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Video monitoring of the River Lákšjohka salmon migrations in 2009-2011

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Abstract			
An underwater video monitoring study for counting adult salmon and smolt numbers was conducted in 2009-2011 in the River Lákšjohka, a tributary of the River Tana. On the video monitoring site the natural river channel was narrowed from both riverbanks to allow full monitoring efficiency with four underwater video cameras. The annual numbers of ascending salmon (336-587 ind.) and descending smolts (901-2105 ind.) observed were rather low bearing in mind that the River Lákšjohka and its tributaries represent a relatively large watershed suitable for salmon production. The exploitation rate of the Lákšjohka salmon fisheries was rather high (c. 30 %, only rod and line fishing) when compared to the fishing effort. It is evident that the Lákšjohka salmon population did not meet the defined spawning targets (> 1100 female salmon/year) in 2009-2011 and management measures should thus be applied. Overall, the River Lákšjohka is an ideal index river of the lower Tana area and easily monitored by using underwater video cameras. Continuation of the Lákšjohka video counts would add a highly valuable part in assessing the status of the River Tana salmon stocks and to ensure biologically sound management decisions in long term.			
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Kutuvaelluksellaan olleiden nousulohien ja laskuvaellukselle lähteneiden lohen vaelluspoikasten määriä selvitettiin Tenoon Norjan puolelta laskevassa Lákšjohkassa vedenalaisella videoseurannalla vuosina 2009-2011. Laskentapaikalla joki kavennettiin ohjausaidon molemmilta rannoilta täyden havaitsemistehokkuuden saavuttamiseksi. Vuosittain seurannassa havaittujen nousulohien (336-587 yks.) ja vaelluspoikasten (901-2105 yks.) määrät osoittautuivat sangen alhaisiksi huomioon ottaen vesistön tuotantoaluieden laajuuden. Lákšjohkan lohenkalastuksen pyyntitehokkuus (exploitation rate) oli varsin korkea (n. 30 %, vain vapakalastusta) verrattuna kalastuksen määrään. Videoseurantatulosten perusteella on selvää, että Lákšjohkan lohikanta ei saavuttanut joelle määritettyä kutukantatavoitetta (>1100 naaraslohta/vuosi) vuosina 2009-2011 ja näin ollen joen lohikantojen hoitotoimenpiteitä olisi syytä tehostaa. Kokonaisuudessaan Lákšjohka osoittautui erinomaiseksi Tenon alajuoksun seurantajoeksi (indeksijoeksi) ja joen vuosittainen monitorointi on helppo järjestää vedenalaisen videokuvauksen avulla. Lákšjohkan videoseurannan jatkaminen tuottaisi arvokasta tietoa Tenon lohikantojen tilasta ja varmistaisi osaltaan biologisesti perustellun lohikantojen hoidon toteutusta.			
Asiasanat			
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Contents

1. Introduction

The annual variations of the River Tana (Deatnu in Samish, Teno in Finnish) salmon populations are normally monitored by collecting catch data from the fishermen, and by conducting large-scale electrofishing of juvenile salmon densities. Collection of catch data and estimation of juvenile densities are valuable monitoring approaches and they provide index information on annual variation of salmon stocks. However, both monitoring methods include significant amount of uncertainty, which complicates their use in the management of the River Tana salmon populations. Catch data combined with the knowledge of salmon actually ascending the river or tributary would give better opportunities for plausible fisheries management and conservation of salmon populations.

Active monitoring of the numbers of ascending salmon was started in the River Tana watershed in 2002 by the "Laks i Nord" –project, which was funded by the Norwegian Research Council. One key objective of this project was to conduct annual counting of ascending salmon and descending smolt numbers in the River Utsjoki, a major tributary of the River Tana, by using underwater video camera technology. This monitoring approach was soon found effective, providing high-quality information for scientist and fishery managers. In 2009 Finnish Game and Fisheries Research Institute (FGFRI), County Governor of Finnmark (FMFI) and Norwegian Institute for Nature Research (NINA) decided to start collecting additional video monitoring data from an another tributary of the River Tana for reference and management purposes. Based on scientist's discussions, an ideal monitoring river was found from the Norwegian side of the River Tana, the River Lákšjohka. The River Lákšjohka has very clear water and it is rather narrow near the junction to the River Tana making the river optimal for underwater video monitoring.

