

The timing, sex and age composition of the wild and reared Atlantic salmon ascending the Simojoki River, northern Finland

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Summary

In the Simojoki River in the northern Gulf of Bothnia, reared salmon stocked as smolts produced considerable numbers of ascending one-sea-winter (1 SW) males, whereas the proportion of male 1 SW salmon was low among spawning migrants of wild or reared parr origin. The sex ratio among ascending wild fish and reared salmon stocked as parr was similar, with females predominating, while reared salmon stocked as smolts were mainly males. The multi-sea-winter (MSW) salmon entered the river annually within a fairly short time period from the beginning of the migration season, independent of their sex or origin. 1 SW males migrated into the river significantly later in the season than MSW males. The results indicate that the delayed opening of the fishing season in the Gulf of Bothnia is effective in reducing the harvest of MSW salmon at sea. However, as the timing of the ascent may vary by several weeks from year to year, the effect of this regulation bound to certain calendar days may also vary considerably from year to year.

Introduction

After leaving their home river as smolts, Atlantic salmon (*Salmo salar* L.) usually migrate for one or more years at sea (Jonsson et al., 1991; Hansen and Quinn, 1998; Kallio-Nyberg et al., 2000). They return as maturing adults to their native river or to their release site where they were imprinted and began their sea migration (Hansen and Jonsson, 1994; Insulander and Ragnarsson, 2001). In the Baltic Sea, the return migration to the river occurs from the spring to the autumn (Lindroth et al., 1982; Kallio-Nyberg and Romakkaniemi, 1998). The age and size composition of the spawning stock varies seasonally, annually and from stock to stock (Alm, 1934; Schaffer and Elson, 1975; Jonsson et al., 1990b, 1991). In addition, differences between the sexes may appear in the life cycle as different age structures and behavioural traits among maturing females and males (McKinnell et al., 1994). During the ascent, reared and wild salmon can also behave differently (Jonsson et al., 1990a; Økland et al., 1995; Jokikokko, 2002).

In the Baltic Sea area, wild and reared Atlantic salmon are known to follow different migration patterns (Ikonen and Kallio-Nyberg, 1993; Karlsson and Karlström, 1994; McKinnell et al., 1994; Karlsson et al., 1999), and this variation can be utilized in stock management by regulating fishing (Karlsson and Karlström, 1994; Karlsson et al., 1999). Regulation has been necessary to maintain salmon stocks because they have been weakened as a result of the damming

of rivers and overexploitation of salmon in the sea. Intensive releases of salmon parr and smolts have therefore also been necessary and widely used in the management of salmon stocks in the Baltic Sea area (Jutila and Pruuki, 1988; Karlsson and Karlström, 1994). During the return migration of salmon to the spawning rivers in the northern Gulf of Bothnia, a ban on spring and early summer salmon fishing has been implemented since the late 1990s to decrease the coastal exploitation of salmon. This regulation has been aimed at protecting wild multi-sea-winter (MSW) female salmon, as they migrate earlier than reared and smaller fish (Karlsson et al., 1999), but the timing of their river ascent is not known as precisely. Comparisons between wild and reared fish after river entry have mainly been carried out in rivers which have fish ladders (McKinnell et al., 1994) or when monitored by echo-sounding and rod catch surveys (Romakkaniemi et al., 2000b). As the present fishing regulations are based on differences in timing between wild and reared fish during the sea migration, it is important to determine whether these differences also exist in the river entry phase.

In the Simojoki River, northern Gulf of Bothnia, we used a trap net to record the timing of the ascent of salmon and also to study the stock composition. We observed and compared the timing of the river entry of wild and reared salmon on the basis of this sampling. The reared salmon were released into the river as 2-year-old smolts or as 1-year-old or one-summer-old parr. The reared smolts had left the river in the year of release, but the parr spent one or more years in the river before smolting and sea migration (Jokikokko and Jutila, 1998). The age and size composition, proportion of grilse and sex ratio were also compared between these three groups. The objective of this study was to compare the timing of the ascent of salmon differing in origin (wild, stocked as parr or smolt) and assess the effect of fishing regulation on the management of the Simojoki salmon.

