Region- and stock-specific catch and migration models of Barents Sea salmon

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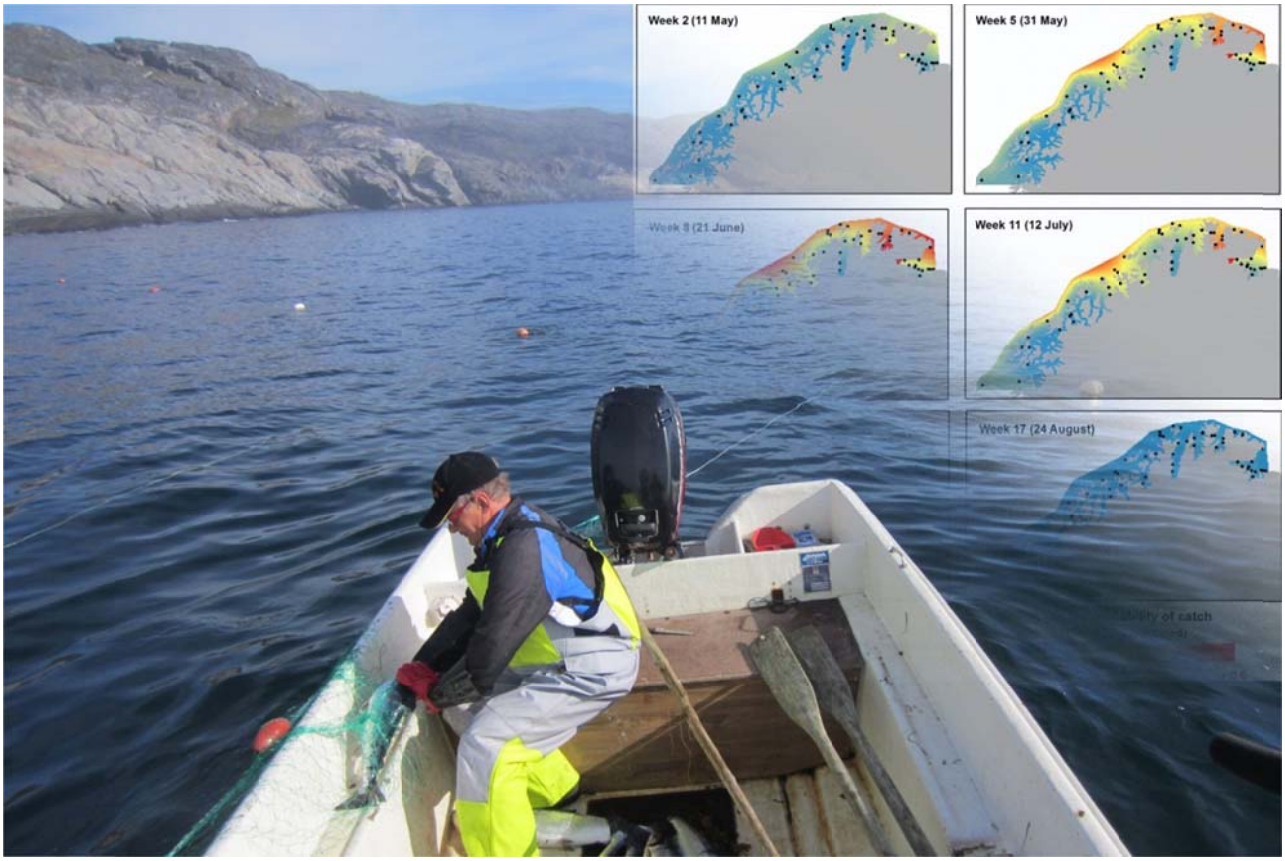

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Abstract

The key element in the life history of Atlantic salmon is the accurate return migration from feeding areas at sea to the natal river to reproduce. Because of this accurate natal homing, individuals from the river interbreed, but are to a large extent reproductively isolated from salmon in other rivers. As a result of this reproductive isolation and divergent selection, salmon inhabiting different rivers have accumulated significant inter-population genetic variation which can be used to identify the river origin of catch samples from the coastal mixed-stock fishery of northern Norway.

Sampling was conducted over four years (2008, 2009, 2011, 2012), of which the first two years were pilot studies limited to Finnmark only, and the latter two years were the full-scale sampling covering northern Nordland, Troms and Finnmark. A total of 24 922 salmon were captured from 2008 to 2012. Of these, 22 554 individuals were wild salmon. In 2011 and 2012, a total of 17 383 wild salmon were captured and of these, 16 096 salmon were stock identified using microsatellite genetic markers.

Catch per unit effort (CPUE) is the most useful and relevant way of analysing the catch data for management purposes. CPUE was relatively similar between 2011 and 2012 (3.4 and 4.3 salmon per day per gear, respectively). The highest monthly CPUE was found in July and lowest in May for all three counties and both years. Of the three counties, the highest monthly CPUE was found in Troms (up to 12 salmon per day per gear), followed by Finnmark (up to 7.3 salmon per day per gear) and Nordland (up to 3.0 salmon per day per gear).

The coastal salmon fishery in Norway is divided into a number of management regions. These regions are defined either as outer coastal regions or inner (fjord) regions. Under this management regime, the coastal fishery in an outer region is expected to exploit salmon stocks from a large area, while the fishery in an inner region is expected to exploit salmon stocks locally within the inner region. Tests of these assumptions in the present dataset show that they are mostly true. The stock diversity was much higher in outer regions (49-134 stocks present in catches of the various outer regions) than in inner regions (23-55 stocks present), while the percentage of the catch belonging to local stocks was much higher in inner (3-83 %) than in outer regions (0-47 %). There were two main exceptions. Firstly, the Varanger area. The catch in the current *Inner Varanger*-region is comparable to the catch in outer coastal areas, and the stock composition is similar throughout the Varangerfjord. We therefore replace the current *Inner Varanger*-region with an expanded *Varangerfjord*-region that covers the municipalities Sør-Varanger, Nesseby and Vadsø, in the region-based analyses of the report. Secondly, the salmon catch in the *Inner Nordland*-region was relatively diverse for an inner region (55 stocks), and the percentage local stocks was very low at only 3 %.

When looking at the regional catch of salmon in the different regions, two main patterns emerge: Firstly, it is clear that the salmon catch in all inner regions except *Inner Nordland* was dominated by local stocks. Secondly, the salmon catch in the outer coastal regions was dominated by a combination of local stocks and salmon from neighbouring regions. The latter point indicates that the salmon spawning migration from the open ocean is reasonably accurate, bringing the salmon to coastal waters relatively close to their home regions.

We provide some stock-specific examples of the current salmon management regime and how the pre-fishery abundance was divided into coastal catch, riverine catch and spawning stock in 2011 and 2012. The relative proportion of the PFA taken in coastal fisheries varied greatly among the example stocks. The lowest coastal catch proportions were found for the example stocks located in outer coastal regions, while the highest proportions were found for the inner region-stocks.