The River Lákšjohka is a medium-sized tributary and it connects to the River Tana mainstem c. 80 km upstream from the sea. The spawning target for Lákšjohka is set at 1656 kg of female salmon with a mean weight of 1,5 kg, which gives potential smolt production at 19 939 smolt (Hindar et al 2007). The River Lákšjohka supports a genetically unique salmon population (Vähä et al. 2011), which is largely dominated by one-sea-winter (1SW) salmon, although two-sea-winter (2SW) and repeat spawning salmon are also ascending the river on annual basis (FGFRI, unpublished data). A fish ladder was built in 1970-s to Lákšjohgorži waterfall situated c. 9 km upstream from the river mouth to enhance the salmon migration to headwater spawning areas (Fig. 1, appendix 1). The River Lákšjohka is a popular site for recreational salmon fishing and catch data information is collected on annual basis by the FMFI and the Tana River Fish Management (TF).

The River Lákšjohka video monitoring and analysis of collected video data has been conducted by FGFRI. FGFRI has also provided the equipment needed in the monitoring, whereas FMFI and Norwegian Directorate for Nature Management (DN) have been the major funding organizations of the personnel costs.

This working report presents the most important results obtained from the River Lákšjohka video monitoring in 2009-2011. The results are compared to the data obtained from the River Utsjoki.

Figure 1. The Lákšjohgorži waterfall. Fish ladder entrance is located on the left hand side. Photos: P. Orell and K-M. Johnsen.

2. Material and methods

2.1. Video monitoring procedure

Four underwater cameras (Camera: Watec, WAT-902 DM 2S, housing: custom made by Lamberg Bio-Marin) with 3.5 mm wide angle lenses were installed annually c. 100 m upstream from the river mouth of Lákšjohka (see appendix 1). The cameras were installed to a line 90^{o} against the current and anchored c. 20 cm above the river bottom by using 15-20 kg weighing pedestals. To gain best possible setup for the monitoring the river channel (original width 18.0 m) was narrowed with guiding fences from both river banks. Thus the camera system covered totally the area (width 8.2 m) where adult salmon and smolts had to swim when passing the monitoring site (Fig. 2).

The video signals from the four cameras were combined together by a video quad (Eneo) and the data was recorded to 500 GB hard disks by using SANYO DSR-300P digital video recorder. The data was saved at enhanced quality with a recording rate of 3.13 or 5.00 fields/second. The 5.00 fields/second recording option were used during the smolt migration periods, between mid-June and Mid-July. Artificial illumination (4 underwater halogen lights, 50 W) was used after 10th of August to be able to record data also during the darkening nights.

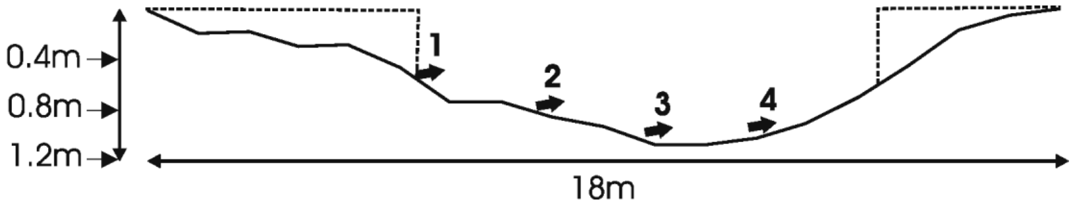

Figure 2. The installation of underwater cameras (arrows 1-4), halogen lights (arrows 1-4) and guiding fences (dotted area) at the video monitoring site (width 18 m) of the River Lákšjohka in 2009-2011. The river depth is indicated on the left hand side of the figure.

The starting dates of the video monitoring differed slightly between years (Table 1). In 2011, spring flood together with heavy rains caused the installation of cameras to be delayed until mid-June. Monitoring data were collected until the end of August in each study year (Table 1).

2.2. Video analysis

The collected video data was analysed by experienced staff at the River Tenojoki Fisheries Research Station (FGFRI). The analysis was based on fast-forward playing, which significantly decreased time needed for the analysis. When a fish was observed analyser used slow motion and frame by frame options to recognize species (salmon, trout) and the size of the fish (only in 2011). The species, size-category and date and time of the passing fish was recorded and saved to an excel-file.