Materials and methods

Study area

The boreal Simojoki River (65°38'N, 25°00'E, Fig. 1) flows into the northernmost part of the Gulf of Bothnia in northern Finland. The river is 175 km long with a mean discharge of 38 m³ s⁻¹. The entire river is accessible to salmon and supports its own natural salmon stock. Nowadays, most spawning takes place up to 110 km from the river mouth (Jokikokko and Jutila, 1998).

In recent years about 100,000 reared salmon parr and 50,000 smolts have been released annually into the rapids of the river

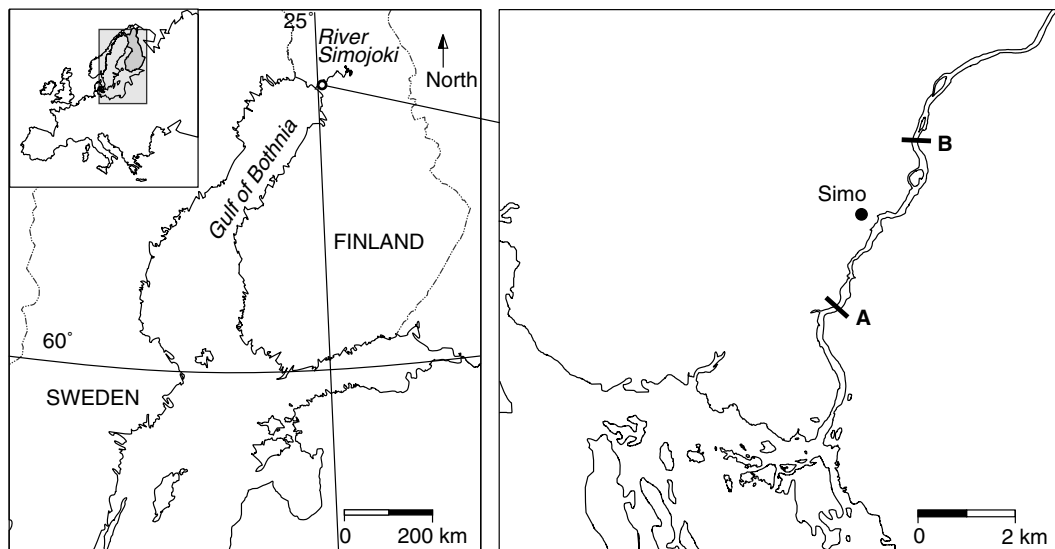


Fig. 1. Study area showing the trap net location in the Simojoki River in 1996–1997 (A) and 1998 (B)

in order to strengthen the natural stock, and in the 1990s the stocked numbers were almost twice as high. The number of reared smolts in the population has been higher than that of wild smolts during the 1980s and 1990s (Anon., 2001). Before release, all reared fish were fin-clipped by removing the adipose fin, a pelvic fin, or both, depending on the age of the fish at stocking, in order to distinguish them from wild fish in later life phases. Only fish originating from the river's native salmon stock have been used for stocking. The main stocking area for salmon parr has been to about 110 km upstream from the river mouth. Smolts have usually been released into the rapids situated about 50 km from the sea.

Trapping of ascending salmon

Trapping was conducted in three consecutive years, from 1996 to 1998. In 1996 and 1997 we placed a trap net in a pool situated about 4 km upstream from the river mouth (Fig. 1). In 1998, the trap was placed 4 km upstream from its previous location because of the disturbance and negative reaction it caused among anglers (Jokikokko, 2002). In all 3 years we tried to close the entire river to fishing in order to catch all ascending salmon. The sampling and measuring of trapped salmon and checking for fin clips were conducted on a boat attached along the bag of the trap net. Salmon were taken with a dip net from the trap and placed in a container filled with fresh water.

Sex was determined visually by comparing the length of the head to the body size and from the length and form of the

lower and upper jaw. In males the typical hook in the lower jaw starts to develop in mid-summer. Although not measured, the upper snout was longer in males than in females. Therefore, the head was proportionally longer in males compared with females, who have quite a short, triangular snout when viewed from above. This external morphology has been successfully used by the staff of the Simojoki hatchery in capturing broodfish with a trap net near the river mouth. Because broodfish are stripped in the hatchery in autumn, their sex is confirmed at this time, and less than 5% have been found to be incorrectly sexed (J. Ryttilahti, pers. comm.). External morphology has similarly been used by Jonsson et al. (1991) to determine the sex of salmon.