There were also a tendency for the highest coastal proportions to be found in the inner regions located in the middle of the study area (Inner Troms, Fjords in West-Finnmark and Porsanger). The highest coastal catch proportion was observed for the Alta stock (*Fjords in West-Finnmark*) with up to 49 % of the PFA taken in coastal fisheries in 2011. The lowest coastal catch proportion was observed for the Roksdal stock (*Outer Nordland*) with 1-3 %.

A stock-specific migratory model was developed for the four largest stocks, i.e. Målselv salmon in Troms county, Alta and Tana salmon in Finnmark county and the Kola salmon (Kola peninsula, Russia). All these stocks reached the North-Norwegian coast mainly in June-July, with the MSW-salmon arriving almost a month earlier than 1SW-salmon. The two westernmost stocks, i.e. the Målselv and Alta stock, both seemed to approach the western coast of northern Troms and western Finnmark, more or less directly from the open sea. Thus, for instance the Målselv stock was mostly exploited around islands and coastlines in western Troms and close to the Malangen fjord system. Analyses show that both MSW and 1SW Målselv salmon reach the coast in a narrow pattern from the west. This indicates a fairly accurate homing from open ocean, with the Målselv-salmon being able to swim almost straight into the Malangen area with a minimum amount of navigation along the outer coast. This coastal migration pattern minimize the exposure of Målselv-salmon to exploitation in the outer coastal region, and most sea fishery exploitation of Målselv salmon take place in the Inner Troms-region. Based on the strong regulations in salmon sea fishery in Troms, a relatively small fraction of the Målselv-stock is exploited through the formal sea fishery (18-23 %).

In general terms, the Alta stock seem to have a fairly similar migrating pattern as the Målselv stock, i.e. reaching the coast of Troms and western Finnmark more or less from the west and northwest. Most of the coastal exploitation happens within the Alta fjord. Still, as the Alta-salmon arrive at the coast in a broader area than Målselv-salmon, a significant fraction of the Alta-salmon must navigate eastwards along the outer coast of Troms and western Finnmark, meaning that Alta-salmon are more exposed to outer coastal fisheries than Målselv-salmon. Based on the migration model, some of the 1SW salmon enters Alta fjord from the north, being slight differently compared to the MSW Alta stock. Although MSW Alta salmon reach the coast several weeks earlier than 1SW, MSW salmon was quite heavily exploited already in late May, and this continued in June and July. Some MSW salmon from Alta were even caught in August. The Alta stock therefore suffers a very high exploitation rate from the salmon sea fishery, especially within the Alta fjord in July and early August. Based on the catch pattern a reduction in the salmon sea fishery in the Altafjord and outer coastal areas of western Finnmark would probably decrease the exploitation of the Alta stock significantly.

Tana salmon, as opposed to Målselv and Alta salmon, was recorded in the coastal catches from all fishing regions in the study area. Although the highest number of salmon (CPUE) was captured in the Tana fjord, relatively high CPUE-values were observed both in the outer coast of Troms as well as the western, middle and eastern outer coast of Finnmark. The catches were rather high in all areas during the same periods/weeks. The observed spatial and temporal catch pattern strongly suggest that Tana salmon reach the coastal areas both from southwest, west, north and east. Still, the number of Tana salmon in the coastal catches was surprisingly low, especially in light of the dominating position the Tana river system has in terms of total salmon production potential in northern Norway. As a result of the relatively low coastal catches of Tana salmon in 2011 and 2012, the estimated proportions of the pre-fishery abundance that were caught in the coastal fisheries were also low (9-13 %) in these particular years. These low estimates are inconsistent with e.g. the Alta coastal estimate of 40-50 %.

There are 20-30 reproductively discrete salmon stocks within the Tana river system. Many of these are early-migrating stocks that are caught in the Tana main stem as soon as the river fishing

season starts (May 20). Some of these salmon had therefore likely passed the outer coastal areas before the coastal sampling commenced, and this might contribute to the low proportion of Tanasalmon in the coastal catch. Another possible contributing factor in explaining the low coastal catch of Tana salmon might be that catchability in general is lowest for early migrating salmon and that the efficiency of the coastal fisheries vary between regions, perhaps being naturally low in the Tanafjord.

Salmon originating from Russian rivers comprised more than 20 % of the recorded catches. Still, the incidence of Russian salmon in the catches varied strongly within season and among fishing regions, being less than 9 % in the coastal catches from Nordland, Troms and Finnmark, while nearly 50 % of all salmon captured in the Varangerfjord had Russian origin. The catch of Russian salmon decreased by time within season, e.g. in Varanger the incidence of Russian salmon decreased from ca. 70 % in May to ca. 20 % in August. Thus, catches of Russian salmon was much higher before the start of formal fishing season in Eastern Finnmark, but, still a fairly high amount of the recorded catch in this area consisted of salmon stocks originated from Russian rivers.

Kola salmon, both 1SW and MSW, was most frequently recorded in catches in Eastern Finnmark, i.e. especially in Varangerfjord, whereas some Kola salmon were caught in western Finnmark in very early season. This may indicate that most Kola salmon reached the coast in Eastern Finnmark, whereas some fishes migrated from the west, but fairly far from the North-Norwegian coastal areas. The CPUE-values of MSW Kola salmon in Varangerfjord was highest in June/July, while Kola salmon was more or less absent in catches from early August an onwards.

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Sammendrag

Nøkkelparameteren i livshistoria til Atlantisk laks er at den etter beiteoppholdet i havet - med stor presisjon – vandrer tilbake for å gyte i den elva den var født i. Ulike miljøutfordringer i vassdragene, samt den presise tilbakevandringen, bidrar til at det over tid oppstår genetiske forskjeller mellom laks fra ulike vassdrag, og til dels også innen enkelte elver. På grunn av reproduktiv isolasjon og ulik seleksjon, akkumuleres genetisk variasjon mellom de ulike elvebestandene. Dersom en kjenner disse laksetypene, dvs. har etablert en genetisk database over bestandene, kan en ved å analysere enkeltindivider av laks som for eksempel fanges under sjølaksefisket langs kysten av Nord-Norge, sannsynliggjøre fra hvilken elv laksen kommer fra.

I Kolarctic Salmon prosjektet ble det fanget laks i fire år (2008, 2009, 2011 og 2012), hvor det i de to første årene (pilotprosjekt) kun ble fanget laks langs Finnmarkskysten, mens det under hovedprosjektet (2011 og 2012) ble gjennomført en fullskala prøvesamling fra både Nordland, Troms og Finnmark. Totalt ble 24 922 laks fanget i disse fire årene, hvorav 22 554 ble klassifisert som villaks. I 2011 og 2012 ble det fanget 17 383 villaks, hvorav 16 096 fisk ble identifisert til hjemelv ved bruk av mikrosatellitter.

Fangst per innsats (CPUE) er den mest relevante og nyttige måten å framstille og analysere fangstdata på i forvaltningsøyemed. CPUE var rimelig lik i 2011 og 2012 (henholdsvis 3.4 og 4.3 laks fanget pr dag pr redskap). For alle fylkene ble det i begge årene registrert høyest CPUE i juli og lavest i mai. Høyeste gjennomsnittlige månedlig CPUE ble registrert i Troms (12 laks/redskap/dag), mens høyeste registrerte i Finnmark og Nordland var henholdsvis 7.3 og 3.0 fisk/redskap/dag.

