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METSÄHALLITUS



Statsforvalteren i Troms og Finnmark

*Romssa ja Finnmarkku stáhtahálddašeaddji
Tromssan ja Finnmarkun staatinhallittija*

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Abstract

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Biological reference points in a form of spawning targets have been estimated and established for the whole Neidenelva system in 2022. These spawning targets give now a biological goal, number of female salmon, that should be annually reached to ensure the long-term viability of the Neidenelva salmon populations. For estimating the spawning target attainment, information on the salmon run size together with salmon catches are needed.

To estimate the salmon run size, all fish ascending to the River Neidenelva were monitored during the summer 2022, for the first time ever, by using an ARIS-sonar close to the river mouth. Sonar monitoring was a joint Finnish-Norwegian project and was executed by the Natural Resources Institute Finland (Luke). Underwater video cameras were used in parallel with the sonar for species determination.

The total salmon run estimate in 2022 was c. 6900 individuals. Proportion of small (50–65cm), medium (65–90 cm) and large salmon (≥ 90 cm) were 49 %, 47 % and 4 %, respectively. Salmon migration was most active from mid-June to mid-July, whereafter the migration activity decreased significantly. In addition to salmon c. 300 sea trout ≥ 45 cm was estimated to ascend to Neidenelva. Significant numbers of large whitefish were also detected at the monitoring site, but their numbers were not estimated because of frequent back-and-forth movements.

Based on long-term catch statistics and salmon counts at the Skoltefossen fishway, the salmon season 2022 was estimated to be poor. If the current relationship between the sonar count and catch/fishway data was used as a predictor, the salmon run sizes could have been c. 3 times higher (c. 20 000 salmon) in the best years during the period 2006–2022.

Overall, the salmon run estimate contains some significant uncertainty. First, high incidence of back-and forth swimming complicated the counting process. Secondly, it was estimated that proportionally more downstream migrating fish are undetected compared to upstream migrating fish, i.e., the total run estimate is most probably an overestimate. Thirdly, sonar length measurement results indicate that especially smaller fish may have been measured too large, affecting the estimated salmon size distribution. The use on video cameras considerably decreased the above-mentioned problems.

When considering the challenges observed in the sonar monitoring in 2022, it would be reasonable to re-evaluate the location of the sonar site for future studies. An obvious choice would be a site shortly above the Skoltefossen waterfall. This location would basically exclude other species (e.g., whitefish) than salmon and sea trout. It would also most probably reduce the number of back-and-forth movements of salmon and sea trout clarifying and quickening the sonar data analysis.

Keywords: *Salmo salar*, run size, monitoring, Aris, Näätämöjoki, Neidenelva

Tiivistelmä

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Vuonna 2022 määritettiin ja asetettiin kutukantatavoitteet koko Näätamöjoen (Neidenelva) vesistölle. Kutukantatavoitteella tarkoitetaan kutualueille selviytyvien naaraslohien lukumäärää, joka tulisi vuosittain saavuttaa elinvoimaisen lohikannan ylläpitämiseen pitkällä aikavälillä. Jotta kutukantatavoitteen saavuttamista voidaan arvioida, tarvitaan saalistietojen lisäksi tietoa myös jokeen nousevien lohien kokonaismäärästä.

Näätamöjokeen nousevien lohien kokonaismäärää arvioitiin ensimmäistä kertaa kesällä 2022 käyttämällä ARIS-viistokaikuluotainta joen alajuoksulla. Kaikuluotauseuranta suoritettiin suomalais-norjalaisena yhteistyönä ja projektin toteutuksesta vastasi Luonnonvarakeskus. Kaikuluotaimen lisäksi kalojen lajintunnistukseen käytettiin vedenalaisia videokameroita.

Jokeen nousseiden lohien kokonaismääräksi arvioitiin noin 6900 yksilöä. Tästä määrästä pieniä lohia (50–65 cm) oli 49 %, keskikokoisia lohia (65–90 cm) 47 %, ja suuria lohia (≥ 90 %) 4 %. Lohien nousu oli aktiivisinta kesäkuun puolivälistä heinäkuun puoliväliin, jonka jälkeen nousu väheni merkittävästi. Lohien lisäksi jokeen arvioitiin nousseen noin 300 yli 45 cm meritaimenta. Kaikuluotausalueella havaittiin myös merkittävä määrä suuria siikoja, joiden tarkempaa lukumäärää ei kuitenkaan arvioitu niiden liikkeessä edestakaisin luotausalueella.

Pitkän aikavälin saalistietojen ja Kolttakönkään kalatien laskentatulosten perusteella arvioitiin vuoden 2022 olleen varsin heikko lohivuosi Näätamöjoella. Kesän 2022 kaikuluotauslaskennan sekä pitkäaikaisten (2006–2022) lohisaaliiden ja kalatien kautta nousseiden lohien määrien perusteella Näätamöjokeen on parhaina vuosina voinut nousta jopa kolminkertainen määrä lohia (n. 20 000 kpl) verrattuna vuoteen 2022.

Tuotettu arvio lohien kokonaismäärästä sisältää merkittäviä epävarmuuksia. Ensimmäiseksi, kaikuluotauspaikalla havaittu kalojen edestakainen liikehdintä hankaloitti kalamäärien laskentaa. Toiseksi alavirtaan uivien kalojen arvioitiin olevan jonkin verran heikommin havaittavissa kaikuluotaimella ylävirtaan uiviin kaloihin verrattuna. Tämä tarkoittaa, että nousulohien määrä on todennäköisesti yliarvioitu. Kolmantena, kaikuluotaimen kuvasta havaitut, etenkin pienet kalat, vaikuttavat tulevan mitatuksi usein hieman liian suuriksi. Tämän seurauksena arvio lohien kokojakaumasta voi vääristyä. Luotauslinjalle sijoitetuista videokameroista saadun kuvamateriaalin avulla edellä mainittuja ongelmia voitiin kuitenkin merkittävästi vähentää.

Vuoden 2022 kaikuluotauksessa ilmenneiden haasteiden perusteella on syytä miettiä kaikuluotauspaikan vaihtamista, mikäli laskenta toistetaan tulevaisuudessa. Sopiva luotauspaikka olisi mahdollisesti heti Kolttakönkään yläpuolinen jokialue. Tämä sijainti sulkisi pois suurimman osan muista kalalajeista, jotka eivät lohien ja meritaimenen tavoin vaella Kolttakönkään ohi sen yläpuolisille jokiosuuksille. Kyseisessä paikassa olisi myös todennäköisesti vähemmän kalojen edestakaista liikettä, helpottaen ja nopeuttaen kaikuluotauslaskentaa.

Asiasanat: *Salmo salar*, lohikannan koko, seuranta, Aris, Näätamöjoki, Neidenelva

Sammendrag

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Gytebestandmål for de ulike delene av Neidenvassdraget ble estimert og fastsatt i 2022. Disse gytebestandsmålene representerer den mengden hunnlaks som må overleve til gyting for å sikre langsiktig levedyktighet for Neidenelvas laksebestander. For å estimere oppnåelsen av gytebestandsmålene, trengs informasjon antall laks som kom tilbake til elva for å gyte og antall som ble fanget i fiske.