In 1996 and 1998 almost all fish were aged by scale reading, but in 1997 about half of the salmon (330 fish) were aged from their length; 60 cm or longer salmon were considered to be MSW fish. This size threshold was selected on the basis of the mean lengths of fish aged by scale reading (46 were 1 SW and 263 MSW salmon).

Trapping started some weeks after the ice drift when the spring flood had ended. In 1996 and 1997, trap net fishing started well before the first salmon was caught, indicating that it had begun in time (Table 1). The water temperature was 11–13°C at the time of the first catches, and about 18–20°C at the end of trapping. A high water level and flooding of the river as a result of heavy rains delayed the start of trapping in 1998, and even crushed the trap in early June. Heavy rains caused flooding again in late July to early August, and trapping could not be continued. Thus, the sampling period

Year	Started	Trapping ended	First capture	Sex	Origin		
					Wild (n)	Reared, released as smolt (n)	Reared, released as parr (n)
1996	28 May	7 August	6 June	Male	15	134	11
				Female	50	42	8
1997	2 June	1 August	6 June	Male	30	316	38
				Female	41	131	51
1998	27 June	2 August	15 July	Male	10	184	4
				Female	0	4	0

Table 1
The trapping period in the River Simojoki in 1996–1998 (dates indicate first and last checking of the trap) and the date of capture of the first salmon. The number of male and female salmon of different origin is also provided

was very short in 1998, and only grilse were caught. In 1996–1998, 348, 639 and 231 salmon were caught, respectively. In Table 1 where the sex and origin of fish are presented, the number of fish is lower than the total catch, because determination could not be carried out for every salmon. In all 3 years, trapping ceased while grilse were still migrating. However, although the entire ascending population was not caught, the sampled fish represented the main run in 1996 and 1997, and in all years it was possible to compare the wild and reared fish despite the early end to sampling.

The data were analysed with the SAS statistical package (SAS 8.2) by using different SAS procedures for the chi-square test and the Kruskal–Wallis test (SAS Institute, 2001).

Results

The origin and sex ratio of ascending salmon

The migration peak occurred in early July in 1996, but in late June and early July in 1997 (Fig. 2). Trap net catches increased again towards the end of July in all 3 years. At this time, most of the salmon caught were grilse, as indicated by their small mean length (Fig. 3). The majority of returning salmon in 1996–1998 originated from reared smolts. They were the

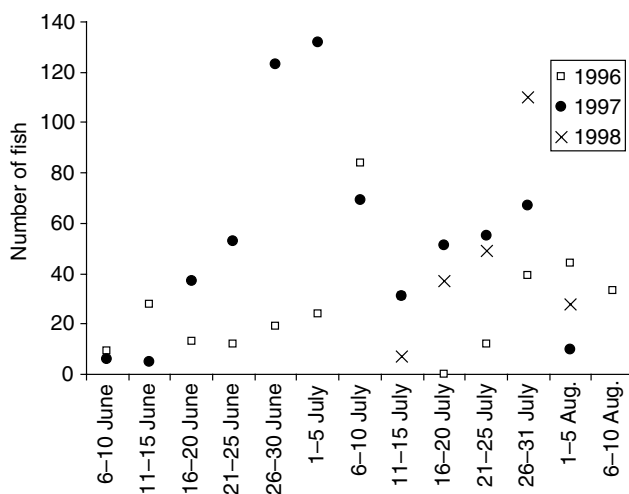


Fig. 2. Timing of the ascent of salmon in the Simojoki River expressed as the number of fish caught in 5-day intervals (n = 348, 639 and 231 in 1996, 1997 and 1998, respectively)

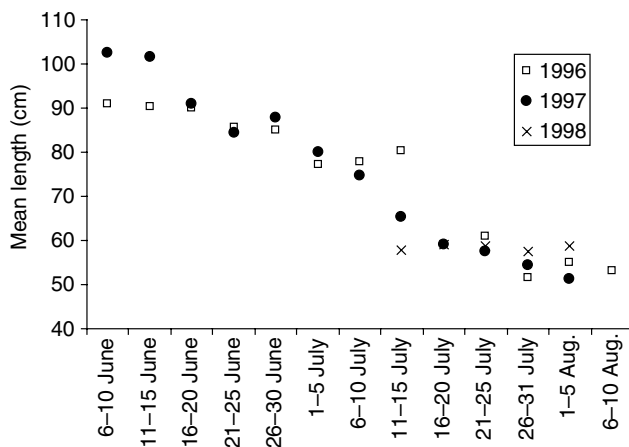


Fig. 3. Mean length of ascending salmon in 5-day intervals caught with a trap net in the Simojoki River in 1996–1998