Sjølaksefisket i Norge er inndelt i flere forvaltningsregioner, definert som enten ytre kyst eller indre fjord regioner. Bakgrunnen for denne inndelingen er at det forventes at det i de ytre fjordstrøkene fanges laks fra mange elver spredt over et relativt stort geografisk område, mens det i de indre fjordområdene forventes å beskatte mer lokale laksestammer. Resultatene fra dette prosjektet viser at denne antagelsen i stor grad var korrekt. I de ytre regionene ble det registrert 49-134 bestander mot bare 23-55 i de indre områdene. Også andelen av lokale stammer var vesentlig lavere i fangstene i de ytre områdene (0-47 %) i forhold til de indre områdene (3-83 %). Vi fant imidlertid to unntak. Det ene var Varangerfjord-området, der vi ikke fant noen forskjell i indre og ytre områder, verken mellom antall bestander i fangstene eller mellom andelen lokale stammer. Vi slo derfor hele dette området, dvs. kommunene Sør-Varanger, Nesseby og Vadsø, sammen til en Varangerfjord-region i de regionbaserte analysene i denne rapporten. Det andre unntaket er de indre fangstområdene i Nordland, hvor fangstene var uventet diverse (55 bestander), samt at andelen lokale stammer var svært lav (3 %).

De regionale fangstene i de ulike regionene viser to klare mønstre; at fangstene i de indre regionene (bortsett fra i Nordland) var dominert av lokale laksestammer, mens fangstene i de ytre regionene var dominert av en kombinasjon av lokale bestander, samt bestander fra naboregioner. Fangstsammensetningen i de ytre områdene indikerer at laksens tilbakevandring er rimelig presis og at laksene kommer inn til kysten relativt nært hjemelva/hjemregionen.

Vi gir noen bestandsspesifikke eksempler på hvordan innsiget av laks i 2011 og 2012 fordeler seg på sjøfangst, elvefangst og gytebestand under dagens fiskeregulering. Den relative andelen av innsiget som fanges i sjølaksefisket varierte betydelig blant eksempelbestandene. De laveste sjølakseandelene ble funnet i de eksempelbestandene som er lokalisert på ytre kyst, mens de høyeste sjølakseandelene ble funnet hos bestandene lokalisert i de indre regionene. Det var også en tendens til at de høyeste sjølakseandelene ble funnet i de indre regionene som er plassert midt i studieområdet (Indre Troms, fjordene i Vest-Finnmark og Porsanger). Den høyeste

sjølaksefangstandelen ble funnet for Altaelva (fjordene i Vest-Finnmark) der 49 % av innsiget ble fanget i sjølaksefisket i 2011. Den laveste fangstandelen fra sjølaksefisket ble observert for Roksdalselva (Ytre Nordland) med 1-3 % i 2011 og 2012.

En bestandsspesifikk migrasjonsmodell ble utviklet for fire av de største bestandene i prosjektområdet: Målselva i Troms, Alta og Tana i Finnmark og Kolaelva i Russland. Alle disse fire bestandene når kysten av Nord-Norge i juni-juli, med flersjøvinterlaks (MSW) nesten en måned tidligere enn ensjøvinterlaks (1SW). De to vestligste bestandene, Målselva og Alta, så begge ut til å komme til den vestlige kysten av Troms og Vest-Finnmark relativt direkte fra åpent hav. Målselv-laksen ble i hovedsak beskattet rundt øyene og kysten vest i Troms og nær Malangen. Både MSW- og 1SW-laks fra Målselva ankom dermed kysten over et relativt trangt område fra vest. Dette indikerer at Målselv-laksen navigerer relativt nøyaktig inn fra åpent hav, og gjør at laksen kan svømme inn mot Malangen uten å måtte navigere langs ytre kyst. Dette migrasjonsmønsteret gjør at Målselv-laksen er minimalt eksponert for sjølaksefisket langs ytre kyst av Troms, og det meste av sjølaksebeskatningen på Målselv-laks finner sted i Malangen i indre Troms. På grunn av den strenge reguleringen av sjølaksefisket i Troms, så blir en relativt lav andel av innsiget av Målselv-laks (18-23 %) fanget i den vanlige fisketiden.

Generelt så ser Alta-laksen ut til å ha omtrent samme vandringsmønster som Målselv-laksen, ved at den kommer inn til kysten av Troms og Vest-Finnmark fra vest og nordvest. Den største andelen av sjølaksebeskatningen av Alta-laks finner sted i selve Altafjorden. Men, ettersom Alta-laksen ankommer kysten i et noe bredere område fra vest enn Målselv-laksen, så må en signifikant andel av Alta-laksen vandre langs den ytre kysten av Troms og Vest-Finnmark. Alta-laksen er derfor mer utsatt for beskatning i de ytre kystområdene. Migrasjonsmodellen antyder også at noe 1SW-laks fra Alta kommer direkte fra nord. Flersjøvinterlaks fra Alta ankommer kysten flere uker tidligere enn ensjøvinterlaksen, og flersjøvinterlaksen blir derfor beskattet høyt allerede i mai. Den høye beskatningen av flersjøvinterlaks fortsetter i juni og juli. Noe flersjøvinterlaks ble også fanget i august. Alta-laksen er dermed utsatt for et omfattende sjølaksefiske, særlig i Altafjorden i juli og tidlig august. Basert på fangstmønsteret så vil en reduksjon i sjølaksefisket i Altafjorden og langs ytre kyst av Vest-Finnmark føre til en betydelig reduksjon i beskatningstrykket på laksen i Alta.

Laksen fra Tana ble funnet over en langt bredere del av studieområdet enn laks fra Målselv og Alta. Den høyeste beskatningsraten ble observert i Tanafjorden, men det ble også funnet relativt høy beskatning langs ytre kyst av både Troms og Finnmark. Beskatningen var relativt høy i alle disse områdene i omtrent samme periode. Dette romlige og temporære beskatningsmønsteret indikerer at laks fra Tana ankommer ytre kyst over et bredt område fra alle retninger (både sørvest, vest, nord og øst). På tross av det brede beskatningsområdet så er den samlede fangsten av Tanalaks overraskende lav i sjølaksefangstene, særlig i lys av den dominerende posisjonen Tana har blant lakseelvene i Nord-Norge. Den lave fangstandelen i 2011 og 2012 gjør at vi estimerer at sjølaksefisket i disse to årene tok 9-13 % av innsiget. Dette er anslag som er ikke er konsistent med estimatet fra Alta på 40-50 %.

Det er 20-30 egne laksebestander innenfor Tanavassdraget. Mange av disse bestandene vandrer tidlig og fanges i selve Tanaelva allerede når fiskesesongen der åpner (20. mai). Denne laksen har dermed passert kystområdene før det ordinære sjølaksefisket starter, og denne tidlige vandringen kan bidra til at andelen Tanalaks i sjølaksefisket er lav. En annen mulig faktor er at fiskeeffektiviteten i sjøen generelt er lav tidlig på sesongen, samt at effektiviteten i sjølaksefisket varierer fra område til område og muligens kan være naturlig lav i Tanafjorden.

