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Return migration of the Atlantic salmon in the Tana River: distribution and exploitation of radiotagged multi-sea-winter salmon

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A total of 174 multi-sea-winter Atlantic salmon (75–115 cm fork length) were radiotagged in the Tanafjord in 1992–1993 and their upstream migration and exploitation in the Tana River (Teno) were studied. Of the tagged fish, 75% and 77% entered the river, and 40% and 69% of them were later recaptured in 1992 and 1993, respectively. The lower 60 km of the river accounted for 36% of the recaptures. Gillnets and weirs took 68% of the fish recaptured in the river in 1992 but only 40% in 1993, the rest being caught by rod and line. Weirs caught more recently entered salmon than gillnets. Rod and line fishery caught smaller fish than gillnets and weirs. There were no differences in the size distributions between the initially tagged salmon, those that entered the river, were recaptured in the river, or the ones survived until spawning. Exploitation rates ($n_{\text{recaptured fish}}/n_{\text{entered the river}}$) were the highest in the upper reaches of the river system.

Introduction

Successful management of the Atlantic salmon (*Salmo salar* L.) stocks would ideally rely upon the availability of a known stock-recruitment relationship or a good knowledge of the run size and catch. Since that type of high-quality data is seldom available, it would be of value to obtain some idea of the exploitation level, at least in the river systems (Mills 1989). There is a possibility to estimate the riverine exploitation rate of salmon based on counts of total run and reliable catch statistics (e.g., Porter *et al.* 1996), by estimating the total run based on catch statistics and assess-

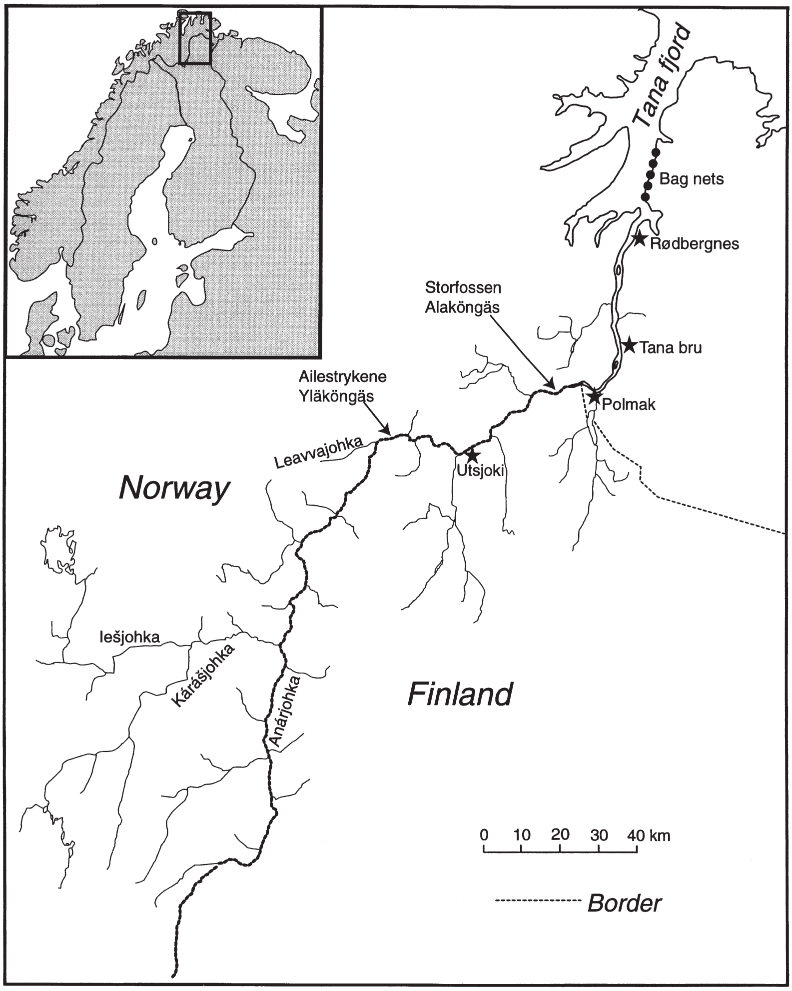

Fig. 1. The study area showing the location of tagging sites (bag nets) in the Tanafjord and the automatic logger stations by the Tana River (stars). One of the three loggers was in Utsjoki (Karnjarga) in 1992, but in Tana bru in 1993.

