STATUS OF THE RIVER TANA SALMON POPULATIONS

REPORT 1-2012 OF THE

WORKING GROUP ON SALMON MONITORING AND RESEARCH
IN THE TANA RIVER SYSTEM

Contents

1   Summary

The Group and its mandate

The permanent monitoring and research group was formally appointed in 2010 by the Ministry of Agriculture and Forestry in Finland and the Ministry of Environment in Norway, based on the Memorandum of Understanding signed in February 2010. Among other points defined in its mandate, the Group should deliver annual reports on the status of the salmon stocks, evaluate their management, and give advice on relevant monitoring and research. This is the first report of the group.

The Tana, its salmon stocks and fisheries

The subarctic River Tana forms the border between northernmost Norway and Finland. The river drains an area of 16 386 km^2 consisting of a multitude of small and large tributaries, most of which (>1 200km) are readily accessible for ascending salmon. The river Tana is also one of the few remaining large river systems that still support abundant Atlantic salmon stocks with little or no human impact to the system, except for fishing.

Tana today supports the largest wild stock of Atlantic salmon in the world, with annual river catches fluctuating between 70 and 250 tonnes, equivalent to an average of 30-50 000 salmon being harvested annually. The total salmon stock with a minimum of 30 different populations consists of a wide variety of life histories. The sea-age groups are ranging from one-sea-winter to five-sea-winter salmon, with various types of previously spawned fish. Proportion of escaped farm fish in the Tana salmon catches has so far been very low, although their proportion after the fishing season is not known (with some few exceptions).

The riverine salmon fisheries in Tana include net fishing methods such as weir, gill net, seine and drift net, in addition to the use of rod and line. In the last five years, the rod catch comprised about 60 % of the total catch of the river system, and the share of different fishing methods has remained about the same over the past 30 years. Most of the fishery in the main stem Tana represents mixed-stocks fishery that is especially emphasized in the lower and middle parts of the main stem. According to the telemetry tagging experiments, harvest rates in the river fisheries could reach the levels of more than 60 %. Together with the sea fishery, the effective exploitation rates for some Tana salmon populations can be significantly high, up to 90 %.

Management of the Tana salmon

Both Norway and Finland (through EU) are members of the North Atlantic Salmon Conservation Organization (NASCO), which is an international organization with an objective to conserve, restore, enhance and rationally manage Atlantic salmon. Bilaterally, the Tana fishery agreement has been negotiated between the Ministries of Foreign Affairs, Ministry of Forestry and Agriculture (Finland) and the Norwegian Ministry of the Environment (Norway). The latest general agreement dates back to 1990. Tourist angling is regulated by regional authorities in both countries (Department of Environmental Affairs, Office of the County Governor of Finnmark, Norway, and the Fishery Unit, Centre for Economic Development, Transport and the Environment in Lapland, Finland). The tourist fishing regulations can be amended on a yearly basis. Local organizations in both countries, especially the newly established River Tana Fisheries Management Board in Norway, also play a role

in managing the fishery. Coastal fisheries are regulated nationally in Norway, and in recent years, more restrictive measures have been introduced.

Local/traditional knowledge
The Group recognizes the potential positive contribution from local/traditional (ecological) knowledge, and will strive to incorporate relevant knowledge of this kind in its work. Some locally raised arguments are discussed:

Predation is a factor that is widely pointed to locally as a threat for salmon. There is very little biological basis for arguing that naturally occurring predators are a threat to salmon, and predation must rather be viewed as an integral and natural part of the ecosystems that salmon live in and it is rarely possible to measure any negative impacts from predation. The best way of counteracting any potential effects of predation is to make sure that management targets for the stocks are met so that stocks are full-recruited on an annual basis.

Other local arguments that are discussed and rebutted in this report include natural variation, increased tourist angling and decreased number of gillnets.

Threat factors
An overview of threat factors in the Tana show that overexploitation of salmon in the different parts of the salmon migratory system is the major threat factor for Tana salmon. There are minor or no effects from other human activities like pollution, hydropower development or fish farming which are affecting Tana salmon. The bullhead is a newly introduced species in the River Utsjoki, and is now expanding up- and downstream in the Tana main stem. In Utsjoki, the bullhead has so far been observed primarily in areas with low densities of salmonids.

Monitoring
Long term monitoring of Tana salmon started in its present form in the 1970s, and represents the main basis for evaluation of stock status. The main elements in the long term monitoring program in Tana are catch and fisheries statistics, catch samples, mainly scale samples, and estimation of juvenile salmon abundance at permanent sampling sites. Other monitoring methods that have been carried out for shorter periods are counting of both ascending and descending salmon in rivers Utsjoki and Lákšjohka. Counting of spawning adult salmon have been carried out in two tributaries since 2003. Evaluation of permanent counting of upstream migrating fish in some of the larger tributaries (Kárášjohka, Máskejohka) is now carried out by introducing modern sonar techniques.

Stock status evaluation and management recommendations
In accordance with NASCOs Precautionary Approach, the stock-status evaluation is based on a target-based approach. The basic procedure of this approach is (1) the definition of stock-specific spawning targets (i.e. the number of spawning female salmon needed to fill the production potential of a stock), (2) an estimation of the number of spawning females in a stock after a fishing season, and (3) a comparison of the target and the spawning stock estimate.

Currently, usable spawning targets have been defined for six Norwegian tributaries. A spawning stock evaluation is done for five of these tributaries: Máskejohka, Lákšjohka, Válljohka, Kárášjohka and Iešjohka. The sixth tributary, Leavvajohka, is omitted due to the very low number of fishermen present there.

The spawning stock evaluation in all five tributaries demonstrates that target attainment currently is very bad in the Tana river system. None of the evaluated tributaries reached their spawning target in the period 2004-2010, and in most years the spawning stocks were far below the targets. The best target attainment was seen with 64 % in the lowermost tributary, Máskejohka, in 2010. In the middle part of the river system, target attainment was lower, up to 50 % in Válljohka in 2006 and 25 % in Lákšjohka in 2006 and 2009. In the upper part, target attainment was up to 35 % in Iešjohka in 2008 and 20 % in Kárášjohka in 2008 and 2010.

The implication of this is that the egg deposition, and accordingly smolt production, in the later years has been at a level far below the potential production capacity of each tributary. In the same period, salmon stocks in neighbouring rivers in Finnmark have had several years of record catches, indicating that the reasons for the bad target attainment in Tana cannot be traced to natural causes (e.g. poor sea conditions causing low sea survival).

Salmon from the Tana river system are exploited over a large area, starting with the coastal fisheries of the outer coast of Finnmark, Troms and Nordland, followed by the coastal fishery in the Tana fjord, then the river fishery in the Tana main stem, and lastly a fishery within the different tributaries. It is only the latter that is a single-stock fishery; the other fisheries are mixed-stock. The fisheries represent a sequence in which the salmon available for exploitation in any region are the ones surviving the fisheries in the preceding regions. The stocks in the Tana river system are therefore under pressure from a sequential accumulated exploitation that increases the total exploitation pressure to high levels even though the fishery in each separate region by itself is not particularly intense.

The total exploitation rate was estimated for the five evaluated stocks in 2009 and 2010 using the following data: (1) either the catch or fish counting from each tributary, (2) an estimated stock-specific catch from the main stem (using catch statistics and genetic stock identification data), and (3) an estimated stock-specific catch from the coastal fisheries (using catch statistics, coastal genetic stock identification data from 2008 and old tagging data).

The lowest total exploitation was found in the lowermost tributary, Máskejohka, with 59 % in 2010 and 66 % in 2009. The estimates were higher in the middle and upper part of the river system, up to 91 % in Iešjohka in 2009, 90 % in Válljohka 2009, 86 % in Kárášjohka 2009 and 73 % in Lákšjohka 2010.

The estimated exploitation of stocks in different fisheries showed some contrasting differences, especially when comparing the lower and upper part of the Tana river system. For all evaluated stocks, approximately 15-25 % of the total catch were taken in the coastal fisheries (with higher coastal fishing pressure for the stocks with a high proportion of MSW-salmon). The contribution from the Tana main stem fisheries differ markedly. In Máskejohka, the lowermost tributary, the main stem contributes around 11 % of the total catch, while in Iešjohka the main stem contribution is around 55-57 %. There are some differences also in the contribution from the within-tributary fishery, with around 30 % of the total catch of Máskejohka-salmon being taken within the Máskejohka itself while only 10 % of the total catch of Iešjohka-salmon were taken within the Iešjohka.

Overexploitation as a threat factor is defined as the extent of a reduction in spawning stock below the spawning target that can be attributed to exploitation. There was extensive overexploitation in all five tributaries in both 2009 and 2010, with 90 % fishing mortality for Iešjohka salmon in 2009 as the worst example.

An estimate of maximum sustainable exploitation (the maximum level of exploitation a stock could sustain while still reaching its spawning target) demonstrates that some of the stocks are depleted to the point of having very low, or even no, sustainable surplus. In Iešjohka (2009), Kárášjohka (2009 and 2010) and Lákšjohka (2009 and 2010) the maximum sustainable exploitation was 0 %. These stocks were then below their spawning targets already before any fish had been caught. The highest estimates of maximum sustainable exploitation were found in Válljohka with 73 % in 2010 and 65 % in 2009.

Only 5 rivers are currently used for the status evaluation, which raises a question about how these are related to the rest of the river system. There are two important considerations here: (1) the problems caused by a high accumulated sequential exploitation is likely common to all stocks in Tana, and (2) the bad target attainment observed in the five evaluated tributaries is, by itself, enough argument to recommend regulatory changes in the mixed-stock fisheries affecting these stocks. Under those terms, a regulatory regime of both mixed-stock fisheries and tributaries that brings the total exploitation down to a sustainable level for the five evaluated stocks is likely to be a regime that does right by the other stocks as well.

Some simple calculations depict the danger of ignoring the effect of a sequential accumulated exploitation and regulate in only parts of the sequence. Using the Iešjohka-stock as an example, the need for a concerted regulatory effort throughout the exploitation sequence (coast – fjord – main stem – tributary) can be demonstrated. For instance, removing the coastal fisheries would result in a 3 % gain (of the total pre-fishery abundance) in the spawning stock, despite closing off a fishery that currently accounts for around 20 % of the pre-fishery abundance. The same 3 % gain would be the result if all fisheries in the lower Norwegian Tana main stem were closed. A small decrease in fishing intensity throughout the sequence would result in a 13 % gain (of the total pre-fishery abundance).

Regulation recommendations:

1) The target attainment situation in the five evaluated stocks in Tana is bad. Exploitation estimates reveal a high accumulated sequential exploitation pressure that is not sustainable. This total pressure must be reduced down to a level at which each stock is likely to reach their spawning target on an annual basis.
2) The sequential nature of the exploitation means that the only effective way of bringing the total exploitation pressure down is by reducing the efficiency of all fisheries in the sequence.
3) New regulations should be target-specific. This is a challenge for mixed-stock fisheries, and specifically tailored monitoring must be employed to ensure a sufficient knowledge level. An example of such monitoring is the current combination of genetic stock identification (Genmix- and Kolarctic-projects) and fish counting (video, DIDSON).
4) The negative trend observed for MSW salmon in the Tana river system further points to an urgent need to implement regulations aimed at reducing especially the exploitation rate of larger salmon.

5) Genetic stock identification of mixed-stock fisheries catch samples demonstrate that a high exploitation of large egg producers (MSW females and previous spawners) belonging to the tributaries takes place early in the season. It is therefore advised to reduce exploitation rates in mixed-stock fisheries (both coastal and main stem) in the first weeks of the current season (May and June).

The Group recommends the following principles in the future management of the Tana salmon populations.

1) The agreement must be built around the use of stock-specific management targets.
2) The evaluation of target attainment must specifically be knowledge-based, with the countries specifically and clearly committing to a monitoring programme that provides the necessary data for target evaluation.
3) There must be a built-in flexibility in the fishing rules. This flexibility should allow for implementation of regulatory measures that operates both within-season and between-season. Within-season measures are necessary to quickly counteract a low pre-fishery abundance (or other unexpected issues that might suddenly arise, e.g. because of a particularly dry summer) and increase the probability that targets are attained.
4) A particularly suitable form of flexibility is pre-agreed regulatory measures that can explicitly be stated in the agreement, with each measure being the pre-agreed response to particular scenarios. Because all these are pre-agreed, they can be quickly implemented by both countries without any time-wasting hearing process.
5) To strengthen and ease the work with preparing the catch statistics, it is essential to have quickly delivered and accurate catch reports from every person fishing in Tana. This should be formalized in the agreement as a personal obligation for everyone.

Long-term monitoring recommendations
Stock status evaluation within an adaptive knowledge-based management regime should be based on the best possible monitoring data, provided through a consistent, long-term monitoring programme. Such a programme should provide (1) a detailed and accurate catch statistics from all different areas and fisheries of the system, (2) catch samples that provide life history data and enable stock identification of the catch in mixed-stock fisheries, and (3) accurate fish counting, either on fish entering e.g. a tributary, or in the form of spawner counts after the fishing season.

There is substantial variation in the exploitation rates experienced by different stocks in different fisheries; the Tana main stem exploitation of salmon being much lower in the lower tributaries compared to that of the tributaries further up in the river system. Therefore, long-term monitoring must be spatially distributed in the lower, middle and upper parts of the Tana system.

The Group strongly endorses finding arenas that allows the communication of local environmental knowledge to the Group and allows dissemination of scientific knowledge to local communities in an accessible manner.

Currently, there is a lack of long-term predictability in most of the research and monitoring activities in the Tana, making it impossible to plan activities for more than 1-2 years ahead. The Group therefore strongly recommends the joint establishment of a permanent Norwegian-Finnish research

and monitoring programme for Tana. This programme, and its details, should be specified in a binding way in the forthcoming new fishery agreement between the two countries.

Short-term monitoring recommendations for 2012

The Group recommends that the following activities are prioritized in 2012, largely following the priorities for 2011: catch statistics, catch sampling, genetic stock identification of the main stem mixed-stock fishery, video counting in Utsjoki and Lákšjohka, further development of acoustic counting of adult salmon in Kárášjohka and/or Máskejohka, and juvenile monitoring.

Research needs

We are currently basing the status evaluation on the use of spawning targets. Currently, usable spawning targets are established only for six Norwegian tributaries, which means that major parts of the river system are lacking in the status evaluation. This calls for the following research needs:

1) Usable spawning targets must be established for the Tana main stem, Anárjohka/Inarijoki and a set of Finnish tributaries.
2) A procedure for evaluating the spawning targets in areas with mixed-stock fisheries is needed.

2   The group mandate and presentation of members

The Working Group on Salmon Monitoring and Research in the Tana River System (referred hereafter as the Group or the Tana group) was formally appointed in 2010 by the Ministry of Agriculture and Forestry in Finland and the Ministry of Environment in Norway, based on the Memorandum of Understanding signed in February 2010. Among other points defined in its mandate, the Group should deliver annual reports on the status of the salmon stocks, evaluate their management, and give advice on relevant monitoring and research.

The following mandate was given for the group:

1. *To deliver annual reports on the status of the salmon stocks, including trends in stock development.*
2. *To evaluate the management of stocks in light of relevant NASCO guidelines.*
3. *To integrate local and traditional knowledge of the stocks in their evaluations.*
4. *To identify gaps in knowledge and give advice on relevant monitoring and research.*
5. *To give scientific advice on specific questions from management authorities.*
6. *To collect information from local communities and organizations and cooperate with such bodies in the dissemination of scientific results to the public.*

The present report aims to fully cover points 1, 2 and 4 in the mandate. Point 5 commits the Group to discuss and answer questions raised by management authorities in both countries, either through specific chapters in the annual report, through presentations or through specific notes.

Two points in the mandate, 3 and 6, concerns the interface between the Group and local people living close to the Tana river system. This topic is further discussed in chapter 1.

It was further detailed that the group shall consist of four scientists, two appointed from Norway and two appointed from Finland. The following group members have been appointed:

- Jaakko Erkinaro (Finnish Game and Fisheries Research Institute, FGFRI), leader
- Morten Falkegård (Norwegian Institute for Nature Research, NINA), secretary
- Eero Niemelä (FGFRI), assistant secretary
- Tor G. Heggberget (NINA), assistant leader

The first three of the group members listed above are individually appointed on the basis of their experience and detailed knowledge about the Tana river system, and are as such not acting as representatives of their working institutions. The fourth member was appointed to represent the Norwegian Institute for Nature Research, thus linking the work in the Group with the vast experience of other scientists in NINA.

3 Introduction

Until recently, the Atlantic salmon (*Salmo salar* L.) populations of the River Tana have been typically considered to be in a relatively healthy state with fluctuating population abundances with no apparent declining trend (e.g. Niemelä *et al*. 2005). In their report, however, the Norwegian-Finnish Temporary Working Group on Stock Monitoring and Research in Tana (Johansen *et al*. 2008) raised concerns on the status on certain populations in tributaries of the Tana that was based on the newly established river-specific spawning targets (Hindar *et al*. 2007) and evaluation of their attainment. In addition, the Norwegian Scientific Advisory Group for Salmon Management has pointed out the undesirable status of the Tana salmon stocks in their evaluations over the past couple of years (see Anon. 2011). In fact, some populations of the Tana complex now appear to show one of the worst situations in relation to the 210 Norwegian salmon rivers evaluated by Anon. (2011).

The Tana salmon population complex consists of at least 20-30 different sub-populations (Vähä *et al.* 2007). As clearly demonstrated in the report of the earlier working group (Johansen *et al*. 2008), salmon fisheries in Tana are mostly mixed-stock fisheries. Mixed-stock fishery of salmon stocks greatly complicates the conservation and management of the salmon stocks, and especially the conservation of biodiversity of a complex mixture of sub-populations as is the case in the Tana. Unless it is possible to selectively exploit productive populations, the overall exploitation rate must therefore be carefully controlled to ensure conservation of less healthy populations within an area of mixed-stock fishery. Overexploitation will push the numbers of returning salmon stocks below sustainable levels, and as salmon abundance declines, diversity and resilience are reduced, and the risk of extinction is increased. Populations with low diversity are less resilient to environmental stresses such as disease, pollution or changing climate.

The last decades have shown remarkable declines in the stock levels of Atlantic salmon throughout its distribution area (e.g. ICES 2011). Therefore, the North Atlantic Salmon Conservation Organisation (NASCO) has adopted principles like the "*Agreement on Adoption of a Precautionary Approach*" for conservation, management and exploitation of salmon stocks, and the "*Decision Structure For Management of North Atlantic Salmon Fisheries*" (see www.nasco.org for both documents), a consistent approach to the management of exploitation (see chapter 4.3). Although the NASCO convention required that management should be based upon the "*best available scientific information*", the Precautionary Approach changed this into an emphasis on managers and scientists utilizing all available information, regardless of its imperfection, when developing management options. As the mandate of the Tana working group includes "*evaluation of management of stocks in light of relevant NASCO guidelines*", the approach and background of the NASCO principles was adopted by the Tana group in assessing the status of the Tana salmon populations and in providing management advice.

The aim of the first annual report from the Tana group is to give an updated status evaluation of the Tana salmon populations, with background information on related fisheries, management, threat factors, and monitoring and research activities. The Group will also give advice on prioritized monitoring and research activities based on the major future challenges for the Tana salmon. The report from the previous temporary working group (Johansen *et al*. 2008) contains a more detailed and thorough discussion on monitoring and research needs in Tana.

4   The River Tana, the Tana salmon, salmon fisheries and management

4.1   The Tana and its salmon

The subarctic River Tana (Teno in Finnish, Deatnu in Sami) forms the border between northernmost Norway and Finland (70 ° N, 28 ° E). The river drains an area of 16 386 km^2 (of which almost 70 % is in Norway) and the river system consists of a multitude of small and large tributaries (Figure 1), most of which are readily accessible for ascending salmon. Historically, salmon have been found distributed over a total of over 1 200 km (Table 1).
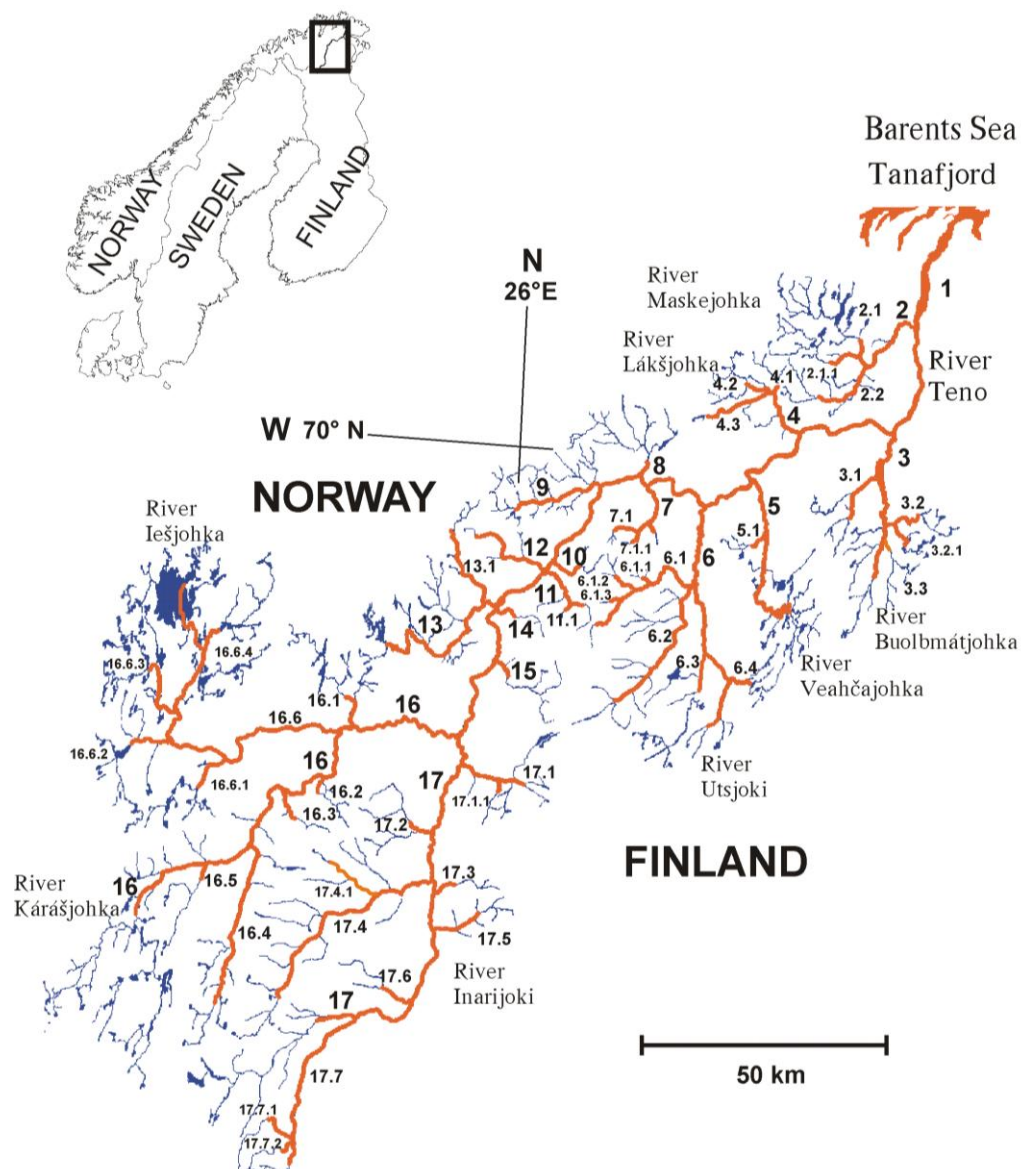

Figure 1. Map of the Tana river system. The orange line indicates the historical distribution of salmon based on historical sources and interviews. The numbers correspond to Table 1. Map from Eero Niemelä, FGFRI.

Table 1. The historical distribution of salmon in the Tana river system. + occurs on a regular basis, (+) occurs occasionally. Distribution numbers are collected and systematized by Eero Niemelä, FGFRI, based on various scattered historical sources (unpublished) and interviews with local people.

	River	km	1SW	2SW	3SW	4-5SW
1	Tana/Teno	211.0	+	+	+	+
2	Maske	30.9	+	+	+	
2.1	Geasis	6.9	+	+	+	
2.1.1	Uvjaladnja	6.7	+	+		
2.2	Ciicujohka	10.9	+			
3	Buolbmát/Pulmanki	39	+	+	(+)	
3.1	Gálddaš	13.5	+	+		
3.2.	Luossa	6.8	+	(+)		
3.2.1	Skiihpa	6.7	+			
3.3	Morešveai	3.4	+			
4	Lákš	13.7	+	+	(+)	
4.1	Garpe	0.7	+	+		
4.2	Gurte	9.4		(+)	(+)	
4.3	Deavkehan	17.5		(+)	(+)	
5	Veahća/Vetsi	42.6	+	+	+	
5.1	Váis	5.8	+			
6	Utsjoki (lower)	22.2	+	+	+	+
6.1	Ćárse/Tsars	31.2	+	+		
6.1.1	Njiðgu	4.9	+			
6.1.2	Liŋkin	5	+	(+)		
6.1.3	Uhtsa-Ćárse	3.9	+			
6.2	Geavvu/Kevo	35.7	+	+	+	
6	Utsjoki (upper)	36	(+)	+	+	(+)
6.3	Cuoggá	7.6	+	+	(+)	
6.4	Gukće	7.3	+	(+)	(+)	
7	Goahppelaš/Kuoppilas	13.4	+	+	(+)	
7.1	Birke	9.7	+	+		
7.1.1	Koaskim	2.6	+	+		
8	Borse	5	+	+		
9	Leavva	24.1	+	+	+	
10	Nuvvos	7.9	+	+		
11	Njilj	12.7	+	+		
11.1	Mávnnáveai	2.1				
12	Báiš	19	+	+	(+)	
13	Válj	45.1	+	+	+	(+)
13.1	Áste	18.7	+			
14	Jeagelveai	4.3	+			
15	Áhko	5.1	+	+	(+)	
16	Káráš	73.5	+	+	+	+
16.1	Geaimme	9.8	+	+		
16.2	Noaidat	7.9	+			
16.3	Suolga	3.9	+			
16.4	Bavta	44.9	(+)	+	+	+
16.5	Suorbmu	2.7	+	(+)		
16.6	Ieš	87.1	+	+	+	+
16.6.1	Áste	8.2	+	+		
16.6.2	Vuottaš	15	+	+		
16.6.3	Ráges	14.7	+	+	+	
16.6.4	Molleš	4.3	+	+	+	
17	Inari	93.2	+	+	+	(+)
17.1	Gáregas	18.2	+	+	(+)	
17.1.1	Vuorgoćearáv	0.9	+			
17.2	Iškoras	5	+			
17.3	Guoldná	6.1	+			
17.4	Gorzze	38.1	+	+	+	
17.4.1	Vuzzul	17.4	+	+		
17.5	Vuopmaveai	12.9	+			
17.6	Casken	8	+	(+)		
17.7	Skiehććan	37.1	+	+	+	
17.7.1	Njuolas	8	+	+		
17.7.2	Rádjá	2.5	+	+		
	Total length (km)	**1 268**				

The Tana salmon shows an extremely large variation in life histories, with smolt ages ranging from two to eight years (mostly 3-6 years), and adult sea-ages ranging from one (one-sea-winter-salmon, 1SW) to five sea-winters. In addition, there are different types of previously spawned salmon. The smallest tributaries are dominated by 1SW fish (both males and females) with a small to medium percentage 2SW females (Figure 2). Multi-sea-winter (MSW) salmon are mainly found in Tana main stem, the Norwegian tributary Máskejohka, Finnish tributary Utsjoki, and the uppermost large tributaries Anárjohka, Kárášjohka and Iešjohka. In these tributaries, the female spawning stocks are almost exclusively 2- and 3SW fish and previous spawners.
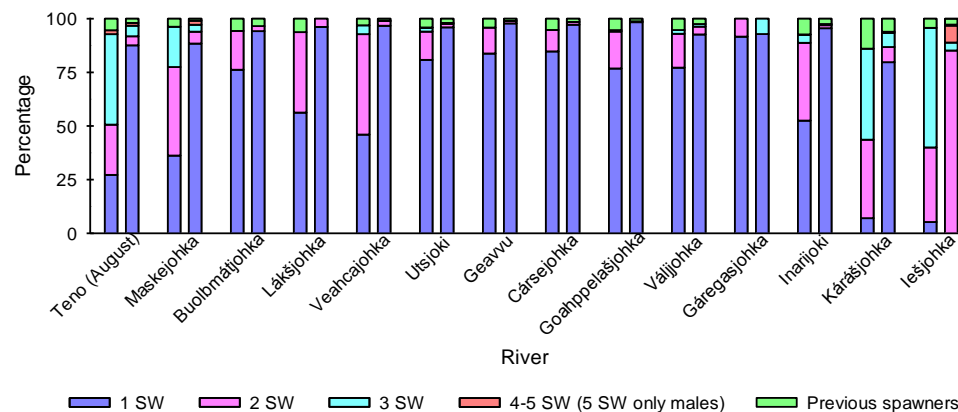

Figure 2. Sea-age distribution of salmon catch in different parts of the Tana river system. Left-hand bars: female salmon; right-hand bars: males. Figure from Niemelä (2004).

In addition to the productive main stem, there are more than 30 tributaries supporting distinct spawning stocks (Berg 1964; Moen 1991; Elo *et al.* 1994) (Figure 1), and by use of polymorphic microsatellite markers high genetic differentiation among stocks from the different tributaries has been revealed (Vähä *et al.* 2007) (Figure 3). DNA microsatellites have indicated pairwise F_{ST}[1] values between inferred populations ranging from 1.5 % to 20.1 % with an average of 9.2 %.

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[1] F_{ST} refers to the proportion of the total genetic variance contained in a subpopulation relative to the total genetic variance. Values can range from 0 to 100% (or from 0 to 1). High F_{ST} implies a considerable degree of differentiation among populations.
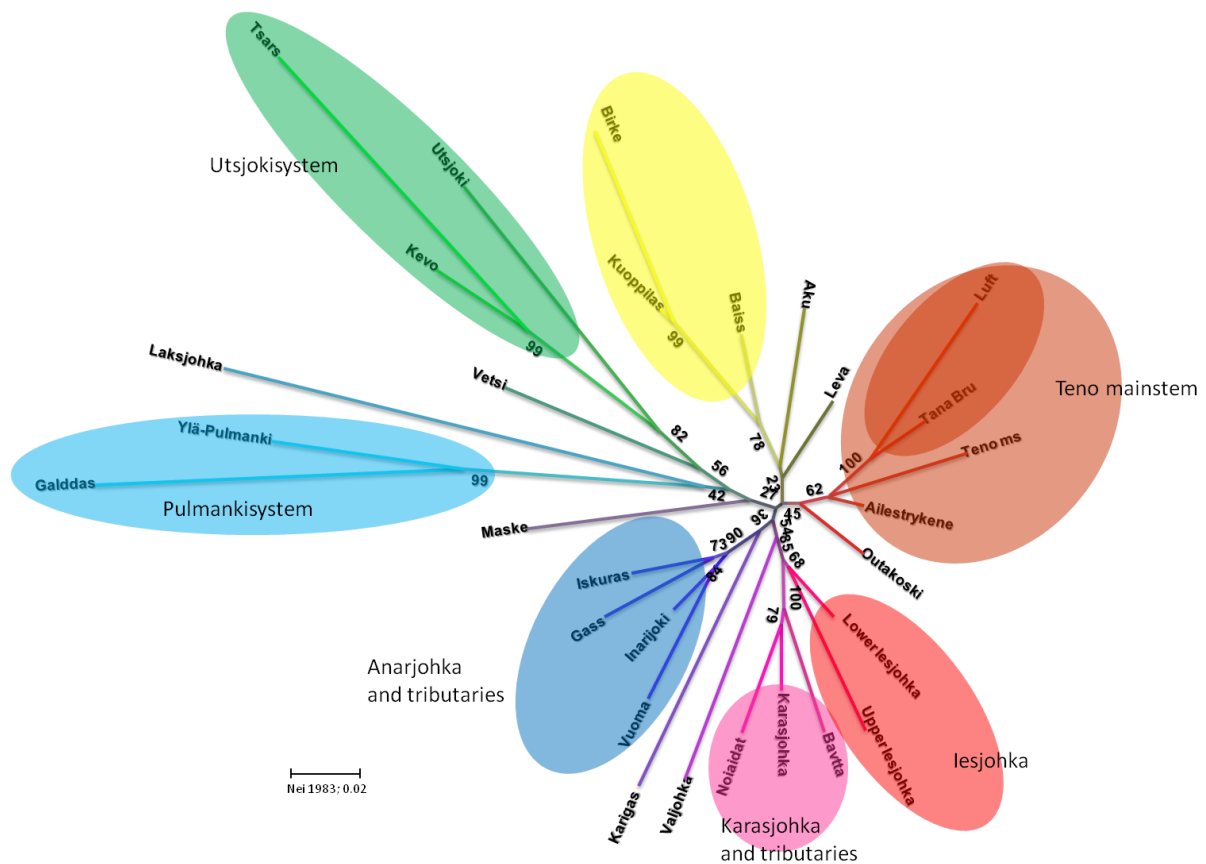
Figure 3. Stock complex of the Tana river system, based on genetic baseline samples from various tributaries and areas (figure from J.-P. Vähä, University of Turku).