Laks fra russiske elver utgjorde mer enn 20 % av fangstene i prosjektet. Innslaget av russisk laks varierte imidlertid betydelig innenfor sesongen og mellom de ulike regionene. Under 9 % av kystfangsten i Nordland, Troms og Finnmark var russisk laks, mens helt øst i Finnmark, særlig

Varangerfjorden, var nesten 50 % av laksen russisk. Fangsten av russisk laks sank utover fiskesesongen, for eksempel fra 70 % i mai til 20 % i august øst i Finnmark. Fangsten av russisk laks var dermed på sitt høyeste i perioden før den ordinære fiskesongen starter, men også i den ordinære fiskesesongen så er en stor andel av fangsten, særlig i Varanger, russisk laks.

Laks fra Kolaelva, både ensjøvinter og flersjøvinter, ble for det meste fanget i Varangerfjorden. Noen ble også fanget vest i Finnmark helt i starten av prøvefiskeperioden. Dette kan indikere at det meste av Kolalaks ankommer kysten øst for Finnmark, og at bare en liten andel migrerer fra vest. Fangstratene av flersjøvinter Kolalaks var høyest i Varangerfjorden i juni/juli, mens i august var Kolalaksen stort sett fraværende.

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Contents

Foreword

This report forms part of the final reporting of the Kolarctic salmon 2011-2013-project ("Trilateral cooperation on our common resource; the Atlantic salmon in the Barents region"), and focuses on migration and exploitation of salmon, both on a management region basis and a stock-specific basis, within the coastal fishery in northern Nordland, Troms and Finnmark. The report mainly answers activity 15 ("stock specific migration") in the project plan, but also pertains strongly to activities 11, 13 and 14.

Project partners are the County Governor of Finnmark (lead partner), Institute of Marine Research – Tromsø (IMR), Norwegian Institute for Nature Research – Tromsø (NINA), Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO) – Murmansk and Archangelsk, University of Turku – The Kevo Research Station (UTU-Kevo) and the Finnish Game and Fisheries Research Institute (FGFRI).

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Martin-A. Svenning Morten Falkegård

1 Introduction

Atlantic salmon (*Salmo salar*) have a compex life cycle, spending their first years as juveniles in freshwater, and then migrating out into the open sea to feed and grow large for one to several years before returning to their home river to spawn (Mills 1989). Their complex life history is influenced by factors encompassing various freshwater and marine habitats that span large spatial and temporal scales (Kocik & Ferreri 1998), and salmon stocks are characterized by strong annual fluctuations in survival and abundance that can be severe and occur over wide areas (Dempson *et al*. 1998). The number of salmon returning to coastal areas depends on smolt production (Jonsson *et al*. 1998) and variability in ocean conditions that influence survival, growth and subsequent sea-age at maturation (Crozier & Kennedy 1999). In addition, coastal and riverine exploitation, during the salmon spawning migration, add substantive additional mortality and may contribute to strong declines in the number of salmon eventually reaching their spawning home areas (e.g. Dempson *et al*. 2001).

The key element in the life history of Atlantic salmon is the accurate return migration from feeding areas at sea to the natal river to spawn. Because of this accurate natal homing, individuals from the same river interbreed, but are to a large extent reproductively isolated from salmon in other rivers. Divergent selection on heritable variation of traits enhancing survival and reproductive success of individuals under particular physical and biotic determinants has led to significant variation in many morphological and life-history traits, as well as in behavioural characteristics both within and among populations (reviewed in García de Leániz *et al*. 2007). As a result of the reproductive isolation and divergent selection, salmon inhabiting different rivers have accumulated significant inter-population genetic variation. High levels of differentiation have been shown even at a sub-basin level, for instance between tributary populations of Atlantic salmon in the River Tana system (Vähä *et al*. 2007).

Rivers in northernmost Norway, Finland and Russia, i.e. the Barents Sea area, support the world's largest wild Atlantic salmon stocks and resources, and salmon has a high socio-economic value in these areas both through commercial and subsistence coastal fisheries and recreational fisheries in rivers. The fisheries represent a significant cultural heritage for indigenous people employing traditional knowledge and old harvesting methods. Presently, the salmon stocks in the Barents Sea area are highly important, as stocks elsewhere on both sides of the Atlantic have declined greatly in the last 50 years while the Barents Sea stocks still retain a high level of production (ICES 2013). Unfortunately, there have been some signs in recent years that the abundance also in some of these northernmost salmon stocks, for instance the Tana river, has declined, maybe driven by processes connected to overfishing, habitat degradation and/or climate.

Conservation and management of these unique and important stocks is of extreme importance, but the migratory behaviour of the species imposes a great challenge as this joint natural resource is exploited along huge coastal, estuarine and in-rivers areas. A multistock Atlantic salmon sea-fishery operates off the coast of North-Norway, i.e. in the three northernmost counties of Norway (Nordland, Troms and Finnmark). Average annual landings the last 15-20 years have been close to 300 tonnes (official national catch statistics from Statistics Norway). This coastal catch approximately equals the total annual river landing from the approximately 65 salmon rivers in the area, while the total river and coastal catch in North-Norway constitutes more than 60 % of the total Norwegian salmon catch. Thus, one of the greatest challenges in salmon management and conservation in this area is to gain insight into the salmon spatial and temporal ecological use of the marine coastal environment. Tens of different salmon river stocks may migrate along the coastal areas at the same time and exploitation targets two or more river stocks at a time (mixed-stock fishery). For example, to what extent is the coastal fishery in North-Norway exploiting salmon from other countries, primarily Russia and Finland? And to what extent are struggling

stocks such as Tana salmon exploited in the coastal fisheries along the Norwegian coast? Answering these kinds of questions is of essential importance for the management, conservation and research cooperation of the Atlantic salmon in the Barents area.

It is often argued that in the absence of detailed knowledge, mixed-stock fisheries should be limited, although such limitations should be balanced against the need to preserve the rich tradition and local economic importance of the coastal mixed-stock fishery (e.g. Crozier *et al*. 2004). The salmon sea-fishery in North-Norway, and especially in Finnmark, has long cultural traditions. It has also been strongly debated during the last 10-15 years due to the complexities involved in the potential mixed stocks harvesting, especially since Russian salmon from more than 75 rivers in Kola, White Sea area and further east to Pechora may also be harvested during their potentially homeward spawning migration along the North-Norwegian coast line. It is widely acknowledged that in order to manage fisheries effectively and to optimize their yield in a sustainable manner, each contributing stock must be managed separately.

While stock specific conservation and management plans can be made for each river, this may not be sufficient because of the biology and especially the migratory behaviour of salmon. Increased knowledge of the variation in the occurrence time and space of different salmon populations along the Barents and White Sea coast will allow for more precise management of the salmon fisheries in this region. Building on such information, managers can regulate mixed-stock fisheries in such a way that populations are not exploited beyond their harvestable surplus, thus providing a sound foundation for the long term management of this important resource. The present situation, where regulatory measures are based on limited knowledge, may lead not only to over-exploitation of weaker populations, but also to the implementation of stricter regulations in areas where sustainable harvest is possible.