ment of the spawning escapement (Sægrov and Kalås 1996) or based on recapture rates of fish that have been tagged, released and recaptured (Hansen *et al.* 1986).

Traditional tagging-recapture studies provide estimates of mortality, stocking success or exploitation rates of fish, but the fate of the unrecovered tags remains unknown and may hamper reliable estimation. Radiotagged fish can be located without recapturing the fish, and thus, the fate of unrecaptured fish is usually well known, which makes biotelemetry methods capable e.g. of detecting spatial and temporal patterns in freshwater fishing mortality and gear selectivity. Radio telemetry has rapidly been developed into a viable tool for studying a variety of biological factors of anadromous salmonids during their riverine migration (Laughton and Smith 1992, Heggberget *et al.* 1996, Hinch *et al.* 1996). Besides, in gathering basic biological data there is an increasing demand for using radiotelemetry for management purposes, especially in studies assessing the potential impacts of man-made structures, such as dams, fishways etc., on the migration, behaviour and survival of salmonids (Stier and Kynard 1986, Jokikokko and Viitala 1995).

The aim of this study was to investigate the exploitation, survival and distribution of radiotagged adult multi-sea-winter (MSW) Atlantic salmon during their upstream migration in the large subarctic Tana River in the far north of Scandinavia. Exploitation in the river was analysed in more detail including different fishing methods and spatial and temporal variability of recaptures within the river system.

Material and methods

Study area

The subarctic Tana River (Teno in Finnish, Deatnu in Sámi) forms the border between northern Norway and Finland (70°N, 28°E, Fig. 1). It is one of the largest (catchment area 16 386 km^2) and the most productive salmon rivers of both countries with annual river catches between 100 and 200 tonnes of the Atlantic salmon (Niemelä *et al.* 1996). In the northernmost Norwegian county, Finnmark, approximately 45% of the salmon catch is taken in the rivers and 55% is taken in the sea (Anon. 1996). The Tana is one of the few remaining large salmon rivers which has an abundant and, in practice, pristine distribution area for Atlantic salmon with no man-made obstructions (e.g. dams) on the riverine migration route. About 1 100 km of different stretches of the system are accessible to ascending salmon. The longest distance salmon may migrate from the sea is approximately 300 km along all three major headwater branches, Anárjohka, Kárášjohka and Iešjohka (Fig. 1).

The most important methods in the Tana River salmon fishery are weirs, fixed gill nets, drift nets and rod and line (Niemelä *et al.* 1996). Weirs include a fence made of wood or metal bars and a gillnet which is attached to the outer end of the fence. The nets in weirs are set in a hook-like position to drive the fish in a narrow-angle corner. Other fixed gillnets are set straight. Weirs and gillnets are used in most parts of the Tana River main stem, Kárášjohka and Anárjohka, whereas angling activity is mostly concentrated on the Tana bru area and within the river stretch between the two major rapids, Storfossen (Alaköngäs) and Ailestrykene (Yläköngäs, Fig. 1). Given this variety of fishing methods in use, it is a challenge for managers to regulate the salmon resource and the fishery which is also an important part of the culture of the indigenous Sámi people in the area.

