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Video monitoring of the River Neidenelva salmon and sea-trout migrations in 2006-2011

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Abstract An underwater video monitoring study for counting adult salmon and sea-trout numbers was conducted in 2006-2011 in the Skoltefossen rapids at the River Neidenelva. The main aim of the study was to evaluate the effectivity of the Skoltefossen fish ladder and the significance of natural migration routes (straight through the waterfall) for salmon migration. The fish ladder was found as an important migration route for small sized salmon (one-sea-winter, 1SW) and sea-trout, and annually c. 2000-4400 salmon and c. 400-700 sea-trout individuals ascended via the fish ladder. Larger salmon individuals (multi-sea-winter, MSW) were found to ascend more frequently straight through the waterfall itself, close to the southern shoreline of the Skoltefossen rapid. Changes in discharge was observed to affect the migration activity of salmon at Skoltefossen, high discharge peaks caused significant migration depressions in both the fish ladder and at waterfall itself. Overall, the river stretch below the Skoltefossen waterfall is one of the key areas regarding the management of the River Neidenelva salmon populations. Alternative management measures for enhancing the salmon production are presented.			
Keywords Salmon, sea-trout, underwater, fishway, Neidenelva, Skoltefossen, management			
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Nousuvaelluksellaan olevien lohien ja meritaimenien määrää selvitettiin Näätämöjoen Kolttakönkäällä vuosina 2006-2011 hyödyntäen vedenalaista videoseurantaa. Videoseurannan päätavoitteena oli arvioida Kolttakönkään kalatien toimivuutta sekä selvittää suoraan Kolttäkönkään läpi uivien kalojen määriä ja kokojakaumaa. Seurantatulosten perusteleella Kolttakönkään kalatie on tärkeä vaellusreitti erityisesti pienille yhden merivuoden lohille ja meritaimenille. Vuosittain kalatietä havaittiin käyttäneen 2000-4400 lohta ja 400-700 meritaimenta. Isompien, useamman merivuoden lohien havaittiin nousevan merkittävissä määrin myös suoraan putouksen läpi, joen etelänpuoleisen rannan tuntumasta. Virtaamien muutokset Kolttakönkäällä vaikuttivat lohien nousuaktiivisuuteen, voimakkaat virtaamapiikit aiheuttivat merkittävää vaelluksen pysähtymistä sekä kalatiessä että itse könkäässä. Kokonaisuudessaan Kolttakönkään alapuolinen jokialue on keskeisessä asemassa Näätämöjoen lohikantojen tulevaisuuden turvaamisessa sekä lohikantojen hoitoa suunniteltaessa. Erilaisia lohenkalastuksen säätelyvaihtoehtoja esitetään Näätämöjoen lohentuotannon ja lohikantojen tilan parantamiseksi.			
Asiasanat			
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Contents

1. Introduction

The River Neidenelva (Näätämöjoki in Finnish, drainage area 2962 km^2) is one of the most important Atlantic salmon (Salmo salar) rivers in Norway and Finland with annual in-river catches varying between 3 and 16 tonnes (1972-2010, mean catch 8.5 t). Salmon ascends the river up to the Lake Iijärvi, c. 80 km upstream from the river mouth. In addition to the mainstem, salmon populates the tributaries Silisjoki and Kallojoki (Fig. 1, Niemelä et al. 2001). Most of the salmon production areas (c. 75 %) are situated on the Finnish side of the watershed (Erkinaro et al. 2000), although the river flows the lowermost 30 km in Norway.

In addition to Atlantic salmon, the River Neidenelva is also an important sea-trout (Salmo trutta) river. Sea-trout is mainly occupying the lower reaches of the watershed including some tributary rivers, e.g. the River Nuortijoki (see Fig. 1). Annual sea-trout catches in the Norwegian part of the River Neidenelva have recently (2007-2011) varied between 300 and 400 kg (see www.scanatura.no).

A strong waterfall, Skoltefossen, is located c. 12 km upstream from the sea on the Norwegian part of the River Neidenelva (Fig. 1). This waterfall has been estimated to hinder the upstream migration of salmon and sea-trout. Based on bilateral agreement between Finland and Norway in 1951, a fish ladder was built to Skoltefossen waterfall in 1968 to enhance the passage of adult salmon and sea-trout.

The efficiency of the Skoltefossen fish ladder has been studied occasionally by using underwater video monitoring techniques. The most recent efficacy studies have been conducted in 2002-2003 (by Lamberg Bio-Marin), 2006 and 2009-2011. In 2011, one additional video camera was also tested above the Skoltefossen waterfall to study the proportion and size-distribution of salmon ascending straight trough the waterfall.

Since 2006 the video monitoring of the Skoltefossen fish ladder has been conducted by the Finnish Game and Fisheries Research Institute (FGFRI). The main funding of the video monitoring has been arranged by the County Governor of Finnmark (FMFI) and Norwegian Directorate for Nature Management (DN) and FGFRI. FGFRI has provided the video equipment and Neiden Fiskefelleskap has organized the electricity and helped with maintenance of the video system.

This working report presents the most important results from the video monitoring studies conducted since 2006 in the Skoltefossen fish ladder and in the waterfall itself.