For å estimere laksebestandens størrelse ble all fisk som vandret opp i Neidenelva overvåket ved bruk av ARIS-sonar nær munningen av elva sommeren 2022. Sonarovervåkingen var et felles finsk-norsk prosjekt og ble utført av det finske Naturressursinstituttet (Luke) og er første gang sonar er brukt i til å registrere oppgang i Neidenelva. Undervannskameraer ble brukt sammen med sonaren for artsbestemmelse av fisken og validere tellingene.

Totalt ble det estimert at 6900 laks vandret opp i 2022. Andelen små (50–65 cm), mellomstore (65–90 cm) og store lakser (≥ 90 cm) var henholdsvis 49 %, 47 % og 4 %. Oppgangen av laks var størst fra midten av juni til midten av juli, etter dette avtok aktiviteten betydelig. I tillegg ble det estimert at omtrent 300 sjørret ≥ 45 cm vandret opp til Neidenelva. Et betydelig antall store sik ble også registrert, men antallet ble ikke estimert siden disse vandret veldig mye opp og ned forbi tellestedet.

Sett opp mot tidligere års fangststatistikk og tellinger fra laksetrappa i Skoltefossen, er lakseoppgangen i 2022 relativt dårlig. Hvis en bruker forholdet mellom sonartellingen i 2022 og antall laks registrert i fangst/laksetrapp til å estimere tidligere års lakseopp ganger, ser en at den totale lakseoppgangen kan ha vært omtrent tre ganger høyere (ca. 20 000 laks) i de beste årene i perioden 2006–2022.

Sonartellingen av laks har av flere grunner betydelig usikkerhet knyttet til seg. For det første kompliserte høy forekomst av opp- og nedvandring forbi sonaren tellingen. For det andre var det større sjanse for at nedvandrende fisk ikke ble registeret av sonaren enn oppvandrende fisk, noe som medfører at det totale estimatet for laksebestanden trolig er for høyt. For det tredje kan lengdemålingene fra sonaren være overestimerer, noe som påvirker størrelsesfordelingen av laks. Bruk av videokameraer reduserte disse problemene betydelig.

Utfordringene sonarovervåkingen hadde i 2022 gjør at en bør revurdere plasseringen av sonaren for fremtidige studier. En gunstigere plassering vil åpenbart være et sted like ovenfor Skoltefossen. Dette vil i stor grad ekskludere andre arter enn laks og sjørret fra tellingene. En plassering ovenfor Skoltefossen vil mest sannsynlig også redusere mengden forflytning av fisk opp og ned forbi tellestedet, og dermed gjøre analysen av sonardataene enklere og raskere.

Nøkkelord: *Salmo salar*, gytebestand, overvåking, Aris, Näätämojoki, Neidenelva

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1. Introduction

The transboundary river Neidenelva (Näätämöjoki in Finnish) is one of the most important salmon rivers in Norway and Finland. Salmon ascends the river up to the Lake Iijärvi, c. 80 km upstream from the river mouth. In addition to the mainstem, salmon migrate to tributary rivers Silisjoki, Harrijoki and Kallojoki (Orell et al. 2022). Based on recent genetic studies a population structure has been found from the Neidenelva system, with populations in the main stem and in some tributaries showing genetic differentiation (Sinclair-Waters & Primmer 2021). The Neidenelva system supports a significant and diverse salmon fishery including rod and line fishing for both locals and tourists, as well as local gillnet and seine net fishing.

Monitoring of the Neidenelva salmon populations and their status has historically been based on catch data, catch samples and juvenile densities derived from electrofishing. During the 2000s counting of ascending fish has been conducted frequently in the Skoltefossen fishway and it has provided a partial estimate of the salmon run (Orell 2012). Until recently, there has not been a biologically based reference points and consequent management targets defined for the Neidenelva salmon (Orell et al. 2022). This has hampered the annual estimation of the salmon stock status and has led to suboptimal management of the Neidenelva salmon stocks and salmon fisheries.

Biological reference points in a form of spawning targets have been estimated and established for the whole Neidenelva system in 2022 (Orell et al. 2022). The targets now provide a biological reference for numbers of female salmon that should be annually reached to ensure long-term viability of salmon populations. The next step in the management process is to evaluate whether the spawning target is attained or not. To do this, information on salmon run and salmon catch is needed, as the spawning stock is the run size minus catch.

The total salmon run ascending to the Neidenelva system was estimated for the first time ever during the summer 2022 by using an ARIS-sonar monitoring close to the river mouth. Sonar monitoring was a joint Finnish-Norwegian project and was executed by the Natural Resources Institute Finland (Luke). This report is presenting the key methodological parameters and results of the sonar monitoring. It also aims to give some insights on the future sonar counting studies in the River Neidenelva.

1.1. Study questions

The most important study questions of the sonar monitoring were:

- How many salmon ascend the Neidenelva river in 2022?
- What is the size distribution of the ascending stock?
- When do the salmon ascend?
- What is the relationship between the sonar count and the fishway count?
- How many sea trout and pink salmon ascend in 2022?

2. Study area

The River Neidenelva is located in North-Eastern Finland and Norway, draining the large Lake Iijärvi and running c. 50 km in Finland and thereafter c. 30 km in Norway to Neidenfjorden, Barents Sea. The system has a catchment area of 2962 km² in the birch-dominant subarctic terrain. It includes several lakes and tributaries Silisjoki, Harrijoki, Kallojoki, and Nuortijoki. The mean discharge at the lower mainstem is c. 45 m³/s (2022, NVE).

In addition to being an important salmon river, the Neiden system provides habitats for various other fish species such as brown trout (*Salmo trutta*), European whitefish (*Coregonus lavaretus*), northern pike (*Esox lucius*), and an alien species pink salmon (*Oncorhynchus gorbuscha*).

Circa 12 km upstream from the estuary is the Skoltefossen waterfall, which partially prevents or complicates the upstream migration of fish species. A fishway was built to Skoltefossen in 1968 and it has been monitored on a rather regular basis since 2006 by Finnish Game and Fisheries Research Institute (RKTL) and later by Luke (see e.g., Orell 2012). The fishway has been shown to support especially the ascendance of small one-sea-winter (1SW) salmon and sea trout, while larger salmon ascend mostly through the waterfall (Orell 2012). Thereafter, salmon are ascending the mainstem up to lake Iijärvi and tributaries. Most of the salmon juvenile production areas have been assessed to be on the Finnish side of the system (Erkinaro et al. 2000, Orell et al. 2022).

The sonar monitoring site was situated below the Skoltefossen waterfall at Korpiniva, c. 10 km upstream from the river mouth (Figure 1). This site was chosen based on river habitat mapping in autumn 2021 (Kytökorpi et al. 2021) and had good physical characteristics for sonar monitoring: the river is quite narrow (90 m), the water current is lateral and smooth, and there are no significant blind spots caused by bottom structures. The discharge during the monitoring period varied between c. 20 and 160 m³/s (Figure 4). Flow velocity and water level at the monitoring site were slightly affected by the tide.