Catching and tagging procedures

Salmon were caught with marine bag nets in the Tanafjord, 518 kilometres from the rivermouth (Fig. 1). Eighty-one and 93 multi-sea-winter (MSW) Atlantic salmon were radiotagged in June-July 1992 and 1993, respectively, and released immediately at the site of capture. Every care was taken to minimize the handling of the fish and the exposure of gills to air. The fish were removed from the nets using a plastic bag, which allowed some water to stay with the fish, lifted on board, and placed into a plastic tube with the top part removed to allow fish to fit in. The tube was filled with fresh sea water. Only salmon without physical damage were tagged. The fork length (FL) was measured and a scale sample was taken for age determination (Table 1). The sex determination was made based on external characteristics. While

Table 1. Age distribution of 152 virgin radiotagged salmon (% by sex and year in parenthesis). Note that only 163 salmon out of the 174 could be aged and 11 repeat spawners are not shown in the table.

	Smolt age	Males sea age			Females sea age	
		2	3	4	2	3
1992						
	2	1 (5)	–	–	–	–
	3	3 (14)	2 (9)	–	2 (4)	4 (8)
	4	5 (23)	6 (27)	2 (9)	15 (28)	25 (48)
	5	2 (9)	1 (5)	–	4 (8)	2 (4)
1993						
	2	1 (5)	–	–	–	–
	3	3 (16)	1 (5)	–	5 (8)	13 (22)
	4	3 (16)	10 (53)	1 (5)	7 (12)	22 (38)
	5	–	–	–	7 (12)	5 (8)

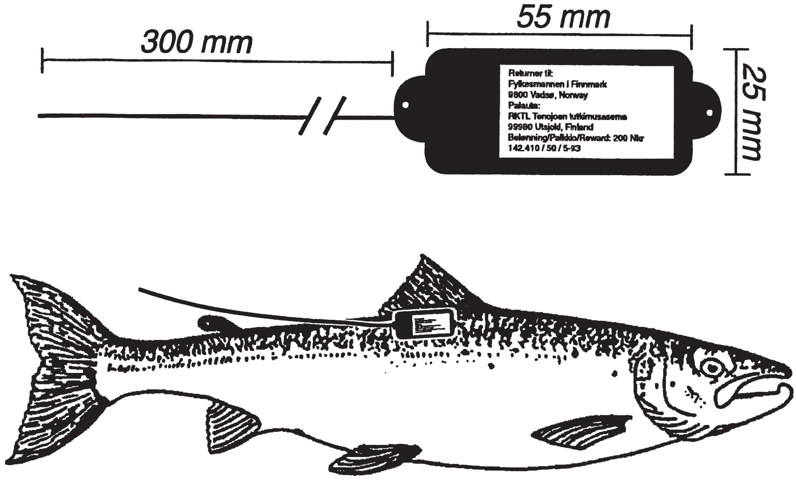

Fig. 2. Illustration of the radiotransmitter used in the study and its location when attached to a salmon. The return instructions are written on the tag in Norwegian and in Finnish.

attaching the radio tags, the head of the fish was kept in the dark end of the tube and covered with a wet cloth to keep the fish quiet. No anaesthetics were used.

The radio tags used were Model 16 M (ATS, Advanced Telemetry Systems Inc.) standard transmitters with dimensions of 5.5 cm (length) × 2.5 cm (width) × 1.0 cm (height) and a weight of 26 g in air (Fig. 2). Each transmitter had a unique combination of transmitting frequency (142.010–142.500 Mhz, 10 kHz apart) and pulse rate (50 or 80 min^{-1}). An often recommended maximum transmitter-weight to fish-weight ratio of 2% (Winter 1983) was not even close in this study, as the ratio ranged approximately between 0.1% and 0.6%. Thus, the tag size used should not have any major effect on the fish of the size range used in this study (Mellas and Haynes 1985).