Table 2

The number of ascending one-sea-winter (1 SW) and multi-sea-winter (MSW) male and female salmon in three origin groups (w = wild, s = smolt, p = parr) in the Simojoki River in 1996–1997, and their median capture day (numbered consecutively from 1 June). Md (Q1–Q3) = median (lower and upper quartiles)

Year	Origin	Sea years	Males (n)	Capture day [Md (Q1–Q3)]	Females (n)	Capture day [Md (Q1–Q3)]
1996	w	1 SW	3	63 (63–68)	0	
1996	w	MSW	12	38 (25–39)	50	39 (34–39)
1996	s	1 SW	114	61 (59–66)	3	39
1996	s	MSW	19	39 (39–39)	39	39 (39–42)
1996	p	1 SW	1	61	0	
1996	p	MSW	10	32 (14–39)	8	39 (32–41)
1997	w	1 SW	1	57	0	
1997	w	MSW	16	26 (18–28)	26	25 (23–28)
1997	s	1 SW	39	54 (47–58)	2	26 (25–26)
1997	s	MSW	69	27 (25–28)	89	27 (25–30)
1997	p	1 SW	1	34	0	
1997	p	MSW	17	27 (23–28)	35	27 (26–28)

predominant group among both male (85%, 634 of 742) and female (54%, 177 of 327) ascending salmon (Table 2). Females formed the majority of wild adults in 1996 and 1997 (77 and 58%, respectively), but the minority of adults originating from reared salmon released as smolts (24 and 29%, respectively) (1996: $\chi^2 = 56.6$, d.f. = 1, $P < 0.001$ and 1997: $\chi^2 = 22.3$, d.f. = 1, $P < 0.001$; Table 1). The migrants originating from released parr also had a different sex ratio from fish released as smolts (42 and 57% of parr origin were females) (1996: $\chi^2 = 2.9$, d.f. = 1, $P = 0.084$ and 1997: $\chi^2 = 25.9$, d.f. = 1, $P < 0.001$). In 1997, the ascending wild fish and those originating from reared salmon released as parr had a similar sex ratio ($P = 0.995$). Thus, the fish that had spent part or all of their juvenile life in the river (wild or reared fish released as parr) tended to produce proportionally more returning females than reared fish released as smolts.

Proportion of grilse and timing of ascent in male and female salmon

In 1996 and 1997 combined, grilse comprised 53% (159 of 302) of all ascending males but only 2% (5 of 252) of ascending females ($P < 0.001$) (Table 2). The timing of the river ascent of MSW salmon was equal in each year irrespective of their sex (Kruskal–Wallis test, $P > 0.05$). Male grilse returned to the river one to four weeks later than MSW male spawners. In 1996 and 1997, respectively, grilse ascended 22 days ($\chi^2 = 41.7$, df = 1, $P < 0.001$) and 27 days ($\chi^2 = 68.7$, df = 1, $P < 0.001$) later than MSW males among salmon stocked as smolts. Thus, the timing of the spawning migration into the river was linked to the sea age of the males. The length of the fish significantly explained the time of ascent of male salmon ($R^2 = 56\%$), but not of females ($R^2 = 6\%$).

Proportion of grilse and timing of ascent in reared and wild fish

In 1996 and 1997, the proportion of the grilse was higher among reared male salmon released as smolts (63%, 153 of 241) than among male wild salmon (13%, four of 32) ($\chi^2 = 30.1$, d.f. = 1, $P < 0.001$; Table 2). The timing of the annual ascent of MSW salmon was similarly independent of origin among both males and females as seen, for example, from MSW males in 1996 (Kruskal–Wallis test: wild vs smolt: $P = 0.073$; parr vs smolt: $P = 0.083$ and wild vs parr: $P = 0.662$). However, when all age groups are pooled, reared