Salmon migrating to the upper parts of the river system must cover long distances. From this it could be expected that salmon belonging to upper tributaries such as Anárjohka/Inarijoki, Kárášjohka and Iešjohka, are harvested relatively late in the season (Figure 4). Data from scale samples however, show that most of the MSW salmon in Kárášjohka and Iešjohka are caught by the end of June. Median dates of capture in these uppermost areas are comparable to median dates for the lower part of Tana main stem (and slightly earlier than median dates for the middle part of Tana main stem), indicating that the salmon ascending to Kárášjohka and Iešjohka enter the River Tana very early in the season (Johansen *et al*. 2008). This early run timing also indicates that these stocks are exposed early in the summer in the coastal fisheries and river fisheries in the main stem Tana.
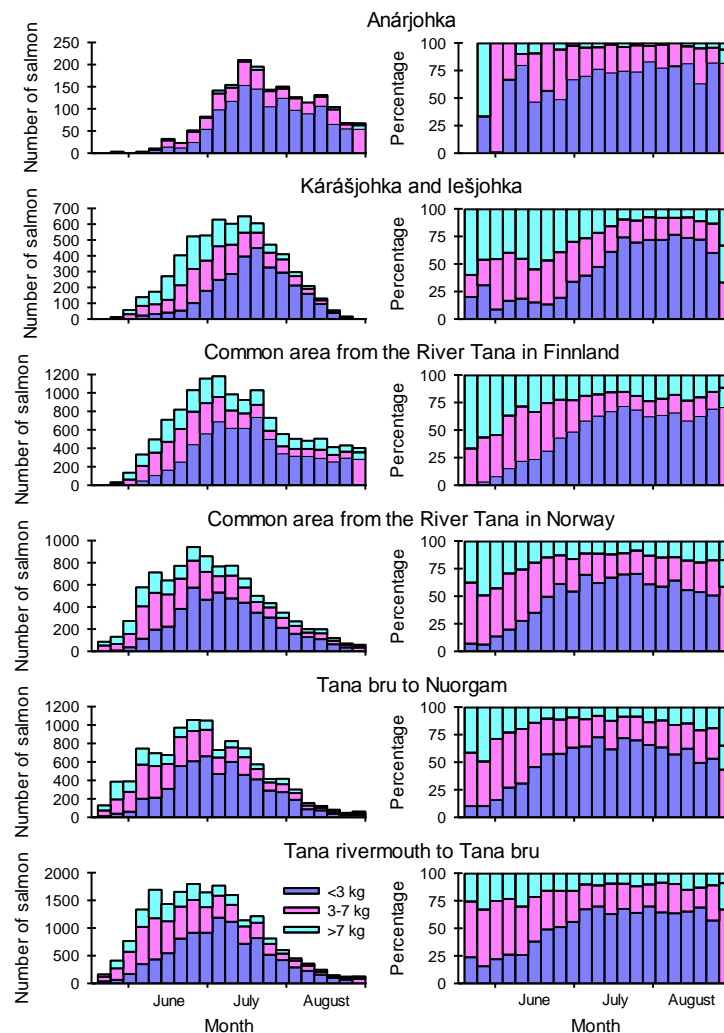
Figure 4. Catch distribution throughout the summer in the Tana river system. Data from the years 2004-2010 are combined. The figure is based on salmon catch statistics for the areas Tana rivermouth to Tana bru, Tana bru to Nuorgam, common area from the River Tana in Norway, Kárášjohka and Iešjohka. Scale sampling data were used for the common area from the River Tana in Finland. For Anárjohka, a combination of Norwegian catch statistics and Finnish scale sampling data were used.

While return rates of adult salmon has decreased significantly during the last half of the 1900s in most salmon rivers on both sides of the Atlantic, the northernmost salmon stocks in Finnmark (including the river Tana) and the Kola Peninsula have fluctuated in a cyclic manner with no clear declining trend. During the last two decades, however, some negative developments have been observed in the Tana river system. A negative trend for large MSW (3- and 4SW) salmon, especially the females, is particularly worrying. Even though the numbers vary from year to year, there is a negative trend indicating that the return of large fish has been decreasing during the two last decades. During the same period, the trend for 2SW fish is positive while the abundance of 1SW salmon in the river system has been below the long-term average during the last eight-nine years. Earlier observations of positive correlations among Tana and some other western Finnmark rivers seem to have changed during the last 10 years, i.e. supporting these negative trends. This could be due to factors connected with heavy exploitation (sea and/or river fishery), changes in prey availability in the Barents Sea, climate change and so on. However, Tana still today likely supports the largest wild stock complex of Atlantic salmon in the world.

4.2   Tana salmon fisheries

The riverine salmon fisheries in Tana include a variety of fishing methods such as weir, gill net, seine and drift net, in addition to rod and line. The net fisheries are practiced by local people and it is permitted by fishing rights based on land owning, agriculture production or inherited rights. Fishing in the lower section is mixed-stock fishery throughout the season, whereas this is true for the upper section until the second half of July, when stocks from the tributaries have mostly ascended into their spawning rivers. In the upper section, fishing in August is directed to sub-stocks reproducing mainly in the main stem. According to the telemetry tagging experiments in the early 1990s, harvest rates in the river fisheries could reach the levels of more than 60 % (Erkinaro *et al.* 1999; Karppinen *et al.* 2004). A recent study in the large tributary, Utsjoki, even suggested exploitation rates of more than 80 % on MSW salmon. It should be emphasised, that by including the sea fishery, the effective exploitation rates for Tana salmon is even significantly higher.

Tana salmon is further exploited in the sea fisheries along the coast of northern Norway. This coastal fishery has historically had yearly catches up to 700 tonnes, but regulations in the later years have brought the catch down to well under 200 tonnes. Tagging experiments indicate that around a third of this coastal catch might be Tana salmon and the total salmon production of the River Tana system has then been estimated to be up to 600 tonnes (NOU 1999). Tagging of smolts from the River Tana in the 1970s indicated a fifty-fifty distribution of the catch between the coastal fisheries and the River Tana in terms of number of salmon (Rikstad & Niemelä 2009). Over the past three-year period (2008-2010), the salmon catches in the sea fisheries along the Finnmark coast with bagnets and bendnets have varied between 120 and 150 tonnes; 122 tonnes of salmon was captured in 2011.
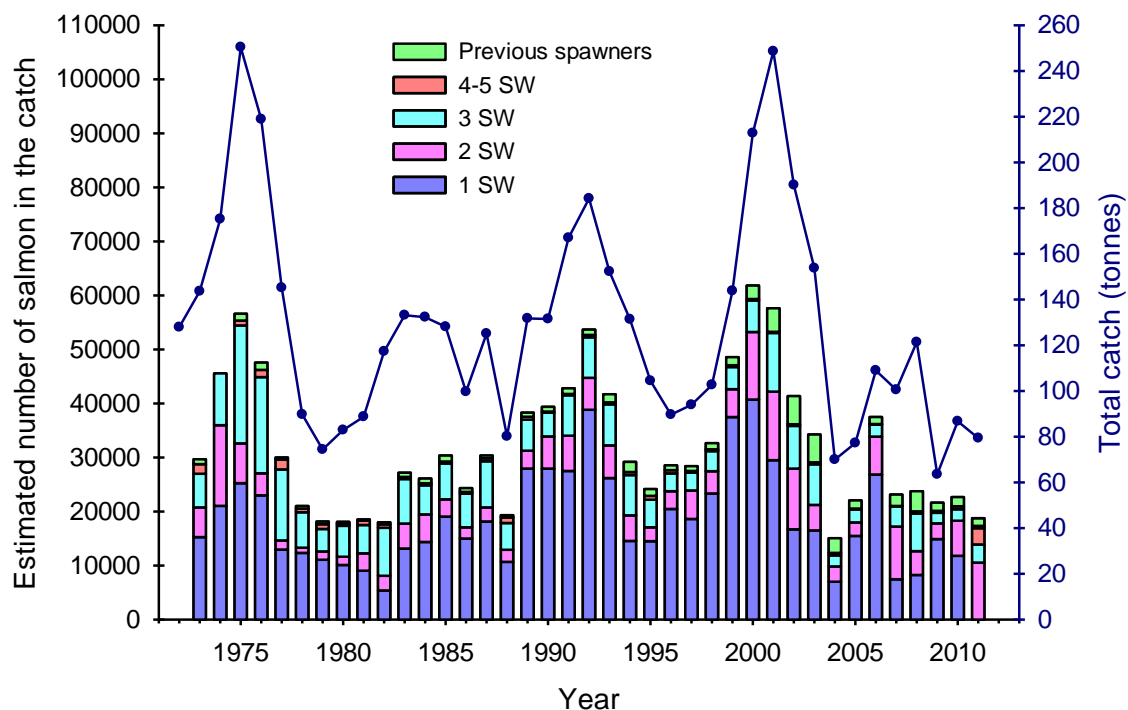

Figure 5. Total salmon catch in the River Tana system (both Norway and Finland) in 1972-2011 in terms of mass (line) and number of fish (bars). Bars are separated into different sea age groups.

The catch statistics for the Tana River system have historically been divided into two separate parts, the Norwegian catch and the Finnish catch. The Norwegian catch statistics were calculated by the County Governor of Finnmark up until and including 2010. In 2011 the responsibility were transferred to the new local River Tana Fisheries Management Board. The Finnish Game and Fisheries Research Institute (FGFRI) compile the catch on the Finnish side.

Between 1972 and 2010, the annual salmon catch in the river have fluctuated between 63 and 250 t with an average of 130 t (Figure 5). Total number of salmon caught in the entire Tana system typically vary between 30 000 and 50 000, exceeding 60 000 fish in the best years and sinking to around 15 000 fish in the worst years.

The total salmon catch in the River Tana system has historically fluctuated in a seemingly periodic manner, with peaks every 8-9 years (Figure 5). This period length corresponds roughly with the average generation time of female spawners in the system. For example, good catches in the early 1990s resulted in good catches in the early 2000s. Worryingly, these periodic cycles seem to have broken down in the last years. The good catches in early 2000s did not result in high catches in 2006-2008, even though the catches of 1SW salmon in 2006, 2SW in 2007 and 3SW in 2008 were higher than the long-term average. Effective salmon fishery of Tana River stocks in coastal areas and within the entire Tana River system in the early 2000s might therefore have resulted in too low spawning stocks. In the last five years, salmon catches in Tana have been below the long-term average both in terms of numbers and mass. Following the long-term fluctuations in the total catch, much higher catches were expected in 2009, 2010 and 2011. The catch in terms of numbers of salmon in 2011 was one of the smallest during the 40 years research period.

Salmon catches have fluctuated in the same manner in Norway and in Finland (Figure 6). However, the relative development in catch level is very different between the two countries. Since 2004, the Norwegian catches have been much lower relative to the long-term average than the catches in Finland. This reflects a general trend of lower fishing intensity in Norway, especially in the lower Norwegian part of the Tana main stem. The extent of the Norwegian fishery is, thus, declining while the Finnish catches make up a larger proportion. During the 1970s and 1980s, the Norwegian catch was responsible for 60-70 % of the total catch. During the 1990s, this proportion gradually declined towards 50 %, and in the 2000s, the Finnish catch has made up over 50 % of the total (Figure 6).

Despite a large annual variation in the salmon catch estimates, the proportion of salmon caught with different fishing methods have remained relatively stable (Figure 7). The proportion of salmon caught with rod increased slightly from the 1970s until the early 2000s. There are, however, clear differences between the two countries. Around 75 % of the salmon caught in Finland have been taken with rod, while more than half (60-70 %) of the Norwegian catch is caught by nets. In Norway the proportion of rod catch has declined since the early 1990s, while in Finland it has increased since the early 2000s. In Norway the proportion of salmon caught with driftnets has increased since the mid-1990s.
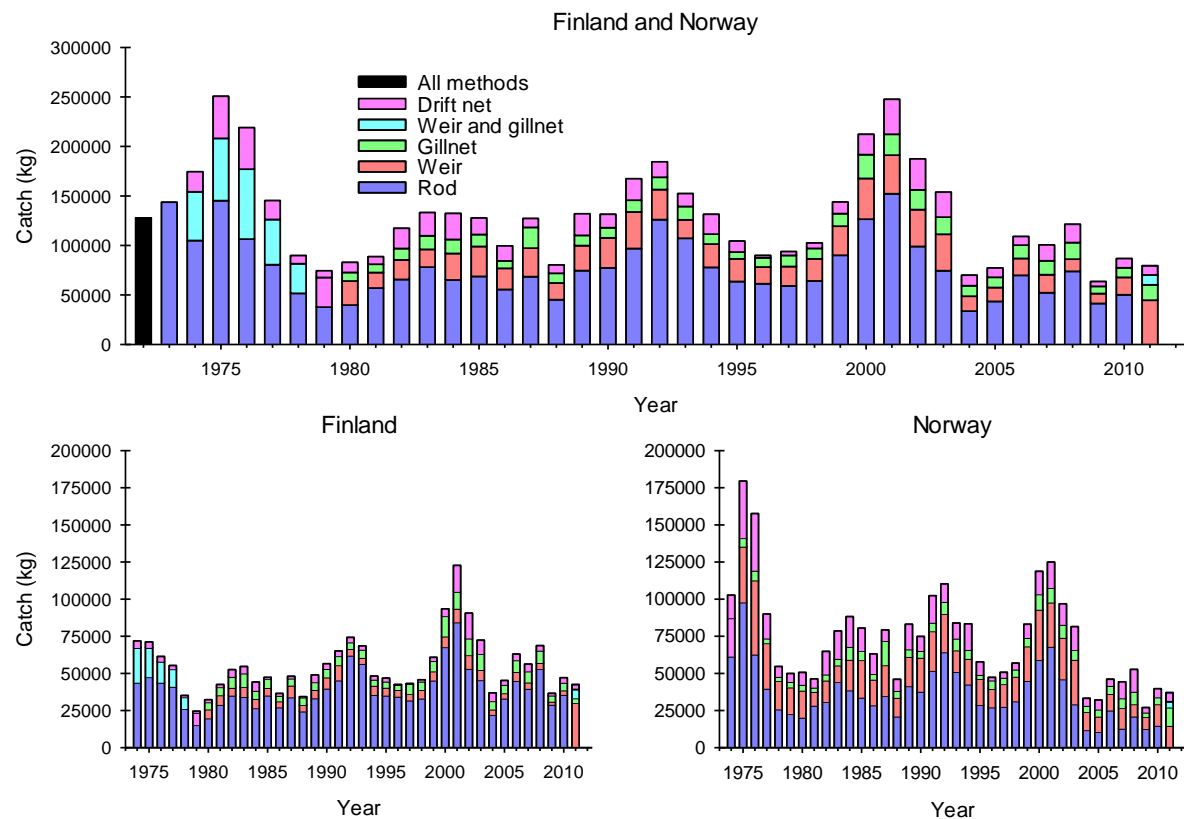
Figure 6. Total salmon catches in the Tana river system by countries and fishing methods.
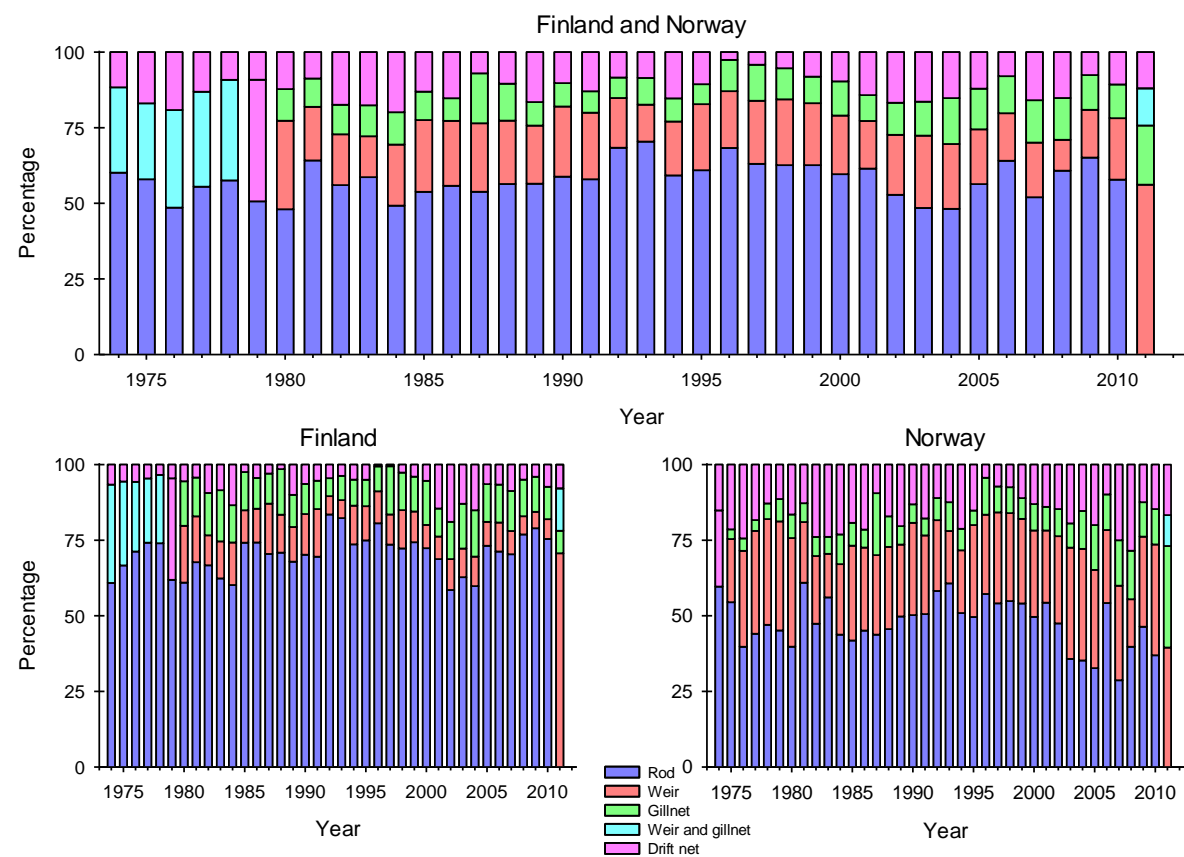

Figure 7. Percentage distribution of salmon catches in terms of mass for fishing gears in Norway and Finland.

In general, the proportion of rod-caught salmon in terms of numbers increased from the 1970s until the mid-1990s (Figure 8). After 1996, the proportion decreased steadily until 2004 followed by an increase until 2009. The proportion of salmon caught on gillnets has shown an increasing trend since mid-1980s. Large annual variations in the proportion of salmon caught on driftnet largely reflects annual variations in environmental conditions, especially the ice-break-up, following discharge and water level, which are determining the practical length of the drift net fishing season.
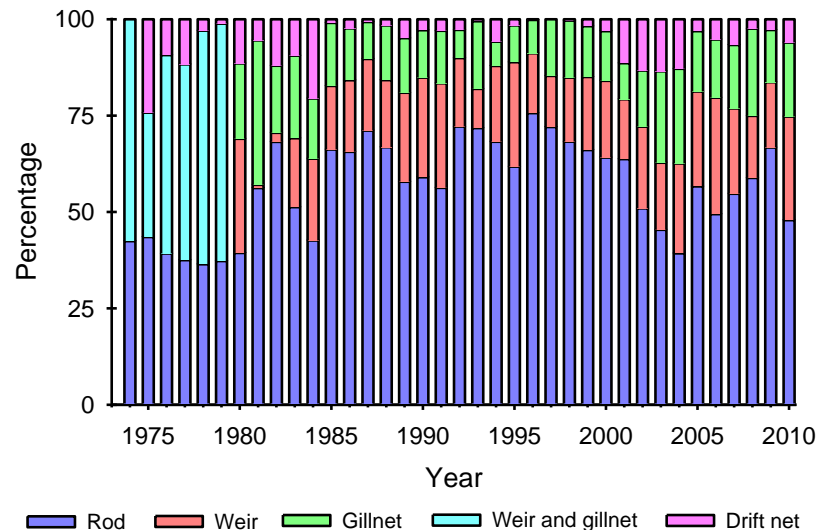
Figure 8. Percentage distribution of salmon catch (based on number of fish) between fishing methods in the River Tana system.

Based on scale reading, it is possible to estimate the relative abundance of different sea age-classes captured throughout the season. The time series dating back to 1973 demonstrates how the fishing exploits salmon of different sea age-classes (Figure 9 and Figure 10). Both virgin fish and previous spawners are caught every year. Most virgin female spawners have been two (2SW) or three years (3SW) at sea, while most virgin males have spent only one year (1SW) at sea. There are also quite a few 1SW females, many of which belong to smaller tributaries, and also some large 4SW females. The largest males are 4SW and 5SW fish.

Both the number and mass of female and male salmon have fluctuated simultaneously (Figure 9 and Figure 10). The expected increase in salmon abundance in 2006-2009 did not occur, and in particular, the catches of females have been low in the later years. The catches of 1SW salmon in 2010 and 2011 were recruited mainly from the spawning stocks of 2004 and 2005, which were the lowest in the Tana salmon catch records since 1973.
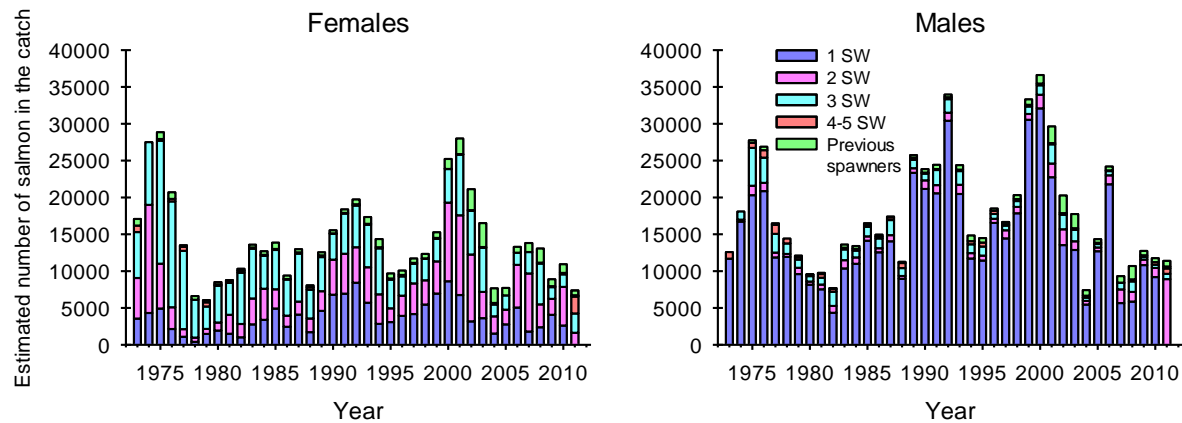
Figure 9. Estimated numbers of salmon in the River Tana catches for 1SW–4-5SW salmon and previous spawners.
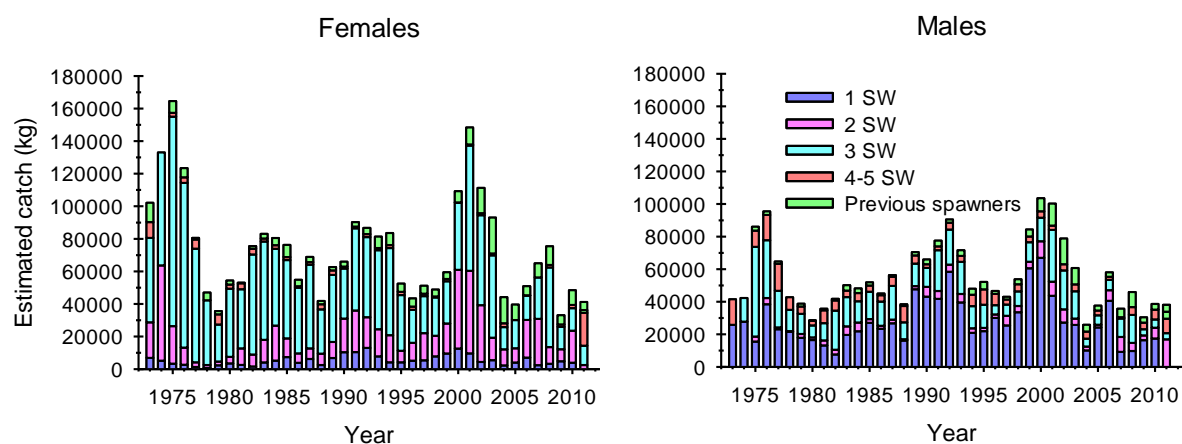
Figure 10. Estimated mass of salmon in the River Tana catches for 1SW–4-5SW salmon and previous spawners.

Female 2- and 3SW fish make an important contribution in the catches by mass because of their larger size compared to male-dominated 1SW fish. Large fishes are also attractive for tourist fishery and important catch for local fishermen. The estimated catches of large salmon have been low over the last eight years except for the year 2008 (Figure 9 and Figure 10).

The estimated number of salmon of different sea- age classes show a decreasing trend for especially large fish (3SW-4SW salmon, Figure 11), while the patterns for smaller salmon (1-2 SW) are less clear. There is a significant increasing trend for previous spawners. The long-term data show large annual variations, e.g. the numbers of 1SW salmon can vary 4-5 folds between the years of highest and lowest abundance.
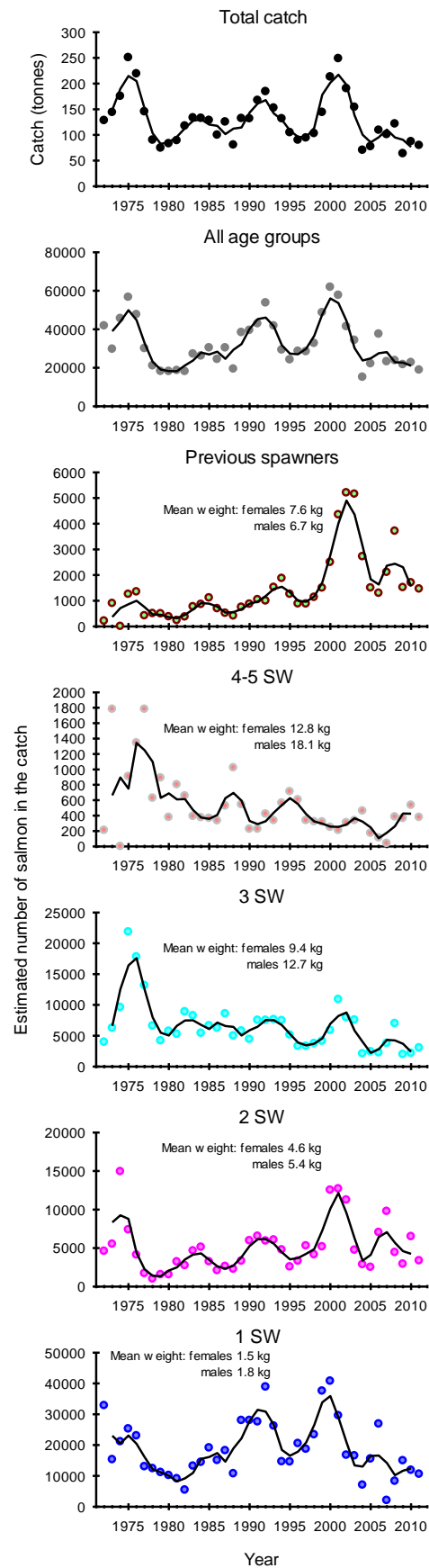
Figure 11. Estimated numbers of captured salmon in different age groups, and the total catch in tonnes.

The decreasing trend for larger salmon is evident both for females and males (Figure 12), but mostly for females. The numbers of female salmon in the catches all sea-ages combined has been below the long-term average during the last seven years. During the last years the numbers of previous spawners have also declined from the record high figures to the level of long-term average. Between the years with high catches, there have always been periods of low catches. The duration of low catches has typically been 5-7 years.
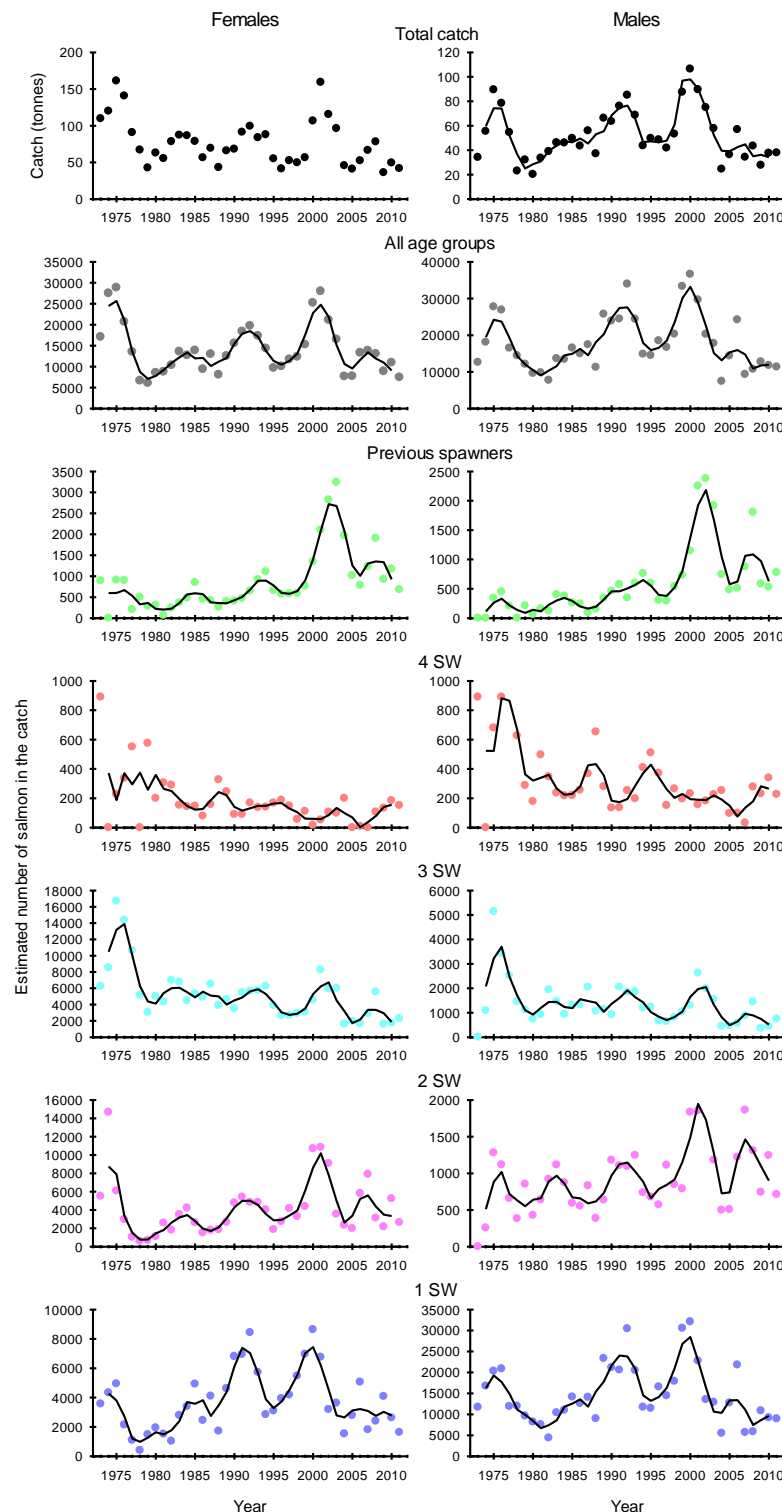
Figure 12. Estimated numbers of salmon of different sea-age-groups in catches of the River Tana system in 1973-2011.

The salmon catches in terms of numbers are fluctuating more or less simultaneously between the fishing gears used in the Tana system (Figure 13). The proportions of different sea ages of salmon are also fluctuating simultaneously between the fishing methods. Interestingly, in the last decade previous spawners have made up an extremely high proportion (up to 50 %) of the salmon caught with drift net. This high proportion of previous spawners also partly masks the worryingly low catch of virgin MSW spawners, especially the 3SW females.
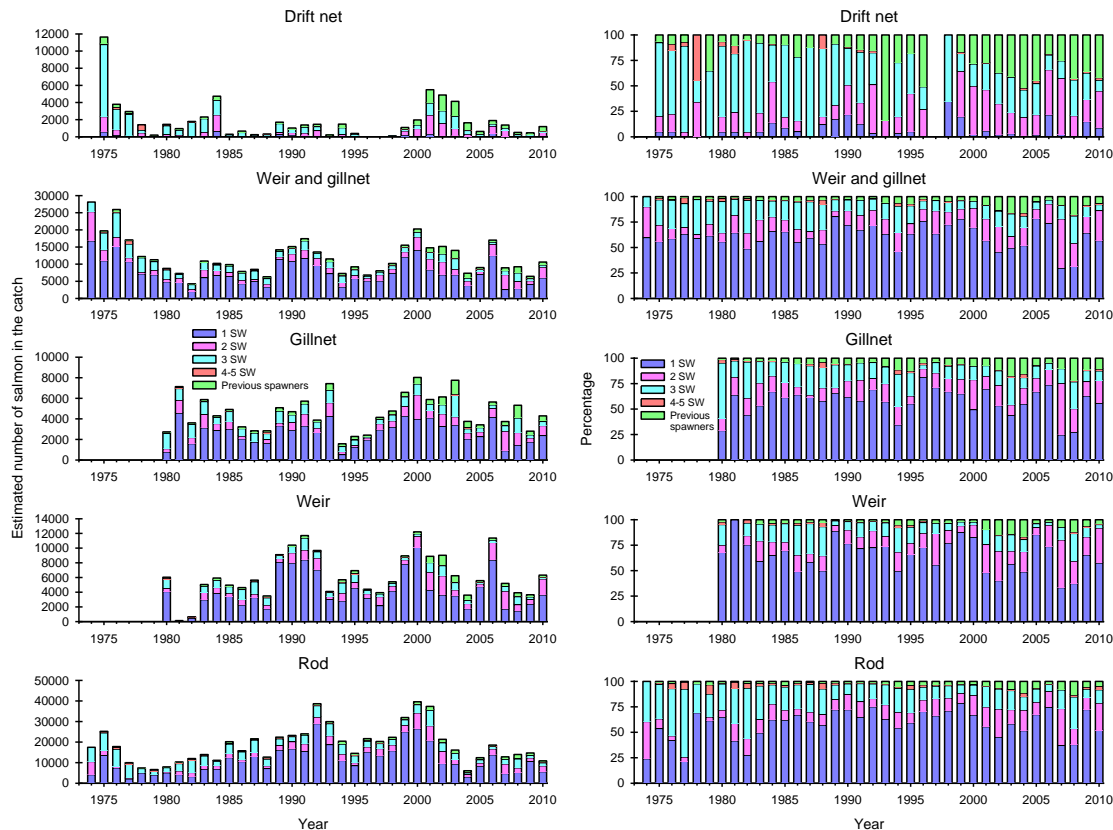
Figure 13. Numbers (figure on the left) and in percentages from the numbers (figure on the right) of salmon (1SW, 2SW, 3SW, 4-5SW, previous spawners) caught in the River Tana system with four different fishing methods.