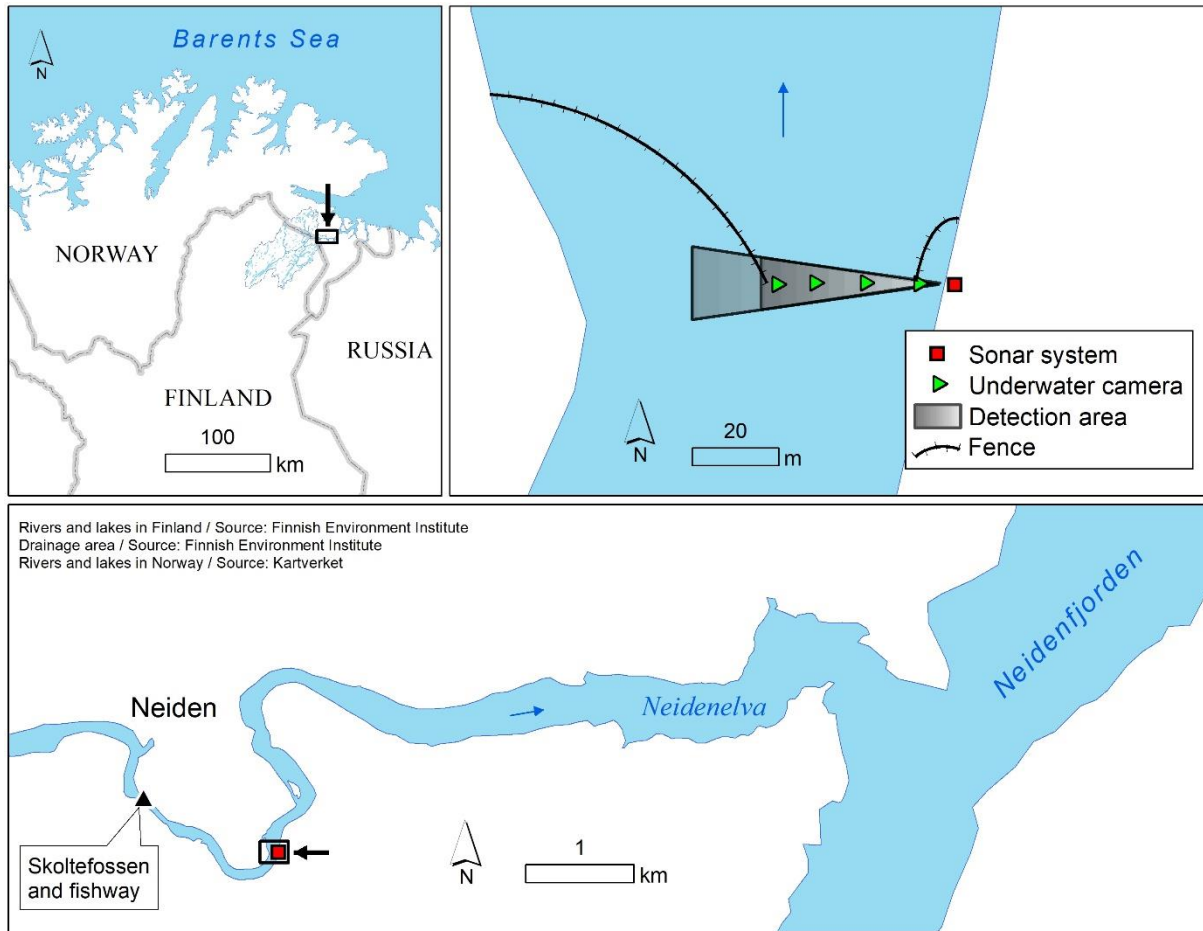


Figure 1. Study area and sonar monitoring set-up in the River Neidenelva in 2022. In addition to the sonar unit, four underwater cameras at the same site were used for species recognition.

2.1. Sonar and video equipment

Sound Metrics ARIS Explorer 1200 sonar device was used for the Neidenelva sonar monitoring (Figure 2). Explorer 1200 creates a fan beam that consists of 48 individual parallel sonar beams (each of the beams being 0,6 degrees horizontally). Explorer 1200 uses two kinds of frequencies. The higher 1.2 MHz frequency creates a high-quality image for short ranges up to 35 m. The lower 0.7 MHz frequency detects objects up to 80 m range but does not create a high-quality image, especially with long distances.

In Explorer 1200 the horizontal spread angle of the fan beam is c. 30 degrees and the vertical angle 14 degrees (normal lens) without additional lenses. With removable telephoto-lens, it is possible to increase the image quality when utilizing long sonar windows. However, when using a telephoto lens, the vertical spread angle is only 3 degrees. With an additional spreader lens, it is possible to expand this angle up to 8 or 14 degrees, for example.

In addition to the sonar device, four custom made underwater video cameras (Skynordic, PAL, 720x576) with 3,5 mm wide-angle lenses were placed into the sonar window for fish species recognition (Figure 1).

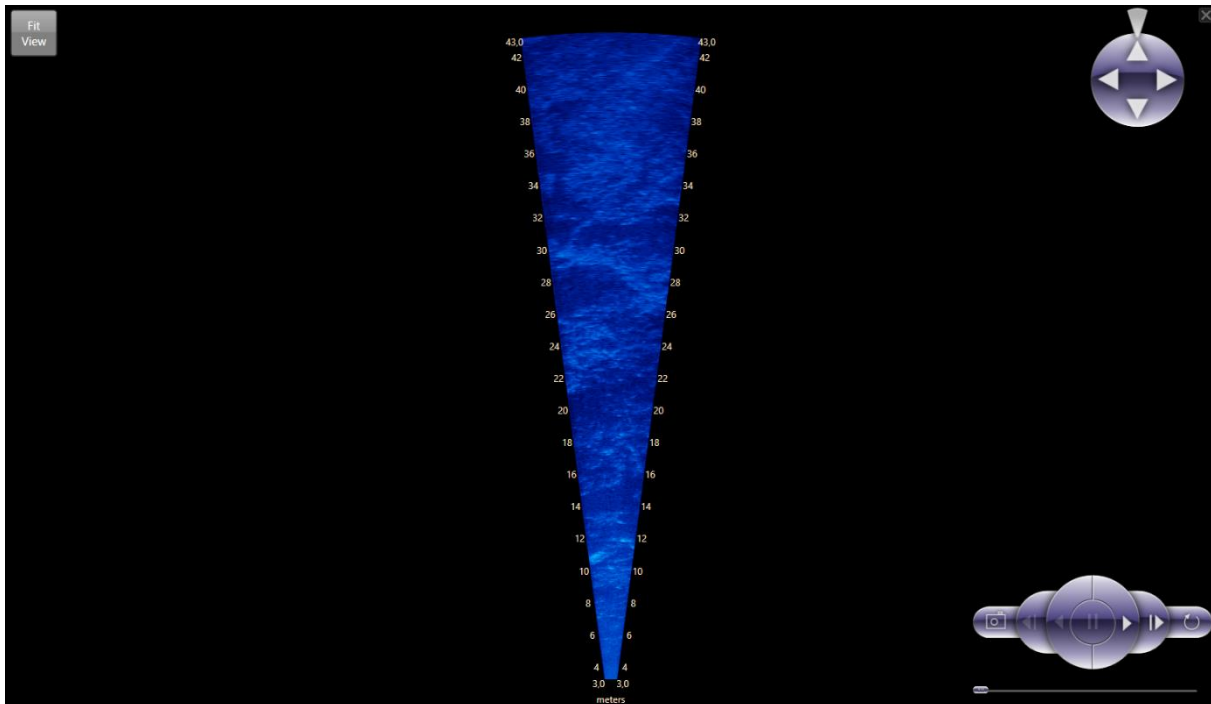


Figure 2. ARIS Explorer 1200 sonar image (with a telephoto lens) showing the bottom of Neidenelva horizontally from 3 to 43 meters. Sonar direction was from east to west (see Figure 1).