In 2009-2010 observed salmon individuals were not size classified from the video material (see section 3.1.2). In 2011, observed salmon were classified into two different size categories including 1SW (one-sea winter, salmon <65 cm) and 2SW (two sea-winter, salmon 65-90 cm) salmon. The size estimation of the fish was based on subjective determination and therefore they may not be fully accurate in all cases.

3. Results

3.1. Adult salmon

3.1.1. Numbers and migration timing of adult salmon

The numbers of salmon ascending to the River Lákšjohka varied between c. 340-590 individuals (net amount) in 2009-2011 (Table 1). The back and forth movements of salmon was reduced from year 2009 onwards due to slightly new positioning of the cameras to a faster flowing glide (c. 5 m downstream from the site used in 2009) (Table 1).

Salmon migration activated annually at mid-June and continued active until mid-July, where after the numbers of salmon decreased heavily (Fig. 3). Salmon ascendance in August was extremely low, with <3 % of migrants ascending during August (Fig. 3). The timing of the salmon run was rather similar in all three study years (Fig. 3).

Table 1. The numbers of adult salmon observed during monitoring periods in 2009-2011. Spawning population size is estimated based on the net amount of salmon minus numbers of salmon caught (from catch statistics, provided by County Governor of Finnmark).

Time	Salmon up	Salmon down	Net amount	Catch	Spawners
26.5.-31.8.2009	1389	802	587	194	393
1.6.-31.8.2010	598	113	485	129	356
16.6.-31.8.2011*	404	68	336	116	220

* Some salmon missed because of the late start of the video monitoring

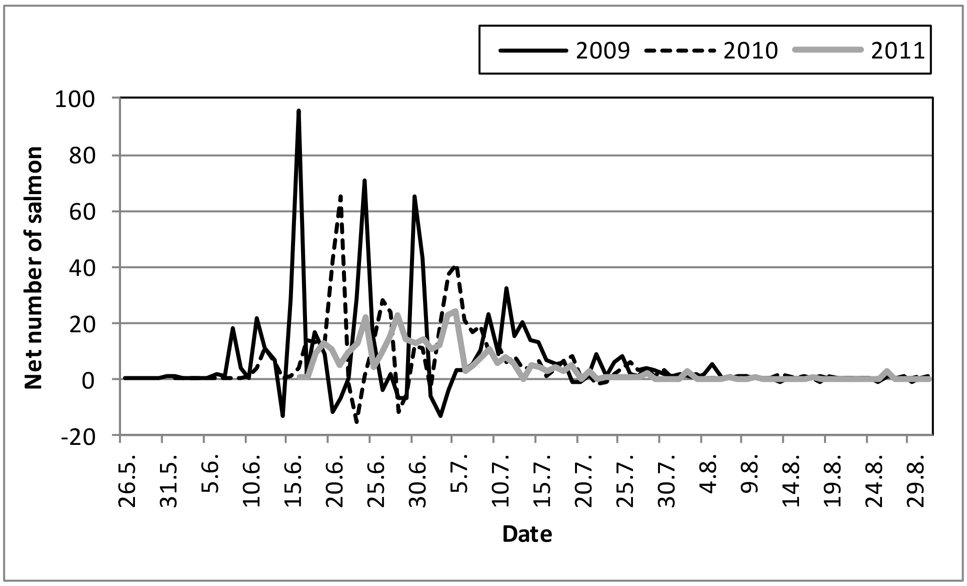

Figure 3. Daily net numbers of salmon observed in the River Lákšjohka in 2009-2011. Daily net numbers are counted by subtracting daily negative (salmon down) numbers from the daily positive (salmon up) numbers. See table 1 for monitoring periods.

3.1.2. Sea-age distribution

The sea-ages of ascending salmon were not determined from the video material in 2009-2010. For these two years the sea-age distribution of the ascending salmon population was estimated by using the sea-age distribution of the recreational (rod and line) salmon catch assuming that fish <3 kg were 1SW salmon and fish >3 kg were 2SW salmon (or repeat spawners). This approach, however, probably cause some small 2SW and 1S1 repeat spawning salmon to be misclassified as 1SW salmon (FGFRI, unpublished data; Morten Falkegård, personal communication). In 2011 sea-ages were also estimated from the video material itself (Table 2).