Although the distribution and ecology of Atlantic salmon in freshwater have been well documented, our knowledge of the ocean phase of their life cycle is still rather scarce (Svenning & Prusov 2011). This is mostly due to the very high costs associated with sampling over very large marine areas as opposed to sampling in rivers and coastal waters (Holm *et al*. 2003). Most of our past and current knowledge of the distribution of adult salmon has therefore been obtained through commercial catches and elements of recaptures from both high-seas and coastal fisheries during the past 100 years. Atlantic salmon are distributed over large areas of the North Atlantic. On the basis of tagging of adult salmon captured north of the Faroe Islands, recaptures were reported in rivers in ten European countries as far south as Spain and as far northeast as the White Sea rivers in Russia, as well as rivers in North America (Hansen & Jacobsen 2003). Using capture/recapture to indicate patterns of migration in the sea is somewhat questionable, since such recoveries depend both on the distribution of the fishery and on the fishing effort involved. Nonetheless, such a wide geographical distribution of recaptured wild salmon suggests that most of the North Atlantic salmon stock, at least at some stage of their life cycle, is present in the Norwegian Sea north of the Faroes (Hansen & Jacobsen 2000). During a period of 13 years (1962–1974) a total of 240 salmon captured in coastal bag nets, tagged and released close to the south-western coast of Finnmark, were recaptured in Russian home waters 9-97 days after tagging (Svenning & Prusov 2011). Two fish were recaptured in the Pechora River more than a year after tagging, suggesting that salmon from Russian rivers migrate through Norwegian coastal waters not only to spawn but also to feed (Bakshtansky & Nesterov 1973). Also tagging studies in 1937 showed that a relatively high frequency of recaptures was made in Russian rivers. On the basis of the four northernmost recoveries of salmon (70-78°N), tagged and released in the Drammen River in southeastern Norway and in the Alta River in the north of the country, it has been suggested that Norwegian Atlantic salmon, especially fish from northern populations, may use the northern Barents Sea as a feeding area during part of their life cycle (Rikardsen *et al*. 2008, Svenning &

Prusov 2011). Data obtained from 15 descending kelts from the Tana River, northeastern Norway, tagged with satellite archival pop-up tags (Svenning, unpublished data), all turned up in the Barents Sea (72-75°N), further supporting this idea (Svenning & Prusov 2011). Thus, it is suggested that Atlantic salmon from North-Norwegian and Russian rivers use the Barents Sea as their main feeding area, and that at least some of the stocks approach the coastal areas in Troms and western Finnmark in summer and migrate eastwards along the Finnmark coast heading for their home rivers to spawn. This also indicates that the Norwegian coastal sea salmon fishery, at least in northern Troms and Finnmark may exploit a significant amount of salmon originating from Russian rivers.

To date it has not been possible to identify the detailed origin (home rivers) of wild salmon caught in a mixed-stock coastal fishery (Svenning & Prusov 2011). However, by using genetic stock identification, where a set of genetic markers are used to compare samples of a known origin (a comprehensive genetic baseline consisting of juvenile salmon samples from rivers in the study area) with the unknown salmon from the coastal mixed-stock catch, it is now possible with high precision to define the home region or even the specific river origin of each captured salmon. For example, Vähä *et al* (2011) identified the origin of salmon in mixed-stock fisheries and showed that salmon originating from different tributaries of the Tana River actually show significant variation in run timing (migration) to fresh water. The ultimate utility of using these genetic techniques to discriminate among different salmon stocks depends on the degree of isolation among the populations or regions, the diversity and numbers of markers used and a sufficient representation of spatial genetic diversity in the genetic baseline. During this study/project, i.e. Kolarctic salmon (http://www2.fylkesmannen.no/hoved.aspx?m=67246) we have developed a genetic base line for Atlantic salmon populations in North-Norway and Russia, and are able to not only confirm from which home region or country the salmon originate, but also in most cases determine the home river for each salmon caught.

Thus, the aim of this study was to define and quantify the amount of the different salmon stocks contributing to the coastal sea salmon fisheries along the North-Norwegian coast and try to develop a stock-specific migration model for some of the largest Barents Sea salmon populations, i.e. the Målselv, Alta, Tana and Kola stock. To determine the home or river origin of the Barents Sea salmon in this study, the genetic data of more than 20 000 wild adult salmon caught at more than 75 localities along the North-Norwegian coast in the years 2008-2012, were compared to a database of genetic profiles, based on salmon juveniles sampled from 185 rivers in North-Norway and Russia and analysed for variation in 31 microsatellite markers. Further, this knowledge may contribute towards more precise and informed regulatory measures in the Barents Sea area, to improve the management of salmon stocks homing to Barents Sea rivers, and giving the management authorities a new tool to ensure a future sustainable exploitation of the northernmost Atlantic salmon populations in Europe.

2 Methods

2.1 Sampling procedure

The sampling of adult Atlantic salmon was conducted along the North-Norwegian coast in 2011 and 2012 by professional sea fishermen using commercial fishing gear (hook nets and/or bag nets). They were given a special fishing permission, connected to each person and his legal fishing site/sites. Sampling was conducted from early May to mid-September. A total of 39 and 54 fishermen were sampling salmon in 2011 and 2012, respectively, and sampling was conducted both in Nordland, Troms and Finnmark county (**Figure 1**). In the pilot project in 2008 and 2009 fishing was conducted only in Finnmark county, including 27 and 16 fishermen, respectively.