2.2. Monitoring setup and data collection

A sonar unit with a telephoto lens installed on a scaffolding stand was placed on the eastern side of the river c. 2 m from the shoreline (Figures 1 and 3). Sonar window direction was from east to west. Together with the telephoto lens either a 14° or an 8° spreader lens was used.

Underwater guiding fences were used on both sides of the river to narrow the monitoring area to c. 35 m (Figures 1 and 3). The underwater guiding fences were built from orange plastic tubes (\varnothing 27,5 mm) of different heights (1,5–3,0 m). The plastic tubes were plugged from both ends for buoyancy and attached to a steel chain. The western fence was about 45 m long, and the eastern fence was about 10 m (Figure 3). The fences were set diagonally downstream from the sonar device to guide the upstream swimming fish into the sonar window. The other end of the fence was attached to a steel pole in the middle of the river and the other end was secured onto the shore (Figure 3).

For species determination purposes four underwater cameras were also installed (18.6.) in the sonar monitoring area (window). They were placed 8, 20, 32, and 41 meters from the sonar and directed from east to west (Figure 1). Cameras were continuously recording (5 fps) and data were saved on 2 TB hard discs by using Timespace X300 digital video recorder.

The sonar monitoring was started on the 2nd of June and was continued 24h/day until 13.9.2022. There were three major changes in the set-up during the monitoring period:

- Sonar window length 3–50 m, no guiding fences or video cameras (2.–9.6.)
- Sonar window length 3–60 m, guiding fences installed, no video cameras (10.6.–17.6.)
- Sonar window length 3–43 m (50/60 min) and 3–60 m (10/60 min), guiding fences installed, video cameras installed (18.6.–13.9., the main set-up)

ARIScope software (version 2.8.0) was used for sonar data recording and adjusting sonar settings. Sonar data was saved on one-hour intervals (60 min) on external hard drives via a laptop on the site and then automatically uploaded into a cloud service.

During mid-July, the telephoto lens was broken, and a normal lens was used in the monitoring for a few days (18.–21.7.) before a replacement telephoto lens was available. This caused a two-day gap in the data. In addition, occasional shorter gaps were caused by other maintenance work.



Figure 3. The sonar monitoring set-up in the River Neidenelva in 2022.

2.3. Data analysis

ARISFish software (version 2.8.0) was used for the sonar data analysis. ARISFish enables to detect moving objects from stationary objects such as boulders and bottom formations. It is possible to manually measure the objects and somewhat identify them (e.g., fish, diving bird, or a boat).

Collected sonar data were analysed between 2.6. and 31.8.2022 by experienced staff. All material (24 hours/day) was analysed from 2.6. to 19.6. due to uncertainties caused by the spring flood and early sonar adjustments. Thereafter, 50 % of the sampling time (every second hour) was analysed as the sonar set-up and accuracy of detection improved, and the remaining hours were estimated based on this sample.

The detection data included length of fish, direction of movement, and distance from the sonar. Since the main purpose was to count ascending salmon, only fish ≥ 45 cm were measured and saved to data. Every individually passing fish were measured. In the case of larger schools of approximately similar sized fish, only one individual was measured, and the same length estimate was used for the other fish in the same school. If there were different sized fish in a school, they were separately measured.

Underwater video data was analysed from 18.6. to 31.8.2022 by using two different methods. For species identification purposes, a sample of every fourth recorded hour was analysed from every second recorded day. With this method, only detections from the sonar data were verified and identified. The species information was then added to the sonar data and extrapolated to the whole material. With another method, a sample of every second hour from every fifth recorded day was analysed without preliminary information from the sonar detections. The video from all four cameras was systematically watched at 10x speed to potentially see fish that was not detected in the sonar monitoring. The species, estimated size, direction, date, and time were saved into a separate excel file.

2.4. Estimation procedure

After the data analysis, the total number of sonar detections was 18 057 fish (≥ 45 cm, upstream and downstream) (Table 1). The species distribution was calculated by using the video detections. It was calculated for each week and only for 50–65 and 65–90 cm fish groups separately since the species distribution varied in time and between size groups. Thereafter, the number of salmon was estimated for each monitoring day (2.6.–31.8.) with following steps:

- Detected fish were divided into groups by direction (upstream, downstream) and size (50–65, 65–90, >90 cm). Detections of 45–50 cm fish were deleted since based on video data, there were only a few salmon among other species in this size group.
- The downstream detections were subtracted daily from the upstream detections separately in each size group. Here, the daily estimation of the undetected fish was also added to each group. The estimation was based on systematic video analysis (see 2.3.).
- The result was then multiplied by a “salmon-coefficient”, which represented the probability for the detected fish to be salmon on that given week. The coefficient was based on the species identification from the video monitoring.
- Finally, the daily result was multiplied by 1 or 2 if either 24h or 12h of data was analysed on that day. If there were missing minutes in the sonar data on that day, it was taken into account at this point.
- On the first week of sonar monitoring (2.–8.6.) the number of salmon was multiplied roughly by 1.3, due to the spring flood and missing guiding fence on the northern side of the river.

- 2.6.–19.6. the number of downstream passing fish was multiplied by a rate (0.10–0.95), which was increasing daily. These downstream migrating fish were mostly considered as salmon kelts, which normally migrate to sea during May–June (Niemelä et al. 2018b).
- During the two days gap due to the broken lens (16.–17.7.) the salmon number was estimated by using linear regression based on the numbers three days before and after the gap.
- The number of ascended sea trout was estimated rather simply by calculating the species distribution from the video data and extrapolating this to the estimation of total number of fish above the sonar (upstream minus downstream counts). The data from Skoltefossen fishway and catches was used to support this estimation.

There were some uncertainty factors in the estimation procedure, and they are considered more broadly in the discussion chapter.

Table 1. Summary of the sonar detections in 2.6.–31.8.2022 and estimates of salmon numbers divided to three different size categories and total salmon numbers. Missing minutes of the sonar monitoring are also shown.

Detections upstream	Detections downstream	Detections total	Estimated upstream	Estimated downstream	Estimated total	Salmon estimate, 50–65 cm	Salmon estimate, 65–90 cm	Salmon estimate, ≥ 90 cm	Salmon estimate, total	Missing minutes
12317	5740	18057	24458	13444	37902	3374	3223	333	6930	2464

3. Results

3.1. Salmon run size and migration timing

The estimated total salmon run size in 2.6.–31.8.2022 was c. 6900 individuals (Figure 4, Table 1). During the first week of the monitoring salmon numbers were low (<50 ind./day). Migration intensity increased significantly during the second week of June and showed the first peak in mid-June. Two clear migration peaks also took place during the first and second weeks of July (Figure 4). The salmon run peaked on 13th July, whereafter the daily salmon numbers started to decrease and remained low from c. 20th July until the end of the monitoring (Figure 4). The main migration period lasted basically only 35 days. Back-and-forth movement of fish was substantial in the sonar monitoring area, which caused heavy fluctuations to the daily salmon estimates.