One-sea-winter (1SW) salmon clearly dominated the ascending population in Lákšjohka in 2009-2011 (Table 2). The proportion of 2SW salmon varied between c. 5 % and 10 % (Table 2). In 2011 the two different estimating methods produced rather similar sea-age distributions (Table 2).

Table 2. The sea-age (1SW=one-sea-winter; 2SW=two-sea-winter) distributions (n, %) of the ascending salmon population in Lákšjohka in 2009-2011. The estimates in 2009-2010 are based on catch statistics (fish < 3 kg classified as 1SW salmon) and in 2011 both the catch statistics and video analysis were used to produce the sea-age distribution estimates.

Year	Net amount	1SW	2SW	Method
2009	587	533 (90,72 %)	54 (9,28 %)	Catch stat.
2010	485	459 (94,57 %)	26 (5,43 %)	Catch stat.
2011	336	313 (93,10 %)	23 (6,90 %)	Catch stat.
2011	336	316 (94,05 %)	20 (5,95 %)	Video analysis

3.1.3. Spawning population and exploitation rate

Net amount of ascending salmon together with salmon catch data provided by County Governor of Finnmark were used to calculate the sizes of the spawning population (Table 1) and in-river exploitation rates. Without natural mortality taken into account the estimated spawning population size varied between c. 220-400 individuals in 2009-2011 (Table 1). The numbers of larger, 2SW individuals in the spawning population was estimated to vary between c. 15-36 individuals during the same time period.

Estimated in-river exploitation rates in 2009-2011 were 33.0%, 26.6% and 34.5%, respectively. The exploitation rate of 2011 is an over-estimate because some ascending salmon was most probably missed during the first half of June, when the video cameras could not be used.

3.2. Smolts

3.2.1. Smolt numbers

The numbers of descending smolts varied significantly during the study years and extremely low smolt numbers were observed in 2011 (Table 3). Although the video monitoring was started later in 2011 than in other study years, this is probably not explaining the observed low smolt numbers in 2011 as the migration activity started to increase at 20th June, several days after the installation of the underwater cameras.

Table 3. Numbers and timing of the River Lákšjohka salmon smolt migration in 2009-2011. Median date is the day when 50 % of smolts have passed the monitoring site (Q_1=25 %; Q_3=75 %).

Year	Numbers	Median date	Q_1 Date	Q_3 Date
2009	1682	1.7.	26.6.	10.7.
2010	2105	30.6.	26.6.	6.7.
2011	901	25.6.	22.6.	28.6.

3.2.2. Migration timing and behaviour

The smolt migration started annually at mid-June and it continued active about one month (Fig. 4). In addition to the low smolt numbers in 2011 the active migration period was clearly shorter in 2011 compared to 2009-2010 (Fig. 4, Table 3). There were 2-3 separate migration peaks in 2009-2010, but in 2011 the activity peaked only once (Fig. 4).

Smolts migrated actively throughout the day, although there was a slight tendency of maximum activity during daytime, specifically between 10:00 and 19:00 (Fig. 5, Finnish time zone). Least active migration was observed between 00:00-04:00 (Fig. 5). The Lákšjohka smolts descended individually or in small schools with mostly less than 5 fish. The largest smolt school included only 35 individuals.