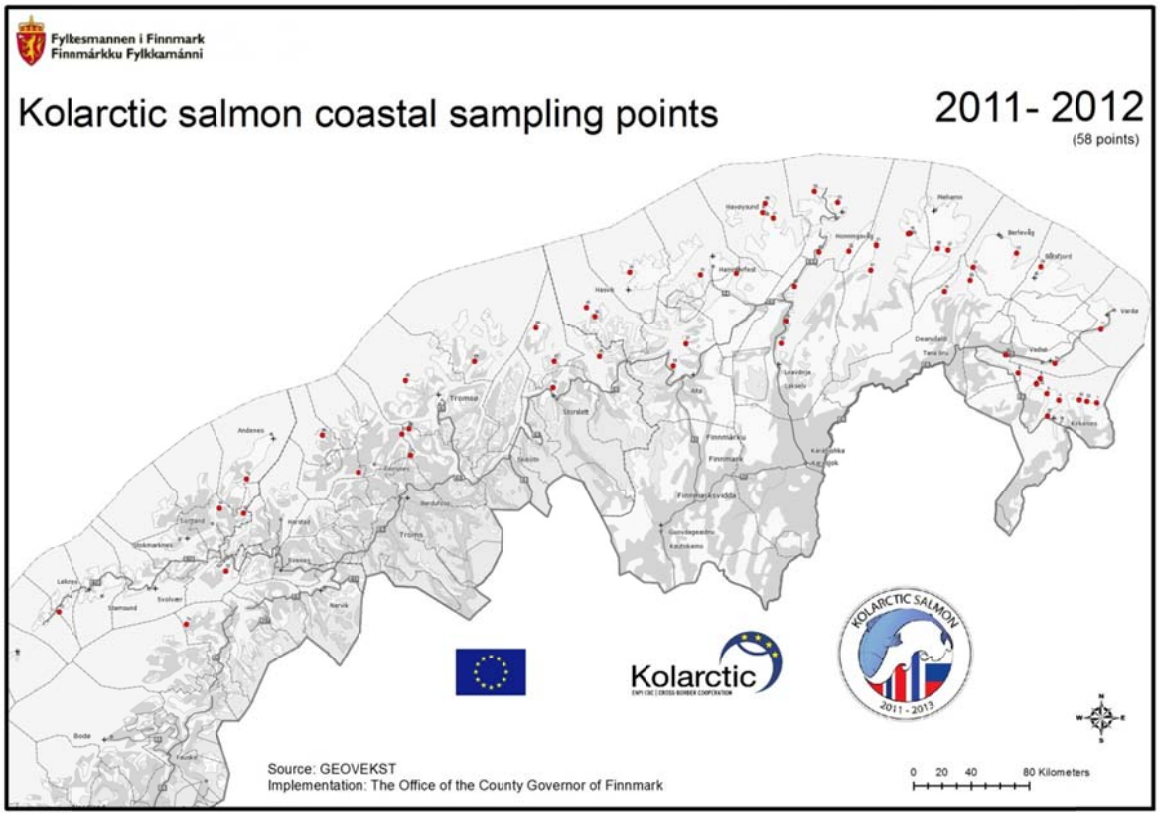


***Figure 1**. Map of the Kolarctic-salmon study area with 2011-2012 fisherman locations marked with red dots.*

Each fisherman has to note (daily) when the fishing gear has been set and hauled, to estimate the number of salmon captured per unit effort (CPUE). Wind direction and other environmental conditions affecting the fishery were as well noted in a logbook. All captured salmon were measured and weighted, while sex, maturation, infection of parasites etc. was registered. Scales were sampled for age and growth determination, for genetic analyses and for establishing the frequency of farmed fish in the catches. More details about the sampling of adult salmon are given in Niemelä *et al*. (2014).

2.2 Genetic methodology

To determine the river of origin of the more than 20 700 wild salmon caught in the coastal fisheries, multi locus genotypes from 31 DNA markers was compared to a genetic baseline consisting of genetic profiles from 185 rivers in North-Norway and Russia. All sampled salmon was then assigned to their home river, or in some cases region of origin, with an associated probability. More details about the genetic baseline, the genetic analyses of adult salmon and the assignment to their potential home rivers are given in Vähä et al. 2014.

2.3 Statistical methodology

To calculate catch per unit effort, we combined the catch data (data on individual fish) with data on fishing effort (reports on fishing effort from individual fishers). Because fishing effort was regulated by a maximum allowed number of fishing days per week, week was used as the basic unit in the calculations. CPUE was defined as the number of fish caught during a week divided by the number of fishing days in the same week. The data were averaged over months to provide monthly maps of CPUE of fish of different origin.

Catch data of salmon from four specific river systems (Målselv, Alta, Tana and Kola) were used to model the inshore migration pattern of salmon. Initial analyses and visual inspections of the data suggested that the migration pattern in 2011 and 2012 was similar. Because we wanted to investigate the general pattern, irrespective of year, we adopted to combine data from the two years in the analyses. Initial analyses also suggested difference in the timing of migration of different age classes. Consequently, we modeled fish with a sea age of one year and fish with a sea age of more than one year separately.

We used Generalized Additive Models (GAM) from the “mgcv“ library (Wood 2006) in R v.2.13.0 (R_Development_Core_Team 2011) to model how CPUE of salmon of different origin (river system) changed geographically over time. Due to zero-inflated data, we adopted to model the probability of fishing one or more salmon (with a specific origin) per fishing week (CpueS) as the dependent variable using a logit link and a binomial distribution. Instead of using latitude/longitude to model geographic location, we used a two-dimensional coordinate system determined by the outer Norwegian coastline where: CoastX (Axis 1) is the inhore-offshore gradient, defined by the shortest distance (in km) from the fishing location to the outer Norwegian coastline; and CoastY (Axis 2) is the position along the Norwegian coast from southwest to northeast. CoastY was defined as the distance (in km) from an arbitrary point along the Norwegian coastline to the point on the coastline with the shortest distance to the fishing location. Time is week since 1 May. CpueS was modeled with a three-dimensional smooth function; g(CoastX, CoastY, Time). Thin plate regression splines were used. Because each fishing location had many observations, the model was prone to geographic overfitting and the basis dimension (k) was set to 20. Based on the fitted models, we used the “predict” function in the “mgcv” library to predict the average spatial distribution for given weeks on a 2x2 km2 grid covering the area inshore of the outer coastline from Vesterålen in south to the Norwegian boarder to Russia in northeast. This area covered all fishing locations.

3 Results

3.1 Number of salmon captured (May-August, 2008-2012)

In 2008 and 2009 fishing was conducted only in Finnmark county, including 27 and 16 fishermen, respectively, while fishing was extended to Nordland and Troms county in 2011 and 2012, including a total of 39 and 54 fishermen, respectively. A total of 72 fishermen delivered samples (scales) to the project during these four years.

A total of 24 922 salmon were captured from 2008 to 2012, and based on scale characteristics 22 554 individuals (90.5 %) were determined to be wild salmon (**Table 1**). Most wild salmon was caught in July and August (83 %), while total catch in May and August was fairly similar and amounted to 16.7 % (**Table 2**). Of the 22 496 salmon caught from May-September (99.7 %), a total of 20 754 individuals (92.3 %) were analysed for microsatellite genetic markers (**Table 2**). Only 64 wild salmon (0.3 %) were caught in September.

For the years 2011 and 2012, when fishing was conducted both in Nordland, Troms and Finnmark, a total of 17 383 wild salmon was captured and of these 16 096 salmon were analysed for microsatellite genetic markers (**Table 2**). In this report, only salmon captured during the formal Kolarctic salmon project period (KOL 197) are included in further descriptions and analyses.