Year	Sex	Sample (n)	Origin	Capture day [Md (Q1–Q3)]	P ^a	Length (cm) [Md (Q1–Q3)]	P ^a
1996	f	50	w	39 (34–39)	w vs s 0.163	79 (73–88)	0.492
1996	f	42	s	39 (39–42)	s vs p 0.353	82 (76–88)	0.313
1996	f	8	p	39 (32–40)	p vs w 0.705	87 (81–90)	0.218
1997	f	41	w	28 (25–33)	w vs s 0.167	87 (82–96)	0.011
1997	f	131	s	30 (26–34)	s vs p 0.287	83 (76–88) ¹	0.358
1997	f	51	p	27 (26–33)	p vs w 0.515	85 (77–95)	0.239
1998	f	4	s	58 (29–62)		75 (60–83)	
1996	m	15	w	39 (32–41)	w vs s < 0.001	75 (69–95)	< 0.001
1996	m	134	s	60 (54–66)	s vs p < 0.001	55 (49–59)	< 0.001
1996	m	11	p	32 (14–42)	p vs w 0.372	85 (78–95)	0.150
1997	m	30	w	30 (25–49)	w vs s 0.003	80 (57–95)	0.017
1997	m	316	s	42 (33–55)	s vs < 0.001	61 (54–80) ²	< 0.001
1997	m	38	p	33 (27–39)	p vs w 0.852	82 (69–88)	0.616
1998	m	10	w	56 (47–58)	w vs s 0.404	56 (50–60)	0.284
1998	m	184	s	58 (53–58)	s vs p ^b	58 (53–63)	0.548
1998	m	4	p	59 (52–62)	p vs w ^b	61 (56–64)	0.177

¹n = 130; ²n = 314.

^aKruskal–Wallis test.

^bnot tested due to a low number of fish.

Table 3

Timing and length of the spawners of all ages in groups differing in origin in the Simojoki River in 1996–1998. Wild salmon (w) and reared salmon released as smolt (s) or as one-summer- or 1-year-old parr (p), females (f) and males (m) are shown separately. Median capture day and quartiles calculated in days from 1 June. Md (Q1–Q3) = median (the lower and upper quartiles). Differences in the median capture day or median length between the different origin groups were tested with the Kruskal–Wallis test

male salmon released as smolts ascended the river later than wild salmon or those of parr origin (Table 3). This is clearly visible, for example, among male groups in 1996 ($P < 0.001$). The late timing of the ascent of reared males released as smolts was thus linked to their high grilse proportion, which was 86% (114 of 133) in 1996 and 36% (39 of 108) in 1997, and the late seasonal return time of male grilse (Tables 2 and 3). The reared MSW salmon of parr origin ascended earlier or at the same time as wild fish, whereas reared MSW salmon stocked as smolts migrated later than either group above (Fig. 4).

Discussion

Effects of origin on the sex ratio and proportion of grilse

The origin of smolts had a clear influence on the sex ratio of the ascending salmon. In the natural stock, the sex ratio was in favour of females, but among adults stocked as smolts the males were proportionally over-represented in the returning migrants. At hatching, Atlantic salmon are believed to have a sex ratio of 1 : 1 (Österdahl, 1969), but during the freshwater phase the sex ratios of wild and reared smolt populations develop differently. The proportion of females among wild smolts has been about 75% (Virtanen et al., 1988) or 70% (Jokikokko and Jutila, 1998) in the Simojoki River. In other rivers, the proportion of females in the natural smolt population has varied from 65 to 67% in the Tornionjoki River (a border river between Finland and Sweden) (Romakkaniemi et al., 2000a; Haikonen et al., 2001) or from 81 to 91% in Newfoundland (Dalley et al., 1983). By contrast, in the stocked population, about half of the reared smolts were females (Virtanen et al., 1988; Jokikokko and Jutila, 1998; Romakkaniemi et al., 2000a), which is common in smolt populations in the Baltic rivers (Christensen and Larsson, 1979).

The deviation from a 1 : 1 sex ratio in the natural smolt population is probably a result of early maturation in male parr. This proportion of male salmon does not leave the river but takes part in spawning as mature parr and, as a result, suffers high mortality (Lundqvist and Friberg, 1982; Dalley et al., 1983). By contrast, the hatchery-reared male smolts stocked in the main stream have little possibility of staying in the river. Also, domestic selection may increase the smolting

rate and decrease parr maturity (Fleming and Einum, 1997). The proportion of precocious males was not checked among any smolt groups in this study.