The transmitters were attached externally below the dorsal fin of the fish (Fig. 2) using surgical steel wire, which was led through the tissue by hollow needles. Two needles were pushed through the skin and the dorsal muscles of the fish, 2 cm below the dorsal fin. Spacing between the needles on the tag side was equivalent with the length of the tag. On the opposite side, the spacing was reduced by 50% to reduce both the angle of the wire and the erosion of the tissue caused by the wire. No plastic back plate was therefore used. The total handling time of each fish varied between 3 and 5 minutes.

Tracking

The radio-tagged fish were first detected at Rødbergneset, 10.5 km upstream the river mouth (Fig. 1) with an automatic data logger (ATS Model D5041) connected to a receiver (ATS Model R2100) that recorded the time of entering the river for each fish. The logger was located above the tidal zone since radio signals are not transmitted in salt water due to its high electrolytic content. Two other data loggers were used in three different localities in the lower part of the river; the locations varied between the two years (Fig. 1). After entering fresh water, fish were located in the river to the nearest 500 m employing a nine-element Yagi antenna installed on the roof of a car, and a receiver (ATS Model R2100). After locating the fish, a more precise location (10–100 m) was determined using a four-element hand-held antenna and a manual receiver. In most of the cases the radio signals were detectable at a minimum distance of one kilometre, but occasionally the signals were received at distances up to five kilometres.

The fish were located at intervals of three days in 1992 and daily in 1993 during the main migration period of 6 June–9 August. From 10 August until the end of the spawning period in October, the fish were located once a week. Recapture data were collected from the fishermen who sent the tags by mail or informed the research team. The fate of the unrecaptured fish was confirmed by carefully detecting their movements until the spawning time and further over the following winter.

2.4. Data analysis

The 95% confidence intervals (presented as a half of the C.L., e.g. ± 5%) for the various proportions of detected, recaptured and survived fish (Table 2 and in the text) were estimated based on normal approximation of the binominal distribution (Snedecor and Cochran 1980). Comparisons of distributions of the variables were conducted using a non-parametric Kolmogorov-Smirnov Two-sample test.

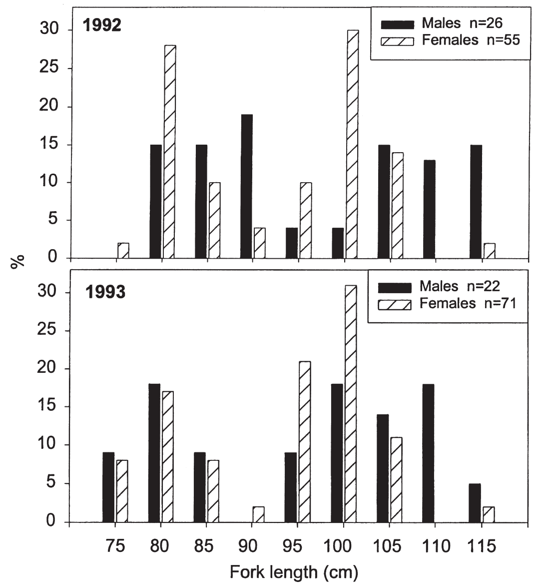

Fig. 3. Size distribution of the radiotagged fish (fork length) in 1992 and 1993.

3. Results

The size distribution of the tagged fish showed an excess of females in 90–104 cm FL group (age 3 SW), but an excess of males in the largest size group (> 105 cm, 3–4 SW) (Kolmogorov-Smirnov two-sample test, $p = 0.05$; Table 1, Fig. 3).

Ten salmon were lost both in 1992 (12% of the tagged fish, 95% confidence limits: ± 7%) and 1993 (11% ± 6%), i.e. no signals were recorded from the transmitters after releasing the tagged

Table 2. Numbers (% and 95% confidence limits [± C.L./2] in parenthesis) of fish that were radiotagged, recaptured in the sea or lost (a), and numbers of fish that entered the Tana River, and were recaptured in the river (b). Proportions of fish recaptured in the sea, lost (a) and those that entered the Tana (b) are presented as % of all tagged fish, while recaptures in freshwater and survived fish as % of fish that entered the river (b).