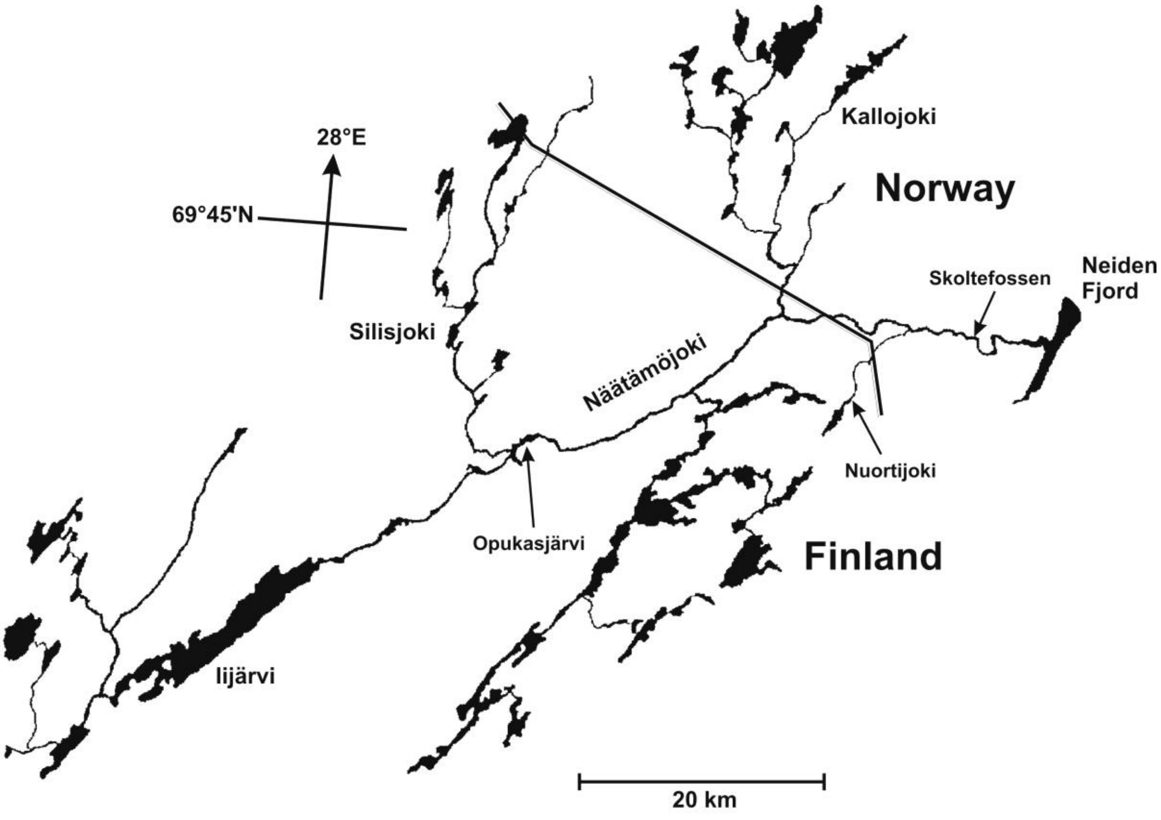

Figure 1. The map of the River Näätämöjoki (Neidenelva in Norwegian) watershed.

2. Material and methods

2.1. Video monitoring procedure

One underwater camera (Camera: Watec, WAT-902 H, housing: custom made by Lamberg Bio-Marin) with a 3.5 mm wide angle lens was installed above the last pool of the fish ladder in each study year (Fig. 2). The camera was placed on the right side of the fish ladder (looking from the upstream) and the camera view covered fully the migration route of fish passing the fish ladder and ascending to the natural river channel.

In 2011, an additional underwater camera (model same as above) was installed just above the waterfall, to the opposite river bank from the fish ladder (Fig. 3). The site selection of this camera was based on traditional knowledge and visual observations about salmon migration routes. Most of the salmon ascending straight through the waterfall is supposed to pass close to the southern shoreline.

All video data was saved to 400-500 GB hard disks by using SANYO DSR-300P digital video recorder. The data was saved at “enhanced” quality with a recording rate of 2.72 or 3.13 fields/second. Artificial illumination, a 50 W underwater halogen light was used at the video monitoring site during August to compensate the low natural illumination at nights (Fig. 4).

Figure 2. Installation of the underwater camera and halogen light (arrow) above the Skoltefossen fish ladder in the River Neiden. Photos: P. Orell.

The video monitoring was started annually at early-mid June and the data collection was continued at least to the end of August (Table 1). The annually monitored period covered efficiently the salmon migration "window" and a significant part of the sea-trout migration. The monitoring above the waterfall in 2011 took place between 1st July and 6th August.

2.2. Video analysis

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

The observed salmon were classified into three different size categories including 1SW (one-sea winter, salmon <65 cm), 2SW (two sea-winter, salmon 65-90 cm) and MSW (multi-sea winter, salmon >90 cm) salmon. The sea-trout included all trout that were estimated to be ≥ 30 cm in length. The size estimation of the fish was based on subjective determination, and therefore they may not be fully accurate in all cases.

Figure 3. Installation of the underwater camera tested in 2011 above the waterfall, opposite to the fish ladder. The arrow indicates the location of the camera and the transparent triangle is roughly illustrating the camera view. Photo: P. Orell.

Figure 4. Stability of the underwater video camera (right) and halogen light (left) was secured by using 20 kg weighing pedestals. Photo: P. Orell.

3. Results

3.1. Salmon ascendance at the fish ladder

The numbers of salmon passing the Skoltefossen fish ladder varied between c. 2000-4400 individuals during the study periods in 2006-2011 (Table 1). In 2002-2003 the numbers of salmon were somewhat lower (Table 1), although the years are not fully comparable, because of different monitoring approaches (mechanical triggering of the videomonitoring) and missed days (pauses in the monitoring) in 2002-2003 compared to the more recent years.

Most of the salmon passing the fish ladder were classified as 1SW fish (Fig. 5). The proportion on larger (2SW+MSW) salmon varied between c. 10 % and 30 % (Fig. 5).

Table 1. The numbers of salmon and sea-trout passing the Skoltefossen fish ladder in 2002-2003, 2006 and 2009-2011 and the time-periods when the video monitoring was conducted. In 2002-2003 the monitoring period included some days when the video system was not operating. Data from 2002-2003 is provided by Lamberg Bio-Marin (Norway).

Year	1SW	2SW	MSW	Total	Sea trout	Undefined*	Monitoring period
2002	1048	294	108	1450	304	243	17.6.-17.8.
2003	1184	158	67	1409	240	11	9.6.-31.8.
2006	3616	667	133	4416	470	0	7.6.-31.8.
2009	1681	229	30	1940	524	0	15.6.-31.8.
2010	2544	276	21	2841	433	2	1.6.-31.8.
2011	2084	334	38	2456	714	15	7.6.-31.8.

*= Fish that could not be classified to species or to sea-age

The salmon migration at the fish ladder activated yearly at late June-early July and it continued active to early-mid August, when the numbers of salmon decreased significantly (Fig. 6). The median date (50 % of salmon passed the ladder) of salmon migration varied between 19th and 23rd July in 2006-2011. In each study year the migration activity peaked several times (2-6 peaks/year), e.g. in 2006 six clear activity peaks was observed (Fig. 6). Maximum daily ascendance varied between 101 (in 2009) and 190 (in 2006) individuals.