The wild and the reared salmon released as parr had similar sex ratios. This suggests that the same proportion of wild and stocked male parr leave the river in the smolt phase, although this proportion may vary from year to year. Jokikokko and Jutila (1998) observed that in the Simojoki River the mean proportion of females stocked as parr was 52%. This was linked to the smolt age, as the proportion of females increased with age. In the Tornionjoki River, the sex ratio of the wild smolts and the reared smolts released as parr was not equal in every year, and it seemed to be intermediate between the wild and reared smolts (Romakkaniemi et al., 2000a; Haikonen et al., 2001).

Unlike salmon stocked as smolts, the ascending spawners originating from reared parr had a similar sex ratio, proportion of grilse and timing of ascent to the wild salmon. However, smolts stocked as parr have generally been younger and smaller than wild smolts in the Simojoki River (Jokikokko and Jutila, 1998). The sex ratio of the returning adults is affected by the coastal fishery. The heavy exploitation at sea removes proportionally more MSW salmon than male grilse before their return migration (Scarnecchia et al., 1988). In the Baltic Sea, the grilse are only partly recruited into the fishery because, only a fraction of them attain the minimum legal size of 60 cm during the feeding migration. The grilse thus suffer much lower exploitation because of their smaller size (McKinnell, 1997). In addition, the annual variation in sexual maturation affects the proportion of grilse and, thus, the proportion of males in the spawning population in the Baltic Sea (Alm, 1934).

Although the numbers of stocked smolt may be high, only an increase in the number of ascending females has an effect on the reproductive potential of the stock. However, it is known that their spawning success is lower than that of wild females (Fleming et al., 2000), and especially that stocked males do not participate as actively in spawning as their wild counterparts (Fleming et al., 1997, 2000). The high proportion of grilse among reared salmon released as smolt also illustrates the importance of ascending wild females. Salminen (1997) has found that the proportion of grilse was linked to the size of

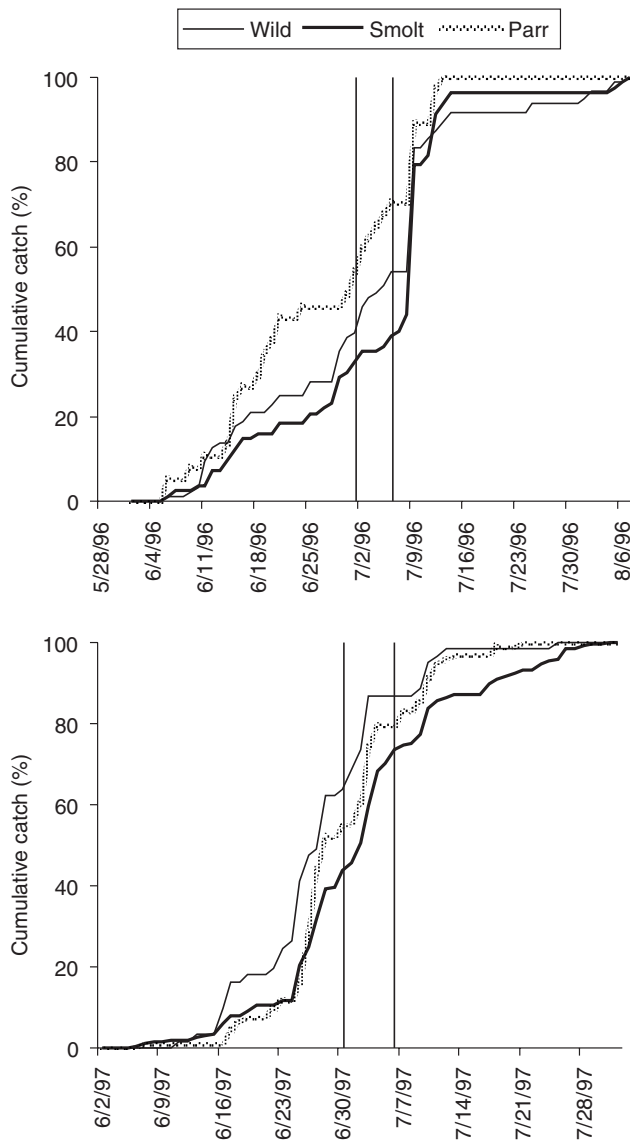


Fig. 4. Cumulative catch of ascending multi-sea-winter (MSW) salmon of different origin in 1996 and 1997 in the Simojoki River. Vertical lines show the opening days for coastal fishing in the northern Gulf of Bothnia in 1996–1997 (6 July) and since 1998 (1 July). The ageing of fish was based on scale reading or, if the scales were not read, on the fish length (salmon of 60 cm or longer were considered to be MSW fish)