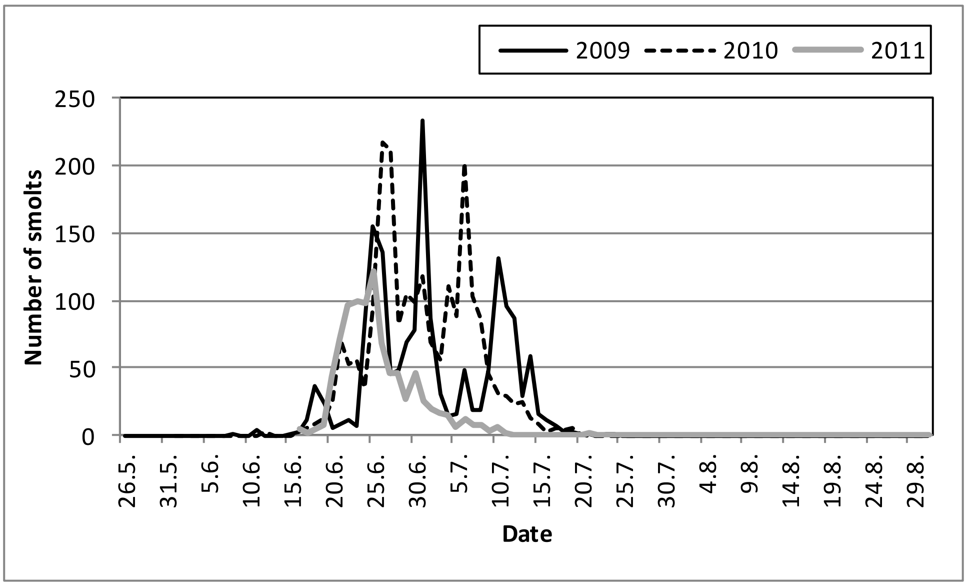

Figure 4. Daily numbers of salmon smolts observed descending past the monitoring site in 2009-2011.

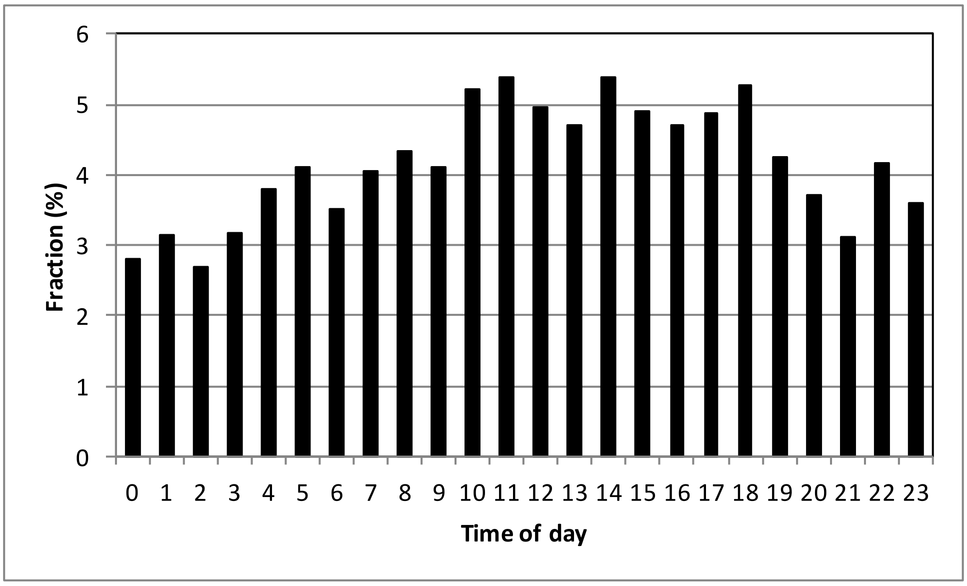

Figure 5. Hourly migration pattern (% from all observed smolts, n=4688) of the River Lákšjohka smolts in 2009-2011.

4. Discussion and conclusions

4.1. Adult salmon

4.1.1. Numbers of salmon and exploitation rates

According to the biological reference point set to River Lákšjohka (c. 1100 spawning female salmon individuals) by Hindar et. al. (2007) the annual numbers of ascending salmon counted were rather low.

Overall, the River Lákšjohka and its tributaries represent a relatively large watershed suitable for adult salmon (appendix 1). The best and most important spawning areas are, however, concentrated rather far upstream from the river mouth and the lower 9 km below the Lákšjohgorži waterfall are less optimal for reproduction and juvenile rearing (see appendix 1).

In autumn 2010 some areas of the Lákšjohka main tributary, Deavkkehanjohka, were electrofished by FGFRI personnel (Orell 2011). The electrofishing results showed that salmon are using the reproduction areas upstream from the waterfall. The densities of salmon fry (0+) and parr (≥1+) found from the headwaters were, however, quite low and especially low when considering only 0+ and 1+ age-classes (Orell 2011). These results supports the findings of the video monitoring, namely low annual spawner numbers at least during the last few years.