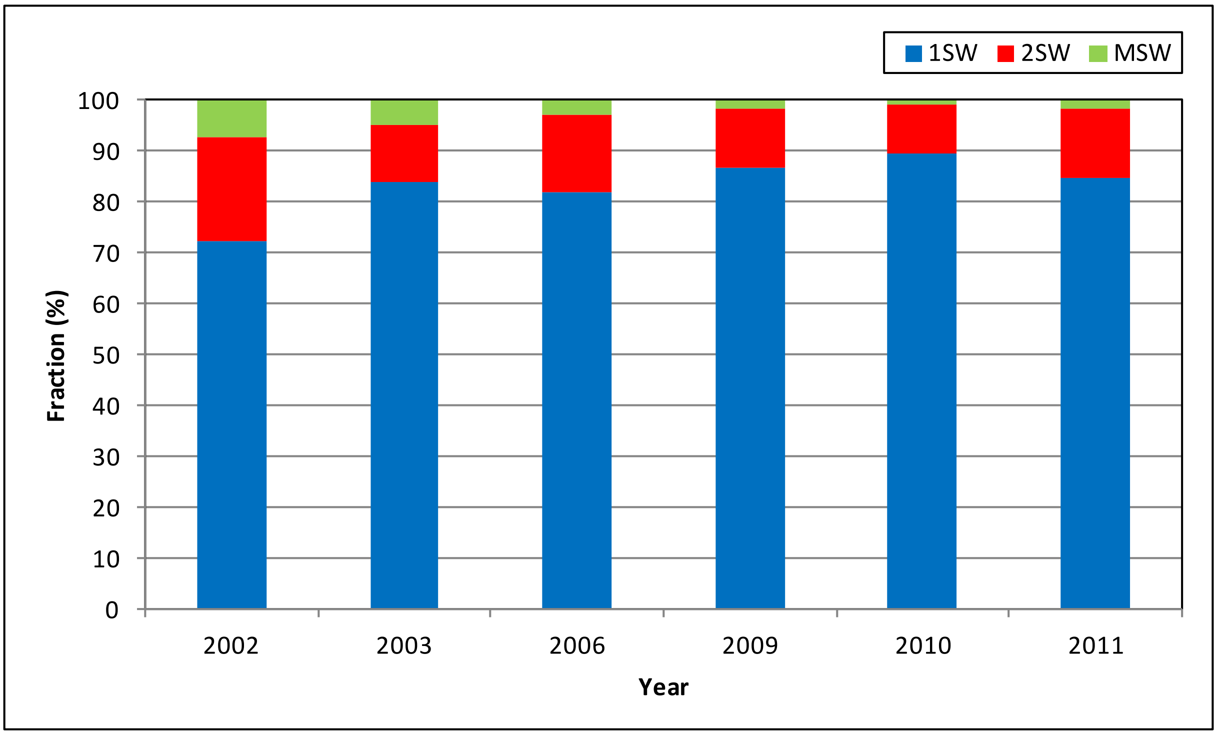

Figure 5. The estimated percentage (%) distribution of salmon sea-age groups at the Skoltefossen fish ladder in 2002-2003, 2006, 2009-2011.

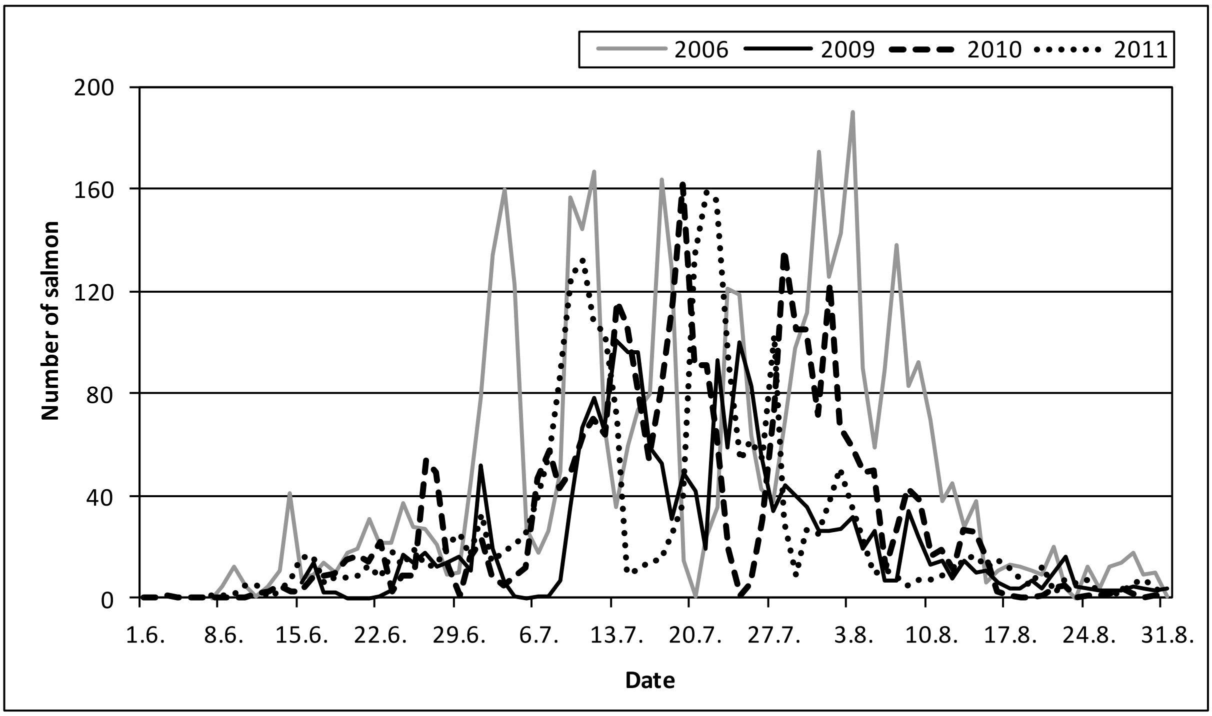

Figure 6. The daily numbers of salmon ascending the Skoltefossen fish ladder in 2006 and 2009-2011 during June-August. Note: monitoring periods in different years are slightly different from the beginning of the season (see Table 1.).

