996, 500 spawners were allowed to pass the counting fence (300 males, 200 females) to ascend to the upper parts of the river, and during electrofishing in 1997, several 0+ salmon were caught. In 1997, 50 % of the spawners were retained at the fence while the other half ascended further upstream. The effect of this new strategy will be unveiled during field work in 1998.

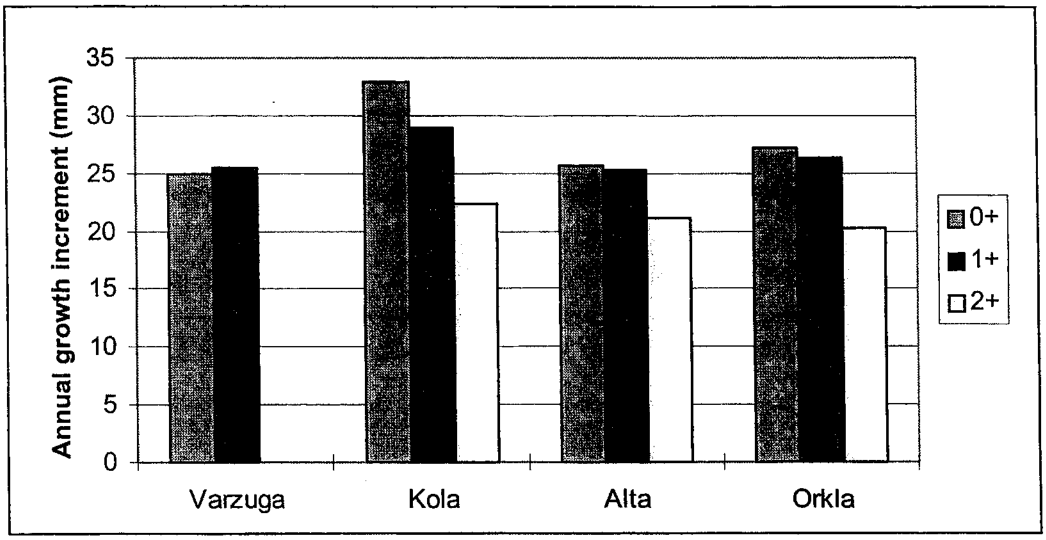


Figure 23. Annual growth rates (mm) of 0+, 1+ and 2+ Atlantic salmon in the Rivers Varzuga, Kola, Alta and Orkla. The data are mean values for fish sampled during the period 1993-1997 (1994-1997 in Varzuga).

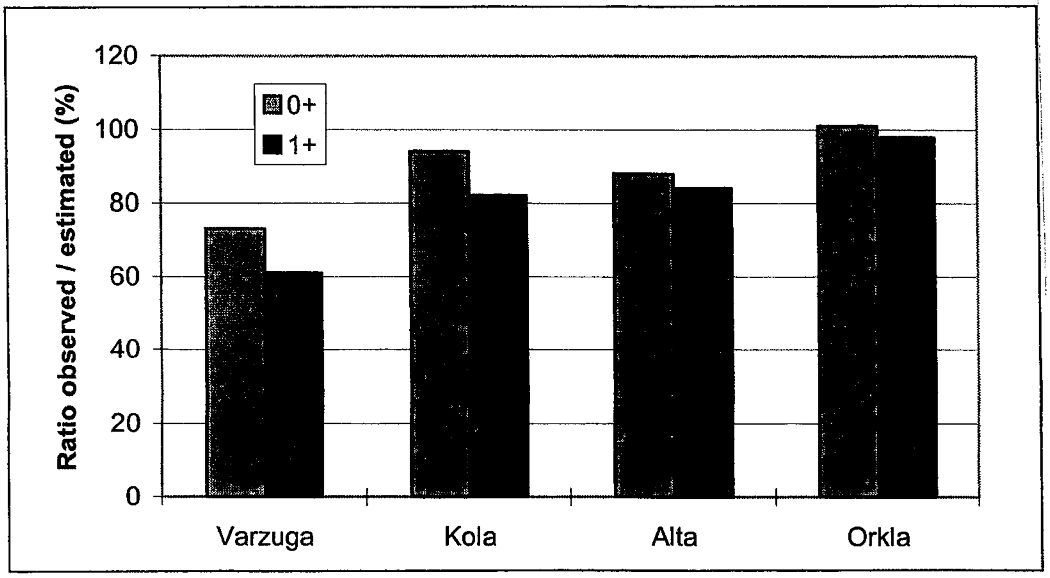


Figure 24. Ratios between observed and estimated annual growth rates (in percent) of Atlantic salmon parr in the Rivers Varzuga, Kola, Alta and Orkla. Average values for data collected during the period 1993-1997.