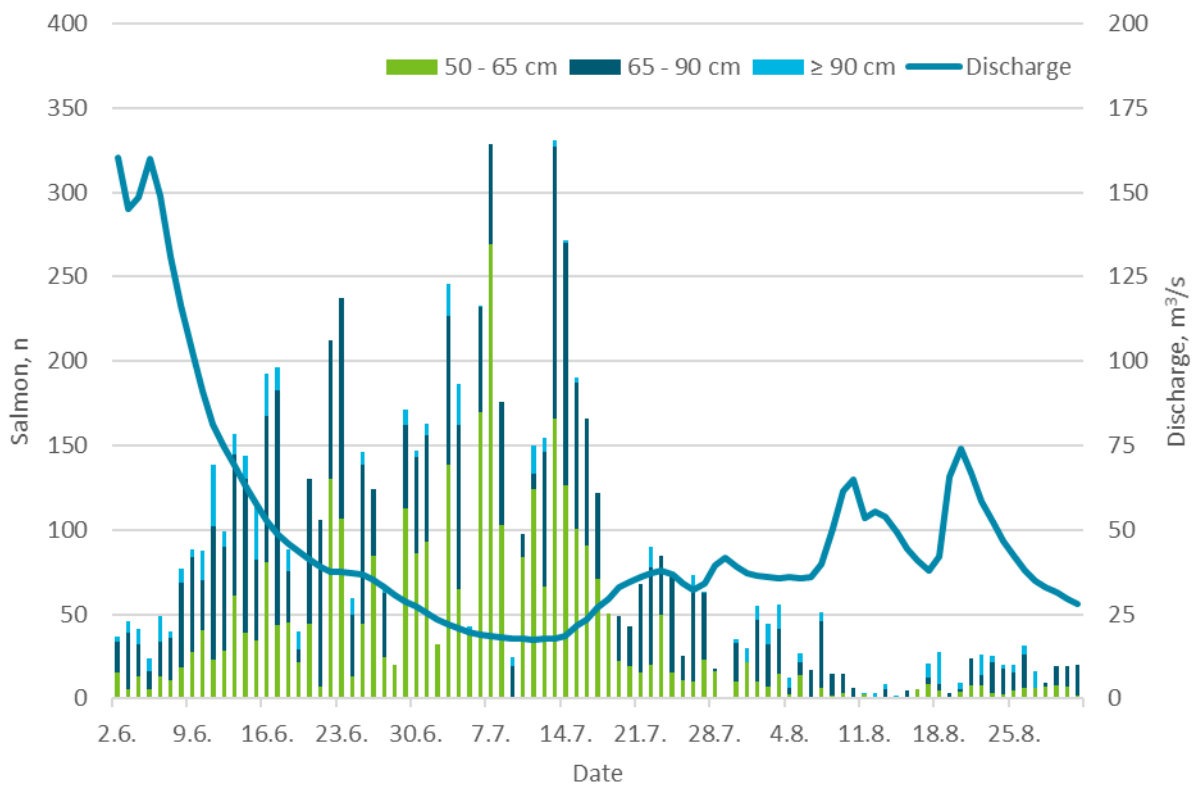


Figure 4. The estimated daily ascending salmon numbers in the river Neidenelva divided into three size categories in 2.6.–31.8.2022. Blue curve indicates the daily mean discharges of the lower Neidenelva (Source: NVE).

Salmon migration past the sonar monitoring site started somewhat earlier compared to the migration through the Skoltefossen fishway, located 1.5 km upstream from the sonar site (Figure 5). The active migration period in the fishway continued slightly later compared to the sonar site, but migration activity after early-August was minimal in both sites (Figure 5).

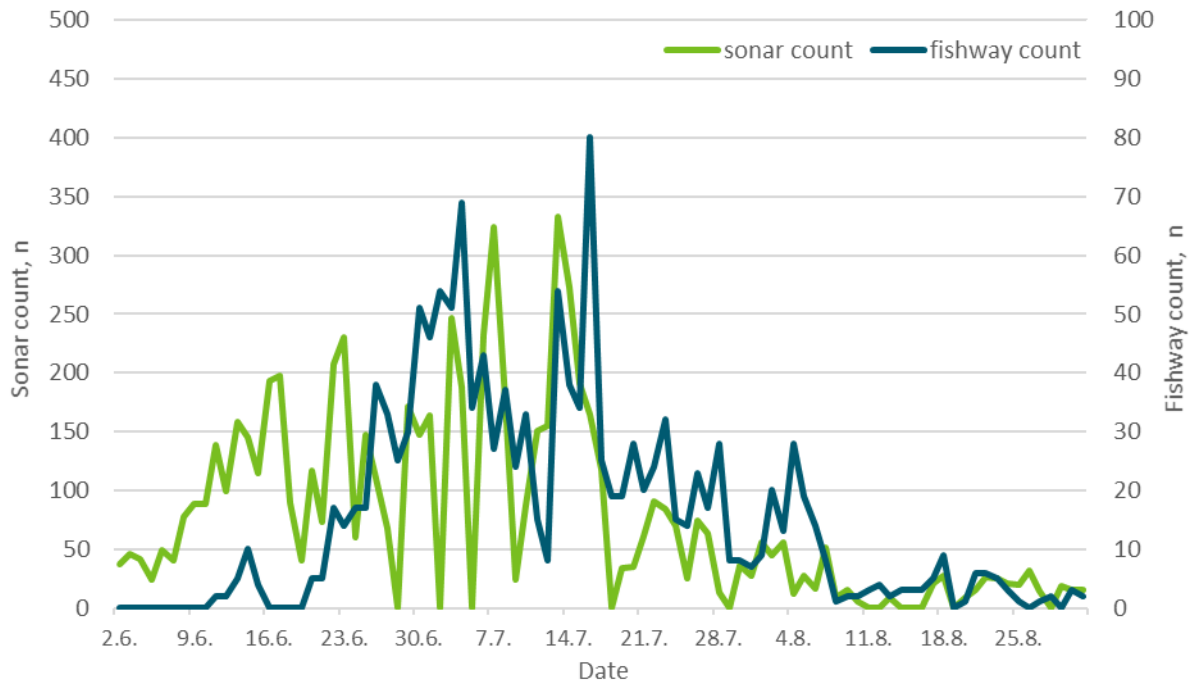


Figure 5. Salmon migration timing at the sonar monitoring site (green line) in comparison to timing of salmon passing the Skoltefossen waterfall via fishway (blue line). Note the different scaling of the y-axis and that the fishway monitoring started on 11th June.