3.2. Sea-trout ascendance at the fish ladder

The numbers of sea-trout passing the Skoltefossen fish ladder was rather stable during the study years, although a slight increase in 2011 was evident (Table 1).

The migration activity of sea-trout was low until late July, when the numbers of migrants increased significantly in all four study years (Fig. 7). In 2006 and 2009-2010 the sea-trout migration was most active between late-July and mid-August, but in 2011 the peak activity was observed slightly later (Fig. 7). It is clear, however, that the migration of sea-trout continues also in September, as was observed in 2010, when the video monitoring was conducted until 11th September (Figs. 7-8). This implies that the estimates presented until the end of August clearly underestimates of the true sea-trout ascendance via the fish ladder.

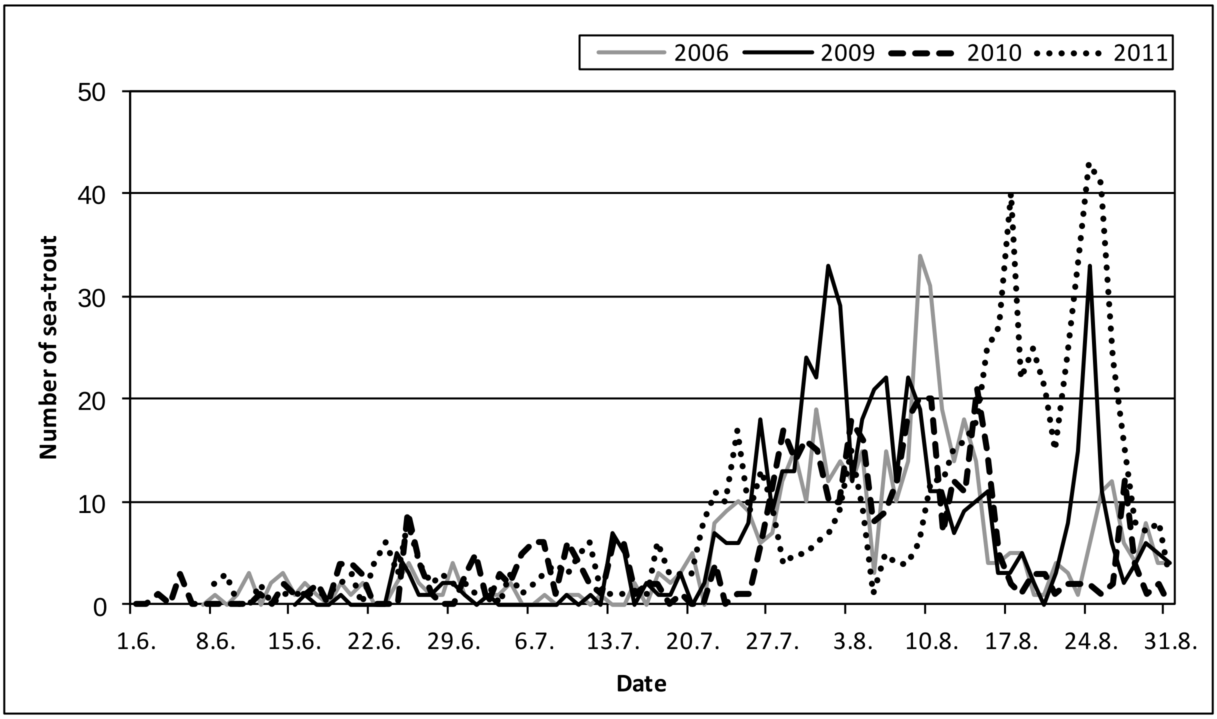

Figure 7. The daily numbers of sea trout (≥ 30 cm in length) ascending the Skoltefossen fish ladder in 2006 and 2009-2011 during June-August. Note: monitoring periods in different years are slightly different from the beginning of the season (see Table 1.).

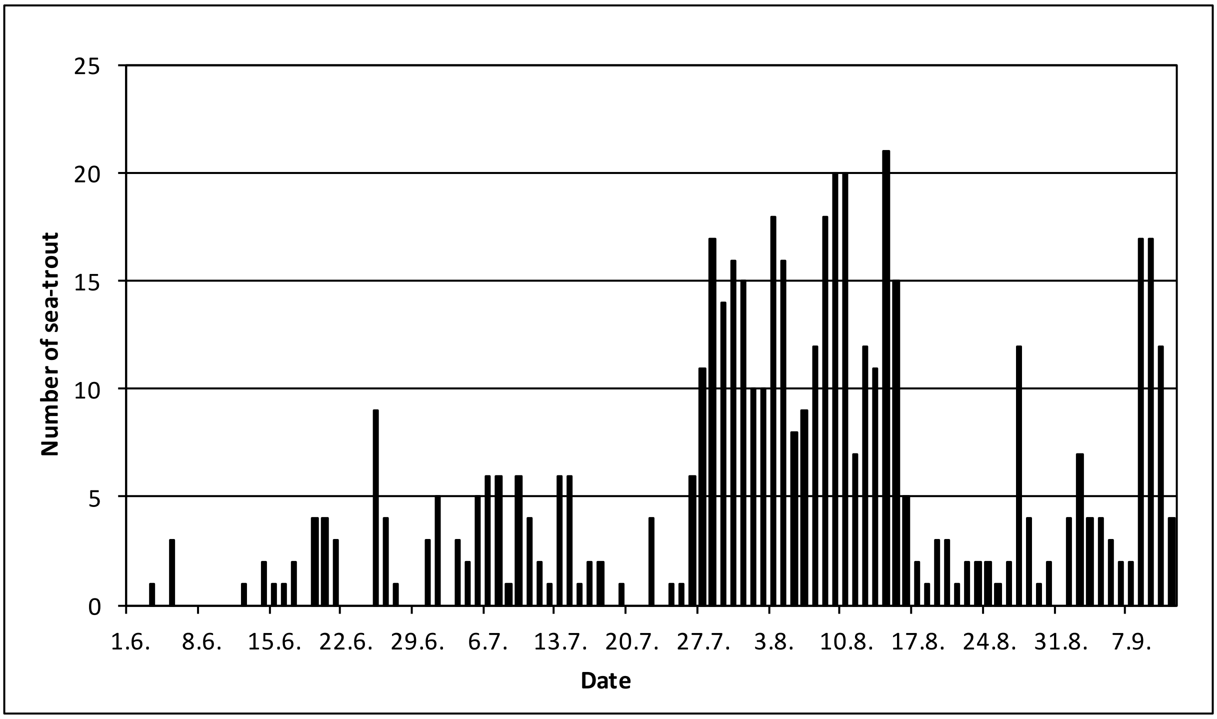

Figure 8. The daily numbers of sea trout (≥ 30 cm in length) ascending the Skoltefossen fish ladder during 1.6.-11.9.2010.