	1992		1993		Total	
	n	% ± C.L./2	*n*	% ± C.L./2	*n*	% ± C.L./2
(a) Tagged	81	(100)	93	(100)	174	(100)
Recaptured outside Tanafjord	1	(1 ± 3)	–	–	1	(1 ± 1)
Recaptured in the Tanafjord	8	(10 ± 7)	13	(14 ± 7)	21	(12 ± 5)
Bagnet	2	(3 ± 3)	6	(6 ± 5)	8	(5 ± 3)
Bendnet	6	(7 ± 6)	7	(8 ± 5)	13	(7 ± 4)
Lost	10	(12 ± 7)	10	(11 ± 6)	20	(11 ± 5)
(b) Entered the Tana River	62	(77 ± 9)	70	(75 ± 9)	132	(76 ± 6)
Recaptured in the Tana River	25	(40 ± 12)	48	(69 ± 11)	73	(55 ± 8)
Gillnet	10	(16 ± 9)	8	(12 ± 7)	18	(14 ± 6)
Driftnet	1	(2 ± 3)	1	(2 ± 3)	2	(1 ± 2)
Weir	6	(9 ± 7)	10	(14 ± 8)	16	(12 ± 6)
Rod and line	8	(13 ± 8)	29	(41 ± 12)	37	(28 ± 8)
Survived until spawning	37	(60 ± 12)	22	(31 ± 11)	59	(45 ± 8)

Fig. 4. The locations where the radiotagged salmon were recaptured (open circles) and the locations of survived fish (filled squares) prior to the spawning period in September in 1992 (left panel) and 1993 (right panel).

fish (Table 2). Part of these fish may well be salmon that were on their way to other rivers running to the Arctic Ocean, as was indicated by one recapture in the sea on the other side of the Varanger Peninsula in Berlevåg and in one recapture in the Langfjord close to the River Langfjorelva in 1992 (points easternmost and westernmost in the sea in Fig. 4). Sea fishery in the fiord accounted for 10 and 14% (± 6% and 7%) of the recaptured salmon in 1992 and 1993, respectively (Table 2).

Sixty-two and 70 salmon were recorded in the river in 1992 and 1993, and their upstream migration and survival were able to be followed. Exploitation rates ($n_{\text{recaptured fish}}/n_{\text{entered the river}}$) in the river varied from 40% (± 12%) in 1992 to 69% (± 11%) in 1993 (Table 2). The majority of the river catch was taken with nets (weirs, gillnets and driftnets)

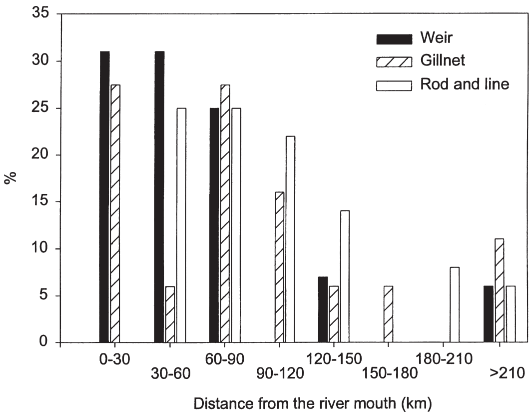

Fig. 5. Recaptures (%) of the radiotagged salmon at different distances from the river mouth captured with different fishing gear.