The largest proportion of salmon counted in the sonar monitoring belonged to the size group of 50–65 cm, with c. 3400 individuals (49 % from the total amount). The size group of 65–90 cm salmon was almost similar in abundance: c. 3200 fish (47 %). Numbers of large salmon (≥ 90 cm) were rather low (c. 300 fish, 4 %) (Figure 6, Table 1). Small salmon numbers and their proportion peaked during the first half of July, whereas numbers of medium sized salmon (65–90 cm) did not have a clear peak. Large (≥ 90 cm) salmon showed highest activity during the first half of June (Figure 5).

There were clear differences in the estimated size distributions between different monitoring methods, with sonar data indicating higher proportions of larger salmon than the fishway counts or the catch data (Figure 6). It should be noted, however, that there is considerable uncertainty in the sonar fish measurements, and part of the small salmon are probably grouped into the mid-sized salmon group (see more in the discussion).

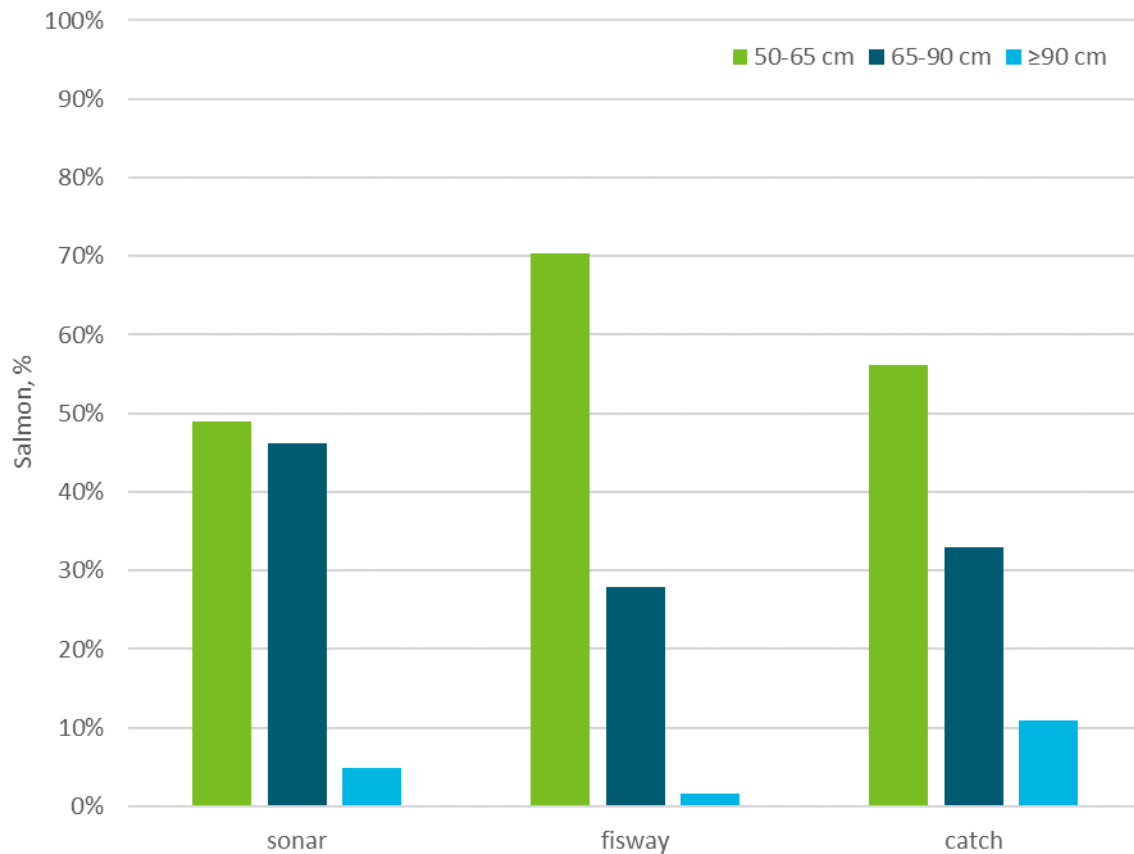


Figure 6. Estimated size distributions (%) of salmon in the River Neidenelva based on sonar monitoring in comparison to Skoltefossen fishway video monitoring and catch reports (rod and cast net catches) from the Norwegian part of the Neidenelva system. The catch numbers in weight classes (salmon <3 kg, 3–7 kg, and ≥7 kg) were converted to catch numbers in length classes (<3 kg→50–65 cm, 3–7 kg→65–90 cm and ≥7 kg→≥90 cm).

Overall, the Neidenelva salmon catch data together with the Skoltefossen fishway count data indicated that the salmon season 2022 was rather poor compared to many earlier years, but slightly better than in 2020–2021 (Figure 7). This also suggests that the sonar count in 2022 was also low and that run size estimates in earlier years could have been much higher if the sonar had been available (Figure 7).