3.3. Migration of fish through the waterfall in 2011

In total 552 salmon individuals were observed to pass straight through the Skoltefossen waterfall within the camera coverage area (c. 3 m) between 1st July and 6th August 2011 (Fig. 9, see also camera setup: Fig. 3). Migration peaked at late July and there was only one day when salmon were not observed to ascend (15.7.).

Salmon ascending straight through the waterfall were significantly larger than salmon observed passing the fish ladder (Fig. 10). Waterfall passing salmon were mostly 2SW and MSW fish, whereas 1SW salmon clearly dominated the fish ladder migrants (Fig. 10). In total 614 large salmon (2SW+MSW) were observed in the two video cameras during 1.7.-6.8., and out of these c. 65% used the natural migration route, while only 35% ascended via the fish ladder. Out of the 1958 one-sea-winter salmon only 8% used the natural migration route (waterfall) and the rest passed via the fish ladder.

In addition to salmon, 17 sea-trout individuals were counted during the monitoring period. This, however, was only <9% of the numbers counted at the fish ladder during the same time. Two fish individuals couldn't be determined to species.

Most of the observed fish ascended the Skoltefossen waterfall very close to the southern river bank, being easily counted and specified by the installed video camera (see Fig. 3). Some individuals, however, seemed to ascend more apart from the river bank and it is likely that a fraction of fish may overcome the waterfall outside the camera coverage area (see Fig. 3).

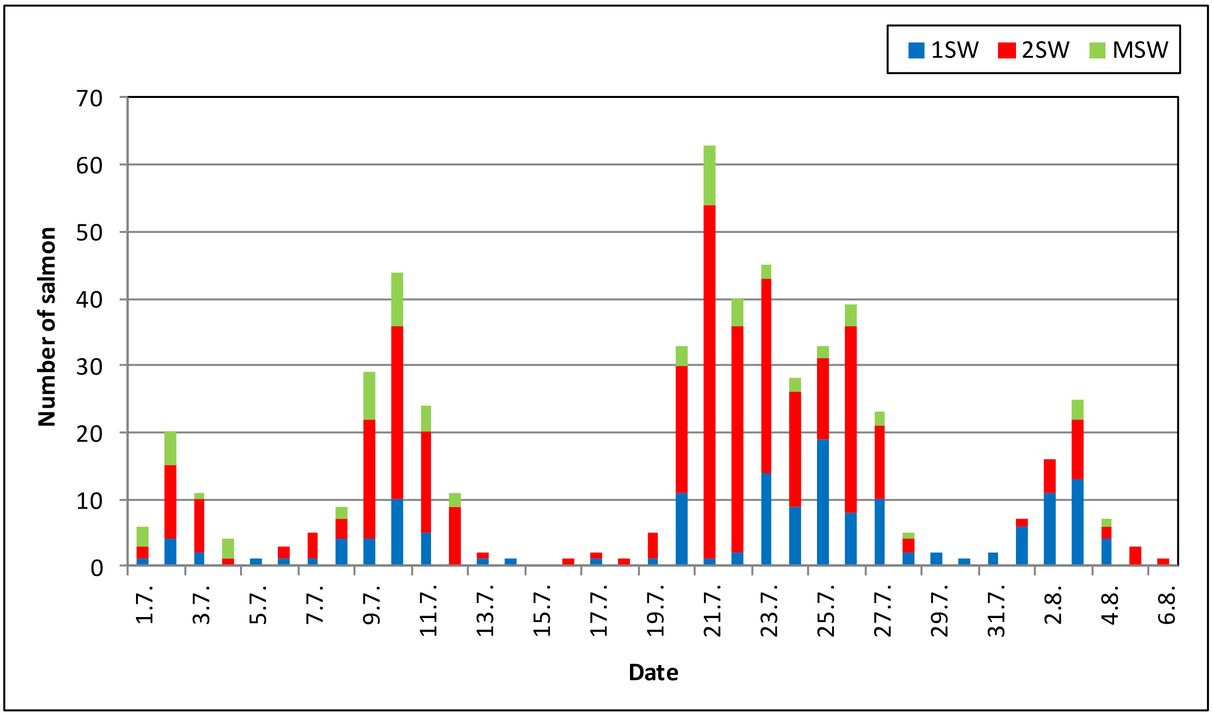

Figure 9. The daily numbers of 1SW, 2SW and MSW salmon ascending straight through the Skoltefossen waterfall in 1.7.-6.8.2011.