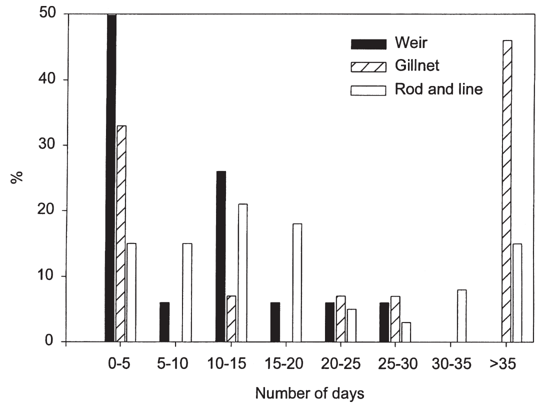

Fig. 6. The number of days the radiotagged fish had spent in the river before being recaptured with different fishing gear.

in 1992 (68% ± 20%), but with rod and line in 1993 (60% ± 15%). The largest spatial concentrations of riverine recaptures were along the lowest part of the river (in 1992), the first riffle and spawning area around Tana bru (especially in 1993), and the first major riffle area, Alaköngäs/Storfossen (Fig. 4). Thirty-six (± 12%) and 63% (± 12%) of the recaptures (years combined) took place within the lowest 60 km (until the Finnish border) and 90 km (before the confluent of the Utsjoki and the Tana) of the river, respectively (Figs. 4 and 5).

Regionally, the exploitation rates were the highest in the uppermost reaches of the river. A majority of the salmon that entered the upper Tana (upstream from the confluent of Leavvajohka and the Tana), Kárášjohka, Iešjohka and Anárjohka were recaptured in both years (Figs. 1 and 4).

Almost 90% of the radiotagged salmon caught with weirs were taken within the first 90 km of the river, and more than two thirds of the weir catch was caught in the lower 60 km of the river (Fig. 5). The lower 60 km of the river included also one third of the gillnet catch. The fish taken by anglers were more evenly spatially distributed (Fig. 5).

Eighty-one percent (± 22%) of the salmon caught with weirs had stayed in the river 0–15 days, whereas the corresponding figure for fish caught by gillnets was 39% (± 25%). Fifty percent (± 26%) of the gillnet-caught fish had stayed in the river more than 35 days. The length of the river residence varied more evenly among the fish caught by anglers (Fig. 6).

The size distribution of the fish caught by rod and line included a significantly larger proportion of fish smaller than 80 cm compared to the size distribution of the tagged fish that entered the river in 1992 (Kolmogorov-Smirnov Two-sample test, $p = 0.005$). There were no significant differences in size distribution between the other groups in 1992 or 1993 (K-S test, $p > 0.05$).

The size distributions of fish that were tagged, that entered the Tana River, were caught in the river and that survived until spawning were fairly similar in both years (Kolmogorov-Smirnov Two-sample test, pairwise, $p > 0.1$).

Discussion

In this study, precise estimates of exploitation of the radiotagged MSW salmon in the Tana River were obtained. The number of fish that entered the river and different parts of it was known and no fish were lost after they entered fresh water. The found exploitation rates were within or close to the range of the levels reported for MSW salmon in some other Norwegian large salmon rivers, such as the Rivers Drammenselv (1985–1992: 28%–53%; Hansen *et al.* 1986, Hansen 1993) and Suldalslågen (1995: 40%–42%; Sægrov and Kalås 1996). In ten other salmon rivers in western Norway the average exploitation rate has been 50% for MSW salmon and 82% for 1SW salmon (1960–1994; Sættem 1995). In contrast, Gee and Milner (1980) reported that fishing mortality increased with fish size in the River Wye, Wales, and salmon over 9 kg could suffer angler exploitation rates close to 100%. In some Newfoundland (Canada) rivers the exploitation of the Atlantic salmon (mostly 1 SW) has been lower than in Scandinavian rivers, varying mostly between 10% and 40% (Dempson 1990, Porter *et al.* 1996, O'Connell *et al.* 1997). Other riverine exploitation rates from different countries, reviewed by Mills (1989), have varied as follows: 11%–82% in four rivers in Iceland (4–42 years of data), 6%–10% in Burrishoole, Ireland (1970–1981), and a mean value of 47% was presented for the River Wye for years 1965–1974. These figures have been based on various estimation methods (see Introduction for examples) and direct comparisons with those acquired from the radiotagging method may not be fully reliable.