The proportions of 3SW female salmon have declined significantly in the River Tana catches (Figure 14), reflecting the same phenomenon as the declining numbers of 3SW females in the catches (Figure 11), their decreasing proportion in the total catch (all different fishing methods) in the entire Tana river system (Figure 12) or only in the River Tana itself (Figure 13). In addition, the same negative trend in the proportions of large females is evident in the August catches when most fish are already close to or at their spawning areas (Figure 14). This might be compensated only partly by the slightly increased numbers and increased proportions of 2SW females in the August catches of the Tana main stem (Figure 14).

In certain Tana tributaries with a consistent long-term data set, previous spawners have shown an increasing contribution in the catches, and this is especially true for female salmon in the River Anárjohka/Inarijoki (Figure 14). In addition, the proportion of larger virgin females (2-3SW) has been higher in 2000s than in the earlier decades.
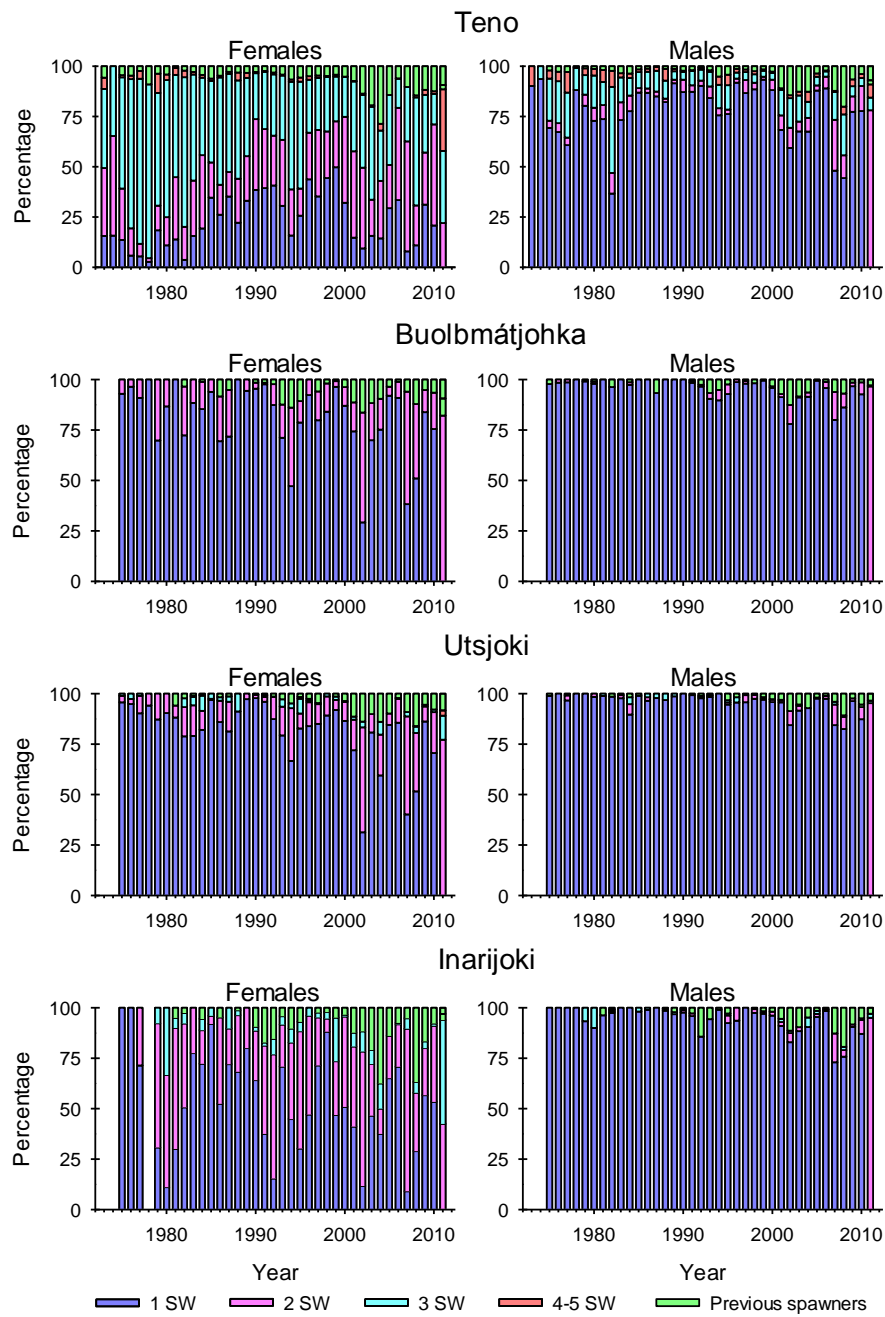
Figure 14. The proportions of various sea ages of salmon caught in Tana main stem and in three major tributaries.
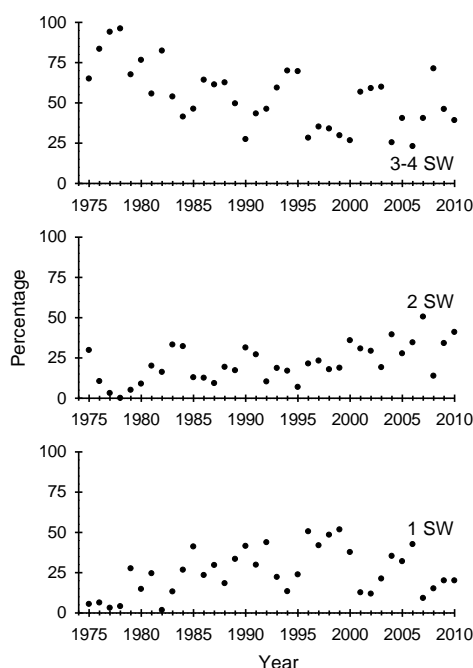
Figure 15. The proportion of female salmon in the spawning stocks (samples from August fishery) in the River Tana main stem.

From 1975 to 2011, the salmon catch of the tourist anglers have varied around 25 % of the total salmon catch in the River Tana system (Figure 16). Since 2005, the tourist catch proportion has increased to 30-40 % of the total catch. Between 1975 and 2011, the tourist catch have varied around 43 % of the total rod catch, and since 2005 this proportion have increased to more than 50 %.
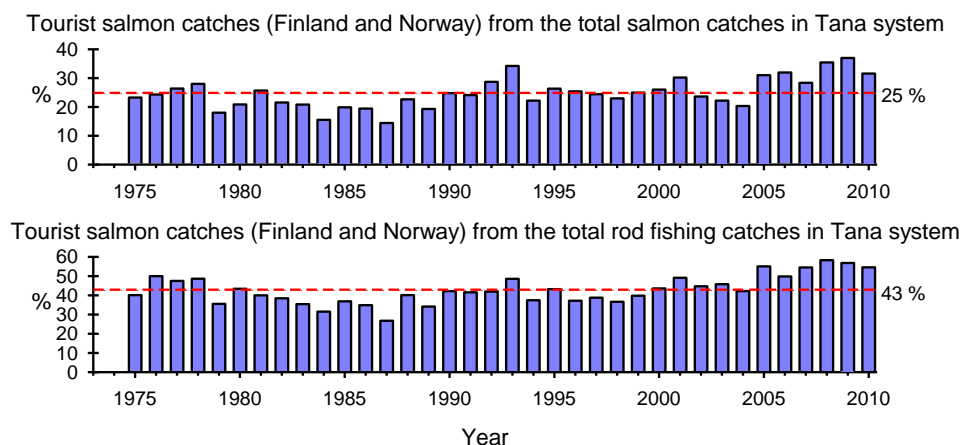
Figure 16. The proportion of tourist salmon catches (Finnish and Norwegian tourist catches together) from the total salmon catches and from the total catches caught with rod fishing methods.

The long-term data set on the Finnish tourist catches indicate an increase in the overall catch levels both in terms of numbers and weight (Figure 17). There is a declining trend of salmon larger than 7 kg, similar to the trend in the total Tana salmon catches. Large salmon have made up around 70 % of the total weight of catch in the 1970s and early 1980s, while in the latest years their proportion has been around 40 %.
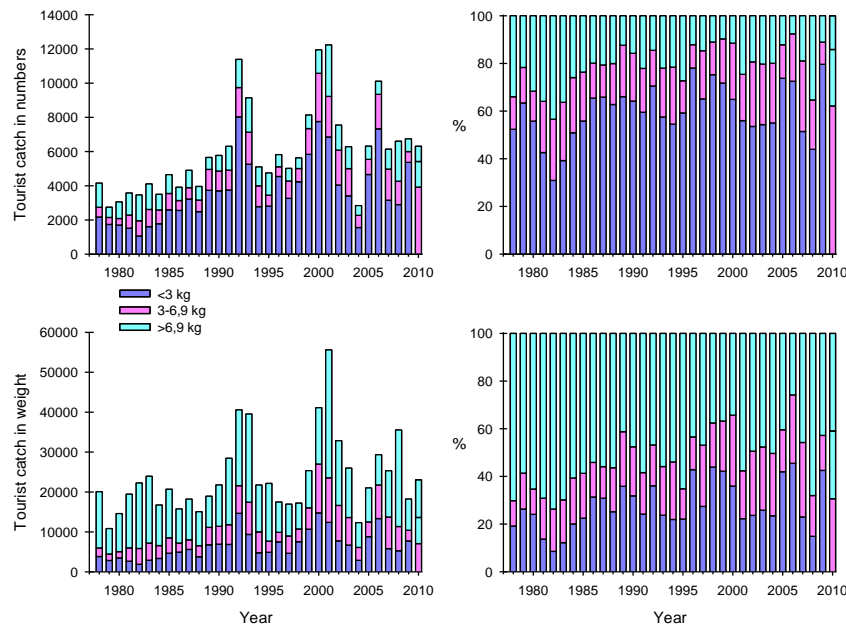
Figure 17. The salmon catches in terms of numbers and weight in three size categories for Finnish tourists in the River Tana and Anárjohka.

The salmon catch of Finnish tourist fishermen further support the conclusion on a declining trend for the 3SW female salmon (Figure 18), but also show the increased proportion of previous spawners.
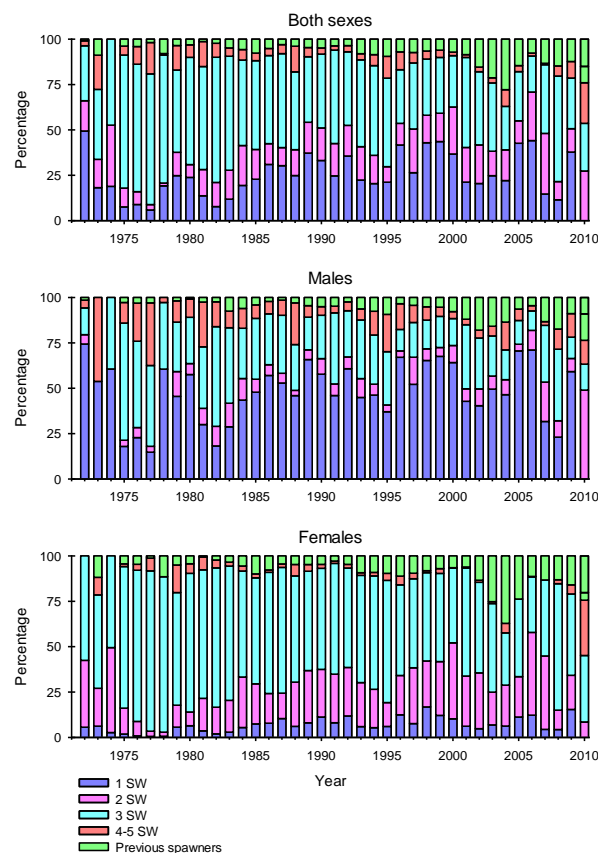
Figure 18. Proportions of different age groups in salmon catches (based on numbers) for Finnish tourist fishers in the Rivers Tana and Anárjohka/Inarijoki.

4.3   Management of the Tana salmon fishing

Both Norway and Finland (through EU) are members of the North Atlantic Salmon Conservation Organization (NASCO, see www.nasco.org), which is an international organization, established by an inter-governmental Convention in 1984. The objective of NASCO is to conserve, restore, enhance and rationally manage Atlantic salmon through international cooperation where NASCO parties are committed to. NASCO parties have agreed to adopt and apply a Precautionary Approach to the conservation and management and exploitation of Atlantic salmon in order to protect the resource and preserve the environments in which it lives. Another key element in NASCO principles is the Decision Structure, which assists in applying the Precautionary Approach by providing a consistent approach to the management of exploitation. The Decision Structure applies reference points (for example conservation limits or spawning targets) or other indicators of stock status to trigger management actions to address any failure in abundance or diversity of salmon stocks (see NASCO 2009).

Salmon fishing in the River Tana has been regulated since 1873 by bilateral agreements between Finland and Norway. General fishery agreements for both river systems are concluded between the governments of Finland and Norway, primarily regulating the local fisheries and their fishing rights. These agreements have been negotiated between the relevant authorities in both countries, in particular Ministries of Foreign Affairs, Ministry of Forestry and Agriculture (Finland) and the Ministry of the Environment (Norway).

The latest general agreement, concluded in 1989, states for example that the fishing season commences on 20 May and terminates on 31 August. Net fishing is allowed for three days per week and drift net fishing can take place only from the beginning of the season until 15 June. All fishing is prohibited for one day per week (Sunday night-Monday night).

Tourist angling is regulated by regional authorities in both countries (Department of Environmental Affairs, Office of the County Governor of Finnmark, Norway, and the Fishery Unit, Centre for Economic Development, Transport and the Environment in Lapland, Finland). These regulations can be amended on a yearly basis.

On the Norwegian side, a lot of the management responsibility has been transferred from the County Governor of Finnmark down to a recently established local organization, the River Tana Fisheries Management Board. This organization organizes the fish licence sale, collects catch statistics, and is responsible for the Norwegian river guards.

Fisheries on salmon originating from the River Tana have been regulated also in the ocean. The most important management actions include the prohibition of the high seas salmon fishing since 1984 in North Atlantic through NASCO convention. Norway has taken further steps in improving salmon stocks by closing entirely the drift net fishery at sea since 1989 and by limiting coastal net fisheries in different ways over the recent years.

Salmon stocks of the River Tana are conserved, maintained and enhanced only by fishery regulations. All fish releases are strictly prohibited in the river system.

5   Local/traditional knowledge and local contact

The potentially valuable role of local/traditional (ecological) knowledge in the management of natural resources has been gathering increased momentum in the last couple of decades, and the Group is tasked with incorporating local/traditional knowledge in its evaluations in mandate points 3 and 6 (see chapter 2).

5.1   How the Group will approach these issues

This is a new dimension in the status evaluation of Tana stocks, and therefore some more elaboration on how the Group will solve these two mandate points is needed.

There are processes currently on-going in Tana, in both countries, that represent a strong development of the contact and cooperation between locals, researchers and managers. The Group strongly endorses these processes, and recognizes how these processes provide an interface through which the Group can further enhance and develop the present constructive and positive tone. The current processes are clearly moving things and relationships in a positive direction and therefore needs to be strongly supported, instead of creating new processes that potentially can derail, delay and complicate things.

To meet point 6, the Group will prioritize participation in local meetings, both to disseminate and discuss results and explicitly be open for local input, to ensure that an avenue exists for both local evaluation of results and for the Group to receive local ecological knowledge.

This leaves us with point 3, which is a topic that deserves a more thorough discussion.

Local (ecological) knowledge (LEK) is tied to a place (e.g. a specific fishing place) and is knowledge acquired through experience and observation, either over a single lifetime or over many generations. In other words, an individual can accumulate LEK over the course of one lifetime interacting with a local environment. Traditional (ecological) knowledge (TEK) is similar to LEK, with the added requirement that it is an ancient or multi-generational accumulation of knowledge that requires the population to be indigenous and requires embedding in a broader shared culture. For simplicity, the rest of the discussion will refer to LEK only, but it will equally pertain to TEK.

It is suggested that supplementing scientific data with local and traditional knowledge can broaden the information base needed for decision-making regarding resource management (e.g. Berkes *et al*. 2000), especially for resources that occur in remote locations where scientific studies are impractical (e.g. Ferguson *et al.* 1998). The contribution from LEK becomes less useful for well-studied species (such as salmon), and the contribution from LEK really needs to be put under scientific scrutiny before it is used as a basis for management decisions (Gilchrist *et al.* 2005).

There has been an increasing formalized emphasis on LEK over the last couple of decades, which has resulted in a segregation of information as either "traditional/local" or "scientific". This segregation might initially seem sensible and genuine, as there are some clear differences between what can be called "traditional/local" and what is "scientific". LEK and TEK is largely oral and visual, intuitive, experience based, subjective and highly qualitative, while science is based on systematic data within a model- or hypothesis-based framework which, through the use of a strict sampling design, are

largely objective and quantitative. The usefulness and relevance of LEK/TEK therefore becomes highly limited.

The attempts at segregating LEK/TEK from science also contain a strong element of misunderstanding what science really is. Science is described as strictly hypothesis-based, linear, oversimplified and reductionistic, and this description is used to illustrate how far removed science is from the realities of nature. This is, of course, a fundamentally wrong description of science, and the attempts at establishing LEK/TEK as an equal alternative to science becomes flawed.

Every bit of information is exactly that, information. And all bits of information have their place within natural science and can be included. This is equally true within applied scientific studies of salmon. So when fishermen, which are the contributors of LEK/TEK, complain that their knowledge is not taken into account when scientific results and evaluations are presented, they largely do so because they fundamentally misunderstand at which level and how LEK/TEK are included and used.

There are two very clear roles of LEK/TEK within scientific studies of salmon. First of all, LEK/TEK represents a source of observations that can lead to new and alternative hypotheses which subsequently can be put to scientific scrutiny. By themselves, local and traditional knowledge cannot provide reliable answers about the actual quantitative effect of observations. For example, an observation that salmon are eaten by a predator is, by itself, a valid descriptive observation of a phenomenon (and therefore local or traditional knowledge), but this observation does not give any indication about what quantitative effects, if any, this predation have on salmon stocks.

Secondly, LEK/TEK plays an important role as a source of observations that scientific results can be tested and interpreted against.

These are the two roles of LEK/TEK that the Group will work towards. It therefore becomes highly important for the Group to frequently attend meetings and have actual contact with local fishermen, and through these interactions where stories are listened to and results are discussed, a richer and broader knowledge-base for the scientific evaluation of stock status becomes possible.

One member of the Group, Tor G. Heggberget, suggests that the discussion above is not sufficient to meet point 3 and 6 in the mandate and therefore proposes the following additional text:

> *To cover the interactions and communication between the Group and local communities, and between local communities in the Tana system, a dialogue process with broad and formalized local participation is needed. To integrate local and traditional knowledge, and to collect information from local communities and organizations and cooperate with such bodies in the dissemination of scientific results to the public, a dialogoue process is recommended to be established as soon as possible. Dialogue processes must have a broad and local participation, and should normally be conducted as early as possible to secure a sound scoping process (i.e. the process of identification from a broad range of potential problems, a limited number of priority issues to be addressed). The priority issues identified in a scoping process will, together with identified drivers make the basis for cause-effect charts and recommendation concerning needed research, monitoring and mitigating measures.*

For the understanding and acceptance of future management regulations of fisheries in Tana from local, regional and national organizations, it is essential with involvement and dissemination of scientific results. Through a dialogue process, a platform for acceptance of future sustainable management of Tana salmon can be established. In situations where acceptance of important knowledge is lacking, it is extremely challenging to establish effective regulations.

5.2   Current locally raised issues

Locally there are three different positions that are put forward as local explanations of the current negative stock development in Tana: (1) predation, (2) natural variation, (3) increasing number of tourist anglers, and (4) decreasing number of gillnets. Each position is discussed individually below.

5.2.1   Predation

Throughout its life cycle, the salmon is an integral part of complicated ecosystems containing a large number of different species. In all these ecosystems, the salmon lives with other animals that it can eat, compete with and be eaten by. The salmon, thus, is a predator in the sense that it eats other animals. Simultaneously, the salmon is a vulnerable prey that continuously risks being eaten. This predation on salmon gets a high level of attention in situations when stocks are declining, expressed in emotional accusations that predators are increasing in number and as a result eating all the salmon. Many salmon predators, especially those that can eat adult salmon, are large and easily spotted animals (e.g. birds, seals, otters), and their predation accordingly become an easily observed source of salmon mortality. The end product is a situation where humans see predators as direct competitors, and demand that predation should be kept in check through some form of predator control.

The reality is that we, despite a century of research effort, still lack any evidence that a negative stock development is directly caused by predators that occur naturally with salmon. Note that this is not equivalent to saying that predation is not important as a regulatory mechanism. A research review of salmonid predation shows that 36 of 45 studies (80 %) found predation to be an important factor for salmon stocks (Mather 1998). But the role of a predator is much bigger than an isolated interaction with salmon, with both direct and indirect effects of predators on salmon. The direct effect is predation itself (the act of actually eating a salmon, which directly translates into a salmon mortality). Indirect effects come from factors such as the predator eating competitors of salmon, meaning that competition is lessened and the salmon will be doing better. Such indirect effects will mitigate and counteract the negative direct effect of predation.

5.2.1.1   The role of predators in ecosystems

Predators are an integrated and fundamental part of all ecosystems, and the predators have an important role in regulating the number of different prey (Begon *et al.* 2006). Predators and prey are in a form of balance in a naturally functioning ecosystem, with the number of prey regulating the number of predators, and vice versa. Salmon stocks will fluctuate up and down, and these fluctuations are the result of a complex relationship between environmental conditions, human exploitation and predation. However, it has not been found that a predator, by itself, has been the sole cause of stock decline. Prey, such as salmon, will have a diverse set of life history adaptations that reduce the predation risk. Despite these adaptations, predation still is one of the most important sources of mortality throughout the salmon life cycle (Mather 1998).

Generally, predation is one of many factors affecting salmon. Predation and other factors such as food availability and habitat availability (e.g. for spawning and juvenile production) are labelled limiting factors for a salmon stock whenever they stop the stock from growing or are the direct cause of decline (Newton 1998). The influence level from predation will vary, depending on other factors. First and foremost, there must be some overlap in time and space between predator and prey. A predator that is not present in a river or estuary when the smolt migration takes place, will not be able to prey on smolt. Predators also have preferences for certain prey sizes, and this size preference change with the predators own size. Often, a small fish will be more exposed to predation than a larger fish (Juanes 1994). Introduced predators, such as mink, can often be seen to have more of an impact than naturally occurring predators (Salo *et al.* 2007).

Intuitively, it seems logical that increasing the number of predators will cause increased mortality and decreasing number of prey. The reality is, however, not quite this simple. The predator effect is modified by how each predator species respond to variation in prey density (Begon *et al.* 2006). A predator can respond either by changing its predation rate (a functional response) or changes in prey density can lead to changes in predator density (a numerical response). Often, a high predator density will result in an initial high predation rate and a rapid decline in prey density. But many predators will respond to a lowered prey density by either moving to new feeding areas or changing prey species, thus lowering the predation rate on the initial prey.

Prey density is, therefore, an important factor. It is also, in itself, a directly limiting factor for predators. An example of this is the effect of shoaling. A shoal of smolt will attract predators and lead to increased predator density. However, the act of shoaling also leads to lowered mortality risk for each individual smolt, and in effect limits the total predation pressure.

If predation is to have a negative effect, it must be the cause of additive mortality, i.e. the predation must cause mortality that exceeds mortality from other natural factors (Begon *et al.* 2006). During the salmon life cycle, such additive mortality takes place both in the smolt and adult marine phase. Here, the mortality is not density dependent, i.e. it does not vary with the salmon abundance (Milner *et al.* 2003). Smolt and adult predation therefore can be considered additive and cause a direct reduction in the number of returning salmon.

5.2.1.2   *Predation during the salmon life cycle*
The salmon life cycle involves the use of and migration between several different habitats. During the first years, the salmon lives as a juvenile in freshwater, before smoltifying and migrating out into the open ocean feeding grounds. After maturing, the adult salmon starts its spawning migration and returns to its natal river. Throughout this life cycle, the salmon meets different predators with differing potential effect.

Predation on eggs
It is the number of eggs produced by spawning females that forms the basis of juvenile production and, consequently, the number of smolts. There are three main factors affecting the egg number: number of females, female size and female fecundity.

During spawning, numerous fish accumulate around the spawning grounds. These fish will eat eggs, particularly those that fall outside the spawning redds. An additional number of eggs will be eaten by birds and benthic invertebrates. In evaluating the importance of egg predation, there is however two

core issues that must be kept in mind. Firstly, eggs falling outside redds will die also without egg predation. Secondly, there are density dependent stages in the life history after the egg stage, and this will largely compensate for eggs lost to predation. For these two reasons, it is highly unlikely that any loss in smolt numbers can be attributed to egg predation.

Predation on juveniles

The salmon spends its first years as a juvenile in freshwater (mostly in rivers and streams, but also lakes). During this time, the juvenile salmon is continuously vulnerable for predation from piscivorous fish (pike, burbot, trout), birds (goosanders, cormorants, herons) and mammals (otters, minks), and research studies demonstrate that a significant proportion of the juvenile mortality rate is due to these predators.

Despite this, it is very difficult to find evidence that show a significant negative effect of juvenile predation on the smolt production in a river. Naturally, in a salmon stock, there is a tremendous reduction in the number of fish during the juvenile years, especially during the first summer when as much as 90 % of the fry (young-of-the-year) dies. Density dependent mechanisms are a core issue here. Each river stretch only has room for a certain number of juveniles, and surplus fish will be outcompeted and more exposed to predation. A significant proportion of juvenile predation will accordingly be on juveniles that would have been outcompeted anyway. The mortality ascribed to predation will therefore be compensated through better conditions and increased survival for the surviving juveniles (Milner *et al.* 2003).

The occurrence of predators in rivers, streams and lakes is not automatically negative. Piscivorous birds and mammals will, for example, eat other fish species in addition to salmon. This will reduce the total number of fish, including a reduction both in the number of piscivorous fish and other species that directly competes with juvenile salmon. These are relationships that also counteract a purely negative effect of predation.

Predation on smolts

The salmon smolt stage has received the most study when it comes to the issue of predation (Mather 1998). There are two main reasons for this. Firstly, smolt predation is likely density independent with few compensatory mechanisms, and this might directly lead to a loss in production. Secondly, the smolt stage involves a concentrated migration period, in which the smolt moves in shoals downstream. During this downstream migration, the smolts move through different habitats, from running water (in some river systems via lakes) out through the estuary into fjords and eventually open ocean.

The smolt from many areas in Tana will have to pass through lakes with dense populations of pike. The pike is an opportunistic piscivore that efficiently will shift between different prey species depending on their relative availability, and it can therefore quickly change its behaviour and focus on smolt when these move downstream. The result of this can be a significant predation rate. Results from Finland indicate that pike larger than 40 cm were able to predate 29 % of the smolt (Kekäläinen *et al.* 2008). Note however that this high predation rate was on hatchery-reared smolt, which is known to be more vulnerable to predation than wild smolt.

Birds, especially goosanders and mergansers, can also significantly decrease the smolt number. These are flexible birds, and results from Scotland demonstrate that they are able to change both

their diet and feeding area and focus on smolt during the smolt migration. These are changes representing an adaptation to smolt as a food resource (Marquiss *et al.* 1991). Estimates from North Esk (north-east Scotland) indicate that goosanders gather in rivers during spring and the resulting predation reduce the smolt numbers by 3-16 % (Feltham 1995). Simplified models of salmon production indicate that this predation can somewhat reduce the number of adult salmon returning to a river (Shearer *et al.* 1987). However, some of these estimates of bird predation have been highly criticized as they both overestimate the amount of fish eaten by these birds and underestimate the number of fish that are produced (Wilson *et al.* 2003).

The occurrence of a large number of predators in an area is not a certain indicator of high predation. Large numbers of goosanders gather in the Tana estuary, around 5 000 are present in the spring and this number increases to 25-30 000 during the summer (Svenning *et al.* 2005b). The resulting high density of goosanders could potentially cause a tremendous loss of smolts if all individuals were feeding on salmon smolt during the smolt migration in June and July. Stomach content analyses from 1981 and 2000 demonstrate, however, that the main food item of goosanders in the estuary is sandeels. An estuary is a highly productive area where high densities of sandeels, flounder and capelin can be found. The estimated yearly food demand of the goosanders in the Tana estuary is around 600 tonnes of fish, and this is largely covered by the high production of sandeels in the area. Sandeels and flounder are probably the main reason also for the gathering of common seal in the area.

Both in the estuary and further out in the fjord, the Tana smolt is exposed to predation by fish such as cod and saithe. These can cause a high predation rate, up to 25 % outside the estuary of Surna (Hvidsten & Møkkelgjerd 1987) and Orkla (Hvidsten & Lund 1988). Acoustic tagging of smolt from the River Alta indicate a mortality rate of over 25 % over a 17 km stretch out the Alta fjord (Davidsen *et al.* 2009), while the mortality rate of smolt tagged in the River Eira was estimated at around 60 % over a 37 km stretch in Romsdalsfjorden (Thorstad *et al.* 2007). Outside Eira, the mortality rate was highest close to the estuary and decreased significantly further out in the fjord. Stomach samples of piscivorous fish caught close to the Tana estuary in 2000 showed that most fish were eating sandeel (Svenning *et al.* 2005a). This indicates that the predation rate in estuaries depends on the availability of alternative prey, which might be the main reason for the large variation in estimates of predation rate, from very low (Hvidsten *et al.* 2000) to over 40 % (Dieperink *et al.* 2002).

The estimated effect of predation on smolts depends on the level of salmon production in the system. If the salmon stock is overexploited and target attainment is bad, the resulting smolt production will be low. During the downstream smolt migration, the smolts gather in shoals and the size of these shoals will to a degree depend on stock status. As the shoals move downstream, they will have to pass through areas with predators. These predators will only have a limited time window available to catch the smolt before the shoal has passed. The ability of a predator to catch smolt is not unlimited; it can only handle a limited number of smolt within a given period of time. An example of this can be created to illustrate: Imagine that the predators in an area of a river are able to catch 20 smolts during the time it takes for the smolt shoal to pass. With low smolt recruitment (from poor stock status), most shoals might consist of 50-100 smolts. In this case, the predators would be able to remove 20-40 % of the smolt. With high recruitment (from a good stock status where the spawning target is attained), smolt shoals might consist of for example 500-1 000 smolts. In this case, the predators would be able to remove only 2-4 % of the smolt.

From this, it can easily be seen that **the best approach to deal with predation really is to make sure that spawning targets are reached**. This ensures that smolt production will be maximized and minimize the relative effect of predation.

Predation on adults

Predation on salmon out in the open ocean feeding areas is little known and, due to logistical reasons, difficult to study. The salmon grows fast while out in the ocean, and this growth gradually makes the salmon less and less vulnerable to predation. There are however lots of reported observations of salmon found in the stomachs of marine fish and mammals and it is therefore probable that adult salmon are exposed to some marine predation (Mills 1989). Especially marine mammals are thought to feed on salmon. Both seals and killer whales are known to eat a significant amount of salmon in the northern Pacific (Quinn 2005). There are observations of minke whale eating salmon in the Atlantic, and there are at times significant numbers of seal and whale (such as killer whales, dolphins and different baleen whales) in the same areas as salmon. It is therefore probable that these forms a predation risk for salmon.

Predation during the salmon spawning migration, when the salmon swims from open ocean feeding areas back to its natal river, has received the most attention. The primary visible predators in this phase are seal, and then especially grey seal and harbour seal which can gather in river estuaries (Middlemas *et al.* 2006). The seal is a direct problem for fishermen, with its ability to take salmon directly from gillnets (Henriksen & Moen 1997). Seal-predation on salmonids in estuaries is commonly observed (Carter *et al.* 2001; Matejusová *et al.* 2008), even in estuaries with lots of alternative prey such as sandeels (Sharples *et al.* 2009).

Models of the potential effect of seal predation show a potential negative effect on small salmon stocks (spawning stock size under 50 salmon), but the effect on a larger stock is very difficult to trace (Butler *et al.* 2006). The reason for this is partly the nature of a predator. A predator such as a seal will never take a fixed percentage share; it will only be able to take a maximum number of prey. With increasing stock size, this maximum number constitutes a decreasing percentage share, and the relative importance of predation will decline correspondingly.

5.2.1.3   Should predators be controlled?

The effect of predation is complex, and it can be very difficult to relate changes in predation pressure to changes in salmon stock status. Predation effects are most likely found in the smolt and adult stage, and the smallest stocks are expected to be most vulnerable to this predation. Small threatened stocks that are under pressure from other threat factors are therefore places where it might be worth following up on potential effects of predation.

A negative salmon stock development almost inevitably leads to demands that the number of predators should be controlled. However, the salmon is, throughout its life cycle, a part of complex ecosystems in which predation pressure varies (Mather 1998). Both in freshwater and out in the ocean, the salmon is part of complex food webs in which species interact through competition and predation. All these interactions make it extremely difficult to predict the outcome of selectively controlling some predator species. For example, reducing the numbers of seal in a fjord might reduce the predation of seal on adult salmon. It might however also reduce the predation on cod and saithe, which might increase the predation on salmon smolt. The net result might be no change (or even an increase) in the predation pressure on salmon (Yodzis 2001; Wiese *et al.* 2008).

Removing piscivorous birds (e.g. goosanders or terns), which feed on juvenile fish from all available fish species, might reduce the predation rate from birds on juvenile salmon. However, it will also reduce the pressure on other fish species, which might lead to increased predation from piscivorous fish (such as pike) and/or increased competition from other fish. And an attempted reduction in the number of pike usually means removing the bigger pike first. These big pike extensively feed on (and regulate the abundance of) smaller pike. Removing the big pike then increases the number of smaller pike, and it is these smaller pike that potentially feed most on juvenile salmon. The end result, again, is a potential increase in predation pressure on salmon, despite attempts to reduce it.