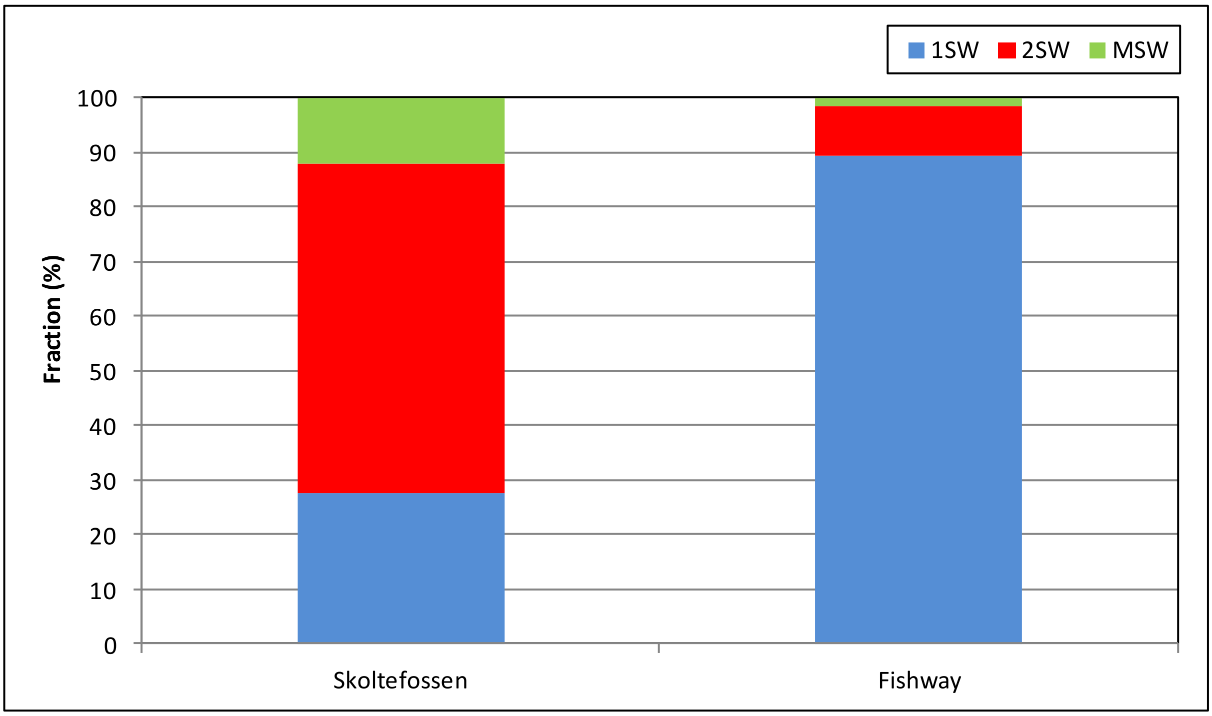

Figure 10. The estimated percentage (%) distribution of salmon sea-age at the fishway (n= 2020) and at the Skoltefossen waterfall (n=552), opposite to the fishway in 1.7.-6.8.2011.

3.4. Discharge is affecting the passing of Skoltefossen

Salmon count data together with daily discharge data (Norwegian Water Resources and Energy Directorate, NVE) were used to search possible effects of changing flow on salmon passage at Skoltefossen.

It was observed that rapid increases in river flow cause a significant depression in the migration activity both in the fish ladder and trough the waterfall itself (Fig. 11). In 2011, the migration depressions lasted from few days to c. one week (Fig. 11). If there are several rapid discharge peaks during the salmon migration season, the daily salmon numbers seem to fluctuate heavily, whereas during years with more stable discharges the daily salmon counts appear to fluctuate to a lesser extent (see appendix 1). It seems that discharge level (at least with discharges < 60 m^3/s) itself is not so important in regulating salmon migration activity, but increases and on the other hand decreases in flow are the main regulating factors (see Fig. 11 and appendix 1).

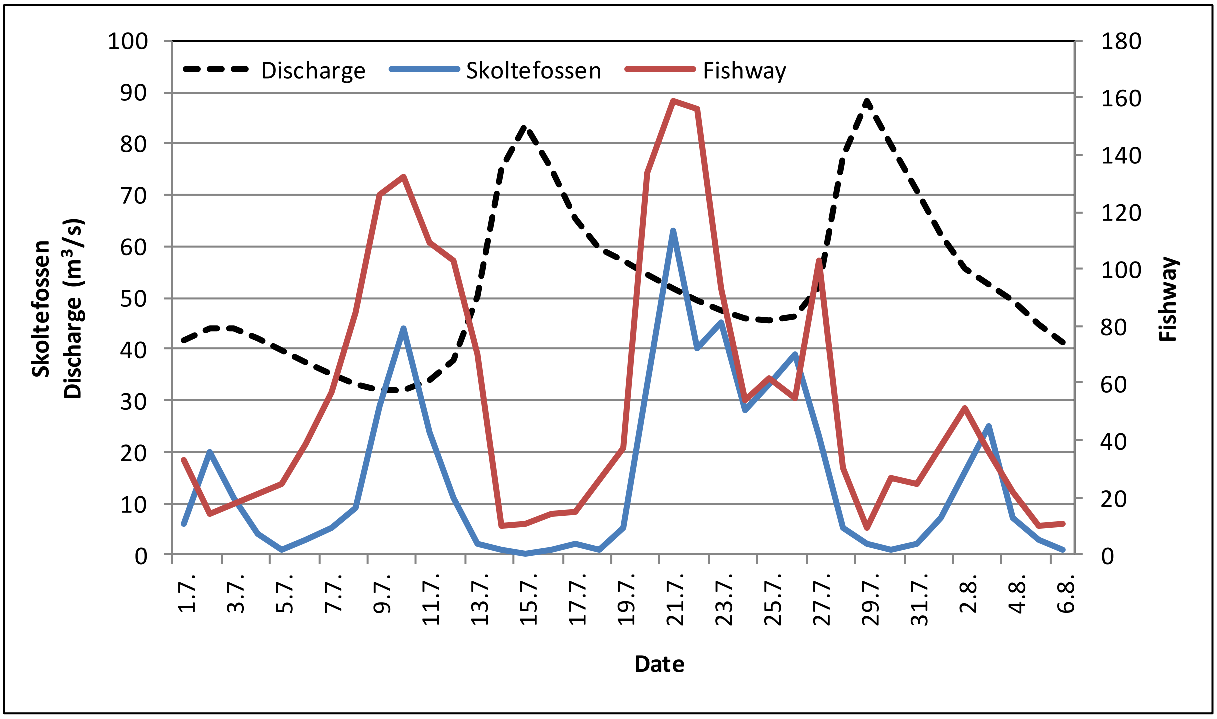

Figure 11. The daily number of salmon observed passing through Skoltefossen fish ladder (red line) and through waterfall itself (blue line) in relation to the daily discharges (dashed black line) in 1.7.-6.8.2011.

4. Discussion and conclusions

4.1. Migration via the fish ladder

The Skoltefossen fish ladder is actively used by both salmon and sea-trout on annual basis and it is evident that the ladder is an important migration route to overcome the waterfall. The fish ladder is especially important for small-sized salmon individuals (1SW) and sea-trout, which are using this migration route most frequently. Larger salmon (2SW and MSW) individuals are more frequently ascending straight through the waterfall itself (see section 4.2.).