In an earlier study by Rikstad (1982), 1 119 salmon were tagged in Tanafjorden with traditional tags (Lea-tags) in 1977–1980. The average recapture rate was 34% (range 18%–43%) for the catch in the Tana River (calculated from Rikstad's Tables 4 and 5 by correcting the yearly total numbers of tagged fish for the recaptures in the sea and in other rivers). These figures represent minimum estimates as there is no data about the number of fish that actually entered the river. Hence, the actual exploitation rates in the river may have been higher and comparable with the results of the present study.

The salmon catch statistics of the Tana (Niemelä *et al.* 1996) show a higher total catch in 1992 (184 tonnes) than in 1993 (152 tonnes), whereas the exploitation rate was higher in 1993 based on the results of this study. Sættem (1995) suggested that when the abundance of salmon is low the relative exploitation may be higher than under the opposite conditions. Whether the high total catch in 1992 reflects a higher abundance of fish is not known. However, the higher water level and the more variable flow in 1992 (E. Niemelä and K. Moen unpubl.) compared to those of 1993 may have influenced the lower relative fishing success, which in turn indicates a clearly greater run of salmon for 1992 than for 1993. On the other hand, the difficulties in relating salmon catch data to the run size have been well documented (e.g. Bielak and Power 1988).

According to catch statistics of the Tana River in 1992 and 1993 (Niemelä *et al.* 1996) the proportions of salmon catch caught with weirs and gillnets were lower than indicated by the results of the present study. In parallel, the relative rod and line catches of the radiotagged fish were lower than their proportion in the total catch (68% in 1992 and 70% in 1993, Niemelä *et al.* 1996). It should be noted, however, that the proportions of the total catch are calculated by weight with 1SW and MSW salmon combined, but those of the present material by numbers and only for MSW salmon. One possible explanation for the differences in the proportions of different fishing gear is that the external tags may have contributed to the high recapture rates of gillnets and weir, or that the handled and tagged fish may be unwilling to take a lure actively. The latter suggestion is not supported by one salmon in 1992 that was caught by an angler who released the fish, which was landed by another angler two weeks later. Since all the tagged fish were large salmon, 75–115 cm in fork length, it seems unlikely that the tag would have a crucial effect in getting the fish tangled in a minimum of 58 mm mesh (knot to knot) gillnet and the similar gillnets in the weirs.

The fish tagged for the present experiment represented only a part of the migration time of the Tana River salmon. The earliest part of the season when drift nets are allowed (until June 15) was not fully covered by the tagging schedule and thus only two of the radiotagged fish that entered the river were caught by drift nets. The catch of the first part of the season consists of MSW females in a large proportion (E. Niemelä and K. Moen unpubl.) and no reliable estimates of the recapture rates of that part of the run could be obtained from the present study.

Salmon were not equally susceptible to different fishing gear. Weirs tended to catch more newly-entered salmon which were on their fast migration stage (cf. Hawkins and Smith 1986), whereas, especially further up in the river system, gill nets were effective in catching late season fish that have stayed in the river for more than a month. This indicates heavy fishing pressure on fish that have ceased their migration in the late season and are staying in pools close to their spawning territories. Rod and line fishery tended to take smaller fish than fixed gear, although one should notice that the "small" fish in this study are MSW (2 SW) salmon, not grilse, which have been shown to experience high exploitation in rod and line fishery in some Norwegian rivers (*see* above).

The use of radio tags allowed inferences to be made about regional exploitation rates since the number of recaptured fish could be related to the total number of tagged fish that entered any particular stretch of the river. High fishing mortality was observed in the uppermost headwater branches of the Tana system, where up to 100% of the tagged MSW salmon entering the area were recaptured. The high exploitation rates may contribute to the observed lower-than-expected levels of juvenile abundance in the headwater rivers (Länsman *et al*. 1998).

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