When speaking with people in the Tana valley, a common viewpoint that is put forward is that "*predators are increasing in numbers*". Implicit in this is that predation is a factor that can run wild if it is not controlled. There are no documented examples of predation, by itself in a functioning ecosystem, running wild and causing a strong negative stock development. We do, however, have examples of how humans, by changing the balance between species, can cause the predation pressure to change between species. For example, at sea, overfishing of one fish species have forced predators to seek alternate prey, and these other prey then experience increased mortality due to predation. There is the potential for something like this in the Tana. The Tana estuary has an incredibly high biomass of sandeels, and if human influence reduces this biomass considerably, predators such as seal and goosander might have to start feeding on alternate prey. This can cause increased predation pressure on salmon and sea trout in the estuary.

In conclusion, existing data and models all point in the same direction: **When it comes to reducing the effect of predation, the single most effective measure is to increase the fish production by making sure that the different salmon stocks reach their respective spawning targets**.

5.2.1.4   Is predation a threat for Tana salmon stocks?

The short and simple answer to this is no. Predation as a mechanism simply does not work in a way that would allow for a negative stock development caused by increased predation. Predation is not the cause of a negative trend, but the presence of predation, especially on smolt and adult salmon, might amplify an existing negative situation (e.g. caused by human overexploitation) through reducing the number of returning adult salmon.

5.2.2   Natural variation

The argument here is that salmon stocks are naturally varying between good and bad years, and the current situation is therefore simply explained as bad years that the system will naturally rebound from.

The existence of natural variation is definitely real. The environmental conditions experienced by salmon both in rivers and in the ocean vary naturally from year to year, and this environmental variation has a direct effect on salmon, causing variation in survival, recruitment and growth. This variation translates into fluctuations up and down from year to year, as seen in Figure 5.

However, pointing to natural variation is a fundamentally flawed argument when it comes to assessing current stock status and its implications for the salmon fisheries in Tana. There are several reasons for this. First of all, this argument demonstrates a misunderstanding about the status evaluation and its implication for fisheries regulations. The status evaluation is very much a current issue, comparing the spawning stock size with an established management target. The future aim of

the fishery regulation is to keep spawning stocks above targets both in good and bad years. The existence of natural variation can therefore not be used as an argument to state that the current spawning stock levels are acceptable because they are caused by bad years.

Secondly, some of natural factors causing fluctuations in a salmon stock are not operating only in Tana, they are regional factors that affect salmon stocks on a larger scale. This is especially true for ocean conditions. If, for instance, the bad spawning stock situation in Tana were caused by low sea survival, we should see an equally bad stock situation also in neighbouring salmon rivers in Finnmark. The reality is that these rivers are seeing a positive development (see chapter 9.7).

Last, but not least, if natural variation were the only factor causing fluctuations in Tana, the overall trend in the long-term time series of Tana should be flat, with the natural variation fluctuating above and below a long-term average. The reality is that a downward slope can be seen, e.g. in the long-term monitoring of large salmon in the river system (Figure 11 and Figure 12). This should be interpreted as a long-term negative trend with natural variation fluctuating up and down around the negative trend.

The inevitable conclusion from this brief discussion is that there must be other external factors (such as exploitation) involved in the negative development seen in the Tana river system. The current situation cannot be written off as simply natural variation.

5.2.3   Increased tourist angling
The argument here is that the substantial increase in number of visiting tourist anglers that were seen in the 1970s and 1980s have led to an increase in the exploitation rate and that this increase are the direct cause of a negative stock development. This argument is correct in that it points to a problem with the total exploitation rate, but it is incorrect in singling out tourist anglers as the source of the current negative situation. Tourist anglers are only one of several sources of exploitation mortality on stocks in the Tana river system, and it is the combined effort of all these different fisheries that, in an accumulated sequential way, causes the total exploitation rate to be unsustainably high. Further discussion on this topic can be found in chapter 9.8.

5.2.4   Decreased number of gillnets
An argument that has been repeatedly raised is that falling catches of salmon can be ascribed to the decrease in number of gillnets in Tana (see chapter 8.5). Fewer gillnet mean less salmon in the catch statistics, and this is presumed to explain the alarming stock situation. There are some problems with this argument. Firstly, the stock situation is evaluated on the basis of spawning stock size in comparison with a spawner target. A falling trend in number of gillnets will therefore not affect the status evaluation in any way. Secondly, there is a clear logical fallacy in this argument. The argument basically states that we have seen no changes in the number of salmon ascending the river system in the last decades and that lower catch numbers are due to lower fishing effort. From this it follows that as the number of gillnets decreases, the number of surviving salmon increases and the fishermen that are still active should experience a perceived increase in the number of salmon available for their fishery. This is, of course, not the case.

6   Threat factors

Very little has changed with regards to the threat factors detailed in the report of the temporary monitoring group (Johansen *et al.* 2008), and with the exception of the chapter on overexploitation only minor details have been changed from the previous text.

6.1   *Gyrodactylus salaris*

The parasite *G. salaris* is not yet found in Finnmark. The nearest Norwegian localities with *G. salaris* are the rivers Skibotnelva and Signaldalselva in Troms. In Finland and Sweden the parasite is found in several rivers flowing into Bottenvika. The parasite belongs to the natural fauna of the large River Tornionjoki/Torneälv, and through fish farming have also been introduced to the Enare lake (which forms the source of the River Paatsjoki/Pasvik). Some of the headwaters of both these systems are situated very close to the source areas of the Tana river.

As of now, we have only a couple of options available with regards to the parasite: (1) preventative measures and (2) monitoring.

Anglers visiting the river are receiving information about the parasite, and on the Norwegian side they are also required to disinfect their fishing equipment before they are allowed to buy a fishing license. On the Finnish side, the responsibility of each angler having clean/dry equipment is a legal obligation in the 2003 Finnish veterinary regulation. In recent years, efforts have been markedly increased in both countries to distribute information in different forms widely to the local and visiting fishermen.

Tana is part of the Norwegian national monitoring of *G. salaris*, and samples of juvenile salmon are taken each year and checked for presence of the parasite in both countries. As of now, however, no plan of actions exists for what to do in case the parasite in the future is discovered in the river system although veterinary authorities (EELA) at least in Finland are working at the moment to prepare such kind of action plan. Also, to ensure early discovery of an infection, the monitoring needs to be redesigned and extended to give a better coverage of different areas within the system. Further restrictions should be introduced to prohibit the back and forth transport of boats between the River Tana system and other watersheds.

6.2   Proliferative kidney disease

Highly reduced catches and significant juvenile mortality in some Norwegian salmon rivers such as Åbjøra (Nordland) and Jølstra (Sogn & Fjordane) were in 2006 suspected and recently found to be associated with proliferative kidney disease (PKD) (Forseth *et al.* 2007). There have been plans to accomplish a pilot screening in Tana, but this has not been carried out so far. We suggest that this pilot should be accomplished as far as possible, associated with other monitoring (e.g. that of *G. salaris*), to confirm the potential of PKD as a threatening factor for Tana salmon.

6.3   *Cottus gobio*

The bullhead (*Cottus gobio*) is a newly introduced fish species in the Tana river system. It was first observed in Utsjoki in 1979, and has increased its distribution in that tributary since. Ten years ago the bullhead was first observed in the Tana main river at quite many places between the river mouth of Utsjoki and downstream to the Storfossen/Alaköngäs area. This new fish species has also been

found already approximately 5-10 km upstream from the river Utsjoki in the River Tana in the Kordsam-Kaava area. The bullhead that have been detected during the annual juvenile salmon survey have been larger than 4 cm, indicating that they most probably have been migrating from the River Utsjoki and they might therefore not be from bullhead that have spawned in the River Tana.

There have been some studies of the potential interactions between bullheads and juvenile salmonids. It is found to be frequent in areas with low salmon density but is seldom found in high abundance in areas with a high salmon density, but decisive answers about its impact on salmon are still lacking. Focus should be kept on the bullhead in the annual juvenile monitoring, especially to see if the observations from Storfossen/Alaköngäs and upstream of the River Utsjoki river mouth represent a new establishment. Most probably there will occur some competition between juvenile salmon and bullhead in the River Tana because there are not such kind of habitat segregation like lakes and pools which can be found in the River Utsjoki, where salmon and bullhead currently can live separately.

6.4 Escaped farmed salmon

The production levels of the aquaculture industry have increased tremendously since its infancy in the early 1970s, and today the natural production of wild salmon is vanishingly small compared to the production of farmed salmon. In 2010, 1 000 000 tonnes farmed salmon were produced in Norway, while the river catch of wild salmon in comparison were only around 430 tonnes, of which approximately 20 % were taken in the River Tana.

Farmed salmon used in Norway can originally be traced back to around 40 Norwegian wild salmon stocks. Through intensive selection in 8-9 generations, the salmon now is very much adapted to a life in fish farms (Gjøen & Bentsen 1997) and genetically very different from wild stocks.

Farmed salmon can potentially escape from fish farms throughout their life cycle, and today escaped farmed salmon are caught in fisheries both out in the open sea, along the coast, within the fjords and in the rivers. It is documented that farmed salmon can spawn successfully in rivers (Lura & Sægrov 1991).

The hybridisation between escaped farmed salmon and locally adapted wild stocks is a major cause of concern, as it will cause potentially detrimental genetic changes to the wild stocks that can reduce viability of the stocks. A high proportion of escaped salmon in the catches can also hide the real population size of the wild salmon, a problem that can complicate the fish management of rivers.

Autumn registrations of the amount of farmed salmon present in rivers have been conducted in Norway since 1985, and in several rivers high proportions have been recorded. In Tana, registrations of farmed salmon have come from two sources: 1) the regular scale samples taken from fishermen during the summer, and 2) monitoring fishing close to the river mouth during the autumn (1990/91, 1996/97 and 2003/04). The proportion of farmed salmon in the catches during the summer has been very low, well below 1 %. In the autumns of 1990 and 1991, the proportions were at their highest with 43-47 % (Erkinaro *et al.* 2010). However, the numbers of fish caught in the samples were only 19 and 7, respectively. The proportions of farmed salmon in the other autumn investigations was 0-13 %, but still with low total numbers of fish (8-21).

After the formal ratification of the Tana fjord as a national salmon fjord in Norway in 2003, all aquaculture in the fjord has been closed.

The Group recommends the continuation of the monitoring through the scale samples. Normally most of the salmon fishermen in the lower section in the Tana system stop their fishery already in the end of July or very beginning of August and therefore their catch does not indicate the abundance and run timing of escaped salmon in that area. Earlier studies have indicated that escaped salmon are ascending also into the River Tana late in the season (September) and therefore some fishermen should continue the fishery to the end of August in the lowermost area of the main stem. In addition, extra post-season sampling should be conducted at regular time intervals, for example every 5th year.

6.5 Water quality

The Tana River valley has settlements on both sides, with extensive agricultural activity both in the lower and upper areas. The human activity can potentially cause pollution and eutrophication, making it necessary to keep a focus on water quality. This aspect will be taken care of through the implementation of the European Water Framework Directive, the work of which started in Tana in 2007.

6.6 Overexploitation

Human exploitation have for a long time now been the most important cause of mortality for adult salmon during their spawning migration. Historically, an increasing number of examples have shown us that it is possible to draw too heavily on salmon stocks through exploitation. However, history also teaches us that it is possible to have a sustainable and at the same time extensive fishery for salmon. The only caution in this comes from the problems that potentially can arise from fisheries induced evolution; a topic that should receive more attention in Tana.

Exploitation is, simultaneously, both a management target and an impact factor for the salmon stocks. The management should aim for stocks that fulfil their production potential, a situation that provides the best possible foundation for a rich fishery that favours local communities, rights holders and visiting anglers. Through the salmon fishery, fish are removed that would otherwise be a part of the spawning stock. It is inherently assumed here that this removal should be sustainable, i.e. that the fishing takes place on a stock surplus. This means that a stock exploitation evaluation should depend heavily on estimates of management target attainment, as management targets (such as the spawning targets that have been developed for some Tana tributaries) defines a lower acceptable limit for stocks. From this, it follows that a full-recruited stock is *overexploited* when fishing reduces the stock below the target (Figure 19).

Overexploitation can therefore be defined as **the extent of a reduction in spawning stock below the target that can be attributed to exploitation**. In a situation when the pre-fisheries abundance of a stock is smaller than the spawning target (i.e. no exploitable surplus exists), the percentage overexploitation can be calculated as:

$$\frac{catch}{spawning\ target} \times 100$$

When the pre-fisheries abundance is higher than the spawning target, the overexploitation is calculated as:

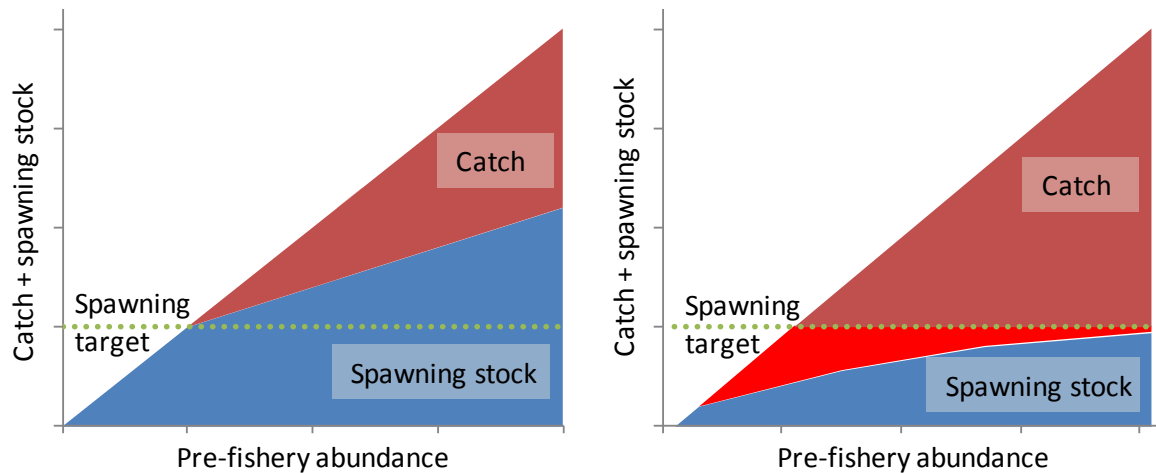$$\frac{spawning\ target - spawning\ stock}{spawning\ target} \times 100$$

Figure 19. The left figure shows a situation *without* overexploitation, as the spawning stock is not reduced below the spawning target because of exploitation. The right figure shows a situation *with* overexploitation, as the spawning stock is reduced by exploitation below the spawning target. The stipled green line represents the spawning target. The bright red part of the right figure (between the blue spawning stock and the dark red catch) depicts the part of the catch that represents overexploitation. Please observe that it is only the part of the catch that is between the spawning target and spawning stock that is characterized as overexploitation, the catch above the spawning target is not included. Figure from Anon. (2010).

A direct consequence of a reduction in spawning stock through overexploitation is reduced smolt production and, consequently, fewer returning adult salmon. There are, however, also other possible negative effects of overexploitation. Exploitation, by its nature, inevitably causes a significant proportion of the adult salmon to die before spawning, and this mortality leads to a high selection pressure that can cause genetic changes in the population (Hard *et al.* 2008). Changes can be seen in the salmon life history, for example reducing the proportion large salmon, shifting the run timing towards later river entry, or change survival, growth and habitat use so that the production potential of the stock becomes reduced. These are examples of unwanted changes that can be difficult to reverse. We have very little knowledge about what level of exploitation can cause such evolutionary changes in salmon stocks, but simulations indicate that exploitation at the level of maximum sustainable yield (F_{msy}) has a low probability of causing evolutionary changes (Hutchings 2009).

In practical terms, sustainable yield is not a fixed quantity. This is a major challenge for salmon management, as stocks must be kept at a sustainable level despite uncertainties in how environmental factors affect salmon stocks at any given time. First of all, salmon survival, both freshwater and oceanic, is very variable both in space and time, making it inherently difficult to estimate run size before the fishing season. Making management decisions therefore becomes difficult. Secondly, there is uncertainty in how different environmental conditions affect salmon survival, and this uncertainty becomes increasingly difficult to cope with as the climate itself appears

to be changing. Thirdly, there is substantial uncertainty about the relationships between management actions, exploitation efficiencies and the resulting spawning stock sizes.

The exploitable surplus will, therefore, vary both with the size of previous spawning stocks (relative to the spawning target) and within the limits set by other influencing factors both in the river and at sea. Environmental factors in the river and size of the spawning stock ultimately decide the smolt production, which, together with sea survival, decides the pre-fishery abundance of adult salmon. The extent to which different stocks can be exploited will therefore have to be calculated individually from stock to stock and year to year, depending on the characteristics of each stock and the available knowledge of environmental factors in river and at sea.

A very simplified model can give a hint about which exploitation levels, given different levels of sea survival and smolt production, a salmon stock can sustain before it falls below its spawning target (Figure 20). A basic premise of the model is the relationship between smolt production and spawning stock from the spawning target model of Hindar *et al.* (2007). With sea survival at a medium level (5 %), a total exploitation of over 50 % can be sustained even if smolt production is somewhat reduced (>75 %). At higher sea survival (>10 %), a total exploitation of up to 80-90 % can be sustained. The maximum sustainable exploitation rapidly declines with both low sea survival and low smolt production (a situation that equals poor target attainment).
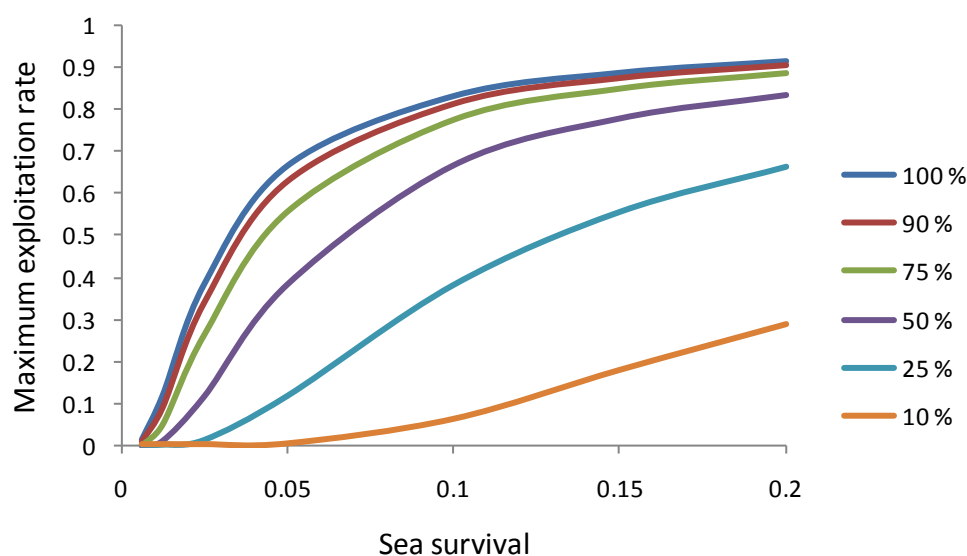
Figure 20. Maximum sustainable exploitation rate in a river under different levels of sea survival and six different smolt production scenarios (from 10 to 100 % of the river capacity). Maximum exploitation is the rate at which the resulting spawning stock falls below the spawning target. The different lines (10-100 % smolt production) corresponds to reduced smolt production that can be caused by earlier spawning below the spawning target and/or impact factors that reduce juvenile/smolt survival. The model is based on the relationship between smolt production and spawning stock from Hindar *et al.* (2007). Figure from Anon. (2010).

The estimated maximum exploitation in Figure 20 is based on the stock recruitment (hockey stick) and smolt production from the spawning target models of Hindar *et al.* (2007). The reproductive rate of a stock is at its maximum when the spawning stock gets close to zero, and this maximum rate can be described by the slope of a stock recruitment curve close to the starting point of the curve. A review of different stock recruitment curves indicate that this slope is relatively consistent among different fish species, with a slope of 3-5 commonly observed for salmon (Myers *et al.* 1999). In the

absence of other affecting factors, a maximum reproductive rate of 3-5 translates to a maximum sustainable exploitation rate of 65-80 %, slightly lower than the estimates from Figure 20.

The estimated maximum exploitation rates are total exploitation of female salmon, accumulated for both coastal and river fisheries. Within Norway, estimates of total exploitation vary substantially from region to region. In southern Norway, the estimated total exploitation is around 50 %, in middle Norway around 40 % and in northern Norway 70-80 %. The observed level of exploitation in northern Norway is very close to the modelled maximum in a situation with good sea survival and little to no reduction in smolt production (Figure 20). The current management regime therefore has very little buffer against changes in environmental conditions in northern areas (including Tana).

The model of maximum sustainable exploitation can be used to simulate the level of negative effects that exploitation can have on spawning target attainment (Figure 21). The maximum sustainable exploitation rate sinks rapidly both with low sea survival and reduced smolt production, illustrating the potential importance of other impact factors for fisheries interests. Noteworthy also in Figure 21 is that there is a very small difference between an exploitation rate that produces a large negative effect and exploitation with no effect, even in a situation with relatively high sea survival and good smolt production. This greatly underlines the importance of managing with a safety margin.
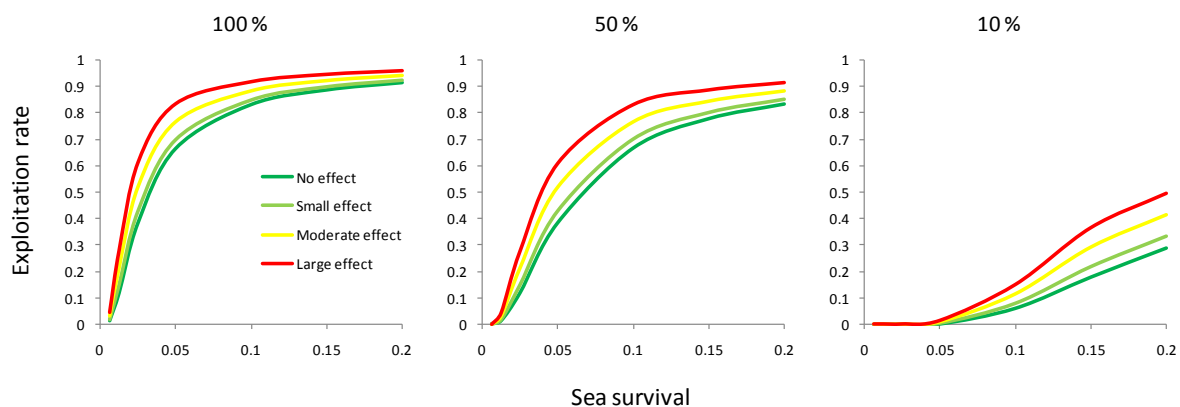
Figure 21. The exploitation rate that leads to no (spawning stock at or above spawning target), small (spawning stock >90 % of target), moderate (70-90 %) or large (<70 %) negative effects on spawning target attainment at different levels of sea survival and smolt production. Three different scenarios for smolt production: 100 % (left), 50 % (middle) and 10 % (right). Reduced smolt production can be caused by spawning stock below spawning target and/or impact factors that reduce juvenile/smolt survival. Figure from Anon. (2010).

Both Figure 20 and Figure 21 demonstrate how the maximum sustainable exploitation rate sinks rapidly with lowered sea survival. This is a vulnerable and difficult situation for the fisheries management, and points to the need for establishing accurate monitoring indicators that can provide early estimates of annual sea survival and can be used to trigger season-specific fisheries regulations in situations with a low pre-fishery abundance. Stocks inevitably become more vulnerable towards fisheries selection when impact factors create lowered survival (both in river and sea). The monitoring must, accordingly, be designed so that it intercepts important demographic factors and life history traits. Examples of important factors are fish size, migration timing, stock-specific exploitation rates, growth (size at age) and ability to reproduce (Kuparinen & Merilä 2007).

6.7   *Paralithodes camchaticus*

The red king crab (*P. camchaticus*) was introduced artificially into the Murmansk fjord (Russia) from the Pacific in the 1960s, and has since this introduction spread rapidly and extensively west along the Norwegian coast. The first crab was caught in Norway in the Varanger fjord in 1976, and since then the crab densities have increased greatly with population sizes today estimated to be close to 1 million.

The crab is an omnivore, digesting everything from cod larvae to other crabs. This, combined with the high densities, is causing some alarming large-scale changes in the benthos species composition, changes that might ripple out through large parts of the marine ecosystem. Presently we have no knowledge about potential effects of this invasive species on the marine phase of Atlantic salmon, but the sheer scale of the changes makes it important to keep an eye on this in the future.

7   Stock monitoring

There is a separation in the present report between stock monitoring (this chapter) and stock status evaluation (chapter 1). This separation might initially be confusing, as the monitoring traditionally has been used directly as a tool for evaluating stock development and status. The primary objective of monitoring is gathering of data and knowledge. In the context of a target-based management, stock-specific targets are defined and the objective of a status evaluation becomes to benchmark these targets using the data gathered through monitoring.

Monitoring of the salmon stocks in the River Tana is based on long-term investigations carried out and funded jointly by Finnish and Norwegian research bodies and authorities. The long-term monitoring programme includes:

- Catch and fishery statistics (present form since 1972)
- Catch samples (since 1972)
- Estimating the juvenile salmon abundances at permanent sampling sites (since 1979)

Following the NASCOs Precautionary Approach and Decision Structure, the need for a closer and more detailed monitoring of the mixed-stock fisheries has become evident. The existence of a mixed-stock fishery raises the complexity of the management and makes it difficult to evaluate how each stock is affected through exploitation. This is the main reason for the implementation of a genetic stock identification project (GenMix, see Chapter 7.2) in 2009.

7.1   Catch sampling

Catch samples (i.e. scale samples) have been collected since 1972 with the aim of covering the river system, different fishing gears and user groups, and the fishing season as well as possible. Dozens of local fishermen using traditional netting methods and rods, and a number of tourist outfitters collecting samples from their clients have participated in sample collection over the years. The samplers have been equipped with standard measuring boards (length) and scales (weight) and carefully instructed to carry out the sampling. Samples reveal the distributions of salmon size, sex and age in catches, and the scales are used primarily for age and growth analyses, but recently also for genetic analyses and Stable Isotope studies.

7.2   Monitoring of the main stem mixed-stock fishery

Rather than being a single entity, the salmon found migrating up the Tana main stem comes from a multitude of different sub-populations that are genetically distinct and demographically independent (Figure 3). Therefore, salmon fishery acting at various locations in the Tana main stem can be considered as a mixed stock fishery exploiting salmon that originate from a number of populations (or stocks) [2] from different parts of the river system. Exploitation of different stocks is

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[2] A population in biology is a collection of inter-breeding organisms of a particular species. Within the Tana river system, there are thus several salmon populations, more or less spatially separated to different areas (mostly separate tributaries) of the system, with a certain degree of reproductive isolation that give rise to genetic differences. A stock usually describes semi-discrete groups with definable attributes of interest to management, and in the case of this proposal these attributes mainly corresponds to the definition of a population. Throughout the text, the terms can thus be used interchangeably.

likely to vary with different fishing methods on a spatial and temporal scale (e.g. within and between seasons). It also seems likely that different stocks in the Tana system show various levels of viability status, i.e. some stocks are more vulnerable than others to a threat factor such as effective exploitation.

The riverine salmon fisheries in Tana include commercial and traditional fishing methods such as weir, gill net, seine and drift net, in addition to the more recreational use of rod and line. Fishing in the lower part of the Tana main stem is mixed-stock fishery throughout the season, whereas this is true for the upper part only until the second half of July, when stocks from the tributaries have mostly ascended into their spawning rivers. In the upper parts of the main stem, fishing in August is directed to sub-stocks reproducing mainly within the main stem.

The use of management targets as a tool for evaluating stock status is a daunting task in the presence of mixed-stock fisheries, and good estimates of exploitation rates for the different stocks within the mixed-stock fishery are an absolute necessity when comparing stock performance to spawning targets. Differing levels of exploitation will greatly affect the probability that a stock reaches its management target.

In the **GenMix**-project, scale samples from the Tana main stem mixed-stock fishery is analysed genetically (see Vähä *et al.* 2011 for a detailed account of the laboratory methodology) and compared with a genetic baseline consisting of genetic data from salmon of known origin. This allows individual fish caught in the mixed-stock fishery to be assigned to a population of origin within the Tana river system.

A broad summary of the stock composition in the Tana main stem mixed-stock fishery in 2008 is provided in Figure 22, demonstrating how the weekly stock composition changes for 1SW, MSW and previous spawners throughout the season. The run timing and stock composition of 1SW, MSW and previous spawners differ. For MSW salmon, the upper stocks arrive early and dominate the catch in the first weeks of the season. This early trend is not evident for 1SW and previous spawners. Later on, after week 25, MSW salmon from different parts of the Tana main stem become predominant in the main stem catch. The same, to a certain degree, is true for 1SW salmon but not for previous spawners. A large proportion of the previous spawners belong to tributaries of the Tana river system, and as for MSW salmon from the upper stocks, these previous spawners also arrive early.

The early arrival of both MSW salmon from upper stocks and previous spawners from tributaries is an example of a highly relevant management result. MSW salmon are the most important contributors of eggs in the Tana main stem and the upper large tributaries (Anárjohka/Inarijoki, Kárášjohka and Iešjohka), and the previous spawners have much the same role in smaller tributaries (in which the previous spawners might well be the largest females present on the spawning grounds). Drift net fishing in the first weeks of the season ensures that there is an efficient fishery present early in the season, in a period where high water level from the spring flood otherwise makes it difficult to fish.

In the Tana main stem fishery, several different fishing gears are used to exploit Tana salmon on its spawning migration towards the spawning grounds within the river system. We have, thus, a situation where different stocks within the system are exploited (mixed-stock) with different methods (mixed-gear) in different areas and seasons. Each fishing method potentially has its own

selectivity in terms of exploitation rate on different life-history traits (e.g. 1SW versus MSW), body size and even sex, making it very challenging to get any control of the actual exploitation rates of each stock.

For the management, this situation is extremely challenging. How do we evaluate stock situations, select which regulations to implement and publicly relate the reasoning behind? What about the specific goals of the regulation and the information basis that is used? And what about natural variation (the existence of which is frequently used as an argument against regulation)?

Tana salmon stocks are exploited by a heterogenic group of people representing various social backgrounds with a lot of cultural and traditional considerations that needs to be considered. This aspect further complicates the regulation process, as the traditional perception is that all regulatory processes will have to be very clearly founded in clear monitoring and research results before some of these traditional aspects can be touched. The ideal situation would therefore be to have tools that could quantitatively and target-specifically evaluate the effect of regulations, a quantitative framework within which managers can implement regulations and evaluate status. The only way of achieving this is through the construction of an exploitation model.
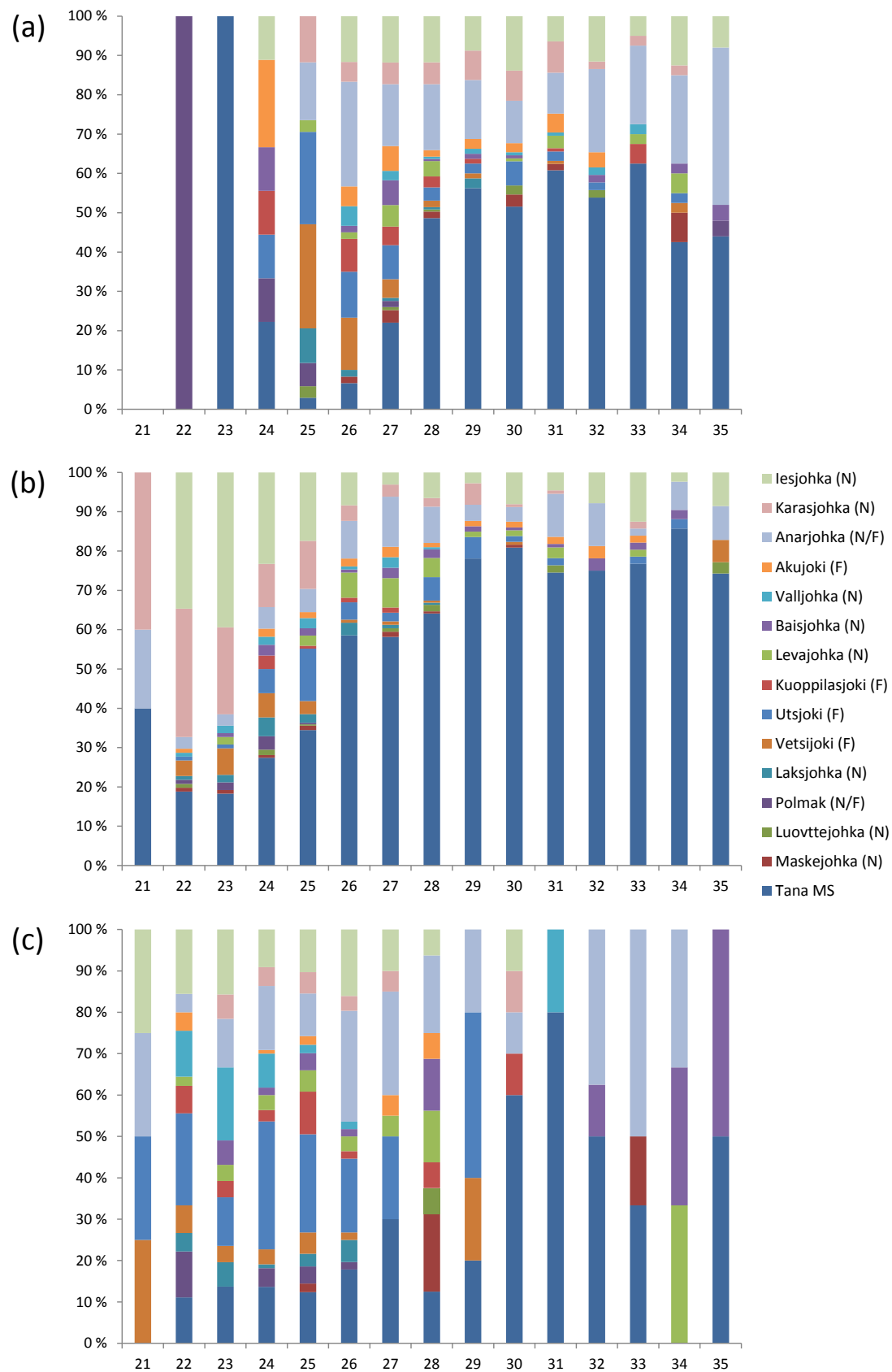
Figure 22. Weekly stock composition of salmon caught in the Tana main stem mixed-stock fishery in 2008. (a) 1SW, (b) MSW, and (c) previous spawners.