The timing of salmon ascendance through the fish ladder seems rather late. For example in the Tana tributaries Utsjoki and Laksjohka, the active migration period is normally between mid-June and Mid-July (Orell et al. 2007; Orell, unpublished data) c. 2-3 weeks earlier than in the Skoltefossen fish ladder. The late passage of salmon at the fish ladder indicates that the waterfall hinders the upstream migration of salmon. If salmon are stopped below the Skoltefossen waterfall, the population may suffer from high fishing mortality as the area is intensively fished by both recreational fishermen (rod and line) and local people using the traditional cast seine (käpälä).

Migration of sea-trout activates later in the season than salmon migration and it is clear that the sea-trout migration season continues also in September. This phenomenon has been observed in several other river systems elsewhere in the Barents Sea region (e.g. in Tana) and in many cases the sea-trout fisheries is permitted longer than the salmon fisheries. As the migration of sea-trout is concentrated to August-September, the exploitation rate may be significantly lower compared to salmon as the fishing effort in Neiden is usually decreasing in late-summer period and the permitted fishing season finishes at end of August. Continuation of sea-trout fishery in autumn (e.g. until 20th September) is thus possible.

4.2. Migration through the waterfall

The video monitoring in 2011 gave valuable new information about fish that pass via the waterfall itself. Based on this dataset, it is evident that a considerable fraction of salmon is using the natural migration route to overcome the Skoltefossen waterfall. These migrants are generally larger than those observed at the fish ladder, indicating significant differences in migration and route-seeking behaviour at natural obstacles of different sized salmon individuals.

As in the fish ladder, the timing of salmon ascendance through the waterfall itself seems late compared to some other river systems, e.g. River Tana, where salmon migration in the lower reaches of the river system is most active clearly earlier. This observation, in addition to earlier radio-tagging data (Vierelä 2008) gives additional evidence about migration delay below the Skoltefossen waterfall, which should be taken into account in the fisheries management of the River Neidenelva salmon populations (see section 4.3.).

4.3. Future directions in monitoring and management

Underwater video monitoring at the Skoltefossen fish ladder has proved to be effective and cost-efficient monitoring approach. The use of video camera on the opposite side of the river in 2011 proved also successful and produced new important information on the fish (e.g. timing, proportions, size-classes) that are migrating straight through the waterfall.

Overall, by video monitoring, the efficiency of the Skoltefossen fish ladder and an index of the status of salmon and sea-trout populations of the River Neiden can be obtained on annual basis. The monitoring of the Skoltefossen fish ladder could also be easily arranged by installing an automatic VAKI-Riverwatcher fish counter (VAKI Inc., Iceland) to the upstream end of the fish ladder. This counter has proved reliable and effective in monitoring different kind of fishways. Some initial investment is needed (c. 40 000 €/350 000 NOK), but in long-term annual fish monitoring is fast and cost-effective. Overall, VAKI counters are nowadays used in several hundreds of fishways throughout the world, including some Finnish and Norwegian rivers (see www.vaki.is).

New full-scale monitoring approaches, e.g. echo-sounding applications (DIDSON, Simsonar) could also be used in the monitoring of the Neidenelva salmonid populations. These applications would provide possibilities to count all fish ascending to the river provided that a suitable (e.g. laminar flow with low amount of air bubbles, smooth river bed, etc.) monitoring site can be found. Several DIDSON units are being utilized e.g. in the Baltic salmon rivers in Finland and the new Simsonar (cheaper than DIDSON) echo-sounder will probably be tested in Tana watershed in 2012.

Overall, the river stretch below the Skoltefossen waterfall is one of the key areas regarding the management of the River Neidenelva salmon populations. Skoltefossen together with fluctuating discharge is regulating the salmon spawning migration, and in certain conditions the upstream migration may be significantly delayed. This phenomenon in combination with rather high fishing effort increases the exploitation rate of salmon. In addition, the käpälä-fishery is clearly targeting the most important stock component, multi-sea-winter salmon (see appendix 2).

As most of the River Neidenelva salmon production areas are situated above the Skoltefossen, it is highly important to regulate the fishery below Skoltefossen to maintain and enhance the possibilities of fish to ascend to the spawning grounds. Main focus should be on conserving the 2SW-MSW salmon component to maximize the juvenile production and long-term population persistence (see e.g. Vähä et al. 2007). Possible management measures at the Skoltefossen area should also be followed by measures at the actual spawning grounds situated mainly on the Finnish territory, where salmon juvenile densities have been rather low during the last two decades (Länsman et al. 2010). This indicates too low spawner abundance levels and thus increasing the spawning escapement in these areas should be a high priority. In summary, the two most important long-term management goals in the River Neidenelva/Näätämöjoki are:

- Increasing the numbers of large salmon (2SW+MSW) surviving to spawning
- Increasing the salmon juvenile production in the main production areas on the Finnish side

Some possible alternative management measures to achieve these management goals may include:

- Bag limit of large salmon (one >3kg salmon/day) for recreational fishermen in the River Neidenelva
  This option would save a fraction of the most important salmon spawners in the Norwegian part of the river. On the Finnish side one salmon/day -rule is already in use in the recreational fishery.

- Fishing day quotas, e.g. limited numbers of fishing licences sold/day for recreational fishermen in the River Neidenelva
  This option 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).

- Release of >3 kg (>70 cm) female salmon from the käpälä-fishery
  This option would save a considerable amount of MSW female salmon provided that the fish can be released in a good condition.

- Decreasing allowed gillnet fishing days and number of gillnets in Finland (e.g. only two days/week and only one gillnet)
  This option would decrease gillnet fishing effort on the Finnish side (in main spawning areas) and save a fraction of spawners especially during the main fishing season in July-August

- Total prohibition of salmon fishing above the lake Opukasjärvi on the Finnish side
  This option would save fish that have been able to ascend to the headwater spawning areas, where salmon juvenile production has been rather weak (=low fry densities observed).

The above mentioned management measures could be implemented individually or in a combination. Other management measures could also be utilized if the assessed status of salmon stocks is weaker than the future management goals. The significance of the possible management measures should be studied and analysed if these measures are being utilized.