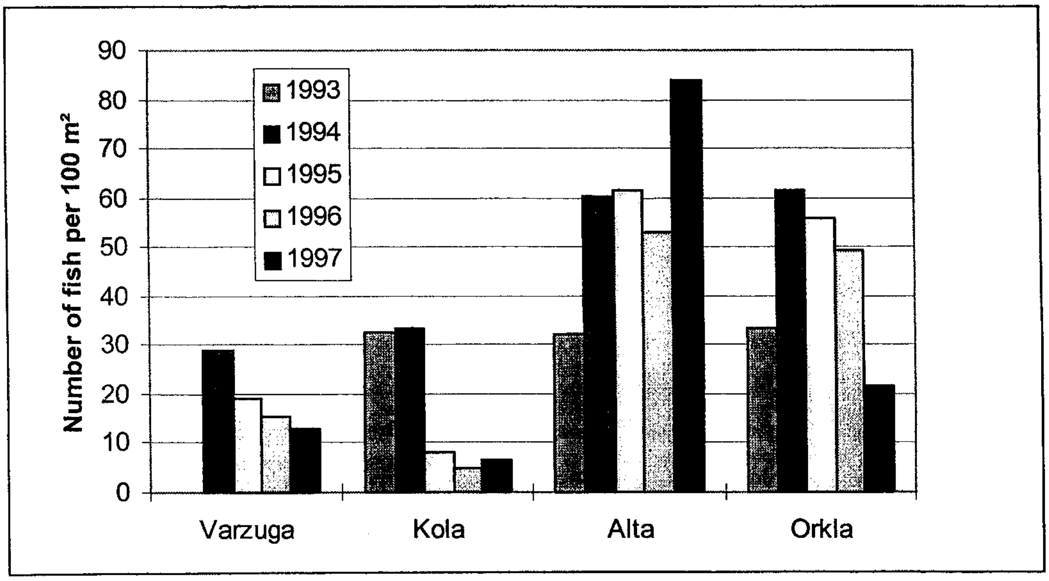


Figure 25. Mean density estimates (numbers per 100 m²) of Atlantic salmon parr (excluding fry) in the Rivers Varzuga, Kola, Alta and Orkla in the period 1993-1997.

The conditions for survival during early life, producing strong or weak cohorts of salmon, may also affect densities of juveniles. In the River Orkla the 1993 year-class of salmon was stronger than average, and that was one reason for the higher density estimates of salmon parr in 1994-1996, than in 1993 **(Figure 25).** During field work in 1997, the water level in the River Orkla was considerably higher than earlier years, which may explain the low estimates that year.

5.3 Status of adult stock

The four rivers are among the most important salmon rivers in Norway and northern Russia. The highest catches of salmon are reported from the River Varzuga. In the period 1961-1989, the annual average catch in the River Varzuga was about 72.5 tonnes. In 1987, as much as 161 tonnes were caught, while a similar amount of salmon was allowed to migrate to the spawning grounds. The last years the catches in the counting fence have been considerably reduced in favour of the recreational sport fishery. In the Rivers Kola, Alta and Orkla reported annual catches as high as 57.5 tonnes, 32.5 tonnes and 26.9 tonnes have been recorded, respectively. However, catches in Russian and Norwegian rivers can not be compared, because about 50 % of the declared catch in Norway is harvested in the sea.

There have been some environmental changes in the two Norwegian rivers during the 1980's, which have affected the salmon populations. Both rivers have been regulated for hydroelectric purposes. In the River Orkla this has resulted in increased Atlantic salmon smolt production (Hvidsten & Ugedal 1991), while in the River Alta densities of juveniles have decreased in upper reaches (Forseth et al. 1996). Juvenile salmonid populations have been reduced considerably in the lower 15 km of the River Orkla, because of heavy metal pollution from the Løkken copper mine. During the 1980's, however, extensive labour to reduce the seeping of heavy metals from the mine has occurred. In recent years densities of juvenile Atlantic salmon in the lower part of the river have increased to almost similar levels as those farther upstream (Jensen et al. 1995, 1998a).