In a large-scale long-term project, close to 200 000 Baltic salmon smolt (both wild and hatchery-reared) have been tagged and released in the period 1987-2003. Tag recovery rates have been only 5-6 %, so although with these huge numbers of initially tagged fish, catch data are still to some extent too limited to allow for detailed modelling of exploitation rates in the Baltic Sea mixed-stock fisheries. The Baltic Sea modelling thus illuminates a basic methodological problem connected with the tagging approach in a multi-stock system: an enormous effort over several years is needed to get even close to a sufficient catch data level. In contrast, with genetic identification methods each fish caught in a mixed-stock fishery in the Tana river is essentially already "tagged" through its genetic profile and can be assigned to its own population (tributary) with a very high accuracy. Although genetic identification methods rely on probabilities, the power of this analysis comes through the amount of data points that are quickly and easily accumulated. Furthermore, genetic methods allow taking advantage of historical data and archived scale samples in addition to present-day data. A genetic approach thus ensures that the data basis for the model has a good spatial and temporal coverage. This coverage is lost in a tagging survey with comparably few fish. The temporal aspect is also problematic in a tagging approach, as the historical annual temporal scale is close to impossible to incorporate.

Through careful parameterization, an exploitation model has the potential to explicitly and quantitatively predict changes in population specific exploitation rates through regulatory changes in e.g. allowed fishing gear, fishing time and/or fishing area. As a result of all this, the model approach should enable managers to pinpoint regulations towards highly specific targets, e.g. find specific regulatory measures that could reduce the exploitation on the large-sized stock component in the upper parts of Kárášjohka and Iešjohka. Also, with the flexibility and modularity provided within a Bayesian modelling framework, future projects and future information on e.g. natural variation, can easily be implemented in the model to refine and increase power of the model output.

Currently, full datasets from 2006 and 2008 are available, while data from 2007 are very close to being finished. The number of stocks in the Tana stock complex combined with the long fishing season, large area and different fishing gears provide a unique challenge for the exploitation modelling, and the current main obstacle is that a high number of fish are needed to ensure relatively stable model parameters.

7.3   Fish counting

Data on salmon run size are essential in several regards: to estimate spawning escapements, exploitation rates, and to investigate the relationships between stock and catch, and between stock and recruitment. Counting of fish is, therefore, a core monitoring activity in an adaptive, knowledge-based management regime.

There are two main approaches to fish counting that have been used for a number of years now in Tana:

- Counting of both ascending adult salmon and descending smolts by a video array in River Utsjoki (since 2001) and Lákšjohka (since 2009)
- Counting of spawning adult salmon by snorkelling in two tributaries (Akujoki, Pulmankijoki, since 2003)

These fish counts have provided highly useful information on salmon abundance and diversity, and by combining data on smolts and adult salmon, marine survival rates have been estimated for these populations. In addition, counts of adult salmon (Figure 23) combined with catch data can be used in estimating the compliance with the spawning targets (see Chapter 1). Fish counting is also a necessary supplement to the genetic stock identification of the mixed-stock fisheries, as they are needed to back-calculate exploitation rates in the main stem and coastal areas.
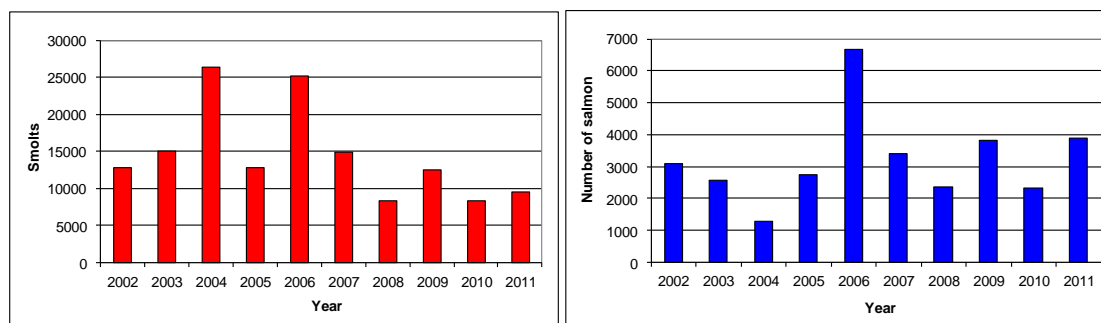

Figure 23. Counts of descending salmon smolts (left) and ascending adult salmon (right) at the River Utsjoki video monitoring site. All sea age groups combined in adult salmon.

Hydro acoustic sonars has the potential to be used in in long-term non-invasive, non-destructive fish counting technique for monitoring the abundance if migratory fish populations. Sonar methodology (SIMRAD split-beam sonar) has first been experimented in the Tana river in the late 1990s with mixed results. More recently, dual-frequency Identification sonar (DIDSON) technology has been tested first in 2008 (Tana bru, Utsjoki), and for a full season counting experiment in 2010 (Kárášjohka; Lilja et al. 2011). The experiment in 2010 proved promising, although certain improvements should be considered in future decisions. A total of around 1 700 fish (>50 cm) migrated upstream the monitoring site including around 650 MSW salmon.

In 2011, potential sites for future sonar counting sites were investigated in Kárášjohka, Anárjohka and Máskejohka (Oraluoma & Orell 2011; Järnegren et al. 2012). Future sonar counting options together with potential funding opportunities are under planning and consideration.

7.4   Juvenile monitoring

In the absence of true measures of the salmon run sizes, the salmon catch is considered to represent a surrogate of abundance. The lack of catch quotas for any fisheries in the Tana, the significant correlations in the Atlantic salmon catches between fishing methods and significant relationships between the estimated numbers of salmon in the catches and the abundance of juveniles in subsequent years indicate that the catch estimate may be a realistic surrogate of the stock size and reflect actual variations in the populations. In addition, juvenile abundance can predict subsequent catches (Niemelä et al. 2005).

The juvenile salmon densities are estimated in a long-term monitoring programme started in 1979. This programme includes 35 sampling sites in the River Tana main stem, 12 in the River Utsjoki and 10 in the River Anárjohka/Inarijoki. Each site has been fished with standardized methods once a year in a strict rotation, so that the fishing took place on almost the same date in successive years. The juvenile salmon densities in the main stem and two large tributaries appear to fluctuate with no apparent trend, and in long perspective (Figure 24), it seems difficult to make conclusions on trends

in stock status based on these data. However, densities of yearling (0+) salmon appear to have been higher in 2000s than before in the rivers Utsjoki and Anárjohka/Inarijoki (Figure 24).
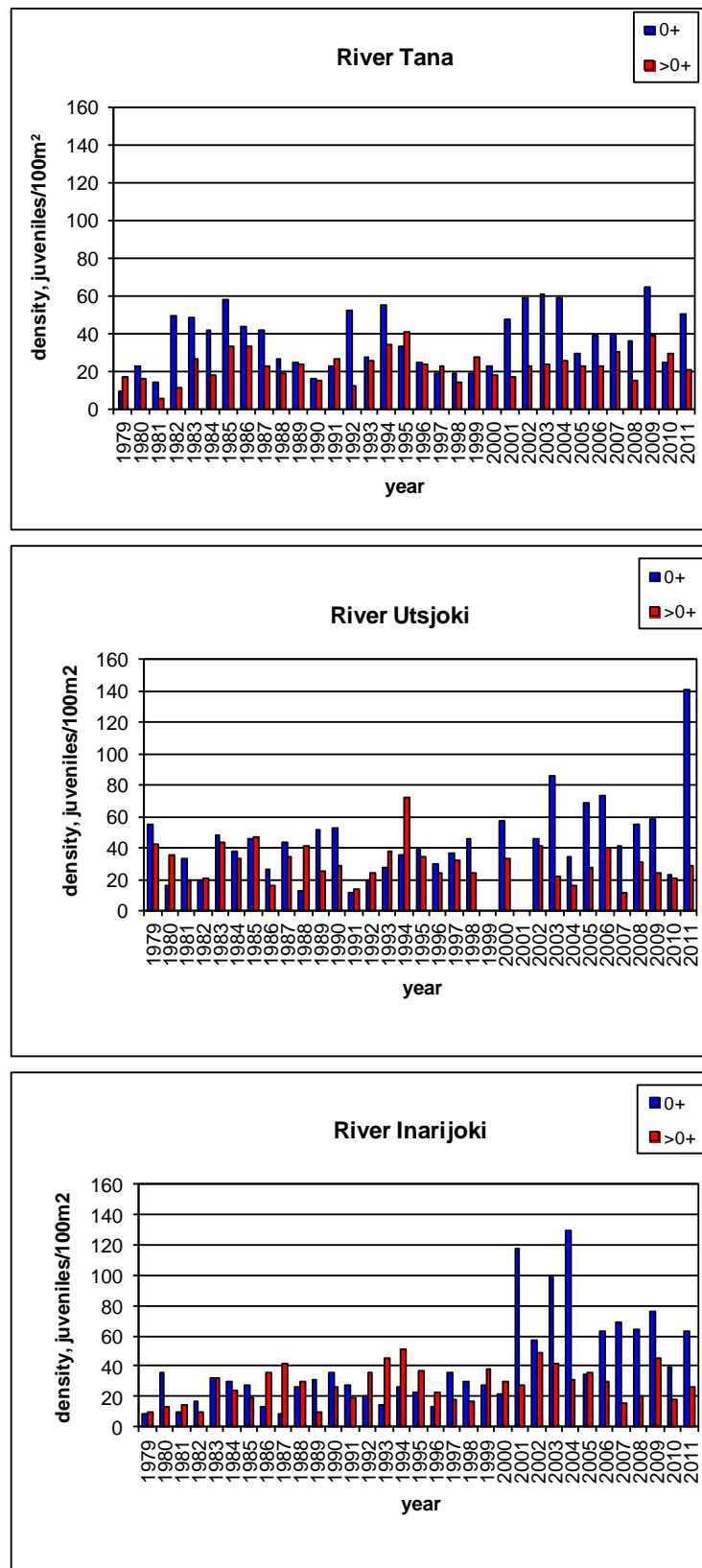

Figure 24. Densities (ind./100 m^2) of juvenile salmon in the Rivers Tana, Utsjoki, and Anárjohka/Inarijoki. Age groups (0+ and >0+) are presented separately.

8   Research projects

In addition to the long-term monitoring work, several shorter research projects on Tana salmonid fish populations have been started and conducted in recent years and some are still underway. Below we list some of the most relevant projects that bear direct consequences to fisheries and environmental management in the Tana area.

8.1   Kolarctic Salmon

A research project funded from the EU-Kolarctic ENPI-programme "*Trilateral cooperation on our common resource; the Atlantic salmon in the Barents region*" aims to merge modern science with traditional knowledge on salmon fishing to create a sustainable, long-term and knowledge-based salmon management regime for the salmon stocks of the Barents region. The project is cooperation between Norwegian, Finnish and Russian partners and is scheduled in 2011-2013. Genetic analysis of salmon caught in the Northern Norwegian coastal and fjord areas are carried out in order to uncover the stock of origin in catches of this mixed-stock fishery, and to shed light on the occurrence, abundance and migratory pattern of the various populations from Russia and Norway, including the River Tana system.

The Monitoring Group recommends that the data from the Kolarctic project should be combined with the data from GenMix in early 2014 at the latest, in order to enable analyses of the sequential exploitation of the Tana salmon stocks in the coastal area, in the fjord, and in different parts of the river system.

8.2   Fisheries Evolutionary Genomics: Tana salmon as a model system

The Tana salmon has a number of features that makes it unique in the world for studying a wild population complex with a view to gaining a better understanding of the genetic basis of local adaptation. There is considerable phenotypic variation of fitness-related traits within and between populations. One example of this is multi-sea winterism: the decision of when to return to spawn has important evolutionary consequences for individuals, but from a fisheries management perspective it is also highly important as multi-sea winter fish are one of the main fishing attractions. In addition, the availability of long-term collection of scale samples, phenotypic and environmental data throughout the Tana system, spanning almost five decades provides a powerful means for conducting statistically powerful genetic association studies as well as adding a temporal angle to our studies.

Combined, these factors provide an opportunity for Tana salmon to be a model system in fisheries evolutionary biology. Further, the recent technological and analytical advances, combined with the sequencing of the salmon genome, which is due to be completed in 2012, provide an ideal timing for a fisheries evolution genomics initiative. Two sub-projects are use different approaches to study different aspects of the main study aim – to understand the genetic basis of local adaptation in salmon.

Assessing the reproductive success of wild-spawning Tana salmon: do locals get more of the action?
A key factor in testing the local adaptation paradigm is demonstrating that 'local' fish have higher reproductive success than 'foreign' (in this context, 'foreign' can also mean a fish originating from another tributary). Extensive annual monitoring and genetic sampling of adult fish migrating up the

study tributaries, and electrofishing of alevins and parr will enable monitoring of the local breeding populations of two tributaries and their breeding success. This will also enable identification of natural hybrid offspring (the result of successful migration) and hence contribute to understanding whether local fish have higher breeding success than migrants and/or local-migrant hybrids, as predicted under a local adaptation 'local *vs* foreign' scenario. It will also enable the establishment of 'pedigrees in the wild'. The two tributaries currently being studied are Akujoki and lower Utsjoki. Utsjoki is particularly interesting as it has a high proportion of multi-sea winter spawners compared to most tributaries.

Genome-wide association studies. The large scale archive that has been collected over the past decades combined with the extensive genomic resources available for Atlantic salmon also enables the application of powerful genetic mapping methods thus far applied only in humans and domestic animals. One such example is genome-wide association mapping (GWAS). The first trait to be studied using a GWAS approach is the multi-sea winterism of the Tana salmon.

Sampling of spawners started in the autumn of 2011 and the genome-wide associations have been started. This study is a collaboration between the University of Turku and RKTL, and is mainly funded through the Academy of Finland.

8.3   PIT-tagging of juvenile salmon in small streams

Within the Tana river system, there are huge differences in the habitat available for salmon. Large areas of the main stem are wide and slow-flowing with a substratum of sand and fine gravel. These areas are not suited for salmon spawning. In between these slow-flowing areas we find areas with higher current velocity, coarser substratum and better conditions for salmon and most of the salmon reproduction is located to these areas.

Research from the Tana river system have showed that juvenile salmon are able to move substantially away from spawning areas and into new habitats. They are for example able to move into lakes where they use the near-shore areas to feed and show enhanced growth (Erkinaro *et al*. 1995; Erkinaro *et al*. 1998a). And mapping of small streams have demonstrated that these are extensively used by juvenile salmon (Erkinaro *et al*. 1998b; Johansen *et al*. 2005a). Since only older juveniles and no young-of-the-year fry were found, it was natural to conclude that the juveniles observed in streams had migrated actively from nursery areas in the Tana main stem or tributary rivers.

Some of the juveniles migrate over very long distances, as they can be found in streams located tens of kilometres from the nearest spawning ground (M. Falkegård, unpublished data) and several kilometres upstream in the streams (e.g. Erkinaro 1995; Johansen *et al*. 2005a). Considering the small body size of the juveniles such migration distances are energetically costly, making this a surprising life history tactic.

The stream migration becomes even more surprising when comparing the water temperature between streams and the Tana main stem. During the summer, the stream water temperature might be as much as 6-7 °C lower than the main stem temperature. Fish growth rates depend on ambient temperature, increasing with rising temperatures up to an optimum temperature for growth. The relatively cold water of the streams can, thus, slow down the juvenile growth.

Relatively high food availability in the streams seems to play an important role (Erkinaro & Erkinaro 1998; Johansen *et al*. 2005b), and parr migrating into streams show enhanced growth compared with their main stem counterparts (Erkinaro & Niemelä 1995). Smolts migrating out of the small streams are larger than smolts from the main stem (Heinimaa *et al*. 1998), which can be important considering that smolt survival is positively correlated with size (Jokikokko *et al*. 2006). An analysis of scales from returning adult salmon revealed that over 30 % of the adults had visited nursery streams while they were parr (Erkinaro *et al*. 1997). This is a surprisingly large percentage, considering the relatively small area of the small streams compared with the total area of the Tana main river.

Unfortunately, small streams are often not viewed by planners, resource managers or the public as having substantial fisheries value. The abundance of the small streams is easy to underestimate and they are often excluded from the planning phases of resource extraction and urban development. Consequently, small streams around the world are potentially subject to serious degradation from forestry, urbanization and agriculture (Elliott *et al*. 1998). Although small streams can harbour high densities of salmon parr, their contribution to total rearing habitat and salmon production within a river system remains difficult to quantify.

An individual-based study was started in 2007 to further illuminate the importance of small streams and the mechanisms behind why some juveniles choose to migrate into the streams. Three streams – Vuolit Vidis, Bajit Vidis and Cavastatjohka – on the Norwegian side of the Tana main stem, a few kilometres above and below the Utsjoki river mouth, were chosen for study. Parr down to 6 cm in length were sampled in the streams and in the Tana main stem outside the stream mouths and tagged with passive integrated transponder (PIT) tags. These are tiny identification chips which are injected into the fish for permanent identification. The chip is read cordless by means of a reader which provides a unique code read out of the chip implanted in the fish. This approach enables individual recognition of small fish without having to kill or recapture the fish.

In the periods 2007-2009 in Vuolit Vidis and 2008-2009 in Bajit Vidis and Cavastatjohka, close to 3 000 salmon parr were tagged and followed with stationary (Figure 25) and wands (portable antennas). The stationary antennas continuously monitored movement of tagged fish into and out of streams, while the wands were used to monitor individual positions of tagged fish on a weekly basis within the streams and in the main stem outside the streams.

The manual tracking of tagged fish with the wands revealed some striking differences in movement strategy of salmon parr, and the tagged parr could effectively be divided into two main groups:

1) **Movers**. These were parr that were changing their position from week to week (assessed with both wanding and from stationary antennas).
2) **Stayers**. These were parr that were found at roughly the same position (within a 5 m area) for extended periods.

Figure 25. The stationary antennas in Vuolit Vidis that monitored the movement of tagged salmon parr into and out of the stream.

The movers could be divided into two different groups:

1) **Main-stem movers**. These were parr that moved around, but only were found in the Tana main stem.
2) **Transient parr**. These were parr that moved around and changed their habitat (often repeatedly) between the Tana main stem and the small streams.

All parr found in the main stem were to some extent movers, as no parr tagged in the main stem moved less than 5 m during the summer. Around a third of the parr tagged in the streams were stayers, another third were transient while the movement strategy of the remaining third are unknown due to insufficient number of recaptures.

The growth data indicate a clear growth advantage for the parr staying put in the streams (Figure 26), while there are no growth differences between transient parr moving into and out of streams and moving parr in the main stem. The tagging data indicates that this growth difference is present almost from the beginning, as 1+ parr that moves into a stream and stays there are larger than moving parr already before entering the stream. The staying parr then enjoys a higher growth rate, and the tagging data clearly indicates that this high growth rate is sustained from year to year. Thus, a high growth rate as a 1+ staying parr means a high growth rate as a 2+, 3+ and even 4+ staying parr.
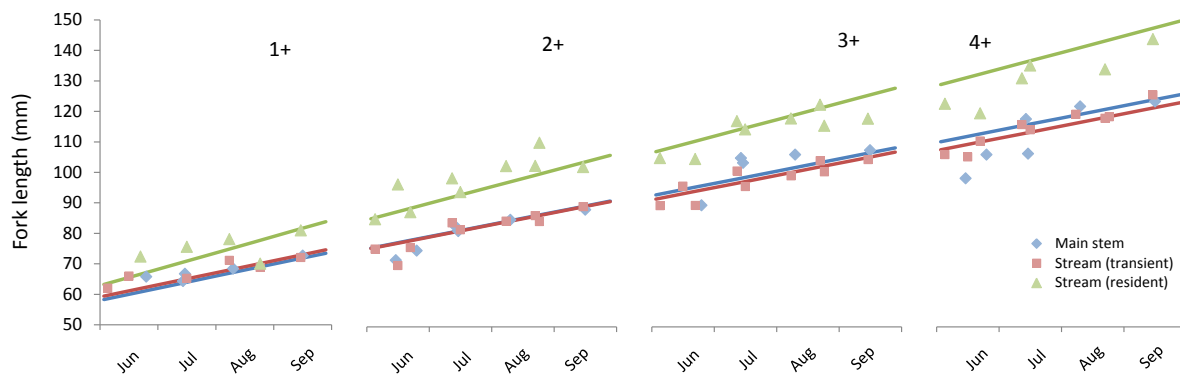
Figure 26. A growth model of salmon parr with different life history strategies. The model is based on a subset of around 1 000 parr (out of the total 3 000) that were tagged and sampled in one of the streams, Vuolit Vidis, in 2007 and 2008.

There are some possible advantages associated with a higher growth rate. A fast-growing parr might either smoltify a year earlier than more slow-growing parr, or it might smoltify at the same age but with a larger size. In both cases, positive survival effects are expected. Smoltifying a year early means one less year spent in freshwater, thus one year less of potential predation. The salmon that smoltify at a larger body size also are less vulnerable to predation during the smolt migration and have a better feeding ability when entering the sea.

In all the study streams, the stationary antennas revealed a relatively high number of fish both entering and leaving the streams throughout the summer. A lot of these fish were short-term visitors to the streams, as they entered the stream, swam upstream for some distance and then subsequently left a few days (or weeks) later. This traffic means that the accumulated number of fish visiting a stream during the summer is much higher than the number of fish observed there at a single point in time, which underscores the potential importance of the small streams as a nursing habitat for juvenile salmon in the Tana river system.

8.4   Biology and exploitation of sea trout

Annual sea-trout catches of the Tana system is estimated to vary between 2 and 9 tonnes, but relatively little is known about the sea-trout populations. At the moment, however, there is a clear need for a comprehensive sea-trout study, as demands of prolonging the sea-trout fishing season are frequently expressed by both fishermen and fisheries managers. Such plans require more thorough knowledge on the sea-trout populations, however, and a three-year project has been started in 2011 to review the existing data on sea trout and investigate the possibilities of expanding the fishing opportunities for sea trout.

The research project consists of three sub-projects:

- The status and catches of the River Teno sea-trout (analysis of the long-term monitoring data)
- The migration behaviour and dispersal of the River Teno sea-trout (telemetry experiment)
- Sea-trout fishing in September: how, where and when? (synthesis)

First tagging experiments were commenced in 2011 with 43 sea trout tagged in different parts of the river and the estuary. Tracking of the fish continues throughout the winter and new group of trout will be tagged in 2012.

8.5   Development in the use of stationary gear in Tana

Tana is one of very few salmon rivers in which net-based fishing gear is still allowed. Four different gear types are allowed: drift nets, seine, weirs and gillnets. The former two can be classified as active gear types, while the latter two can be classified as passive or stationary gear types.

The use of these different gear types has a long history in Tana. This is especially true for weirs that might have been used as early as the 1600s. The use of seines also has a long history, while gillnets and drift nets are relatively recent as their use increased in the river during the 1900s.

In July 1984, both Norwegian and Finnish stationary gears were registered (Ferman and Niemelä, unpublished). This is the first actual counting of the extent of the fishery with stationary gear (Figure 27). This registration, with a corresponding division of areas, was repeated in July 2010 (Kjell-Magne Johnsen, Tana Fisheries Board). Further more detailed registrations were done in June, July and August 2011 (Kjell-Magne Johnsen, Tana Fisheries Board).

There is a huge reduction in the number of stationary fishing gears from 1984 to 2010. In 1984, a total of 697 stationary fishing gears were registered (Table 2), while the corresponding count in 2010 was 222 (Table 3). The count in 2010 is equal to 32 % of the count from 1984. A substantial part of the reduction in number of fishing gears has taken place in the tributaries. In 1984, 236 gears (34 %) were located in tributaries, while the count in 2010 was 63 gears (28 %). The reduction in tributaries is especially evident in Norway, down from 83 gears in 1984 (24 %) to 15 in 2010 (14 %).
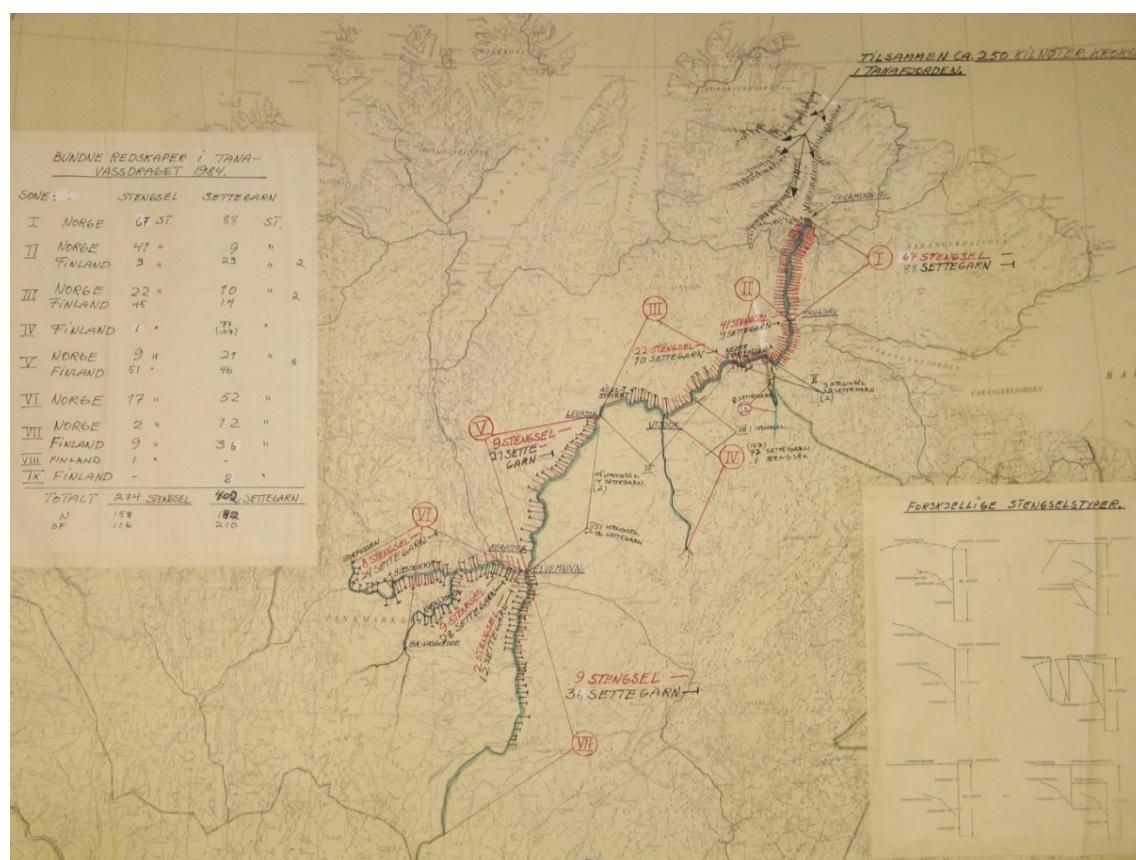

Figure 27. Map showing the stationary fishing gear (gillnets and weirs) registered in the Tana river system in 1984 (Ferman and Niemelä, unpublished).

The total number of stationary fishing gear is distributed almost equally in Norway and Finland. In 1984, a total of 350 gears were registered in Norway, while 347 were registered in Finland. In 2010, a total of 108 gears were registered in Norway and 114 in Finland.

There are some differences between Norway and Finland in the relative number of weirs and gillnets. In Norway, 45 % and 42 % (in 1984 and 2010, respectively) of the gears are weirs. In Finland, the corresponding percentages are 33 % and 19 % in 1984 and 2010, respectively. The relative percentage of weirs is therefore relatively constant in Norway, while the relative use of weirs is decreasing in Finland.

Table 2. Registration of weirs and gillnets in the Tana river system in 1984 (Ferman and Niemelä, unpublished).

Area	Total	Norway			Finland		
		Weir	Gillnet	Total	Weir	Gillnet	Total
Estuary – Tana bru	155	67	88	155			
Tana bru – Boratbokca/Jalve	88	41	9	50	9	29	38
Boratbokca/Jalve – Leavvajohka	91	22	10	32	45	14	59
Leavvajohka – Ráidenjárga[*]	127	9	21	30	51	46	97
Utsjoki	108				1	107	108
Anárjohka/Inarijoki	59	2	12	14	9	36	45
Kárášjohka	37	9	28	37			
Iešjohka	32	8	24	32			
Total	**697**	**158**	**192**	**350**	**115**	**232**	**347**

[*] The confluence between Anárjohka/Inarijoki and Kárášjohka.

Table 3. Registration of weirs and gillnets in the Tana river system in 2010 (Kjell-Magne Johnsen, Tana Fisheries Board).

Area	Total	Norway			Finland		
		Weir	Gillnet	Total	Weir	Gillnet	Total
Estuary – Tana bru	52	16	36	52			
Tana bru – Boratbokca/Jalve	49	21	8	29	5	15	20
Boratbokca/Jalve – Leavvajohka	24	2	4	6	9	9	18
Leavvajohka – Ráidenjárga[*]	34	3	3	6	8	20	28
Utsjoki	30				0	30	30
Anárjohka/Inarijoki	19	0	1	1	0	18	18
Kárášjohka	12	3	9	12			
Iešjohka	2	0	2	2			
Total	**222**	**45**	**63**	**108**	**22**	**92**	**114**

[*] The confluence between Anárjohka/Inarijoki and Kárášjohka.

Interestingly, the decrease in number of stationary fishing gears is not entirely reflected in the catch statistic, especially on the Norwegian side (Figure 28). In 1984, weirs and gillnets accounted for a 30 % of the total catch in both countries, while in 2010 they accounted for 31 %. Separated into country, the relative contribution from weirs and gillnets actually increased in Norway, from 33 % in 1984 to 48 % in 2010. In Finland, the relative contribution decreased, from 26 % down to 18 %.

1984

2010

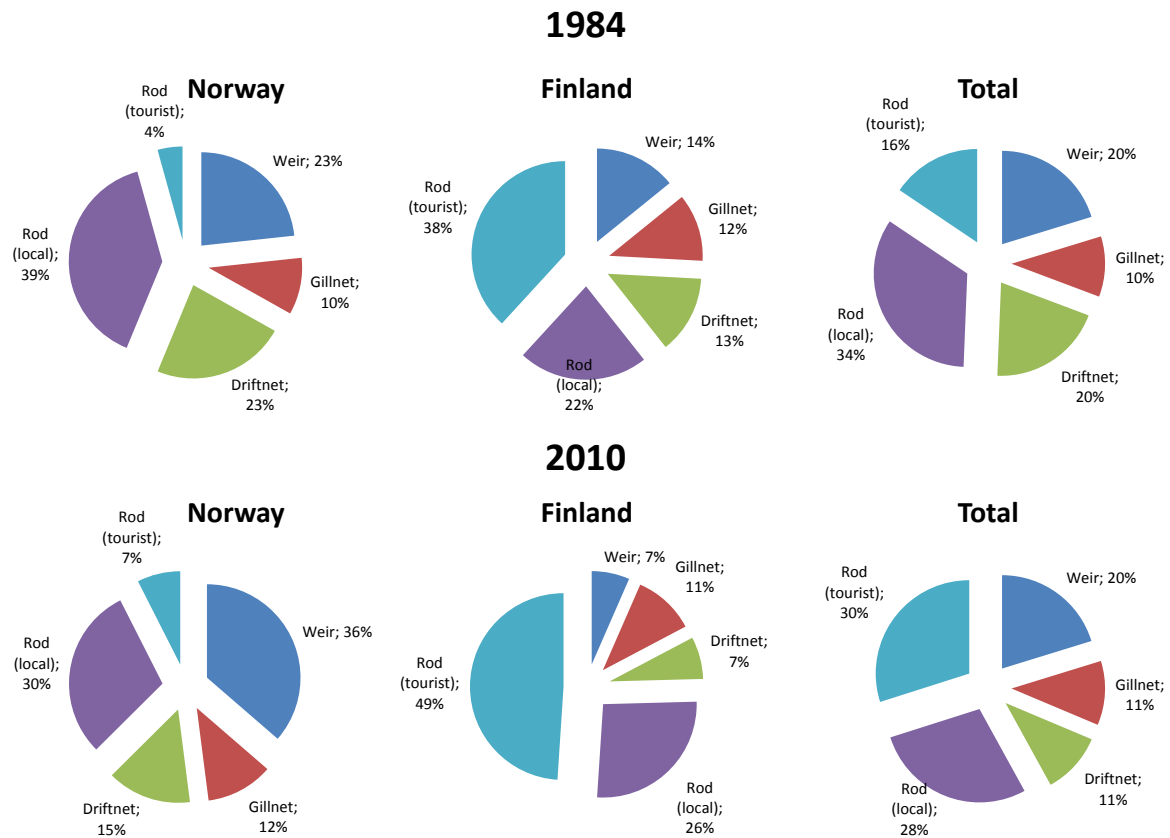**Figure 28. Relative contribution of different fishing gears to the total catch of salmon in 1984 (upper panels) and 2010 (lower panels).**

During the fishing season of 2011, the highest number of Norwegian stationary fishing gears was registered in June while in Finland the highest number was found in July (Figure 29).
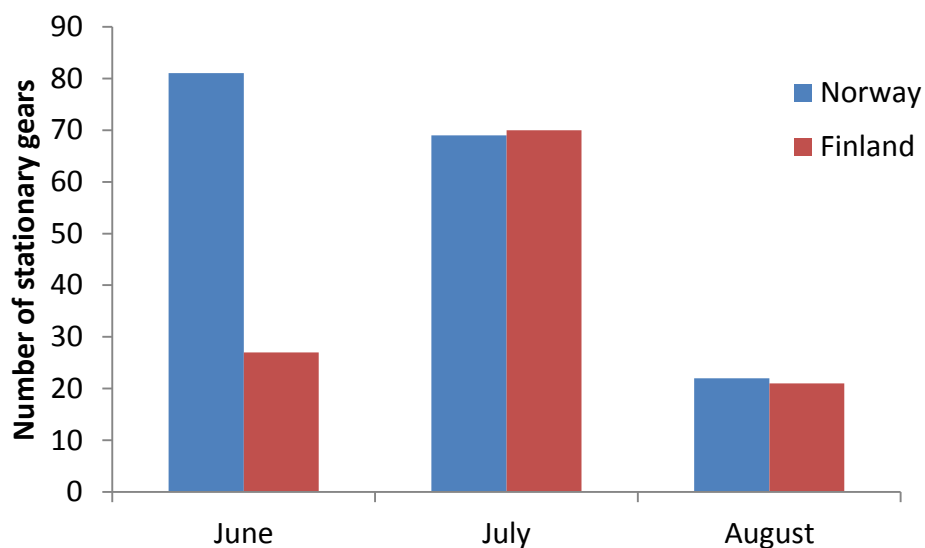

Figure 29. Number of stationary fishing gears in Norway and Finland in June, July and August 2011.