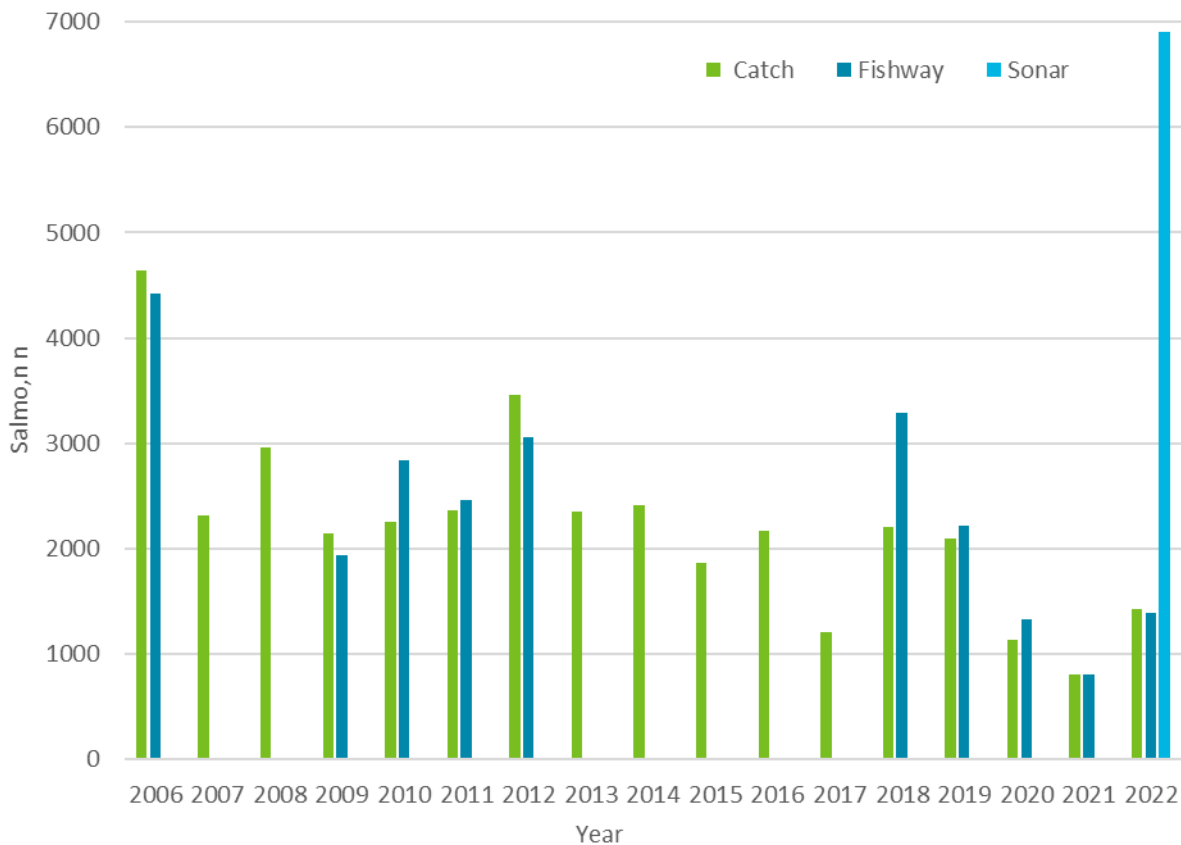


Figure 7. Estimated Neidenelva salmon run size based on sonar count in 2022 (turquoise bar) in comparison to total salmon catch in fish numbers (Norwegian and Finnish catch combined, green bars) and salmon numbers observed in the Skoltefossen fishway (blue bars) in 2006–2022. Note: fishway numbers are not available from all years.

3.2. Observations of other species

Although the sonar monitoring aimed to mainly count numbers of salmon, there was a surprisingly large proportion of other species observed, revealed by the concurrent video monitoring. Especially the size group of 50–65 cm fish included considerable proportion of other species than salmon (Figure 8). Overall, 1258 up- and downstream moving sonar detections were identified to species by video analysis. These detections included 934 salmon, 240 whitefish, 32 sea trout, 14 pink salmon, and few observations of other species such as grayling, pike, eel, and diving birds (goosander).

Based on the numbers presented above, c. 300 (2,6 %) of the ascended ≥ 45 cm fish were sea trout. Proportion of whitefish was 19 %, pink salmon c. 1 %, and other species c. 3 %, respectively. However, based on Skoltefossen fishway data, only salmon and sea trout were migrating further upstream, and the rest of the species were moving back and forth in the lower part of the river.

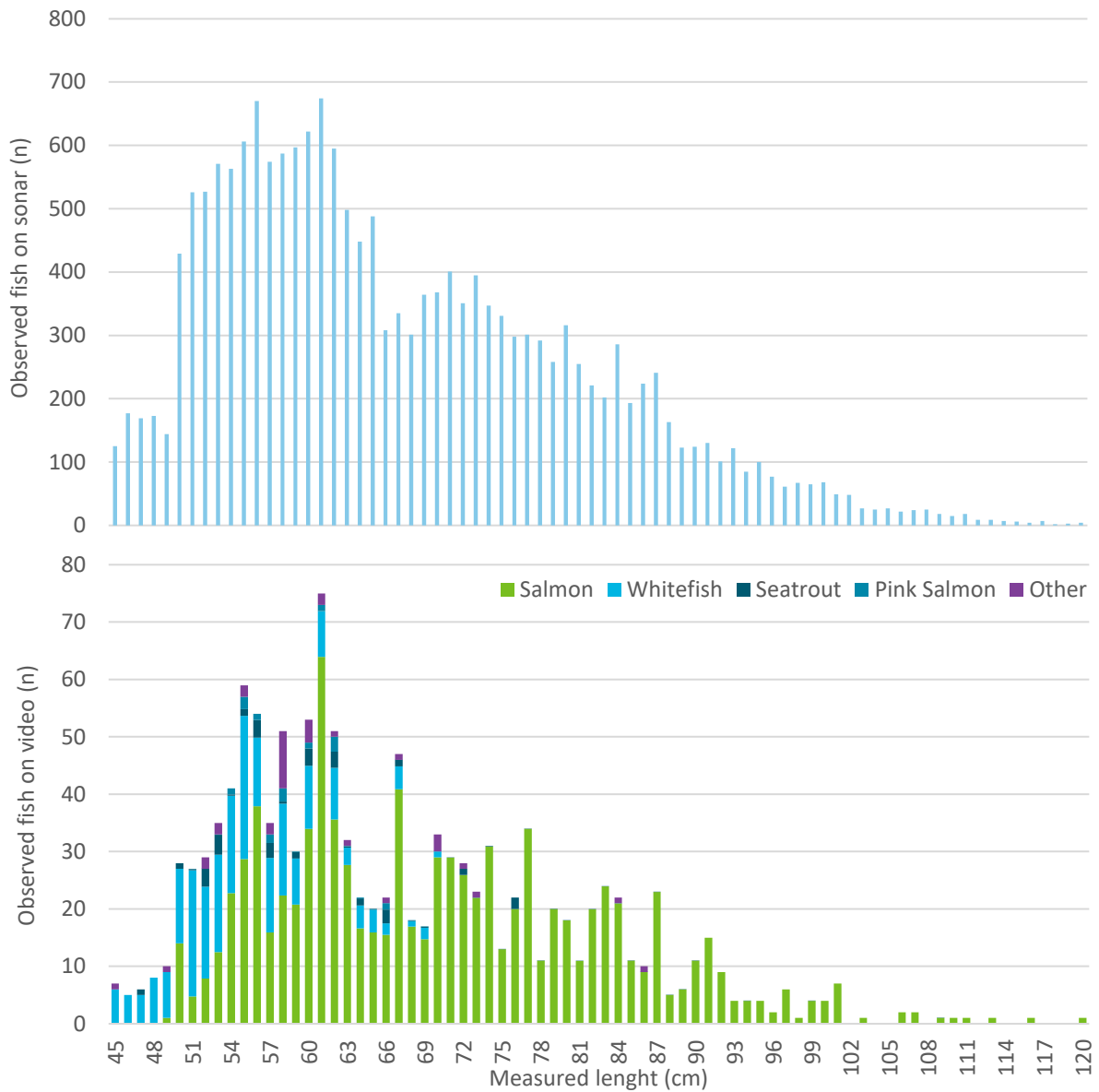


Figure 8. Size distribution of all sonar detections in one cm intervals (upper figure) and size distribution of the most abundant species that were measured by sonar and identified from video data (lower figure). Note the different scale on the y-axis.

4. Discussion

4.1. Salmon run size and size distribution

Since this was the first time that sonar monitoring was conducted in the River Neidenelva, there are no comparable estimates of earlier total salmon run sizes. However, numbers of salmon at the Skoltefossen fishway and salmon catch data from 2022 and previous years can be compared to the numbers observed in the sonar monitoring. Based on these different data sources it can be concluded that the salmon run size in 2022 was probably rather small, but higher than in 2020–2021 (see Figure 7). If the current relationship between the sonar count and fishway/catch data is used as a predictor, the salmon run sizes could have been 2–3 times higher in the best years during the period 2006–2022. This would mean salmon runs sizes up to c. 20 000 fish.