The Atlantic salmon has been exploited heavily both in rivers and in the sea. The number of spawners which ascend the rivers has been strongly influenced by the intensity of the sea fisheries. In Norwegian coastal areas, stationary lift nets, bag nets, bend nets, and drift nets have been the most common fishing gears. Until late 1960's bag nets were the most important gear for catching salmon in sea, and this type of net had been in use in northern Norway for more than one hundred years. In the 1960's about 88 % of the salmon in northern Norway were caught in the sea, mostly in bag nets (Berg 1964). Although drift-net fishing has been carried out for at least 80 years, offshore drift netting began in 1960. The number of drift nets increased rapidly thereafter, and catches increased to a maximum of 1 007 tonnes in 1979 (Anon. 1991). During the last decades several restrictions in the salmon fishery in Norwegian home waters have been introduced, and particularly between 1979-1980, and again in 1989 when several epoch-making regulations were imposed. In 1979-1980, considerable restrictions in the drift net fishery were introduced, and diaries were ordered for drift net fishermen. Casting nets and set nets were prohibited in the sea. The closed season for fishing in the sea was extended from 1 May to 31 May, although some exceptions existed. In most rivers the closed time was expanded to 1 June. However, diminishing returns continued, and therefore new comprehensive regulations were introduced in 1989. Extensive restrictions on utilisation of bend nets were introduced, while drift nets were prohibited. In addition, the fishing season in the rivers was shortened by two weeks in the autumn, and in 74 rivers fishing for Atlantic salmon was banned (Lund et al. 1994).

In Russian waters the Atlantic salmon is harvested in rivers, estuaries and at a few coastal fishing stations located on the White Sea. In addition, evidence from tag recaptures have shown that Russian salmon are harvested by Norwegian and Faroese fishermen during feeding at sea and return migration to home waters (Berg 1935, Danilchenko 1938, Novikov 1953, Bakshtansky & Nesterov 1973, Bakshtansky et al. 1976, Grinyuk 1977, Bugaev 1987, Zubchenko et al. 1995). Salmon have been tagged at several stations along the Norwegian coast. Recoveries have clearly demonstrated that Russian salmon on their migration from feeding areas in the Norwegian Sea to their natal rivers to spawn are intercepted by the Norwegian coastal fishery for salmon in northern Norway. At marking stations between the Lofoten Islands and Sør-Trøndelag, Russian salmon were observed only sporadically, while farther to the south no recoveries from Russia have been reported (Anon. 1974, L. P. Hansen, NINA, unpublished). At the marking station at Breivik, which is located at the island Sørøy 150 km SW of Nordkapp in the county of Finnmark, salmon caught in bag nets have been tagged and released during two periods, 1937-1938 and 1962-1974. Fifteen and thirteen percent, respectively, were reported from Russian rivers at the Kola Peninsula and the White Sea area (Dahl & Sømme 1938, Anon. 1974, L. P. Hansen, NINA, unpublished). Similar results were obtained at Sørvær, which is also located at Sørøy, in the period 1964-1967, were 11 % of the recoveries were Russian (Anon. 1974).

Jensen et al. (1998b) evaluated the effects of the ban of the Norwegian coastal drift net fishery in 1989 on the spawning run of Atlantic salmon populations in four Norwegian (Styn, Namsen, Repparfjord and Alta) and four Russian rivers (B.Z. Litsa, Kola, Tuloma and Varzuga). Catches/escapements, size distribution, sea-age proportions and mean weights of different sea-age groups were collected from official catch statistics and analyses of scale samples. In three of the Norwegian rivers, catches of grilse (1SW) increased significantly after the ban of the drift net fishery. No changes were recorded for multi-sea-winter (MSW) fish. In addition, the proportion of grilse increased in all the

Norwegian rivers, and 2SW salmon increased in three of them. The mean weight of grilse increased in all four Norwegian rivers, whereas the mean weight of 2SW fish decreased in the two rivers in southern Norway. The size of 3SW fish did not change. These changes correspond well to actual net selection curves and reported mean weight of drift net catches in different parts of Norway. Trends in the Russian populations were more varying. In the three rivers draining to the Barents Sea, changes were similar to those in the Norwegian rivers. However, these changes were less obvious than those observed in Norwegian populations. Jensen et al. (1998b) concluded that the ban of the drift net fishery significantly affected the structure of the spawning run in Norwegian Atlantic salmon populations. Furthermore, the results indicated that the drift net fishery affected Russian salmon populations in rivers draining to the Barents Sea to a lesser extent than Norwegian salmon, and had no effect in rivers draining to the White Sea.