9   Stock status evaluation

9.1   How to evaluate stock status?

The traditional approach to stock status evaluation has been through the use of catch statistics. Long time-series of catch data (e.g. Figure 5) can quickly be put together and represents an illustration that initially looks easily interpretable. However, upon closer scrutiny, a number of problems arise with this approach.

First and foremost, it is very difficult to pinpoint the exact reason for fluctuations in catch statistics. Differences between years can arise from several sources in addition to yearly salmon stock changes. Such factors include e.g. differences in number of fishermen, fishing conditions and/or fisheries regulations. All of these extra factors will confound the catch statistics interpretation.

Secondly, it is problematic to relate the catch to any meaningful benchmark of how the stock is doing. The catch statistic provides an estimate of the number of caught fish, and thus is a useful way of describing how the fishermen are doing. It tells us very little, however, about how the stock is doing. How many salmon were left at the spawning grounds and how many should there have been? What was the exploitable surplus and how was that reflected in the catch? These are examples of questions that point to the need for a different approach.

The lack of a meaningful benchmark when using catch statistics (and other related and derived descriptive statistics) becomes a very obvious problem in processes where fisheries regulations are subject to change. It is not immediately apparent how to justify the need for change and the selection and evaluation of which changes to implement. The management regime itself commonly formulates only qualitative goals, and proposed regulations under this regime rarely have specific goals and lack a clear information basis that managers can use for evaluation.

Salmon as a species pose some very special management challenges with its spatially and temporally complex life cycles which span over vast areas and several years. This is especially true in the Tana River system, in which there are 20-30 genetically distinct stocks and a large variety of possible life history combinations. This stock complexity is further complicated by the presence of an extensive mixed-stock fishery both along the coast of Norway and in the Tana main stem.

9.2   Salmon production and spawning targets

A major objective for salmon conservation and fisheries management is to develop a practical basis for managing individual salmon stocks and the environment in which they live in order to optimize sustainable yield. One way of achieving this, is to specify stock-specific targets for reproduction (e.g. egg deposition). For a salmon stock, the number of adults estimated to be lost through exploitation and natural mortality subtracted from the total run size, is called the spawning escapement. This escapement can be converted to a total egg production for the stock and then compared to a stock-specific threshold value for egg production. This threshold is the conservation limit (CL) (or Minimum Biologically Acceptable Limit) recommended by NASCO, and is the stock level that supports maximum yield and thus maximizes potential yield under the life-cycle characteristics applying to the stock. The CL is the threshold level below which stocks should not fall, and it is recommended that

managers should aim to hold escapement at a higher (unspecified) level termed the management target.

The salmon production capacity in different parts of the Tana River system is limited, meaning that there exist a maximum number of salmon smolts that can be produced. This is usually referred to as the production potential. The factors that limit production are of two types, either (1) density-dependent or (2) density-independent.

Density-dependent factors vary in strength depending on the fish density. With increasing fish density, density-dependent factors such as competition become increasingly intensive. Density-dependence is most easily observed for juvenile salmon. As fish density increases, less food and space become available for each individual fish. This inevitably leads to some fish dying, with mortality increasing with the fish density. A river, accordingly, contains room for only a certain number of juveniles, and this number depends on the river area, abiotic factors such as habitat quality (e.g. the number of available hiding places) and biotic factors such as food availability.

When the spawning stock size is small, relatively few eggs are spawned and the density-dependent competition plays a relatively small role. With low stock levels, the number of smolts produced are proportionally dependent on the number of eggs that are spawned (left part of Figure 30). With increasing spawning stock size, the competition effect will gradually become more and more important. Thus, with increasing egg density, the increase in smolt production starts to slow towards an asymptote (middle part of Figure 30). At high levels of egg density, the river reaches its smolt production potential (right part of Figure 30).
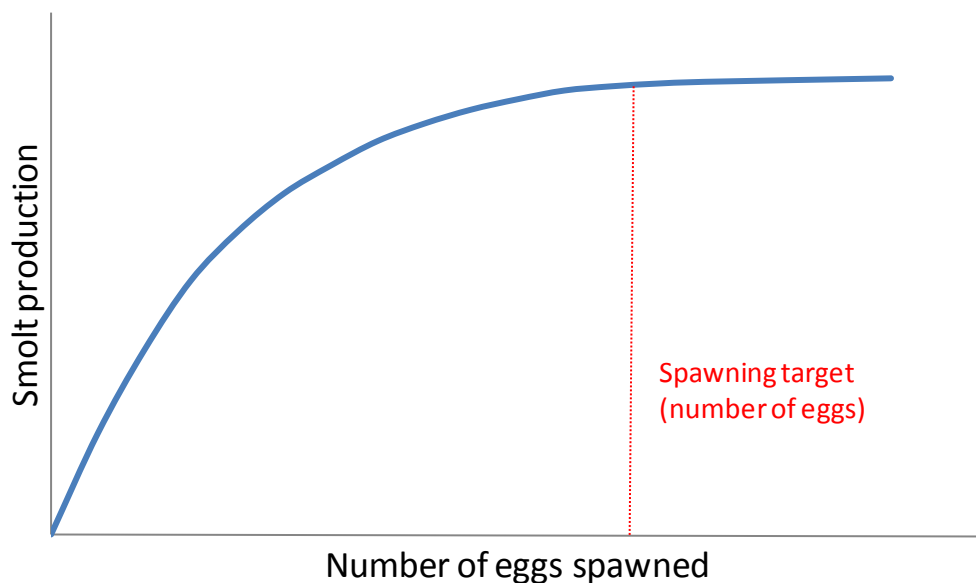
Figure 30. Simplified theoretical relationship between number of eggs spawned and number of smolts produced for a salmon stock.

The production potential varies greatly within different parts of the Tana River system. In some areas of the system, the habitat is predominantly of a good quality with lots of hiding places and rich food availability, and consequently the fish production potential is high. Other areas have predominantly poor habitat quality, with few hiding places available for juveniles and lower food availability, and consequently the fish production potential is low. Habitat factors such as water

velocity, substratum composition and presence of other competitors (such as trout) are also affecting the production capacity.

Density-independent factors are not depending on fish density and occur more randomly. The occurrence of factors such as floods, drought, temperature and predation will result in fish dying. But the occurrence and intensity of these factors can vary greatly from year to year. In some years, the water level and temperature are favourable, resulting in high growth rates and low mortality. Under such conditions, juveniles might even smoltify and migrate to sea a year earlier than average. This will give a boost to the river smolt production, both because the river mortality is reduced by one year and because the remaining juveniles get better conditions because fish density is reduced. Other years can have extreme environmental conditions, e.g. severe droughts or rough spring floods with difficult ice conditions, which will be associated with a high mortality level for juvenile salmon and, accordingly, lowered smolt production.

Random spatial and temporal variation in environmental factors will lead to considerable fluctuations in production and observations both within and between areas of the river system. However, based on long time-series of stock-recruitment data between recruitment (number of eggs or number of spawning females) and production (number of smolts produced), it is possible to estimate the minimum number of spawning females that is needed to ensure that the resulting smolt production is at or near the production capacity of the river. In practice, a small buffer should be added to this minimum number, as a compensating insurance for random events that might cause increased mortality.

First-generation management targets have been established as spawning targets for the Tana river system (Hindar *et al.* 2007). These are summarized in Table 4 with estimates both for different tributaries, main stem and the whole system.

Table 4. Estimated spawning targets for different parts of the Tana river system (Hindar *et al.* 2007).

River	Target (eggs m^{-2})	Area (m^2)	#eggs to meet target	Total weight adult females (kg)	Average weight adult females (kg)	#adult females needed
Tana (main stem)	2	19 060 000	38 120 000	21 178	5	4 236
Anárjohka	2	8 300 000	16 600 000	9 222	4	2 306
Utsjoki	6	600 000	3 600 000	2 000	2.25	889
Kárášjohka	2	10 351 020	20 702 040	11 501	6	1 917
Iešjohka	2	5 175 610	10 351 220	5 751	6	958
Lákšjohka	4	745 365	2 981 460	1 656	1.5	1 104
Máskejohka	4	1 069 238	4 276 950	2 376	4	594
Leavvajohka	1	502 680	502 680	279	2	140
Válljohka	1	618 090	618 090	343	2	172
Other tributaries	1	808 130	808 130	449	2	224
Tana (total)		**47 230 133**	**98 560 570**	**54 756**		**12 539**

There are some issues with these first-generation targets that make some of them problematic to use. The first-generation method established by Hindar *et al*. (2007) is based on two conditions. Firstly, the river area must be calculated in a standardized way. To meet this condition, wetted area was calculated using a GIS-based approach based on maps from the Norwegian N50-map series (scale 1:50 000). These wetted areas are a total area under high-water conditions, and includes both productive and non-productive areas. Secondly, four different egg categories were established, each category corresponding to a different level of productiveness. The lowest density category, 1 egg/m^2, is used in rivers that have large unproductive areas and a relatively low catch of salmon compared with the river area. The highest density category, 6 eggs/m^2, is used in rivers that have a very high proportion of productive areas, high temperatures, low smolt age and a high catch of salmon compared with the river area.

Six of the current spawning targets meet both conditions above. These six are the Norwegian tributaries Kárášjohka, Iešjohka, Válljohka, Leavvajohka, Lákšjohka and Máskejohka. The other targets unfortunately violate the area condition and we are therefore currently unable to assess target attainment in these other areas. The reason for this problem stems from the use of the Norwegian N50-map series. These maps only cover the Norwegian side of the river system, cutting off the Finnish side of both the Tana main stem and Anárjohka. The area estimates for Tana (main stem), Anárjohka, Utsjoki and Other tributaries in Table 4 are production areas estimated by FGFRI and are considerably smaller than the wetted areas that the GIS-based approach would have provided (this would especially be the case for Tana main stem). An additional problem in Utsjoki is that this production area estimate does not include lakes and the tributaries Kevojoki and Tsarsjoki. To compensate for a lowered area, the egg density of these problem areas were increased. This is the reason that Utsjoki were assigned an egg density of 6 eggs/m^2. This approach is invalid, however, as the specific level of the egg categories hinges on the use of the standardized area approach. When other areas are used, entirely new egg categories must be established.

A central point of the NASCO Precautionary Approach is that the management should, as far as possible, be stock-specific. This is a major challenge in the Tana River system with its high number of different stocks, for example due to the lack of data on the spatial boundaries of different stocks. Several of the spawning targets in Table 4 are tributary-specific and represent the closest approximation we currently have to a stock-specific evaluation. There is a need to focus on conservation of each discrete stock, as exchange of individuals among populations appears to be low, at least in the short term, so neighbouring populations do not easily compensate for local shortfalls in production elsewhere (Youngson *et al.* 2003). The main problem here is, of course, that current resource limitations make it impossible to obtain total coverage for assessments of any refinement on any geographical scale within the system, and in practice, compromise approaches have to be taken. Such compromises will however involve using inter-population numbers, and will probably not be able to catch population specific factors.

9.3   A procedure for target-based stock evaluation

The introduction of spawning targets completely changes the management focus, turning it away from a question about how many fish are caught into a question about having a sufficient number of salmon survive to spawn. Obtaining an estimate of the spawning stock size (in terms of number of spawning females) and compare this to the spawning target accordingly becomes the main priority.

There are several possible ways to obtain an estimate of spawning stock size:

1) **Direct counting of spawners**, e.g. through diving. This approach is most useful in small tributaries of the Tana River system (Orell & Erkinaro 2007) where it has been shown to be fairly accurate, especially under good conditions with an experienced diving crew (Orell *et al.* 2011).

2) **Combine fish counting and catch statistics**. A count of ascending salmon, either through video or acoustics (DIDSON), together with a catch estimate provides an estimate of spawning stock size.

3) **Combine estimates of exploitation rate and catch statistics**. For most stocks we lack both spawner counts and fish counts. In these cases, it is necessary to rely directly on the catch statistic and use an estimate of the exploitation rate to calculate the spawning stock size. Because the exploitation rate has to be estimated, it is necessary to have access to monitoring data from comparable rivers in the area where the exploitation rate have been calculated (either through counting of spawners or through counting of ascending salmon).

Common for all three approaches is the use of simulation and probability distributions in all calculations. This includes both the spawning targets themselves and the exploitation rate estimate. The spawning targets are provided as a single number in Table 4. In the actual calculations, a flat probability distribution around these spawning targets is used. A flat probability distribution in this case means that all values within the distribution are considered equally likely, e.g. for a spawning target of 2, the distribution range is 1.5-3 and all values within this range is considered equally likely. The result is an upper and lower limit for the spawning target (Table 5). The reliance on probability distributions means that the evaluation of spawning target attainment can be based on probability, i.e. the probability that the target was reached in a given year, based on the uncertainty in exploitation rate estimates and spawning targets.

Table 5. Estimated spawning targets with lower and upper limits for different parts of the Tana river system.

River	Middle value for target (eggs m^{-2})	Lower and upper target limits (eggs m^{-2})	Total weight adult females (kg) to meet target	Lower limit of target (kg females)	Upper limit of target (kg females)
Tana (main stem)	2	1.5-3	21 178	15 883	31 767
Anárjohka	2	1.5-3	9 222	6 917	13 833
Utsjoki	6	5-7	2 000	1 667	2 333
Kárášjohka	2	1.5-3	11 501	8 626	17 252
Iešjohka	2	1.5-3	5 751	4 313	8 626
Lákšjohka	4	3-5	1 656	1 242	2 070
Máskejohka	4	3-5	2 376	1 782	2 970
Leavvajohka	1	0.5-1.5	279	140	419
Válljohka	1	0.5-1.5	343	172	515
Other tributaries	1	0.5-1.5	449	224	673
Tana (total)			**54 756**	**40 966**	**80 459**

The estimation of spawning stock size and exploitation rates can be further used to evaluate the relative efficiency of different fisheries exploiting a salmon stock and provide estimates of pre-fishery abundances. Salmon belonging to a tributary in Tana will for example experience extensive exploitation in several sequential areas. First of all, the salmon are exploited along the outer coast of northern Norway. The second area of fishing in the sequence is the Tana fjord, before the salmon enters the Tana main stem. In the main stem, the third area of exploitation, the salmon is further exploited before the surviving salmon finally reaches their home tributary (where they are also fished).

The fishing in each area is defined by its own set of regulations, and accordingly each area has its own efficiency. Due to stock differences in run timing and size composition, the vulnerability of each stock to exploitation in an area will differ, and this is one important factor to keep in mind when designing research and monitoring studies.

Most of the exploitation on different stocks in Tana takes place in areas with mixed-stock fisheries. This is the case along the coast, in the Tana fjord and the Tana main stem, leaving only the tributaries themselves as areas of single-stock fisheries. A mixed-stock fishery represents a major impediment when the exploitation rate on different stocks is to be evaluated, as the level of exploitation on each stock participating in a mixed-stock fishery is not apparent without specific knowledge gained e.g. through genetic stock identification of catch samples or some large-scale tagging program.

Tagging studies (a total of 29 000 salmon tagged on 23 tagging stations distributed north to south on the coast of Norway in the period 1935-1982) have shown that the salmon caught in the coastal fisheries belong to a large number of stocks covering a substantial area. The recaptures from this study allow for the construction of a distribution key for the coastal catch statistics (Anon. 2011). Further refinement of the key comes from a recent study that used genetic stock identification of a large number of salmon caught along the coast of Finnmark in 2008 (Svenning *et al.* 2011). The resulting key can be used to estimate the exploitation of Tana salmon in different regions along the Norwegian coast.

The management of Norwegian coastal fisheries is separated into different regions (Figure 31). The regions can be classified as either outer coastal regions or fjord regions. The most extensive mixed-stock fishery occurs in the outer coastal regions, where tagging studies have demonstrated that salmon from several fjord regions are exploited. Comparatively, fjord fisheries exploit mostly stocks belonging to rivers in the fjords themselves.
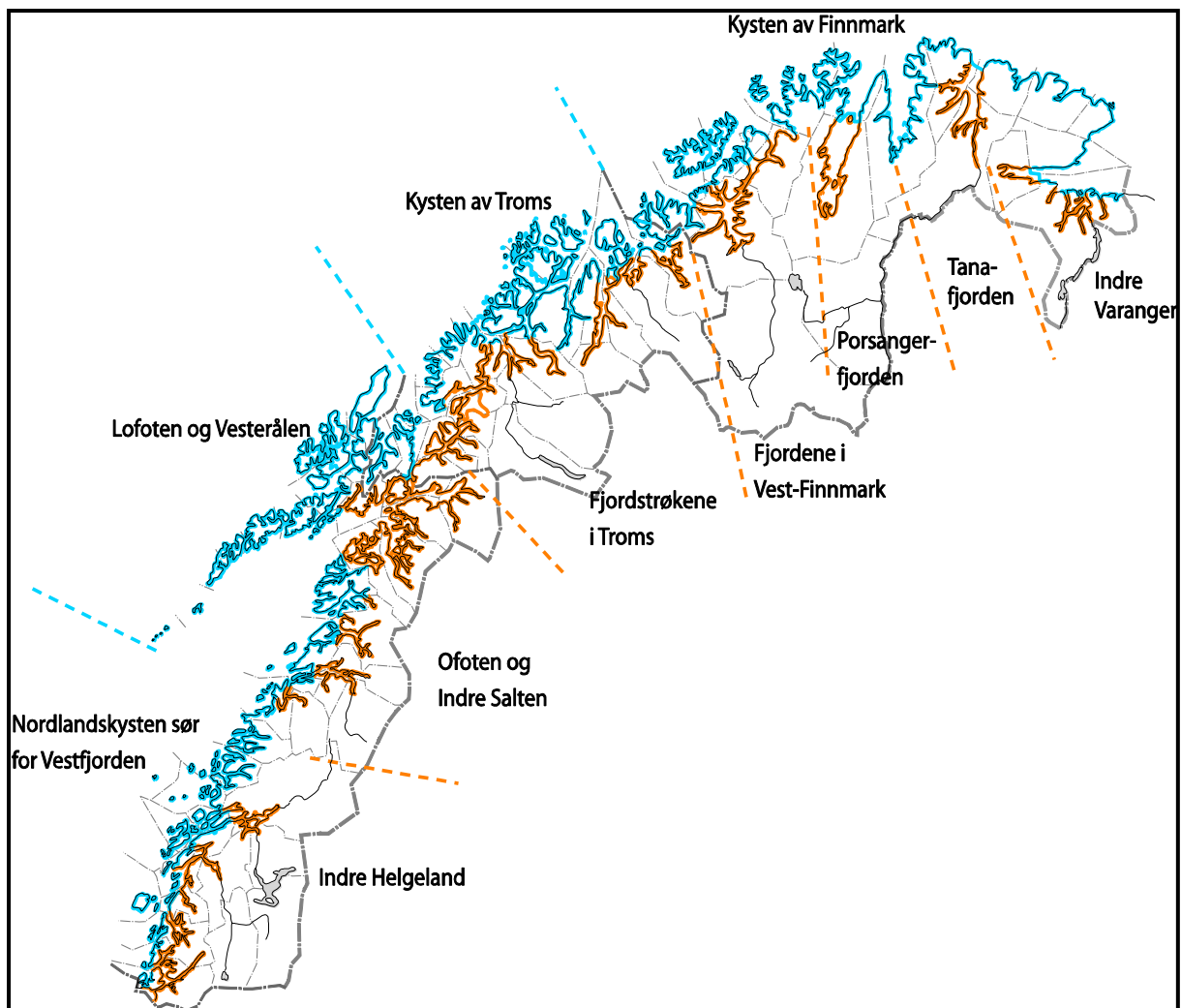
Figure 31. Management regions defined in the salmon management for northern Norway. The outer coastal regions are coloured blue, while the inner fjord regions are orange.

Steps for estimating the Tana catch from the coastal catch statistics:

1) Using the distribution key, 10 % of the catch from the outer coastal area of Troms and 33 % of the outer coastal catch of Finnmark is estimated to belong to the Tana fjord region. The redistributed catch from the outer coastal regions are added to the reported catch in the Tana fjord.

2) There are two salmon rivers in the Tana fjord: Tana and Laggo. The estimated total catch from the Tana fjord is separated into either Tana or Laggo based on the relative abundance of salmon in the two rivers (estimated from the river catch) and each rivers size composition (fish larger than 1.5 kg are positively selected in the coastal fisheries). The resulting number represents the total fishing mortality of Tana salmon in the coastal fisheries.

3) The estimated total coastal catch of Tana salmon is further separated into different Tana stocks (Figure 3) based on the relative abundance and size composition of each stock (inferred from the main stem catch, see below).

Through the GenMix project, genetic stock identification has been done on a large number of salmon caught in the Tana main stem. In this report we have used only data from 2008, but full data sets from 2006 and 2007 will be available for use in later reports. Using the 2008 data, an estimate is

made of the percentage contribution of each Tana stock in the total main stem catch. These percentages are used to estimate the main stem catch of each stock.

After the mixed-stock fisheries catch have been distributed into different Tana stocks, it is possible to estimate the total exploitation, overexploitation, and maximum sustainable exploitation for each stock.

9.4   Explanation of terms (glossary)

Accumulated (sequential) exploitation. This term is used to describe a sequence of fisheries which together exploit a salmon stock. The sequence that impact salmon stocks in Tana is the following: (1) Coastal fisheries in the outer coastal areas of Nordland, Troms and Finnmark; (2) Coastal fishery in the Tana fjord; (3) Tana main stem; and (4) home tributary (only applies to tributary stocks in the system). In such a sequence the exploitation pressures add up.

An example: 100 salmon are returning to a stock in one tributary in Tana. 10 are taken in the outer coastal fisheries, 10 are taken in the fjord, 10 in the Tana main stem and 10 in the tributary. A total of 40 out of 100 salmon are taken, which gives an accumulated exploitation rate of 40 %. The exploitation efficiency in each fishing area is much lower, e.g. 10 % in the outer coastal area in this particular example.

Exploitation rate. The proportion of fish taken in an area out of the total number of fish that is available for catch in the area. For example, if 10 out of 50 fish are taken, the exploitation rate is 20 %.

Exploitation efficiency. See exploitation rate above.

Exploitation estimate. See exploitation rate above. Ideally, we want to have a direct estimate of the exploitation rate through the use of catch statistics and fish counting. Such estimates are available only in rivers with a detailed monitoring. In most cases, indirect estimates of exploitation rates must be used. Such estimates must be based on available data in rivers of comparative size and comparative regulation. A closer discussion on the estimation of exploitation rates in data-poor rivers can be found in Anon. (2011).

Maximum sustainable exploitation. This is the amount of salmon that can be taken in a given year while ensuring that the spawning target is met. The maximum sustainable exploitation therefore equals the production surplus in a year.

Overexploitation. This refers to the extent of a reduction in spawning stock below the target that can be attributed to exploitation. See Chapter 6.6 for a detailed definition.

Pre-fishery abundance. This is the number of salmon that is available for a fishery. For example, the total pre-fishery abundance of a stock is the number of salmon coming to the coast (on their spawning migration) and therefore is available for the outer coastal fisheries. The pre-fishery abundance for a tributary in the Tana river system is the number of salmon of the tributary stock that have survived the coastal and main stem fisheries and therefore are available for fishing within the tributary.

Production potential. Every river with salmon has a limited capacity for salmon production. The level of this capacity is decided by environmental characteristics and river size. See Chapter 9.2.

Spawning stock. These are the salmon that have survived the fishing season (both coastal and river fisheries) and can spawn in the autumn. Usually the spawning stock estimates focus only on females.

Spawning target. This is the management target, defined as the amount of females needed to make sure that the stock reaches its production potential.

Total exploitation. See accumulated exploitation above.

9.5 Tributary-specific stock evaluation

There are methodological problems with some of the assigned spawning targets. The model used to estimate spawning targets in Norwegian rivers assumes that a standardized GIS-based method is used to calculate area. This is violated in some parts of the system, namely the Tana main stem, Anárjohka, Utsjoki and the pooled "*Other tributaries*". This effectively means that only Norwegian tributaries presently have a valid spawning target that can be used for stock status evaluation. Of these, Leavvajohka is omitted from the status evaluation due to very few active fishermen and, consequently, low catch reports. The stock status evaluation in this report is therefore performed for the following five tributaries:

- Máskejohka (in the lower part of the river system)
- Lákšjohka (middle part)
- Válljohka (middle part)
- Iešjohka (upper part)
- Kárášjohka (upper part)

Please observe that there are different exploitation estimates in the following text. The exploitation rate estimates used to simulate spawning target attainment are based on number of salmon in three different size groups (<3 kg, 3-7 kg and >7 kg), while the exploitation estimates used in the stock allocation of salmon from the coastal and Tana main stem mixed-stock fisheries are based on total weight.

9.5.1 Máskejohka

Máskejohka is the lowermost major tributary in the Tana River system, entering the Tana approximately 15 km upstream from the Tana river mouth. It is a middle-sized river with a total of 55 km available for salmon. Of this, 30 km is the main Máskejohka, while the rest is the tributaries Geasis (7 km), Uvjalátnjá (7 km) and Ciikojohka (11 km). In all of these smaller tributaries, salmon distribution is upwards limited by waterfalls. The Máskejohka salmon stock has a good mixture of sea-age groups, mostly 1-3SW and a few 4SW.

The spawning target of Máskejohka is 2 376 kg (1 782-2 970 kg). The lowermost 10 km of the river is slow-flowing and meandering with very little production area available for salmon. Further upstream there are extensive areas available both for spawning and juvenile production.

There is no fish monitoring in Máskejohka, so target evaluation must be based on an exploitation rate estimate (see chapter 9.4). The following exploitation estimates (based on number of fish) were used:

- Salmon <3 kg: 60 % (probability range 50-70 %)
- Salmon 3-7 kg: 40 % (30-60 %)
- Salmon >7 kg: 30 % (20-50 %)

From 2004-2011, the catch in Máskejohka has varied from 156 kg in 2004 up to 1 971 kg in 2010. However, Máskejohka is far from reaching the spawning target (Figure 32). The highest percentage attainment is 64 % in 2010. During the last three years, the average probability of reaching the spawning target was 0.2 % and the average percentage attainment 50 %.
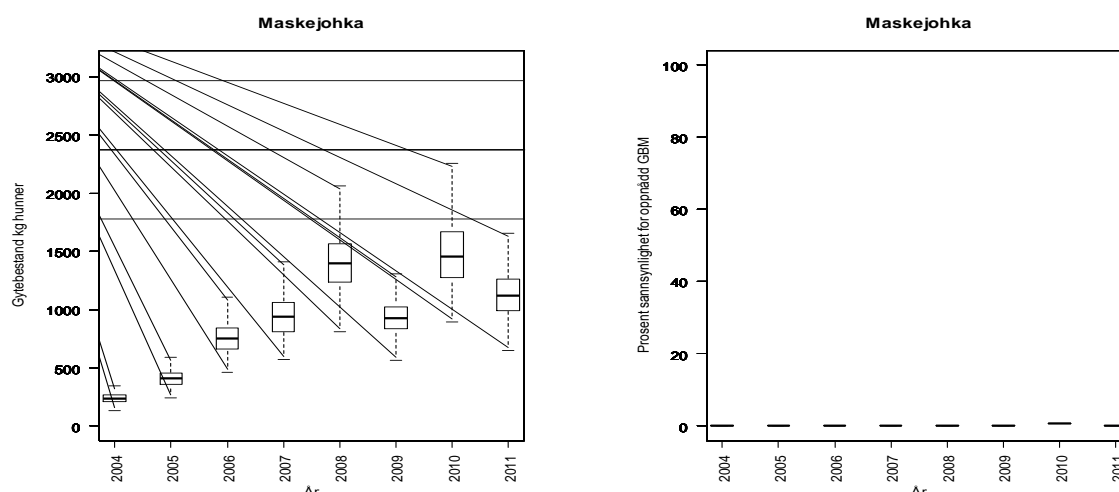

Figure 32. Left: Estimated spawning stock size (kg females) in Máskejohka in 2004-2011. Right: Probability of meeting the spawning target in the years 2004-2011. Figure from the Scientific Advisory Committee for Atlantic Salmon Management in Norway.

The estimated total exploitation (based on weight) in Máskejohka was 66 % in 2009 and 59 % in 2010 (Figure 33). Estimated total pre-fishery abundance was higher in 2010 than 2009 (6 750 kg in 2010, 4 992 kg in 2009). The total catch in the two years were 3 282 kg in 2009 and 4 011 kg in 2010.

The relative catch distribution between coast, main stem and Máskejohka itself varied slightly between the two years. The proportion caught in the coastal fisheries were higher in 2009 than 2010, with 1 226 kg (25 %) estimated to be caught in the coastal fisheries in 2009 and 1 264 kg (19 %) in 2010. The proportion in the main stem fisheries were estimated at 11 % in both years (568 and 776 kg in 2009 and 2010, respectively). In Máskejohka itself, 1 488 kg (30 %) were reported in 2009 and 1 971 kg (29 %) in 2010. The surviving female spawning stock were higher in 2010 than 2009, estimated to be 941 kg (34 % of the pre-fishery abundance) in 2009 and 1 506 kg (41 %) in 2010.
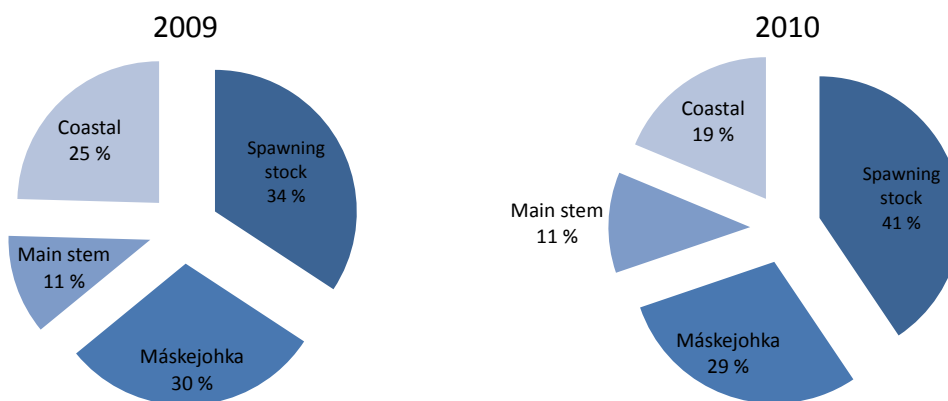
2009

2010

Figure 33. The total amount of salmon belonging to Máskejohka in 2009 (left) and 2010 (right), distributed into surviving spawning stock and salmon caught in fisheries in either coastal, main stem or within-river fisheries.

Estimated relative exploitation efficiencies (based on weight) in 2009 and 2010:

- Coastal: 25 %, 19 %
- Tana main stem: 15 %, 14 %
- Within Máskejohka: 47 %, 42 %

The overexploitation was estimated at 60 % in 2009 and 37 % in 2010.

The maximum sustainable exploitation rate was estimated to be 13 % in 2009 and 36 % in 2010. This means that the entire sustainable surplus in 2009 was caught in the coastal fisheries, while most (over 80 %) of the sustainable surplus in 2010 was caught before the salmon arrived in Máskejohka.

9.5.2   Lákšjohka

Lákšjohka is a small- to medium-sized tributary that enters the Tana just over 60 km upstream from the Tana river mouth. There is a 3 m high vertical waterfall with a fish ladder approximately 9 km from the Lákšjohka river mouth. An inspection of the fish ladder in 2011 revealed the presence of a stone that might have impeded the ladder function. It is presently unknown how long this might have been a problem. There are relatively few spawning grounds available for salmon below the waterfall, while the river habitat above the waterfall is well suited both for spawning and juvenile production. Problems with the ladder will therefore quickly limit salmon production in Lákšjohka.

Total river length used by salmon in the Lákšjohka system is estimated to be at least 41 km. There are no further waterfalls limiting salmon distribution above the fish ladder. The main Lákšjohka is close to 14 km long. Further up the salmon can use two small tributaries, over 17 km in Deavkkehanjohka and 9 km in Gurtejohka.

The salmon in Lákšjohka is relatively small-sized, with 1SW fish weighing around 1 kg and 2SW fish 2-3 kg. Fish larger than 7 kg are rarely caught.

The Lákšjohka spawning target is 1 656 kg (1 242-2 070 kg). Fish counting with video has been done in 2009-2011, and this counting provides a good estimate of exploitation rate. Total exploitation was around 30 % in all the three monitored years.