It is unclear how well salmon are able to overcome the Lákšjohgorži waterfall/fish ladder and continue their migration to the headwater spawning areas. Local observations (e.g. Kjell-Magne Johnsen, personal observations) from earlier years, however, indicate that salmon do not have any major problems to overcome the waterfall via the fish ladder. No quantitative data, however, is available on this issue and future studies should include an efficacy estimation of the Lákšjohgorži fish ladder.

The low salmon numbers in Lákšjohka in 2011 was somewhat surprising, as most of the other Tana tributaries showed a clear increase in adult salmon numbers, including the River Utsjoki (see appendix 2). This may be partly explained by the late installation of the Lákšjohka video cameras, causing some early running salmon to be missed. It is, however, unlikely that a large proportion could have been missed during the first half of June, as in 2009 and 2010 only c. 14 % and 4 % of salmon were observed to ascend during this time period, respectively.

Overall, the 1SW salmon stocks of the River Tana watershed have been at rather low levels since 2006 and most probably this holds true also for Lákšjohka. It is known that the Tana 1SW stock sizes can fluctuate with a factor of 4-6 (Orell, unpublished data). This means that in peak years the numbers of ascending salmon could reach c. 1500-2000 individuals in the River Lákšjohka.

Estimated in-river fishing exploitation rates (c. 30 %) were high considering the fairly low numbers of fishermen. E.g. in 2009 the number of salmon caught were almost similar with the number of fishing days sold. This is a clear indication that environmental and physical characteristics (waterfalls and cascades, Fig. 6) of the River Lákšjohka make salmon relatively vulnerable for rod and line fishing for extended periods. A good example is the lower 1 km of the river where several small waterfalls make the salmon accumulate to small pools below the waterfalls (Orell, personal diving observations), which are easily fished by recreational fishermen (Fig. 6).

Figure 6. Waterfalls and small cascades are typical at lower part of the Lákšjohka main stem. Ascending salmon are accumulating to the pools below the falls and cascades. Photo: P. Orell.

4.1.2. Migration timing

Adult salmon started to enter the River Lákšjohka early in the season, around mid-June, and the migration activity significantly decreased in Mid-July in all three study seasons. Based on genetic stock analysis, Lákšjohka salmon are one of the earliest 1SW stocks entering the River Tana system (Vähä et al. 2011). The migration timing of adult salmon observed in the video monitoring harmonizes well with the findings of Vähä et al. (2011). Thus, it seems evident that salmon enter Lákšjohka without any major pauses in the confluence area of Tana and Lákšjohka itself.

Similar migration "window" has been observed in the long-term video monitoring study in the River Utsjoki during 2002-2011 where one-sea-winter salmon migration activates annually at mid-June and decreases heavily after mid-July (Orell et al. 2007; Orell, unpublished data). Thus, the active migration season of 1SW tributary populations of the River Tana are extremely short and annually concentrated to a same period (see also Vähä et al. 2011). This stable migration pattern gives possibilities for fisheries management, e.g. when considering time restrictions to a fishery.

4.2. Smolts

4.2.1. Smolt numbers

Compared to the estimated smolt production potential (19939 smolts, see Hindar et. al. 2007) the annual smolt counts produced very low smolt production estimates for the Lákšjohka watershed in 2009-2011. Based on these smolt counts the sea-survival of 1SW salmon in 2010-2011 (smolt cohorts 2009-2010) were around 20 %, which is a high survival rate. Similar sea-survival level has been observed in the Utsjoki video monitoring (c. 10-20 %; Orell, unpublished data).

It is clear that the smolt counts are minimum estimates of the true smolt run, but large-scale missing of descending smolts in the video monitoring seems very unlikely in Lákšjohka. The monitoring site is narrow (< 10 m), rather shallow and water is clear; four cameras easily cover the whole migration channel. Video recording (more fields recorded/sec.) and video analysis (lower analysing speed) are also tuned to increase observation efficiency of smolts during the main smolt migration period (from mid-June to mid-July). The habit of smolts descending individually past the monitoring site may, however, decrease the observing efficiency compared to situations where smolts migrate in schools.

It is also possible that some of the Lákšjohka salmon parr or pre-smolts migrate to the mainstem of the River Tana before (either fall or spring) the actual smoltification process and migration to the sea. This kind of phenomenon has been observed e.g. in some Scottish and Canadian salmon rivers (Youngson et al. 1982, Cunjak et al. 1989, McCormick et al. 1998 and references therein). Documented observations on this phenomenon have not been done in the Tana watershed.