We observed significant positive correlation between the catch of Atlantic salmon in the River Alta and ascent of salmon in the River Kola. Both the catch of salmon in the River Alta and the number of salmon ascending the River Kola were significantly correlated to sea water temperatures measured at the Kola Meridian section. These results indicate that similar environmental conditions at sea affect both salmon stocks. Several studies have revealed that environmental conditions at sea affect fish stocks (Jensen 1939, Scarnecchia 1984, Stergiou 1991, Jakobsson 1992). Sea-surface temperatures have been shown to alter the distribution of Atlantic salmon catches in the north-west Atlantic Ocean (Reddin & Shearer 1987). Varying Atlantic salmon catches in several countries have been explained by variable winter habitats for salmon in the Labrador Sea (Friedland et al. 1993). Scarnecchia et al. (1989) found significant relationships between mean June-July sea temperatures and the catch of grilse the following year in some Icelandic rivers. Zubchenko & Kuzmin (1989) demonstrated that the annual spawning run of Atlantic salmon to the Tuloma is significantly related to sea temperatures in the Barents Sea, and later Antonsson et al. (1996) pointed out a similar relation for two other Barents Sea salmon stocks (Kola and Ponoy). Temperatures in the Barents Sea were for example extremely low during the period 1978-1982, and in these years the spawning runs to all these rivers were less than average.

5.4 Population structure

The mean smolt age of Atlantic salmon was about three years in the River Varzuga, 3.5 years in the Rivers Kola and Orkla, and about four years in the River Alta. The mean size of the smolts was about 10 cm in the River Varzuga, about 13 cm in the Rivers Alta and Orkla, and about 15 cm in the River Kola. The smolt age reflects a combination of annual growth rate and smolt size. The low smolt age in the River Varzuga is probably a result of smaller smolt size than in the other rivers, because annual growth seems to be similar to the other rivers (**Figure 23**). Similarly, the annual growth rate of salmon parr in the River Kola is higher than in the two Norwegian rivers, but because of large size of the smolts, the mean smolt age is similar to that in the River Orkla.

The River Varzuga is mainly a grilse river. Most fish, i.e. more than 90 % of both males and females, return to the river after only one winter at sea. Also in the other rivers most males are grilse. However, in the other rivers females are usually 2SW or 3SW fish. The sea-age composition of the River Alta salmon is special. In this river most males are grilse or 3SW fish, while females are predominantly 3SW fish (**Figure 18**). Several investigations have illustrated that age and size of salmonids at sexual maturity has a genetic component (Nævdal et al. 1978, Gjerde 1984, Glebe & Saunders 1986). In Atlantic salmon significant correlations have been found between sea-age and size at sexual maturity and river size in North America, Scotland, Iceland and Norway (Schaffer & Elson 1975, Thorpe & Mitchell 1981, Scarnecchia 1983, Jonsson et al. 1991). Thus, life histories seem to be adapted to local conditions in the habitats exploited by the fish.

Jonsson et al. (1991) observed that in small Norwegian rivers, body length and sea-age at sexual maturity increased with water discharge of the spawning river. However, the positive correlation did not apply to salmon from rivers with a mean annual water discharge larger than 40 m^3/s. The reason may be that the water flow in the small rivers was too low for successful ascent and spawning of large salmon. The mean annual water discharge of all the four rivers in the present study is more than 40 m^3/s (41.2-76.5 m^3/s), with the River Varzuga having the largest water flow. Hence, river discharge can hardly explain the large proportion of grilse in the River Varzuga.

The seasonal salmon run dynamics in the River Varzuga differ from the other rivers. Two peaks occur in the migration of Atlantic salmon in the River Varzuga, one during summer and one during autumn. Almost all fish entering the river later than 20 August are immature. Usually the autumn migration is most intense during the middle of October, but a significant part of the stock migrates as late as November. The autumn run usually contributes about 70 % of the total annual run. It is supposed that immature Atlantic salmon migrating during autumn stay in the river during the whole winter and through the next summer without feeding, and then spawn during September. This life history should be more thoroughly investigated.

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