Throughout the period 2004-2011, Lákšjohka was far from reaching its spawning target (Figure 34). The highest target attainment was around 25 % in 2006 and 2009. During the last three years, the average probability of reaching the spawning target was 0 % and the average percentage attainment 23 %.
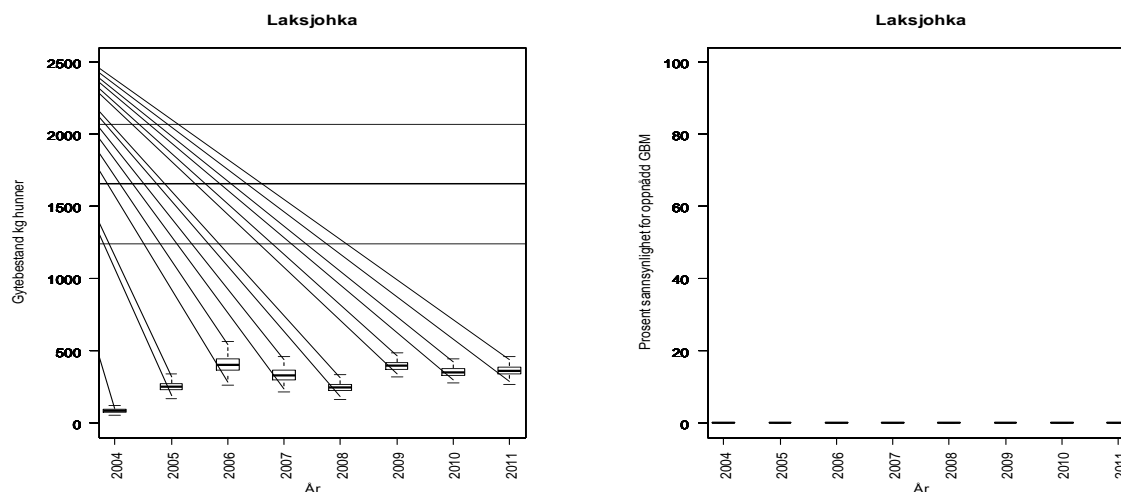

Figure 34. Left: Estimated spawning stock size (kg females) in Lákšjohka in 2004-2011. Right: Probability of meeting the spawning target in the years 2004-2011. Figure from the Scientific Advisory Committee for Atlantic Salmon Management in Norway.

The estimated total exploitation (based on weight) for Lákšjohka salmon was 69 % in 2009 and 73 % in 2010 (Figure 35). The estimated total pre-fishery abundance was 2 294 kg in 2009 and 2 324 kg in 2010, and from this the total catch was estimated to 1 588 kg in 2009 and 1 694 kg in 2010.

The relative proportion caught in the coastal fisheries was slightly higher in 2009 compared with 2010, with 418 kg (18 %) estimated to be caught in the coastal fisheries in 2009 and 317 kg (14 %) in 2010. The exploitation of Lákšjohka salmon in the Tana main stem was estimated to be higher in 2010 than 2009. In 2009, 834 kg (36 %) were estimated caught in the Tana main stem, while the estimate were 1 140 kg (49 %) in 2010. Within Lákšjohka, 336 kg (15 %) were reported in 2009 and 237 kg (10 %) in 2010. The surviving female spawning stock was estimated to be 402 kg (31 % of the pre-fishery abundance) in 2009 and 359 kg (27 %) in 2010.
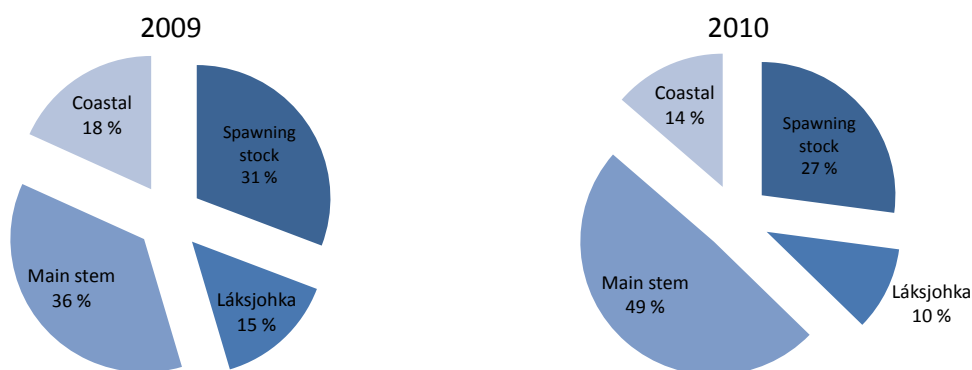

Figure 35. The total amount of salmon belonging to Lákšjohka in 2009 (left) and 2010 (right), distributed into surviving spawning stock and salmon caught in fisheries in either coastal, main stem or within-river fisheries.

Estimated relative exploitation efficiencies (based on weight) in 2009 and 2010:

- Coastal: 18 %, 14 %
- Tana main stem: 44 %, 57 %
- Within Lákšjohka: 32 %, 27 %

The overexploitation was estimated at 55 % in 2009 and 58 % in 2010.

The maximum sustainable exploitation rate was 0 % in both 2009 and 2010, indicating a stock situation with no exploitable surplus.

Video monitoring in Lákšjohka further underlines the bleak consequence of a poor target attainment. The estimated production potential of Lákšjohka is close to 20 000 smolt (Hindar *et al*. 2007). In 2009-2011, smolt numbers from the video counting have fluctuated around 1-2 000 (P. Orell, FGFRI). This is 5-10 % of the production potential (Figure 36).
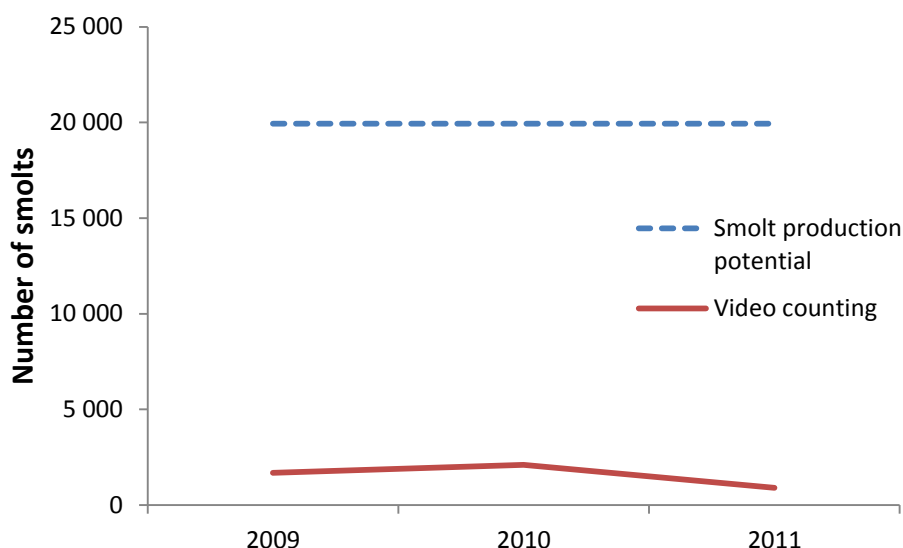

Figure 36. The estimated smolt production potential (from Hindar *et al*. 2007) and the number of smolts observed in the video monitoring.

The smolt counts in Figure 36 are minimum estimates due to two possible methodological problems. First of all, the migratory behaviour of juvenile salmon in Tana (e.g. see Chapter 8.3) means that a number of juveniles will leave the Lákšjohka and enter the Tana main stem at some point during their life cycle. These fish would then not be counted, but would add to the annual smolt output of Lákšjohka. Secondly, some smolts might be missed from the video counting, either by passing the video cameras in such a way that they are not seen and therefore not counted, or by passing the video cameras in the spring before the cameras are installed.

There is, however, a large discrepancy between the estimated smolt production potential and the number of observed smolts, and neither of the two potential methodological problems can be expected to bring the smolt output in 2009-2011 anywhere close to the smolt production potential. The low smolt counts, in combination with the very low number of upstream migrating adults, demonstrate that the bad stock situation in Lákšjohka will continue in the coming years.

9.5.3 Válljohka

Válljohka is a small-sized river flowing into the Tana main stem almost 140 km from the Tana river mouth. The lowermost 5-6 km of Válljohka is relatively slow-flowing, but further upstream the water velocity picks up and more spawning and production areas become available. A total of 45 km is available for salmon in Válljohka itself. In addition almost 19 km is available in the small tributary Ástejohka. Historically the Válljohka has had a mixture of small- and large-sized salmon, but in the last decades the salmon found in the river have mostly been small- and medium-sized. The status of Ástejohka is presently unknown.

The Válljohka spawning target is 343 kg (172-515 kg). An egg density of 1 egg/m² was used when calculating this target (Table 4), meaning that Válljohka was classified as an unproductive river. This is in contrast to most other tributaries of Tana, even though the habitat quality in most parts of Válljohka, except the lowermost kilometers, should suit salmon production (both spawning and juveniles).

There is no fish monitoring in Válljohka, so target evaluation must be based on an exploitation rate estimate. The following exploitation estimates (based on number of fish) were used:

- Salmon <3 kg: 50 % (probability range 40-60 %)
- Salmon 3-7 kg: 30 % (20-50 %)
- Salmon >7 kg: 20 % (10-30 %)

Válljohka did not reach its spawning target throughout the period 2004-2011 (Figure 37). The highest percentage attainment was close to 80 % in 2011 and 50 % in 2006. During the last three years, the average probability of reaching the spawning target was 6 % and the average percentage attainment 51 %.

Figure 37. Left: Estimated spawning stock size (kg females) in Válljohka in 2004-2011. Right: Probability of meeting the spawning target in the years 2004-2011. Figure from the Scientific Advisory Committee for Atlantic Salmon Management in Norway.

The estimated total exploitation (based on weight) for Válljohka salmon was 90 % in 2009 and 88 % in 2010 (Figure 38). The estimated total pre-fishery abundance was 1 806 kg in 2009 and 2 290 kg in 2010, and from this the total catch was estimated to 1 618 kg in 2009 and 2 021 kg in 2010.

The relative proportion of Válljohka salmon caught in the coastal fisheries was higher in 2009 compared with 2010, with 398 kg (22 %) estimated to be caught in the coastal fisheries in 2009 and 382 kg (17 %) in 2010. The exploitation of Válljohka salmon in the Tana main stem was estimated to be higher in 2010 than in 2009. In 2009, 1 100 kg (61 %) was estimated caught in the Tana main stem, while the estimate was 1 503 kg (65 %) in 2010. There is only a small fishery within Válljohka itself, with a reported catch of 120 kg (7 %) in 2009 and 136 kg (6 %) in 2010. The surviving female spawning stock was estimated to be 103 kg (10 %) in 2009 and 148 kg (12 %) in 2010.
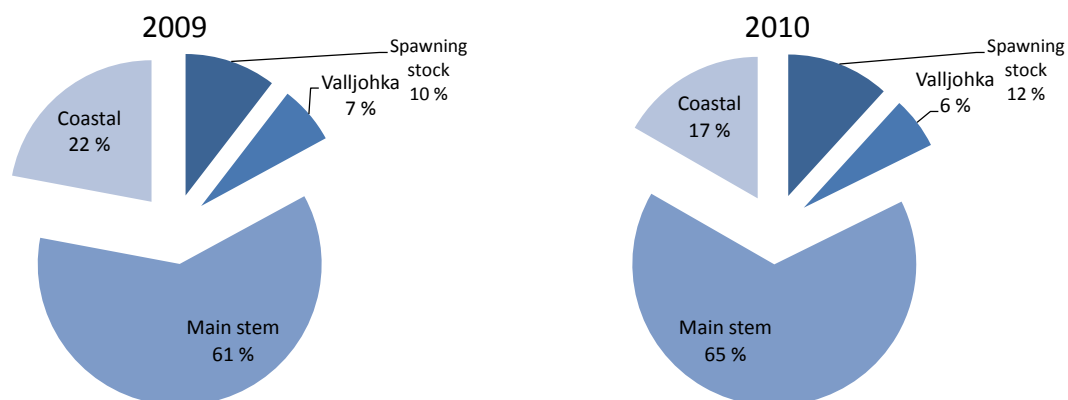
Figure 38. The total amount of salmon belonging to Válljohka in 2009 (left) and 2010 (right), distributed into surviving spawning stock and salmon caught in fisheries in either coastal, main stem or within-river fisheries.

Estimated relative exploitation efficiencies (based on weight) in 2009 and 2010:

- Coastal: 22 %, 17 %
- Tana main stem: 78 %, 79 %
- Within Válljohka: 39 %, 34 %

The overexploitation was estimated at 70 % in 2009 and 57 % in 2010.

The maximum sustainable exploitation rate was 65 % in 2009 and 73 % in 2010. The current exploitation intensities in coastal and main stem areas mean that the entire sustainable surplus in both 2009 and 2010 was caught before the salmon arrived in Válljohka.

9.5.4   Iešjohka

Iešjohka is one of the three large rivers that together form the Tana main stem. Iešjohka flows into the Kárášjohka at Skáidegeahči, and the Kárášjohka then flows close to 40 km before meeting Anárjohka, thus forming the Tana main stem. Iešjohka flow relatively fast, with large riffles and rapids and large slowflowing pools inbetween. The only major obstacle for salmon is a waterfall approximately 75 km upstream. It is likely that salmon are able to pass this waterfall only at low water levels.

The spawning target of Iešjohka is 5 751 kg (4 313-8 626 kg). There is no fish monitoring in Iešjohka, so target evaluation must be based on an exploitation rate estimate. The following exploitation estimates (based on number of fish) were used:

- Salmon <3 kg: 20 % (probability range 15-25 %)
- Salmon 3-7 kg: 40 % (30-50 %)

- Salmon >7 kg: 40 % (30-50 %)

These are equivalent to the estimates used in Kárášjohka, which were derived from the DIDSON monitoring there in 2010.

Iešjohka is far from reaching its spawning target throughout the period 2004-2011 (Figure 39). The highest percentage attainment was close to 35 % in 2008 (around 20 % in most years). During the last three years, the average probability of reaching the spawning target was 0 % and the average percentage attainment 17 %.
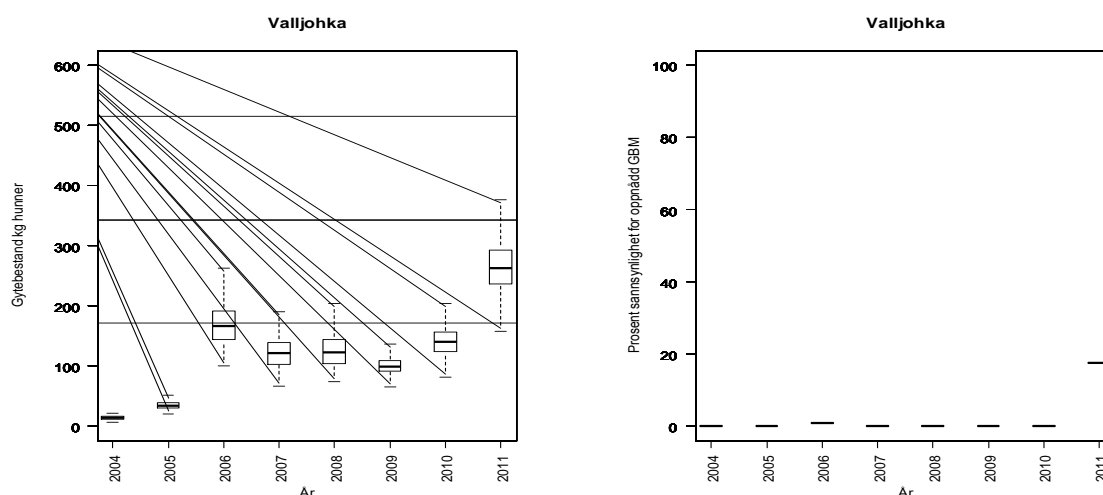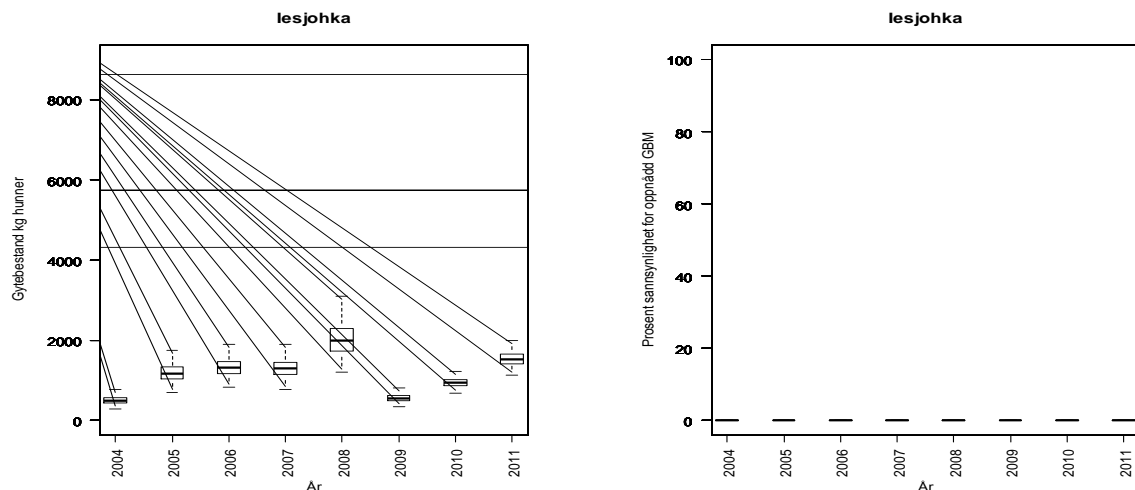

Figure 39. Left: Estimated spawning stock size (kg females) in Iešjohka in 2004-2011. Right: Probability of meeting the spawning target in the years 2004-2011. Figure from the Scientific Advisory Committee for Atlantic Salmon Management in Norway.

The estimated total exploitation (based on weight) for Iešjohka salmon was 91 % in 2009 and 88 % in 2010 (Figure 40). The estimated total pre-fishery abundance was 10 221 kg in 2009 and 13 597 kg in 2010, and from this the total catch was estimated to 9 266 kg in 2009 and 12 004 kg in 2010.

The relative proportion of Iešjohka salmon caught in the coastal fisheries was higher in 2009 than 2010, with 2 631 kg (26 %) estimated to be caught in the coastal fisheries in 2009 and 2 679 kg (19 %) in 2010. This is also a higher proportion than estimated for Máskejohka, Lákšjohka and Válljohka, which reflects the high proportion of large salmon in the Iešjohka stock (large salmon are positively selected for in the coastal fisheries).

The exploitation of Iešjohka salmon in the Tana main stem was estimated to be 5 640 kg (55 %) in 2009 and 7 710 kg (57 %) in 2010. A total of 995 kg (10 %) and 1 615 kg (12 %) was reported caught in the fishery within Iešjohka itself in 2009 and 2010, respectively.
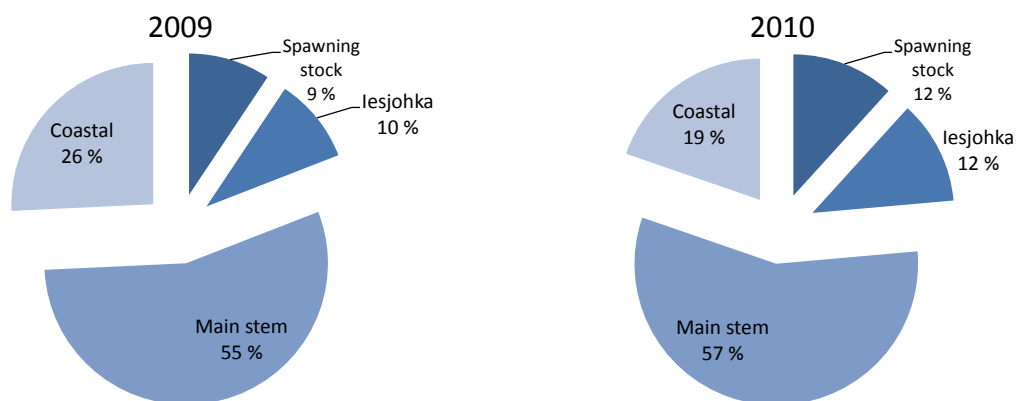
Figure 40. The total amount of salmon belonging to Iešjohka in 2009 (left) and 2010 (right), distributed into surviving spawning stock and salmon caught in fisheries in either coastal, main stem or within-river fisheries.

Estimated relative exploitation efficiencies (based on weight) in 2009 and 2010:

- Coastal: 26%, 19 %
- Tana main stem: 74 %, 71 %
- Within Iešjohka: 51%, 50 %

The overexploitation was estimated to be 90 % in 2009 and 85 % in 2010.

The maximum sustainable exploitation rate was 0 % in 2009 and 24 % in 2010. This indicates a stock situation with very little, if any, sustainable surplus. The current exploitation intensities in coastal and main stem areas mean that the entire sustainable surplus in 2010 was caught before the salmon arrived in Iešjohka.

9.5.5   Kárášjohka

The confluence of Anárjohka (Inarijoki) and Kárášjohka forms the Tana main stem. Close to 40 km upstream, Kárášjohka meets Iešjohka at Skáidegeahči. The lowermost 40 km are relatively slowflowing with sandy bottom, only a couple of places have higher water velocity and suitable conditions for salmon spawning. Above the confluence with Iešjohka, conditions in Kárášjohka become much better suited for salmon. There are several rapids and some waterfalls in Kárášjohka, with Šuorpmogorzi forming a possible obstacle. Electrofishing show, however, that salmon are able to pass and spawn above this waterfall.There is one major tributary, Bavtajohka, approximately 98 km upstream from Skáidegeahči. In this tributary, close to 40 km is available for salmon.

The spawning target of Kárášjohka is 11 501 kg (8 626-17 252 kg). There were fish counting with DIDSON in 2010 at Heastanjárga (the upper bridge over Kárášjohka), approximately 5 km upstream from Skáidegeahči. This counting provided an estimate of the number of salmon of different size groups that migrated up into the upper part, and gave a good estimate of the 2010 exploitation rate in the upper part of Kárášjohka.

The following exploitation estimates (based on number of fish) were used to estimate spawning stock size:

- Salmon <3 kg: 20 % (probability range 15-25 %)
- Salmon 3-7 kg: 40 % (30-50 %)

- Salmon >7 kg: 40 % (30-50 %)

Kárášjohka is far from reaching its spawning target throughout the period 2004-2011 (Figure 41). The highest percentage attainment was around 20 % in 2008, 2010 and 2011. During the last three years, the average probability of reaching the spawning target was 0 % and the average percentage attainment 18 %.
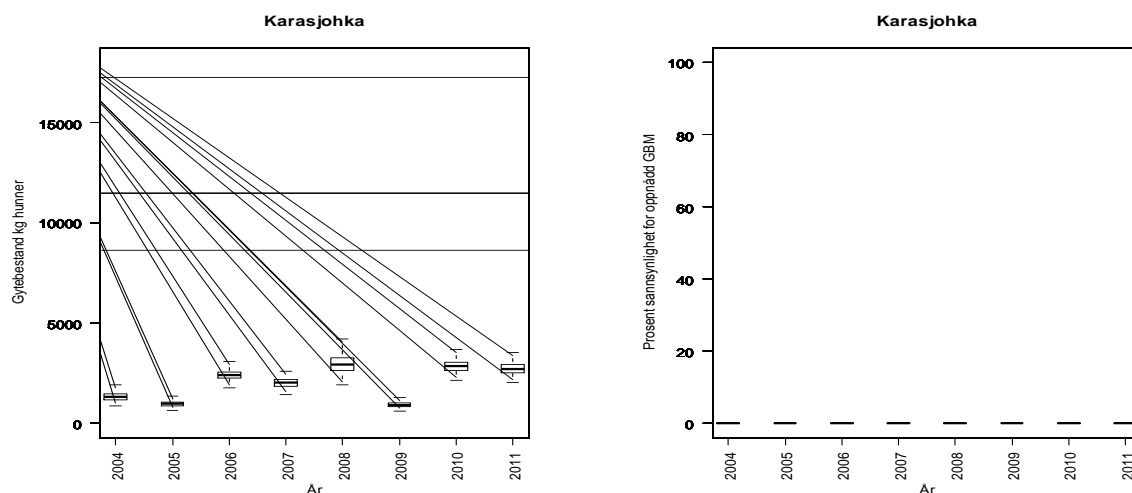

Figure 41. Left: Estimated spawning stock size (kg females) in Kárášjohka in 2004-2011. Right: Probability of meeting the spawning target in the years 2004-2011. Figure from the Scientific Advisory Committee for Atlantic Salmon Management in Norway.

The estimated total exploitation (based on weight) for Kárášjohka salmon was 86 % in 2009 and 73 % in 2010 (Figure 42). The estimated total pre-fishery abundance was 11 864 kg in 2009 and 18 296 kg in 2010, and from this the total catch was estimated to 10 203 kg in 2009 and 13 312 kg in 2010.

The relative proportion of Kárášjohka salmon caught in the coastal fisheries was higher in 2009 than 2010, with 3 031 kg (26 %) estimated to be caught in the coastal fisheries in 2009 and 3 576 kg (20 %) in 2010. As was the case for the Iešjohka stock, the Kárášjohka stock also seem to be more exploited in the coastal fisheries than the Máskejohka, Lákšjohka and Válljohka stocks. This reflects the higher proportion of large salmon in the Kárášjohka stock (large salmon are positively selected for in the coastal fisheries).

The exploitation of Kárášjohka salmon in the Tana main stem was estimated to be 5 629 kg (47 %) in 2009 and 7 328 kg (40 %) in 2010. A total of 1 543 kg (13 %) and 2 408 kg (13 %) was reported caught in the fishery within Kárášjohka itself in 2009 and 2010, respectively.

2009

Spawning
stock
14 %

Coastal
26 %

Karasjohka
13 %

Main stem
47 %

2010

Coastal
20 %

Spawning
stock
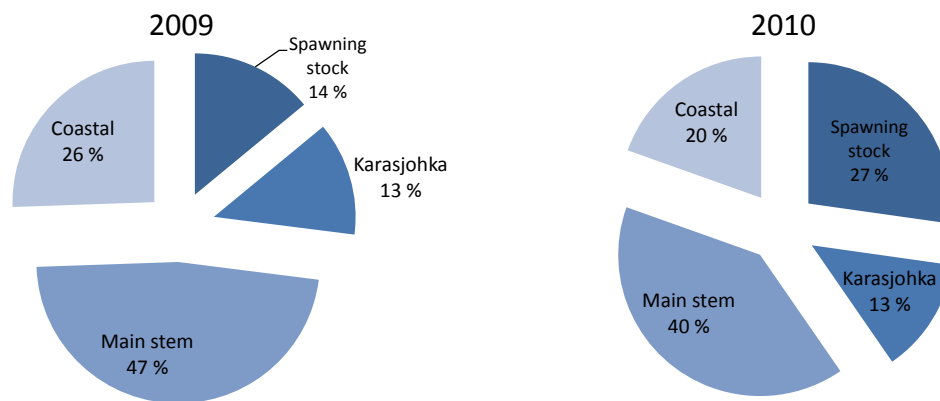27 %

Karasjohka
13 %

Main stem
40 %

Figure 42. The total amount of salmon belonging to Kárášjohka in 2009 (left) and 2010 (right), distributed into surviving spawning stock and salmon caught in fisheries in either coastal, main stem or within-river fisheries.

Estimated relative exploitation efficiencies (based on weight) in 2009 and 2010:

- Coastal: 26 %, 20 %
- Tana main stem: 64 %, 50 %
- Within Kárášjohka: 48 %, 33 %

The overexploitation was estimated at 48 % in 2009 and 63 % in 2010.

The maximum sustainable exploitation rate was 0 % in both 2009 and 2010, indicating a stock situation with no exploitable surplus.

9.6   The importance of spawning target attainment

What are the consequences of not reaching the spawning target, or vice versa, what are the winnings of setting a level of exploitation that makes sure the spawning target is reached? A simple calculation can provide a closer illustration.

The Kárášjohka has a spawning target of 11 501 kg females, and a calculated smolt production capacity of 195 376 smolts (Hindar *et al.* 2007). Based on this smolt production, different scenarios for the pre-fishery abundance of adult salmon can be calculated (Table 6 and Table 7). When conditions at sea are good (Table 6), the stock is able to sustain even very high exploitation rates before a negative development occurs (spawning stock size falling below spawning target). Good sea survival combined with reaching the spawning target also produces a phenomenal number of salmon as an exploitable surplus.

The situation quickly becomes less good in years with a lower sea survival (Table 7). Historically, these low levels of sea survival seem to have become more common in the later years. The sustainable exploitation rate is lowered greatly, and the cost (in terms of lack of an exploitable surplus) of not reaching the spawning target quickly becomes heavy.

Figure 43 illustrates the huge potential that salmon as a species provides. The salmon has a high fecundity and therefore has the potential for remarkable recruitment when environmental conditions are favourable. However, Figure 43 also demonstrates how low the pre-fishery abundance might become either when environmental conditions become worse or high exploitation greatly reduces the spawning stock size. This really underlines the **importance of having a regulation**

that maximizes the probability that enough salmon survives to spawning. Environmental conditions are bound to fluctuate, and making sure that stocks reach their spawning targets really is the only way of securing a reasonably good exploitable surplus every season.

Table 6. Number of smolts out, resulting pre-fishery abundance and exploitable surplus from different levels of spawning stock size (compared with the spawning target) when sea survival is set at a high level.

Spawning stock (as % of the spawning target)	Number of smolts produced	Sea survival	Pre-fishery abundance (adult salmon)	Exploitable surplus (number of salmon)	Sustainable exploitation rate
100 %	195 376	15 %	29 306	25 767	88 %
80 %	156 301	15 %	23 445	19 895	85 %
60 %	117 226	15 %	17 584	14 034	80 %
40 %	78 150	15 %	11 723	8 173	70 %
20 %	39 075	15 %	5 861	2 312	39 %
10 %	19 538	15 %	2 931	0	0 %

Table 7. Number of smolts out, resulting pre-fishery abundance and exploitable surplus from different levels of spawning stock size (compared with the spawning target) when sea survival is set relatively low.

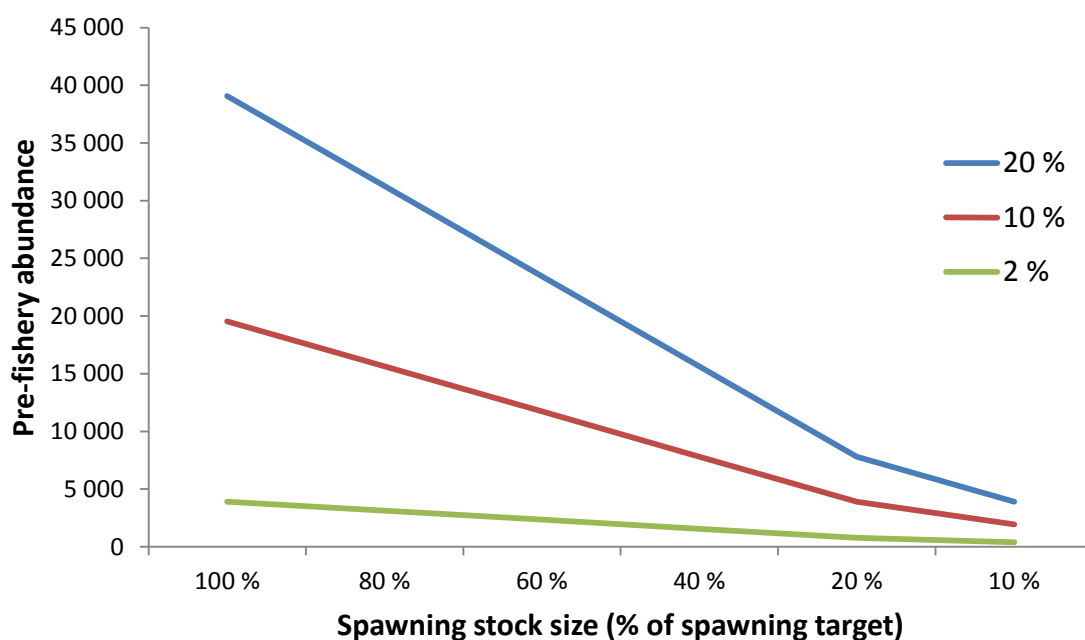| Spawning stock (as % of the spawning target)	Number of smolts produced	Sea survival	Pre-fishery abundance (adult salmon)	Exploitable surplus	Sustainable exploitation rate
100 %	195 376	5 %	9 769	6 219	64 %
80 %	156 301	5 %	7 815	4 265	55 %
60 %	117 226	5 %	5 861	2 312	39 %
40 %	78 150	5 %	3 908	358	9 %
20 %	39 075	5 %	1 954	0	0 %
10 %	19 538	5 %	977	0	0 %

Figure 43. Estimate of the resulting pre-fishery abundance after different levels of spawning stock size, under three different levels of sea survival ranging from relatively bad (2 %) up to very good (20 %).

9.7   Tana stocks vs. neighbouring rivers

One of the major arguments that are used to defend the current stock situation in Tana is that the negative numbers merely reflect a natural variation in the system. At first glance, this might look like a compelling argument. However, upon closer scrutiny, serious flaws become apparent.

The most serious flaw follows directly from the precautionary approach and the target evaluation. The very bad target attainment that has been observed for several years now is, in itself, a definite argument for making management changes. The management target is to keep the stocks above the spawning target, even in the naturally poor years.