Based on sonar measurements of fish sizes, numbers of small (50–65 cm) and mid-sized (65–90 cm) salmon were almost equally large. This size distribution was somewhat different in comparison with both fishway counts and Neidenelva catch data (Norwegian catch), which both showed a larger proportion of small salmon. This indicates that the sonar measurement data may be somewhat biased towards larger fish, i.e., that fish has been measured to be larger than they were. However, the fishway size distribution is also known to be biased, as it has been shown earlier that smaller salmon use the fishway more frequently than larger salmon, which ascend more often straight through the waterfall (Orell 2012). If considering only salmon <65 cm and ≥65 cm the sonar count size distribution is rather similar with the Neidenelva catch size distribution (see Figure 6).

The observed size distribution basically implies that the year 2022 was a rather poor small salmon season. This phenomenon also partly explains the rather low salmon catches and fishway numbers, as small salmon are normally clearly more numerous and constitute a major part of the salmon run.

4.2. Salmon migration timing

The active salmon migration period in the lower Neidenelva area lasted only a bit more than a month, c. from mid-June to mid-July. Migration during August was negligible. Based on the sonar monitoring data some salmon may ascend the Neidenelva system already in late May, but their numbers are presumably very low. Overall, rather similar salmon migration timing windows have been observed in many other rivers of the Finnmark area, e.g., in the Tana River (Anon. 2023).

Salmon ascended the sonar site rather early when compared to migration timing observed in the Skoltefossen fishway, which is located only 1.5 km upstream. In 2022 the active migration via fishway started on 20.6., clearly later compared to the sonar monitoring site (see Figure 5). It is probable that salmon are waiting below the Skoltefossen waterfall, possibly c. 1–2 weeks, before they ascend it, either via fishway or through the waterfall itself. It seems that this delay in 2022 was somewhat longer during the early season, when river discharge was high and water temperatures low. It is well known that salmon naturally delay at migration barriers and migration past them is depending on both discharge and temperature (e.g., Thorstad et al. 2008; Lennox et al. 2018).

The delay below the Skoltefossen waterfall exposes ascending salmon to relatively heavy fishing pressure, as the area below the waterfall is a key fishing area. Based on catch reports, almost half of the total Neidenelva catch (FIN+NOR combined) was caught below or at the waterfall in 2022.

4.3. Other species

The species diversity and their proportions on the monitoring site was rather surprising, although it was known that there are many species inhabiting the lower Neidenelva, below the Skoltefossen waterfall. A considerably large population of whitefish was observed on the monitoring site, representing roughly a fifth of all ≥ 45 cm fish detections. The existence of this estuarine whitefish population has been documented earlier by Fagard (2015). A similar population of large-sized whitefish was observed in the estuary of Tana River in 2022 when beach-seining was done for juvenile pink salmon (Luke, unpublished data). The most interesting observations included an individual European eel.

Based on a rough estimate, there were c. 300 sea trout ≥ 45 cm ascending to Neidenelva. This estimate is, however, not including individuals smaller than 45 cm and is therefore clearly an underestimate. Based on the Skoltefossen fishway data (234 sea trout of which 24,8 % were < 45 cm) and catch reports (201 sea trout of which 54,2 % were < 1 kg) from the lower Neiden system the total ascending sea trout population in 2022 could have been around 500–600 individuals. Overall, both the fishway and catch data indicated a poor sea trout season in 2022. Their numbers in the fishway were lowest of all time (Luke, unpublished data) and catches were low as well, although slightly higher than in 2021 (www.scanatura.no/fangstrapport).

Pink salmon observations in 2022 were predictably low, as the even-year population is generally weak in the North-Atlantic area. The observations based on the video camera material from the sonar counting site indicated somewhat larger number of pink salmon, but it was concluded that they were mainly individual pinks moving back and forth in the counting area. Similar behavior has been observed in several monitoring sites in the Tana system (Luke, unpublished data). Both the Skoltefossen fishway counts (4 pink salmon) and the lower Neidenelva catch reports (4 pink salmon) indicated very low occurrence of pink salmon.

4.4. Challenges and future directions

Sonar monitoring in a large river, like in the Neidenelva, requires a lot of work, sometimes in rather hard environmental conditions and quick responses to appearing problems. Data analysis is also demanding and time-consuming, especially when fish numbers are large and if there is a lot of back-and-forth movement around the monitoring site.

The sonar monitoring in Neidenelva was aimed to begin as early as possible in June after the worst spring flood had passed. This was basically achieved, but the high discharges at early June postponed the installation of guiding fences until 10th June. At the same time the river was quite wide because of high water levels and therefore the sonar window covered only partially the river channel. The high discharges also prevented installing the underwater video cameras at the very beginning of the monitoring. These issues increase the uncertainties of

the sonar monitoring during the first half of June, including both the numbers and species of fish.

In addition to the environmental issues during the early season, one major technical problem was faced during the monitoring period coinciding the most active salmon run. The telephoto lens used in the sonar started to leak its internal fluids causing heavily decreased picture quality in mid-July. This problem meant two days of no monitoring data before a replacement lens was available and installed. The salmon run size during these days was therefore estimated based on data before and after the missing period. We, however, think that our estimation for these days is quite reliable, because of good before-after data was available.

In addition to running and maintaining the monitoring itself, the sonar data analysis required the largest share of working hours. The counting and measuring of the passing fish were done manually by several trained employees. Challenges in the analysis and estimation were mostly in measuring the fish, and the substantial back-and-forth movement of both salmon and other fish species, especially whitefish around the monitoring site. These issues increase the uncertainty on salmon numbers and on their size distribution. These problems were, however, greatly reduced by using underwater video cameras in parallel with the sonar.

When manually measuring fish with imaging sonars, it is known that the operator (person who measures the fish) tends to overestimate the lengths of the small fish but underestimate the lengths of larger fish (Daroux et al. 2019). This human error is not only shifting the small salmon into the larger size group but may also potentially be shifting <45cm fish (other species than salmon) into the small salmon group. Another problem in measuring was that small fish in a group, very close to each other, might be measured and registered as one big fish, basically a salmon (e.g., three whitefish together might look like a large salmon). This potential error was discovered from the video data, again emphasizing the need of having additional reference data to interpret the sonar results.

Many of the upstream passing fish were also passing downstream later. These fish included both salmon but especially other species than salmon that are not passing the Skoltefossen waterfall. It was observed that downstream passing fish are harder to be detected in the sonar data, especially if fish are passing very fast, sideways in relation to the current or at very top of the water column (near surface). This problem basically means that e.g., the salmon run size could be easily overestimated. This issue is especially true in the current Neidenelva sonar site, which is situated close to the river mouth and having a heavy waterfall only 1.5 km upstream. These conditions increase the probability of back-and-forth movements (e.g., salmon ascending to a wrong river and salmon moving downstream when encountering the waterfall) with lower probabilities in observing downstream migrants.

4.4.1. Future sonar monitoring site in Neidenelva

When considering the challenges observed in the sonar monitoring in 2022, it would be reasonable to re-evaluate the location of the sonar site for future studies. An obvious choice would be a site shortly above the Skoltefossen waterfall, at the head of the Skoltefossen rapid. This location would basically exclude other species than salmon and sea trout, e.g., whitefish. It would also most probably reduce the amount of back-and-forth movement of salmon and sea trout clarifying and quickening the sonar data analysis. On the other hand,

there are only very limited spawning areas below the waterfall meaning that only a negligible proportion of salmon would not be counted if using above waterfall monitoring site.

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