On the basis of the smolt numbers in 2010 and 2011 it is expected that the adult salmon run to Lákšjohka in 2012 should be fairly low.

4.2.2. Migration timing and behaviour

The Lákšjohka smolt migration lasted c. one month from mid-June until mid-July, which matches well with the observations on smolt migration in the River Utsjoki (Orell et al. 2007; Orell unpublished data).

Lákšjohka smolts migrated in very small schools or individually. This is a clear contrast to the River Utsjoki, in which schools of more than 100 individuals are observed annually and the mean school size is normally between 10 and 20 individuals (Orell, unpublished data). It seems that either the overall smolt numbers area too low or on the other hand the riverine conditions (e.g. heavy waterfalls and rapids, Fig. 6) do not favour large-scale schooling of smolts in Lákšjohka.

4.3. Future directions and management options

Underwater video counting of adult salmon and smolts has proved as an effective monitoring method in the River Lákšjohka. Reliable information on stock status and smolt production can be collected with reasonable effort. Electricity is easily arranged and the monitoring site is logistically well situated and can be reached by car (c. 30 km from the FGFRI research station in Utsjoki). Thus, the River Lákšjohka is an ideal index-river of the lower Tana area, representing a typical 1SW salmon population.

Underwater video counts together with comprehensive electro fishing surveys and spawner counts (e.g. by snorkeling) in the River Lákšjohka, its tributaries and headwaters could give a more profound view of the ecological characteristics and annual variation of the salmon population inhabiting the watershed. Accurate information on the annual salmon catches and fishing effort should also be available for the estimation of spawning stock size and fishing exploitation rates. Overall, continuing the Lákšjohka and Utsjoki video counts would greatly contribute to assessment of the status of the River Tana salmon stocks and to ensure biologically sound management decisions in long term.

The high in-river exploitation of adult salmon and the low smolt production of the River Lákšjohka combined with the large size of the watershed indicate that fisheries management measures are needed to enhance the salmon production to higher levels. The spawner reference (gytebestandsmål) level for Lákšjohka is set to c. 1100 female salmon with a 1,5 kg mean weight (Hindar et al. 2007). Although this reference level may have been set too high (Lákšjohka egg deposion needs estimated at 4 eggs/m^2, whereas in some other Tana tributaries egg deposition needs are only estimated at 1-2 eggs/m^2; see Hindar et al. 2007), the recent spawner levels have been only a small fraction of the reference level.

There are several optional management measures to enhance the salmon population in Lákšjohka and some of them are presented below:

- Total prohibition of the rod and line fisheries
  This would eliminate totally the exploitation and increase the spawning stock c. 30 % in short term

- Fishing day quotas, e.g. 2 licenses/day
  This would decrease the fishing effort at the peak salmon season and lead to lower exploitation levels, especially when combined with a fish/day rule (only one fish allowable to kill/day/fisherman).

- Small restricted areas below the waterfalls (in the lower 9 km of the river)
  10-50 m long protected pools below the most important waterfalls and cascades could decrease the fishing exploitation significantly, but would leave most of the river (c. 90-95 %) unrestricted.

- Upper size limit of allowable catch, e.g. 60 cm
  This option would save the nowadays small 2SW stock component, especially the largest females, from fisheries exploitation and slightly increase the annual egg-deposition. This would also be important for the long-term existence of the 2SW/repeat spawner stock component in Lákšjohka.

The aforementioned management options could be implemented singly or in a combination. In addition to the possible management measures that could be implemented to the River Lákšjohka fisheries the management of the tributary salmon populations is also largely linked to the fisheries of the mainstem Tana. For example in mid-July 2010 there were >100 weirs and gillnets in use between the Tana estuary and Storfossen (Johnsen 2011). Large scale rod and line fishing in the mainstem Tana is also harvesting the tributary salmon populations, including the River Lákšjohka salmon.

Genetic stock analysis of the lower Tana salmon catch could reveal patterns, which could be used in safeguarding the small tributary populations, e.g. those of the River Lákšjohka. The genetic analyses of the Tana mainstem catches are being conducted in the GenMix-project (partners: NINA, University of Turku, and FGFRI) and these results should be analysed and available for fisheries managers and authorities during 2012.