Historically, the variations in the Tana catch statistic have followed those of the rest of Finnmark fairly closely. Poor salmon years in Tana have been reflected in poor years in neighbouring rivers, indicating that some of the same environmental factors affect stocks in the area. However, in recent years, the covariation between Tana and the rest of Finnmark has broken down (Figure 44). The last 5-6 years have been exceptionally good in most parts of Finnmark, with many rivers showing record catches and good target attainment. This is a clear indication that environmental factors have been much more favourable than the poor catch in Tana seems to indicate, and is a further indication that the negative development in Tana is not caused by natural variation.
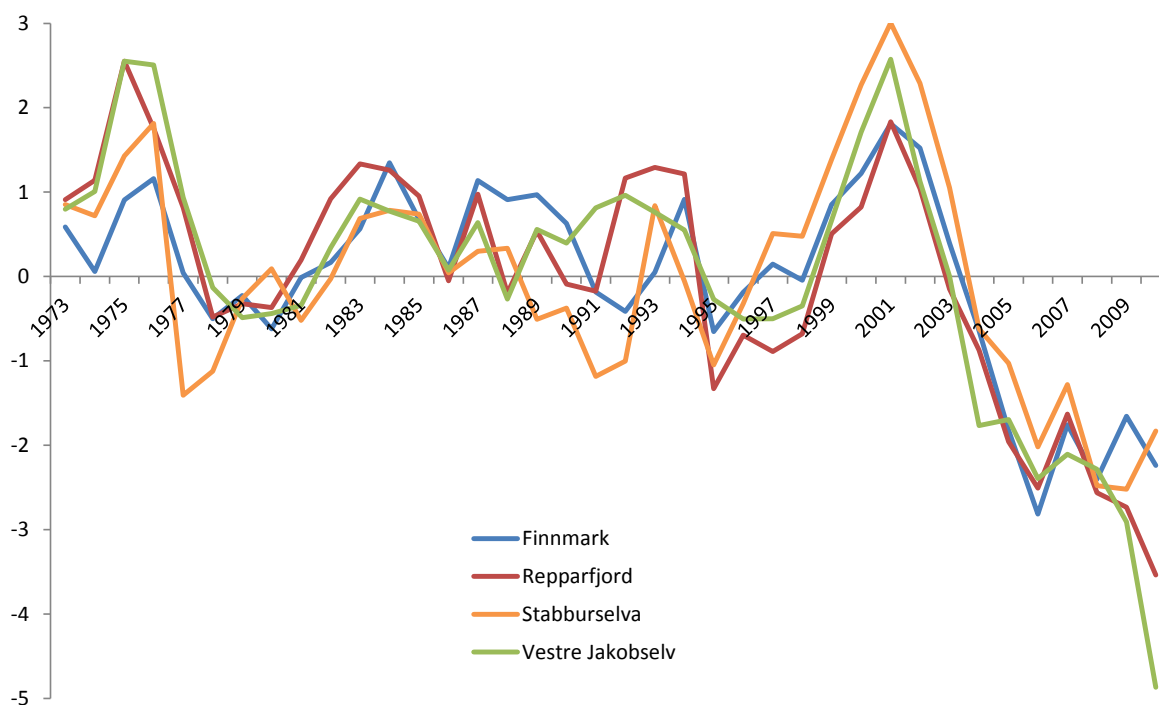
Figure 44. Total catch from Tana compared with the salmon catch in the rest of Finnmark (blue line). In addition, a comparison is provided with a river west in Finnmark (Repparfjordelva, red line), in the middle of Finnmark (Stabburselva, orange line) and east in Finnmark (Vestre Jakobselv, green line). The catch statistics are standardized (catch numbers from each year are subtracted from the mean and divided with the standard deviation), so that numbers from the different rivers vary on the same scale, thus making the catch numbers from each river directly comparable. In the comparison, catch numbers from other rivers are subtracted from the Tana numbers, producing the numbers plotted in the figure. Values below zero indicate years when Tana have done relatively poor compared with other rivers, while values above zero indicates years when Tana have done relatively good.

9.8   The unique problem of sequential accumulated exploitation

Assessing and regulating the fisheries after Tana salmon stocks pose a complex problem for fish managers. A major part of the exploitation is due to mixed-stock fisheries (both with gillnets and rod), and these mixed-stock fisheries take place in a sequence. First, Tana salmon is exploited in the coastal fisheries with bend and bag nets along the outer coast of Nordland, Troms and Finnmark. Then, further exploitation takes place in the Tana fjord towards the Tana River estuary. Next in the sequence is the lower Norwegian main stem, followed by the common border area of the Tana main stem. And then, after being exploited over a distance of hundreds of kilometres, the surviving salmon are able to enter their natal river, where additional exploitation takes place.

Most areas of exploitation are regulated by their own set of rules, which then means that the salmon is subject to different fishing efficiencies in each area. It is possible, using genetic data and back-calculating from catch statistics, to estimate the absolute efficiency in each area and use this information to infer the importance of changing regulations in the different areas.

Assuming 50 % exploitation rate within the tributary Iešjohka, and using genetic data from the 2008 main stem fishery and 2008 coastal fishery, it is possible to do some back-calculations on the exploitation rates experienced by salmon belonging to Iešjohka. The Iešjohka stock is a mixture of both small- and large-sized salmon, with most females being 2- and 3SW. This is a size-group that is considered positively selected in many gillnet fisheries, e.g. the coastal bend nets and the main stem drift nets.

The data indicates the following level of exploitation in different areas:

- Coastal fisheries (outer coast and fjord combined):   19 %
- Lower Tana main stem: 20 %
- Border area: 63 %
- Iešjohka: 50 %[3]

These estimates are based on combining catch statistics, genetic stock identification and tagging data, and putting these data into a sequence, thus inferring the efficiency of each fishery. For example, the coastal catch statistics give the total amount of salmon taken in the coastal fisheries, while the genetic stock identification and tagging data provide an estimate of how much of the coastal catch are Tana salmon. This proportion, then, is also the exploitation efficiency of the coastal fishery. The same logic is applied to the Tana main stem. The catch statistic provides the catch numbers for the lower (Norwegian) Tana main stem, while genetic stock identification provides an estimate of how many of these salmon belonged to the Iešjohka stock. **The efficiency of the lower Tana main stem fishery is calculated by taking the estimated catch of the Iešjohka stock in this area, divided by the pre-fishery abundance of the Tana main stem** (that is, the estimated number of salmon from Iešjohka that have survived the coastal fishery).

The large difference between the estimate for the lower Tana main stem and the border area might initially seem confusing. It is here important to realise that these two estimates are based on two different pre-fishery abundances. The lower Tana main stem pre-fishery abundance is the number of salmon surviving the coastal fishery, while the border area pre-fishery abundance is the number of salmon surviving both the coastal fishery and the lower Tana main stem fishery. Further, in the last years, the catch in the lower Tana main stem have been just over 50 % of the border area catch. The efficiency estimate of the lower Tana main stem must, accordingly, be significantly lower than the border area efficiency estimate.

These estimates have the following practical meaning for the salmon stock[4]: If 10 000 Iešjohka salmon swims towards the coast in the spring, 1 900 will be taken in the coastal fisheries and 8 100 salmon will survive and arrive at the Tana estuary. Of these survivors, 1 620 (20 % of 8 100) will be taken in the lower (Norwegian) Tana main stem, and 6 480 salmon will be able to arrive at the border area of the Tana main stem. In the border area, 4 082 salmon will be taken and 2 398 salmon will survive to enter the Iešjohka. In Iešjohka, 1 199 salmon will be fished, and 1 199 will survive to spawn. This is 12 % of the original 10 000 salmon.

What would be the result if the coastal fisheries were eliminated? Then 10 000 would be able to enter the Tana estuary. Of these, 2 000 would be fished in the lower Tana main stem, 5 040 in the border areas and 1 480 in Iešjohka. The spawning stock would increase from 1 199 to 1 480, a gain of only 281 salmon (3 % of the pre-fishery abundance), despite closing a fishery catching close to 2 000 Iešjohka salmon.

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[3] This is likely an overestimate, if compared with the 2010 exploitation rate estimate from the DIDSON trial in the neighbouring Kárášjohka.
[4] Please remark that the pre-fishery abundance of 10 000 used in these examples is entirely fictitious and is selected purely as a starting point to illustrate the management consequences of various regulation choices.

What about the lower Tana main stem? Closing the fishery here would change the exploitation sequence somewhat. As before, 1 900 salmon would be taken in the coastal fisheries. A further 5 103 salmon would be taken in the border areas, and 1 499 in Iešjohka. The spawning stock would be 1 499, a gain of just 300 salmon (3 % of the pre-fishery abundance) from the first example above.

What about a combined effort, reducing the exploitation rate throughout the sequence? Let us try the calculations with the following exploitation levels in different areas:

- Coastal fisheries: 15 %
- Lower Tana main stem: 15 %
- Border area: 50 %
- Iešjohka: 30 %

In the coastal fisheries, 1 500 salmon would be taken, leaving 8 500 salmon to enter the Tana estuary. In the lower Tana main stem, 1 275 salmon would be taken and 7 225 salmon would survive to the border area. Here 3 613 salmon would be taken, and 3 612 salmon would survive to Iešjohka. Of these, 1 084 salmon would be fished and 2 528 salmon would survive to spawning. This is more than twice the number of salmon surviving to spawning under the current regime (1 199 *versus* 2 528 salmon).

This example illustrates how a combined effort throughout the exploitation sequence produces the highest gain, with a much lower fisherman impact than the total closing of fishing in some areas discussed above.

9.9   Management recommendations in light of the stock status

The current level of knowledge and monitoring means that we are able to do a stock-specific status evaluation in five Norwegian tributaries only. This of course means that the majority of stocks are not evaluated at all at the moment, including the biggest stock of all, the Tana main stem population. This is one of the issues that a future monitoring programme needs to address.

The five tributaries are distributed in different parts of the Tana system: Máskejohka in the lower part, Lákšjohka and Válljohka in the middle part and Iešjohka and Kárášjohka in the upper part. Currently, we have to assume that these evaluated tributaries to a degree are representative of other tributaries in the same area. But even if this assumption is found to be untrue, the bad target attainment found in the status evaluation by itself must have a direct consequence on how the mixed-stock fisheries in the main stem and coastal areas are regulated. This message is not changed by the lack of an evaluation (and possible better status) of other parts of the Tana river system.

The one major issue uncovered by the stock status evaluation is the very poor target attainment that is observed throughout the years 2004-2011. In two rivers, Kárášjohka and Lákšjohka, the estimated pre-fishery abundance was so low that there was no exploitable surplus in both 2009 and 2010. Although no such analyses have been done yet for 2011, a preliminary look at target attainment in these two tributaries in 2011 strongly indicates that there was no exploitable surplus also in 2011. There was also no surplus in a third tributary, Iešjohka, in 2009. The lack of target attainment throughout the period 2004-2011 for all the five evaluated stocks is a clear warning that the Tana stock situation is precarious.

The environment of the Tana river system is still in relatively pristine and good condition, with naturally functioning ecosystems. Accordingly, the only factor currently putting a negative pressure on the Tana salmon stocks is human exploitation. No other threat factors are at a level where they would cause a negative stock development. Due to the bad target attainment, a large part of this exploitation must be classified as **overexploitation**[5].

The lack of target attainment means that spawning stock sizes must be increased. The easiest, and at the moment perhaps only, way of approaching this is to **reduce the exploitation rate of each stock down to a level where the recruitment starts to increase**. This is especially urgent for the MSW components of the Tana stocks, as the number of MSW-salmon is declining.

The estimated total exploitation rates affecting stocks in Tana (especially stocks in the upper part of the system) are considerably higher than those estimated for other rivers in Finnmark (Anon. 2011). This high exploitation can be traced to two likely factors working in combination: (1) the additive effect of a sequential exploitation accumulating over a long distance (outer coast, fjord and main stem), (2) the complex mixed-stock fisheries in coastal areas and in the long and accessible Tana main stem, and (3) the use of several different gear types in the mixed-stock fisheries ensure that the exploitation efficiency remains high almost regardless of fishing conditions.

While on their spawning migration, Tana salmon are exploited over a large area. Late in the winter and early in the spring, the maturing salmon start navigating from the feeding areas towards their natal rivers. The initial route takes the salmon in the general direction of the coast, and Tana salmon might encounter the Norwegian coast both east and west of the Tana river system (Svenning *et al*. 2011). After encountering the coast, the Tana salmon starts navigating near the shore along the coast and in the Tana fjord towards the Tana River. In this phase, the salmon is exploited in coastal and fjord fisheries with bag and bend nets. This exploitation might happen over a scale of hundreds, or even thousands, of kilometres.

When entering the Tana River, the salmon meets a new fishery in the Tana main stem. In the lower Norwegian part, the fishery is predominantly gillnet-based (gillnets, weirs, driftnets), while further upstream, in the common border area, rod-based fisheries become more dominant. The main stem is long and easily accessible, and the different fisheries can therefore be potentially very effective.

The salmon, thus, migrates over a long distance with a continuous risk of being fished. This risk accumulates during the migration, adding up to a considerable accumulated exploitation even though the fisheries in each area might, when seen in isolation, not by themselves be particularly effective. This means that single fisheries (e.g. the coastal or the tourist rod fisheries) cannot be blamed alone for the negative stock development. Rather, it is the **sum of all fisheries** that are problematic.

By their nature, **mixed-stock fisheries** are complex. The catch statistic of a mixed-stock fishery traditionally pools the catch of different stocks in to a single total. It is, thus, difficult to assess the extent at which each stock is exploited. This is further complicated by different stocks having different run timing, and different fishing gear operating efficiently and selectively at different times

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[5] See chapter 6.6 for a definition of overexploitation.

of the season. This variation in fishing gear ensures that salmon are efficiently exploited throughout the season. For example, in the first weeks, drift net ensures efficient exploitation of early-migrating salmon in a situation where high water level makes other types of fishing gears difficult (or even impossible) to operate. The drift net fishery has explicitly been demonstrated to be a major source of exploitation of both MSW salmon and previous spawners (see chapter 1).

Being able to specifically keep track of stock-specific exploitation rates within mixed-stock fisheries should be a highly prioritized continuous monitoring task and this is a paramount knowledge prerequisite to be able to continue with intensive mixed-stock fisheries within the framework of the precautionary approach. Currently, this problem is approached with a combination of genetic stock identification and fish counting. Genetic stock identification – used in projects such as Kolarctic Salmon, which deals with the coastal mixed-stock fishery, and GenMix, which deals with the Tana main stem mixed-stock fishery – is currently the only method we have of separating the catch in the mixed-stock fisheries down to a stock-specific level in a cost-efficient manner.

Regulation recommendations:

1) The target attainment situation in the five evaluated stocks in Tana is bad. Exploitation estimates reveal a high accumulated sequential exploitation pressure that is not sustainable. This total pressure must be reduced down to a level at which each stock is likely to reach their spawning target on an annual basis.
2) The sequential nature of the exploitation means that the only effective way of bringing the total exploitation pressure down is by reducing the efficiency of all fisheries in the sequence.
3) New regulations should be target-specific. This is a challenge for mixed-stock fisheries, and specifically tailored monitoring must be employed to ensure a sufficient knowledge level. An example of such monitoring is the current combination of genetic stock identification (Genmix, Kolarctic) and fish counting (video, DIDSON).
4) The negative trend observed for MSW salmon in the Tana river system further points to an urgent need to implement regulations aimed at reducing especially the exploitation rate of larger salmon.
5) Genetic stock identification of mixed-stock fisheries catch samples demonstrate that a high exploitation of large egg producers (MSW females and previous spawners) belonging to the tributaries takes place early in the season. It is therefore advised to reduce exploitation rates in mixed-stock fisheries (both coastal and main stem) in the first weeks of the current season (May and June).

9.10 Management evaluation in light of the stock status

Salmon fishing in the River Tana system has been regulated since 1873 by bilateral agreements between Finland and Norway. The general fishery agreement is concluded between the governments of Finland and Norway, and this agreement primarily regulates the local fisheries and the associated fishing rights. Regional authorities in both countries regulate the tourist angling, and these regulations can be amended on a yearly basis. The latest general agreement was signed in 1990. In this agreement, regulations are very rigid. The fishing season commences May 20 and stops August 31. Net fishing is allowed three days per week, rod fishing six days per week and drift net fishing can take place only in the beginning of the season (until June 15). All fishing is prohibited one day per week, from Sunday until Monday evening.

Internationally, the management of salmon has increasingly become target-focused following initiatives from NASCO, starting with the agreement of the contracting parties in 1998 to adopt and apply a Precautionary Approach to the conservation, management and exploitation of Atlantic salmon. A procedure for this management regime is further detailed and formalized in the document "*Decision structure for the management of North Atlantic salmon fisheries*" (CNL31.332 2002). The basis for the Decision Structure is to provide a consistent basis and approach for the management and exploitation of salmon throughout the North Atlantic distribution area. Emphasis is put on establishing reference points such as conservation limits and management targets, and management actions that are triggered when the stock status fail to meet the designated targets.

The development of biological reference points should thus provide managers and scientists an ability to assess the fish stock status and evaluate exploitation. The reference points take two forms: *limits* and *targets* (United Nations 1995). The *limit* is a boundary which ideally should not be crossed, and *limit reference points* thus demarcate undesirable stock or fishery levels. The *target* is, on the other hand, a point to aim at, and a *target reference point* thus is the basis for optimizing a particular outcome. Uncertainties and variations will make it virtually impossible to hit a target every year, but the stock level should be fluctuating around the designated target level.

In management these reference points are usually called "*conservation limits*" and "*management targets*". The conservation limit is the stock level below which recruitment would increasingly and significantly fail. The management target is the stock level over which management can be certain that the stock is above the undesired conservation limit. The Precautionary Approach requires "that conservation limits and management targets be set for each river and combined as appropriate for the management of different stock groupings defined by managers" and "that stocks be maintained above conservation limits by means of management targets".

All of the above points towards a **future adaptive knowledge-based management** of the Tana salmon. The **current regulation** (based on the latest agreement between Norway and Finland) is unfortunately severely lacking in this context, and has also utterly failed to stop a negative stock development.

There are a couple of further main issues with the current agreement:

1) There are no targets or goals in the regulation that can be used to evaluate status and stock development.
2) The current regulation is rigid and inflexible, and there is a complete lack of management tools that can be used as a management response to changes in stock development or environment.

All these problems must be fundamentally addressed in the forthcoming negotiation. The Group recommends using the principles of an adaptive, knowledge-based management, built around the following principles:

1) The agreement must be built around the use of stock-specific management targets.
2) The evaluation of target attainment must specifically be knowledge-based, with the countries specifically and clearly committing to a monitoring programme that provides the

necessary data for target evaluation. The required monitoring knowledge needed to evaluate status is detailed in chapter 10.1.

3) There must be a built-in flexibility in the fishing rules. This flexibility should allow for implementation of regulatory measures that operates both within-season and between-season. Within-season measures are necessary to quickly counteract a low pre-fishery abundance (or other unexpected issues that might suddenly arise, e.g. because of a particularly dry summer) and increase the probability that targets are attained.

4) A particularly suitable form of flexibility is pre-agreed regulatory measures that can explicitly be stated in the agreement, with each measure being the pre-agreed response to particular scenarios. Because all these are pre-agreed, they can be quickly implemented by both countries without any time-wasting hearing process.

5) To strengthen and ease the work with preparing the catch statistics, it is essential to have quickly delivered and accurate catch reports from every person fishing in Tana. This should be formalized in the agreement as a personal obligation for everyone.

10 Monitoring and research needs

Riverine and coastal areas of the Tana River represent one of the world's most important systems for Atlantic salmon, and are by far the most important for Atlantic salmon in Norway and Finland. Unlike other Norwegian and Finnish salmon streams, fisheries in and outside the river represent the main factor affecting the salmon. Hydropower development, pollution or fish farming do not exist in or near the Tana River. There are strong indications that several salmon stocks in the Tana system are significantly overharvested, and mixed stock fisheries, both in coastal areas of Finnmark, and in different parts of the Tana River represent major challenges for future management of the Tana salmon. Stock status of Atlantic salmon in different parts of the Tana is largely unknown in detail, but recent estimates of numbers of spawners in five Norwegian tributaries indicate spawning stocks far below established spawning targets.

The NASCO Precautionary Approach (see chapter 4.3) emphasises the use of management targets as a primary tool when evaluating stock status, and the establishment of management actions that are triggered when stock status fail to meet the designated target. This procedure turns the management into an adaptive knowledge-based regime which is transparent and predictable in its decision-making, away from the much more abstract, obscure and rigid traditional regime that current regime that has proven to be insufficient in stopping the negative development in many stocks in the river system.

The present report points towards a target-driven knowledge-based adaptive management which should be fully adopted in the Tana system in the future. Such a management regime puts great demands on the level of monitoring and research that is needed, especially since most of the fisheries in Tana are mixed-stock fisheries. A mixed-stock fishery greatly complicates the management of each stock. Stocks differ in their status, with some stocks doing significantly worse than others. Without detailed exploitation knowledge, the only way to counteract this would be to carefully control the overall exploitation rate in the mixed-stock fishery to ensure the conservation of less-productive stocks within an area of mixed-stock fishery. Overexploitation will, eventually, push the numbers of returning salmon stocks below sustainable levels, and as salmon abundance declines, diversity and resilience are reduced and risk of extinction is increased.

Fish management basically consists of the following four questions:

1) For each stock present in the Tana river system, how many fish should survive to spawn each year?
2) What is the pre-fishery abundance of each stock?
3) Given points 1 and 2, how many fish can then be caught from each stock?
4) And following point 3, where should these fish be caught?

These questions and their implications are summarized in Figure 45. The main challenge for a monitoring programme is to be able to provide accurate information on stock-specific pre-fishery abundance, exploitation and spawning stock size. A detailed discussion on how to achieve some of this is provided in the report from the Norwegian-Finnish temporary working group on monitoring and research in Tana (Johansen *et al*. 2008), and most of this discussion still applies today. A simplified summary of this discussion is provided under long-term recommendations below. In

addition, some short-term recommendations specifically for 2012 are also provided at the end of this chapter.
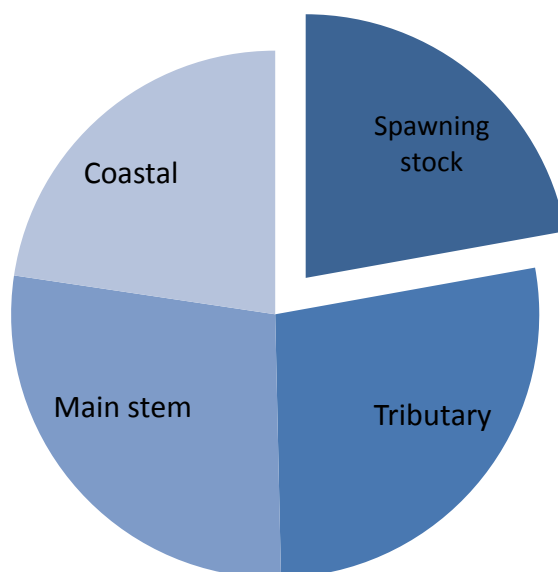

Figure 45. The figure shows how management of a stock really is about allocation. The whole pie chart represents the pre-fishery abundance of a stock, with a proportion caught in different fisheries (coastal, main stem and tributary in this case). The surviving remainder represents the spawning stock size, which should be compared with the stock management target. Ideally, the allocation of catch in different fisheries should be controlled so that the surviving spawning stock remains larger than the target. The pre-fishery abundance will fluctuate from year to year, meaning that the surplus available for exploitation also will vary.

10.1 Long-term monitoring recommendations

A stock status evaluation within an adaptive knowledge-based management regime should be based on the best possible monitoring data, and this data should be provided through a consistent, long-term well-designed monitoring programme. Such a programme should provide (1) a detailed and accurate catch statistics from all different areas and fisheries of the system, (2) catch samples that provide life history data and enable stock identification of the catch in mixed-stock fisheries, and (3) accurate fish counting, either in the form of number of fish entering e.g. a tributary, or in the form of spawner counts after the fishing season. To simplify, the long-term monitoring in the Tana must provide data on two basic levels:

1) **Actual counts of fish** in different areas of the system. This is needed to (1) give data on the actual number of fish present (either before or after fishery), and (2) provide data on exploitation rates that is necessary to calibrate the status evaluation.
2) Data necessary to **separate the catch in mixed-stock fisheries down to a stock-specific level**. Stocks differ in their status, with some stocks doing significantly worse than others. Detailed exploitation data is therefore necessary to be able to defend a continuation of an intensive mixed-stock fishery.

The first point is related to abundance criteria of a stock monitoring and characterisation, the second to diversity criteria (see the NASCO Decision Structure).

The current level of monitoring and research is unfortunately limiting the level of stock detail that can be used in the status evaluation, as seen in Chapter 1 of this report. Currently, usable

management targets are estimated only for six Norwegian tributaries (of which one, Leavvajohka, has to be omitted from the status evaluation due to the very low number of anglers using the river). Further research and more detailed monitoring are needed to allow a broader stock specific evaluation which includes the Tana main stem.

The Tana river system, with its position along the borders of Norway and Finland, represents a joint resource which the two countries have a shared responsibility for. To establish an overall common understanding of this responsibility, it is necessary to collaborate tightly on all levels, both related to management and knowledge (monitoring and research). During the last decade, Norwegian and Finnish researchers have increasingly collaborated on research and monitoring tasks, and today this collaboration is an established matter of course.

In addition to collaboration between researchers, cooperation between researchers and local people has improved markedly over recent years. Incorporation of local knowledge and expertise has become an inherent part of many data collection activities, and establishment of the new local management regime on the Norwegian side has given the local people a contact point that provides local access to knowledge and updated information on scientific results. In addition, contact between Norwegian and Finnish local organizations has been systematically improved. The Group strongly endorses this positive development, and will work to improve its relation with locals on both sides of the border by prioritizing finding arenas that allows the communication of local environmental knowledge to the Group and other scientists, and allows dissemination of scientific knowledge to locals in an accessible manner. This is a task clearly highlighted in the Group Mandate, and in agreement with the recommendations from the recent Norwegian working group established to advice on salmon fisheries regulations in northern Troms and Finnmark.

A problem that remains a major issue in Tana today is the lack of long-term predictability in the research and monitoring activities. Up till now, issues with the funding process have made it impossible to plan activities for more than 1-2 years ahead. This lack of a long-term predictability is currently one of the major obstacles when it comes to research and monitoring in Tana. The Group therefore recommends the **joint establishment of a permanent Norwegian-Finnish research and monitoring programme for Tana**. This programme, and its details, should be specified in a binding way in the agreement.

The contents of such a monitoring programme are described in more detail below.

10.1.1 Fish counting

As demonstrated in chapter 9.5, there is substantial variation in the exploitation rates experienced by different stocks in different fisheries. For instance, the Tana main stem exploitation of salmon from Máskejohka is much lower than the Tana main stem exploitation of salmon from Iešjohka. For this reason, the long-term monitoring must be spatially distributed in the lower, middle and upper parts of the Tana system.

Logistically and technically, fish counting in the Tana main stem remains a daunting task, and it is therefore our current recommendation to focus the counting in tributaries. The following tributaries are recommended for a future counting programme:

1) **Lower part**: Máskejohka. The current stock status of Máskejohka is discussed in chapter 9.5.1. With its relatively medium river size, the Máskejohka could potentially be counted with video, but as the river flows through areas with lots of clay there are long periods of low water visibility that excludes video as an effective solution. Ascending salmon must therefore be counted acoustically (with DIDSON). A suitable site for this was identified during field work in 2011.

2) **Middle part**: Currently, two tributaries are counted in the middle part of Tana. On the Finnish side, video cameras have been operated annually in Utsjoki since 2002, and on the Norwegian side, video cameras have been operated in Lákšjohka since 2009. The main advantage of video is its ability to provide both smolt and adult counts, which can be used both to estimate sea survival and point towards future return rates. This is an established part of the current monitoring that also provides useful data on exploitation rates that have relevance beyond the monitored tributaries, e.g. the exploitation rate in Lákšjohka can provide a guideline for the exploitation rate in other small Norwegian tributaries that are fished only with rod.

3) **Upper part**: There are three large tributaries in the upper part of Tana that each deserves attention. In the current situation, there has been a successful pilot project using DIDSON in Kárášjohka in 2010, and further mapping in 2011 has identified a suitable site for future acoustic fish counting in this system.

In addition to the counting of migrating salmon detailed above, it is recommended to do a count of spawners in smaller tributaries using diving.

10.1.2 Catch samples

The scale sampling project in Tana has, since its beginning in the early 1970s, provided a unique and highly valuable time-series on the composition and diversity of Tana salmon stocks in the Tana main stem mixed-stock fishery. This project is fundamentally important also for the future monitoring of Tana salmon stocks.

10.1.3 Stock identification

A major part of the exploitation of Tana salmon takes place as mixed-stock fisheries in coastal areas and the Tana main stem. The catch statistics of these fisheries are only total numbers with all different stocks lumped together in unknown relative proportions. This has made it almost impossible to properly evaluate the stock-specific effects of the mixed-stock fisheries.

It is now possible, using genetic stock identification, to identify the stock of origin of fish sampled in the Tana scale sampling project. This stock identification, in combination with catch data (fishing gear, time and place of catch) and life history data from scale reading, provides an incredibly powerful tool for the future management of Tana salmon as it allows for the construction of stock-specific exploitation models that can be used to evaluate current exploitation pressure and pinpoint when and where each stock potentially are exploited too efficiently.

Two projects are currently providing directly useful data on this:

1) Mixed-stock fishery in **coastal areas**: The Kolarctic Salmon 2011-2013 project (http://www.fylkesmannen.no/kolarcticsalmon) collects catch samples from fishermen

along the coast of northern Nordland, Troms and Finnmark. Genetic stock identification of these samples can be used to establish a coastal exploitation model for Tana salmon.

2) Mixed-stock fishery in the **Tana main stem**: The Genmix project have been on-going since 2009 with financial support from the Norwegian Directorate of Nature Management and is a major effort undertaken to 1) establish a comprehensive genetic baseline of the stocks in the Tana river system, and 2) do genetic stock identification of catch samples from the scale sampling project in the Tana main stem.

A major obstacle in the establishment of stock-specific exploitation models is the stock diversity of the system. The high number of stocks in combination with large areas, different fishing gears and a long fishing season puts a high demand on the number of fish that must be analysed.

The extensive mixed-stock fisheries affecting stocks in the Tana system necessitates that genetic stock identification of catch samples should be included as a prioritized part of a future monitoring programme.

10.1.4 Juvenile production

Juvenile assessments have been done annually in Tana since 1979, and properly collected juvenile data is highly useful in a future Tana stock monitoring programme. With a well-designed juvenile monitoring programme, in combination with estimates of spawning stock sizes, it is possible to establish stock-recruitment relationships and therefore improve the current management targets.

Juvenile production provides a direct estimate of the success of a spawning stock, and can be a useful estimate of stock status in parts of the river system where we lack other measures of spawning stock size. This is, however, a difficult question to tackle with the current juvenile monitoring programme, which has a sampling design that makes it difficult to tackle important monitoring goals. A detailed discussion on the problems with the current sampling design can be found in chapter 6.1.3 in Johansen *et al*. (2008). It is worth reiterating a couple of the objections here. The most important objection is the selection of electrofishing sites. Sites judged to be good salmon habitats are also the parts of the river system that are least sensitive to changes in overall juvenile density. Most of the existing sampling stations are in the central parts of the river system, areas that are likely to be saturated with juveniles coming from both local spawning and from migrations. Such sites are therefore expected to poorly reflect changes in spawner density.

The second objection is concerning the statistical power of the sampling protocol. Currently, a traditional site-oriented approach is taken with a limited number of sites (each with a certain area) is sampled annually. This approach is highly vulnerable to environmental variation (both from site to site and from year to year), which will greatly diminish the statistical power of the design.

It is therefore recommended to establish a long-term juvenile monitoring programme that builds on the current programme but is also tweaked to be more statistically robust and thereby provide more quantitative status data. This can be done for example by establishing new sampling sites in the uppermost areas of tributaries, at the boundaries of salmon distribution where the number of spawners will likely vary more from year to year, and by adopting a more transect-driven approach to sampling (instead of the current site-driven approach). The latter will greatly increase the number of sampling points and therefore also provide a much improved statistical power. However, the

detailed specifics of a future juvenile monitoring programme must be considered carefully and are beyond the scope of the present report.

10.2 Short-term monitoring recommendations for 2012

The Group recommends that the following activities are prioritized in 2012:

1) **Catch sampling**. The scale sampling project provides important life history and exploitation data from the Tana main stem mixed-stock fishery with a time series dating back to the early 1970s.

2) **Catch statistics**. Collection of best possible catch statistics in both countries remain a high priority and a corner stone of basic monitoring of the Tana salmon stocks.

3) **Genetic stock identification**. Stock identification is a key element in the monitoring of exploitation within the system, as it enables the production of a stock-specific catch statistic that includes both fish caught in each tributary and fish caught in the mixed-stock fisheries (both coastal and main stem). The current project is well underway and is currently accumulating highly interesting management relevant data. The issue of solving the riddles of the Tana mixed-stock fisheries is timely, as this will be an important issue for the forthcoming negotiations.

4) **Video counting in Utsjoki and Lákšjohka**. There is a long time-series in Utsjoki and a short (3 year) series in Lákšjohka, and this data provide a good way of calibrating and validating the genetic results. The video counting is a well-proven and tested method in these two tributaries now, and can be continued with relatively small costs.

5) **Acoustic counting**. After the successful trial in Kárášjohka in 2010, acoustic counting show great promise in areas of the system that are not suitable for video. Further tests with new sites (e.g. Kárášjohka and Máskejohka) should be performed in 2012.

6) **Juvenile monitoring**. The current juvenile monitoring has provided data on changes in juvenile salmon production (densities), occurrence and densities of other fish species, and long-term growth variations of juveniles since 1979.

10.3 Other research needs

The current approach to status evaluation is based on the NASCO Precautionary Approach and uses management targets as the main evaluation tool. Unfortunately, the current management targets, in the form of spawning targets from Hindar *et al*. (2007), only covers a small part of the Tana river system. This will have to be remedied in the coming years, and the Group therefore propose the following research needs connected with the use of spawning targets in Tana:

1) Usable spawning targets must be established for the Tana main stem, Anárjohka/Inarijoki and Finnish tributaries.

2) An approach to evaluating the spawning target in areas of mixed-stock fisheries in the Tana river system must be established. This is currently a methodological problem. For instance, the main spawning population in Tana belongs to the Tana main stem, but the size of this river precludes the use of counting to establish the spawning population. And the catch statistic from the main stem includes salmon from all other areas of Tana in addition to salmon belonging to the main stem. This precludes the direct use of the catch statistic to evaluate the spawning target.

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