Table 1*. Number of salmonids captured by commercial sea-fishermen in Finnmark county in 2008-2009, and from Nordland, Troms and Finnmark counties in 2011 and 2012. Salmon were caught by bag nets or hook nets. The 2011 and 2012 sampling sites are shown in* ***Figure 1****.*

Fish species/types	2008	2009	2011	2012	Total
Pink salmon	3	9	4	2	18
Farmed trout	3	3	0	0	6
Wild trout	0	6	34	69	109
Farmed salmon	158	69	1 027	1 114	2 368
Wild salmon	4 134	1 037	7 277	10 106	22 554
Total	**4 298**	**1 124**	**8 342**	**11 291**	**25 055**

***Table 2**. Number of wild adult Atlantic salmon captured monthly (May-September) from 2008 to 2012, and the number of individuals analyzed for of wild Atlantic salmon captured from May to August (2008-2012), and number microsatellite genetic markers assigned. Salmon caught February-April (n=6) and October-November (n=55) are excluded. The 2011 and 2012 sampling sites are shown in **Figure 1**.*

Year	Salmon	May	June	July	Aug	Sep	Total
2008	wild salmon	718	1 999	1 411	0	0	4 128
	# assigned	629	1 876	1 360	0	0	3 865
2009	wild salmon	1	518	450	9	7	985
	# assigned	1	401	383	8	0	793
2011	wild salmon	783	2 539	3 435	511	9	7 277
	# assigned	757	2 391	2 958	479	4	6 589
2012	wild salmon	381	3 989	4 335	1 353	48	10 106
	# assigned	368	3 750	4 094	1 254	41	9 507
Total	wild salmon	1 883	9 045	9 631	1 873	64	22 496
	# assigned	1 755	8 418	8 795	1 741	45	20 754

3.2 Catch of wild salmon per unit of effort (CPUE); 2011 and 2012

The catch per unit of effort (CPUE) of wild salmon in 2011 (3.9) and 2012 (4.3) was quite similar (t-test, p=0.43; **Table 3**). Highest CPUE was found in July and lowest in May for all three counties and both years (**Table 3**). Among counties, monthly CPUE varied from 0.7-3.0 (Nordland), 0.7-12.0 (Troms) and 1.3-7.3 (Finnmark). For all months combined, the highest CPUE was registered in Troms (6.5) compared to Finnmark (3.9) and Nordland (2.1). The number of captured wild salmon varied from 0 to 23.5 per day per fishing gear among the 53 fishermen that participated in the Kolarctic salmon project in 2011-2012.

***Table 3**. Number of wild salmon captured per fishing day per fishing gear (CPUE) by Kolarctic fishermen in May, June, July and August in 2011 and 2012.*

	May	June	July	August	Total
2011	1.545	4.676	7.879	2.223	**3.907**
2012	0.845	6.678	7.458	2.507	**4.328**
Total	**1.155**	**5.823**	**7.636**	**2.398**	**4.148**

Catches (CPUE) in May and June 2011 and 2012 was dominated by salmon older than 1SW, and very few smaller salmon (1SW) was captured (**Figure 2** and **Figure 3**). The smallest salmon dominated in July catches, although catches of older salmon was also significant, while catches were decreasing during August (**Figure 2** and **Figure 3**). The catch yield in 2012 were a little bit higher than in 2011, still the monthly variations were fairly similar to the 2011 catches.

The incidence of salmon originating from different rivers in different regions, and of different size groups, varied both spatially and temporally (see **Figure 2**). For instance, although salmon belonging to Russian rivers in average comprised 23 % of the total catches, their incidence decreased strongly through season and was significantly higher in Finnmark county (30 %), versus Nordland/Troms county (5 %) (**Figure 4**). The amount of Russian salmon, however, did also show large variation within Finnmark. On average Russian salmon made up 10 % of the catch at fishing sites in western Finnmark, mid Finnmark and the Tana fjord, while in eastern Finnmark, where most fishing sites were located in Varangerfjord, Russian salmon made up almost 50 % of the catch (**Figure 5**). Further, the incidence of Russian salmon in eastern Finnmark decreased strongly through the season, i.e. from ca. 70 % in May to ca. 20 % in August (**Figure 5**). Calculated in catch per unit of effort (CPUE), the amount of Russian salmon in eastern Finnmark was even higher. Regardless of the amount of Norwegian salmon in the catches, the absolute highest number of Russian salmon captured per fishing gear per day was highest in June/July and lowest in May (**Figure 5**). During the Kolarctic salmon project 3 454 out of 16 096 salmon assigned to their home rivers were of Russian origin (see **Figure 6**).

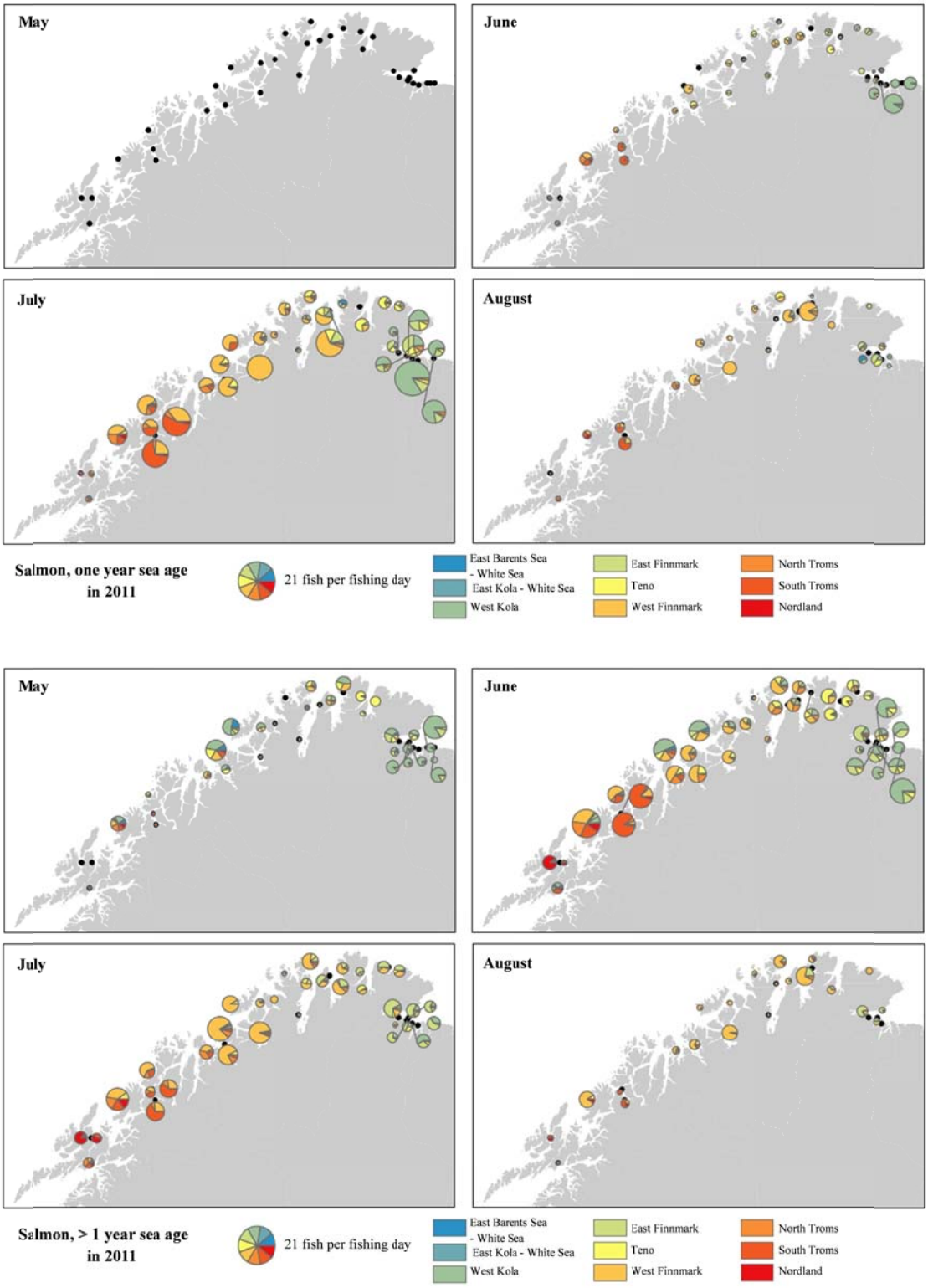


***Figure 2**. Catch per unit of effort (CPUE) of 1SW (upper panel) and MSW (lower panel) wild salmon stocks from six regions in Norway and three regions in Russia in 2011.*