reared smolts, large smolts yielding proportionally more grilse than smaller ones. In the Simojoki River, the stocked smolts have been considerably larger than wild smolts (Juttila et al., 2003), and the smolts of parr origin have been a similar size to or even smaller than wild smolts (Jokikokko and Juttila, 1998). This may partly affect the observed grilse proportions. Also, domesticated selection is known to increase the grilse proportion (Kallio-Nyberg and Koljonen, 1997).

Timing of the ascent

The timing of the ascent was demonstrated to be associated with the sea age of the spawners, especially among males. Reared male salmon released as smolts ascended the river later than wild males. There was, however, no difference in ascent time between MSW wild and MSW reared females. Thus all MSW salmon, independent of their sex or origin, ascended

during the early part of the season. Grilse, being mainly males and originating from released smolts, ascended later in the season. The timing of the return migration among Baltic salmon is also associated with their origin (wild/hatchery), sex and sea-age. For example, a delayed upstream migration of reared Baltic salmon compared with wild salmon of the same size has been documented (McKinnell et al., 1994). Ikonen and Kallio-Nyberg (1993) have reported that males return later than females and 2 SW salmon later than 3 SW salmon in the Gulf of Bothnia. Similarly, the mean length of ascending salmon in the Tornionjoki River decreased during the season (Romakkaniemi et al., 2000b).

The upstream migration of salmon is linked to several seasonal environmental factors and their effects on ascending fish (Hawkins, 1989; Trépanier et al., 1996). Salmon migration into the rivers of the northern Gulf of Bothnia begins in May or June, soon after the ice drift. In the Tornionjoki River, the catch of MSW salmon peaked during the period 1–10 July in 1933–1957 (Kallio-Nyberg and Romakkaniemi, 1998), quite close to the observed peak of MSW salmon in the Simojoki River. Trapping in 1996 began about 1 week and in 1997, several days before the first salmon was caught. Thus, it can be presumed that the first captured salmon represented the beginning of the spawning run. The closing of the river by the trap may have had some effect on the timing of the ascent (Jokikokko, 2002). However, it probably affected both MSW salmon and grilse similarly, irrespective their origin. Trapping ended each year when most of the MSW salmon had ascended but when grilse were still migrating into the river. Thus, the trapping data is biased towards the early season.

An early-season closure of the coastal fishery has been enforced in the Gulf of Bothnia in most years since 1986 to safeguard the early running salmon. These restrictions have meant that MSW salmon have had quite a free ascent to the river (Karlsson and Karlström, 1994; Karlsson et al., 1999). It is, however, possible that these fishing regulations may also have affected the present data. In 1998, the opening dates were five days earlier than in 1996 and 1997, but, because of the late trapping in the river, the change in the regulation of coastal salmon fishing did not affect the catch composition. The MSW salmon that survived the coastal fishing had already ascended before the trap was properly operating.

The timing of the ascent may vary annually by several weeks depending on, for instance, the spring seawater temperature in the feeding area (Karlsson and Karlström, 1994) or the pre-summer river temperatures (McKinnell et al., 1994). Thus, the effect of fishery closure bound firmly to certain calendar days also varies considerably from year to year. In 1996 and 1997 the fishing season in the Gulf of Bothnia was opened much later than in earlier years. The positive development in the Simojoki River salmon stock in recent years (Anon., 2001) proves that the fishing regulations have been effective. The management measures have been successful in reducing the harvest of early ascending MSW spawners and wild fish in particular (Karlsson et al., 1999). The fishing regulations have also been quite effective in safeguarding salmon stocked as parr, which behave similarly to wild fish. This fulfills the original purpose of enhancement stocking, as these fish have been imprinted to the rapids along the river and a substantial proportion of them are females. Nevertheless, as the cumulative catch of MSW salmon in this study shows, shortening the fishing ban by a few days may considerably affect the number of ascending salmon. Therefore, any relaxation of early season fishing restrictions should be viewed with caution.

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