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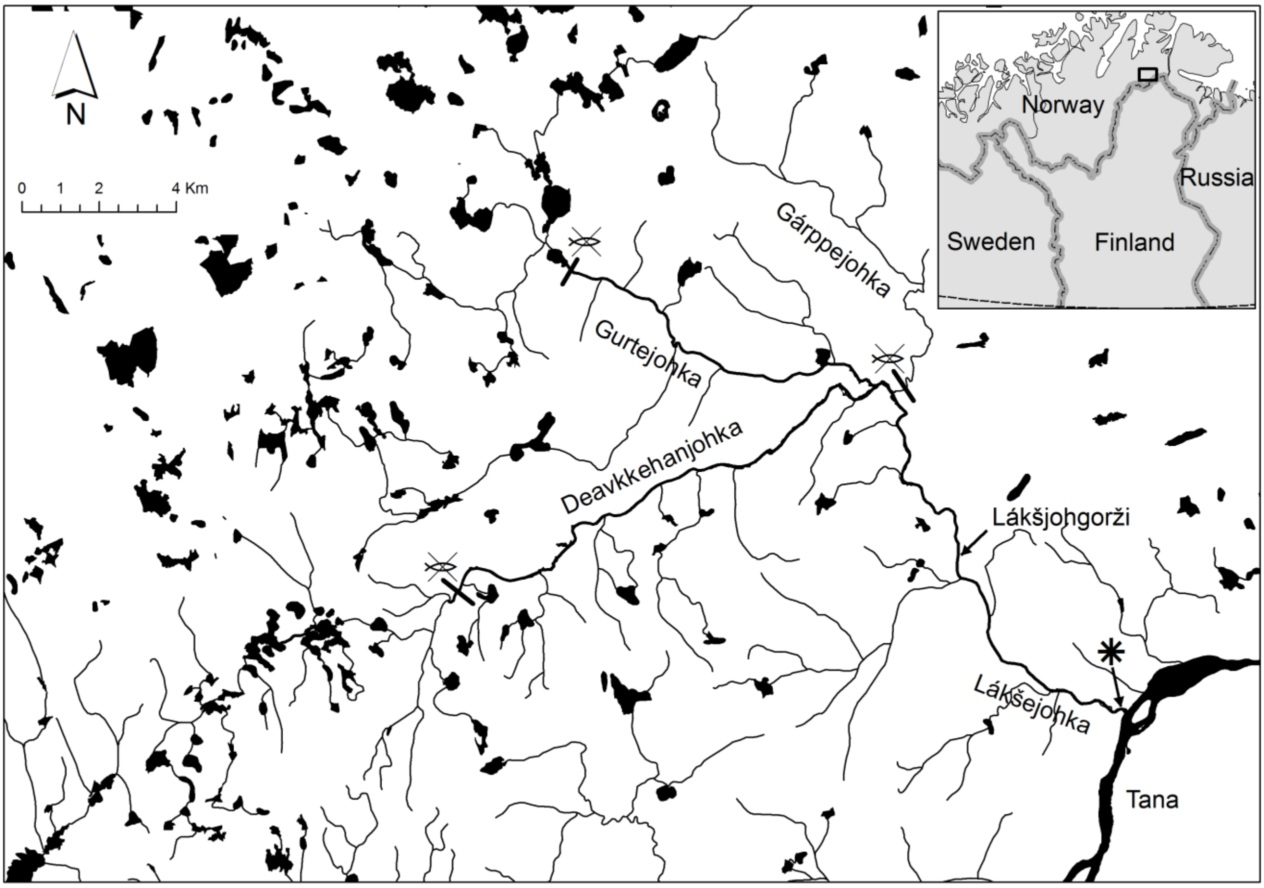
Appendixes

Appendix 1. The map of the River Lákšjohka watershed indicating the location of the video monitoring site (star), Lákšjohgorži waterfall and the estimated regular distribution area (fish symbol and line) of adult salmon (salmon distribution area: K-M. Johnsen).



Appendix 2. The observed adult salmon numbers in the rivers Utsjoki and Lákšjohka in 2003-2011 as inferred by underwater video monitoring.