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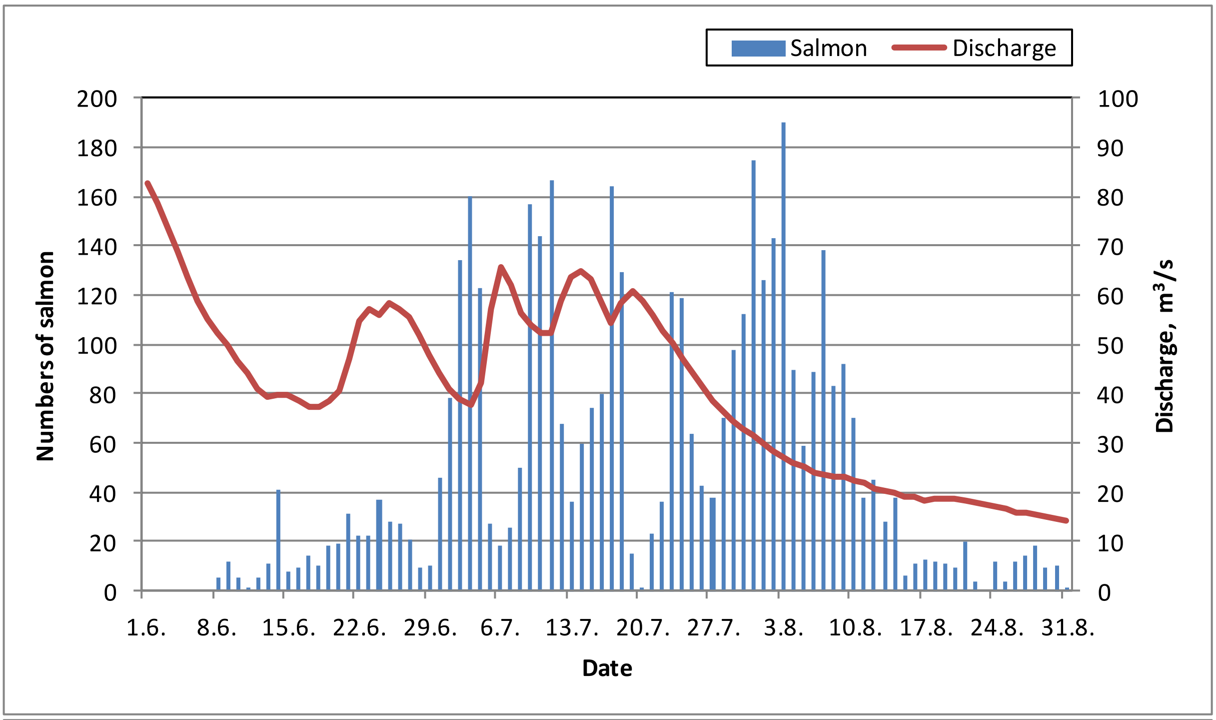
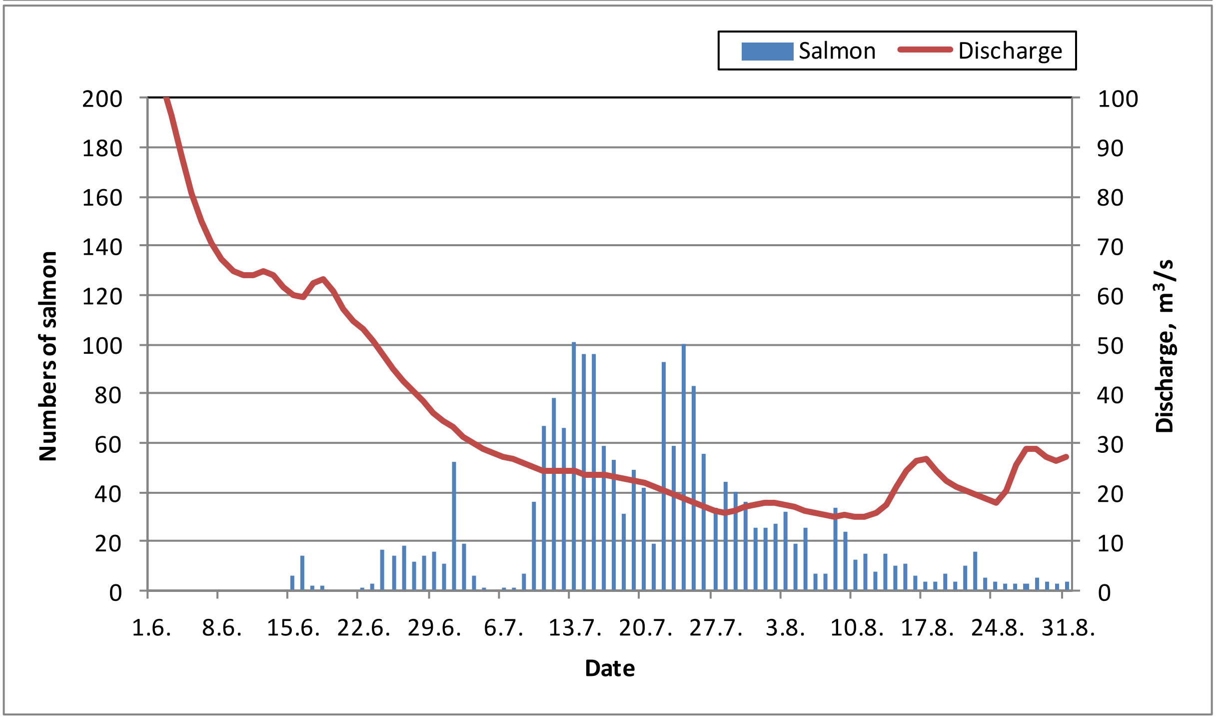
Appendixes

Appendix 1. The daily numbers of salmon passing through the Skoltefossen fish ladder in 2006 (upper panel) and 2009 (lower panel) in relation to daily discharges.





Appendix 2. Sea-age distribution of salmon from the Skoltefossen käpälä-fishery in 2006 and 2009-2010. Data is based on collected scale samples. (1SW=one-sea-winter salmon, 2 SW=two sea-winter salmon, PS=repeat spawner).