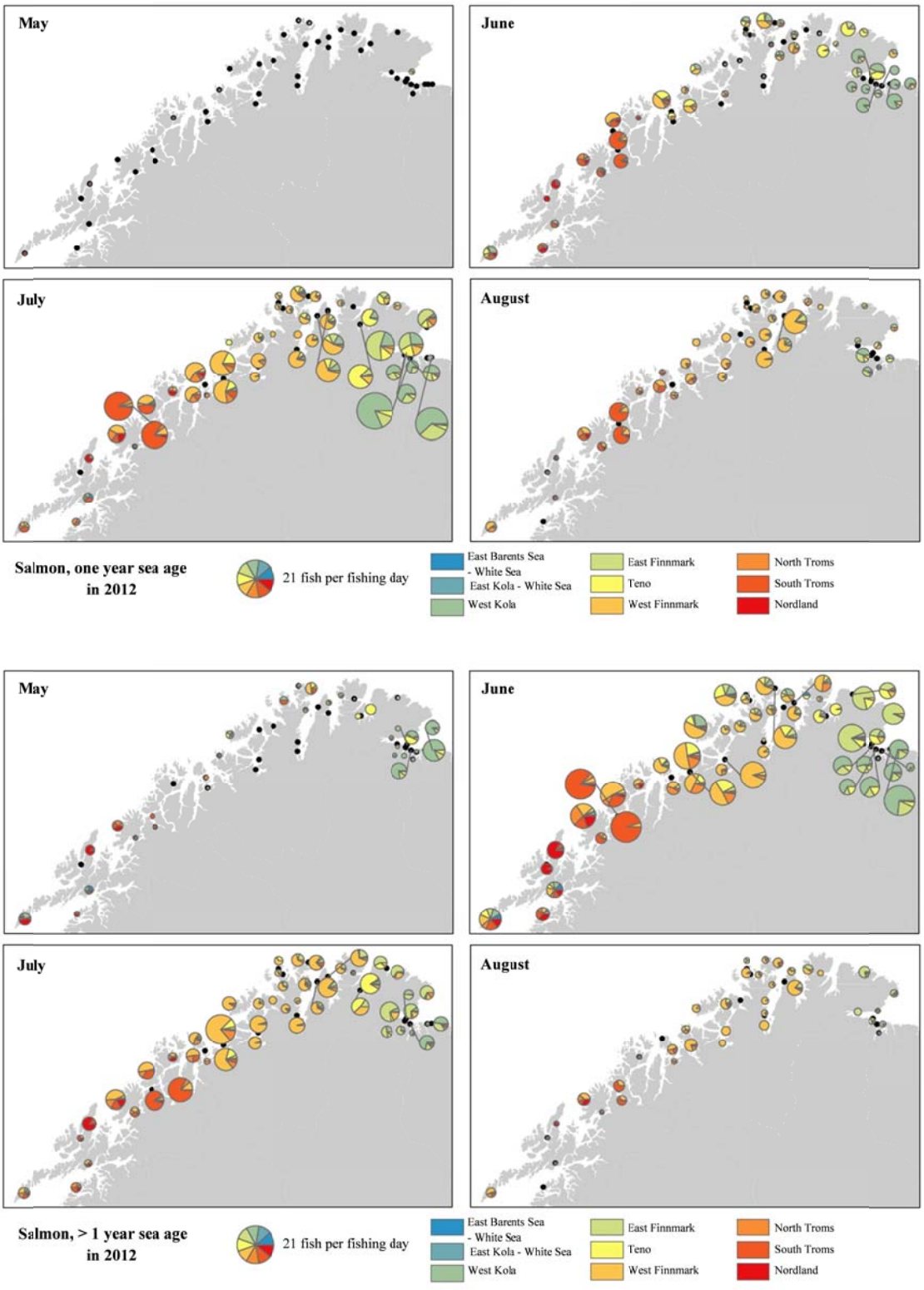


***Figure 3**. Catch per unit of effort (CPUE) of 1SW (upper panel) and MSW (lower panel) wild salmon stocks from six regions in Norway and three regions in Russia in 2012.*

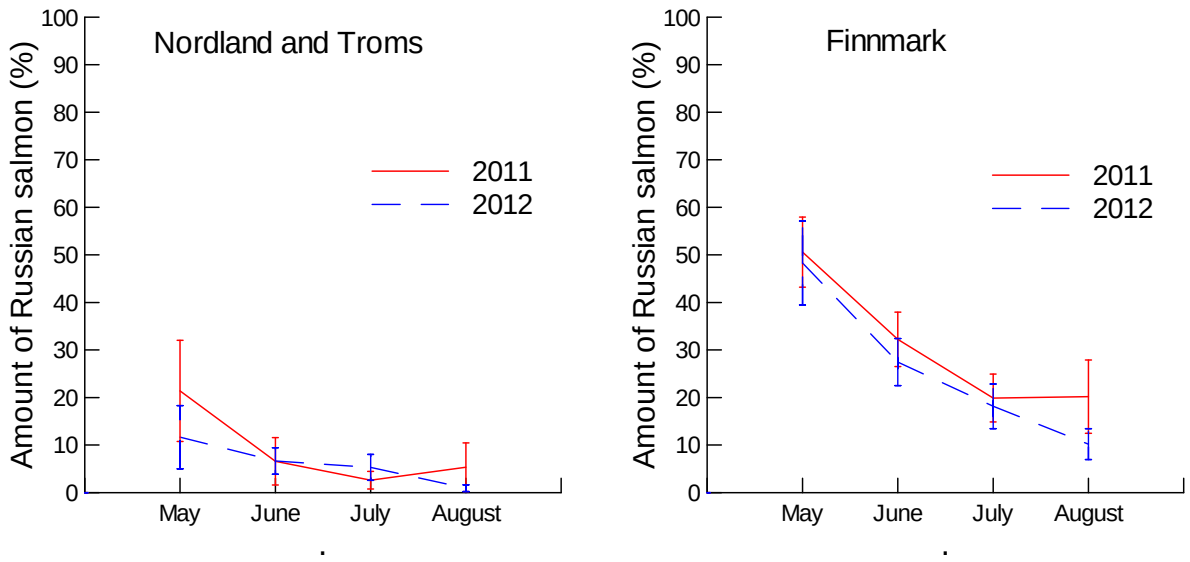


***Figure 4**. Amount (CPUE) of Russian salmon captured in Finnmark county (left) and in Nordland and Troms county (right) in 2011 and 2012.*

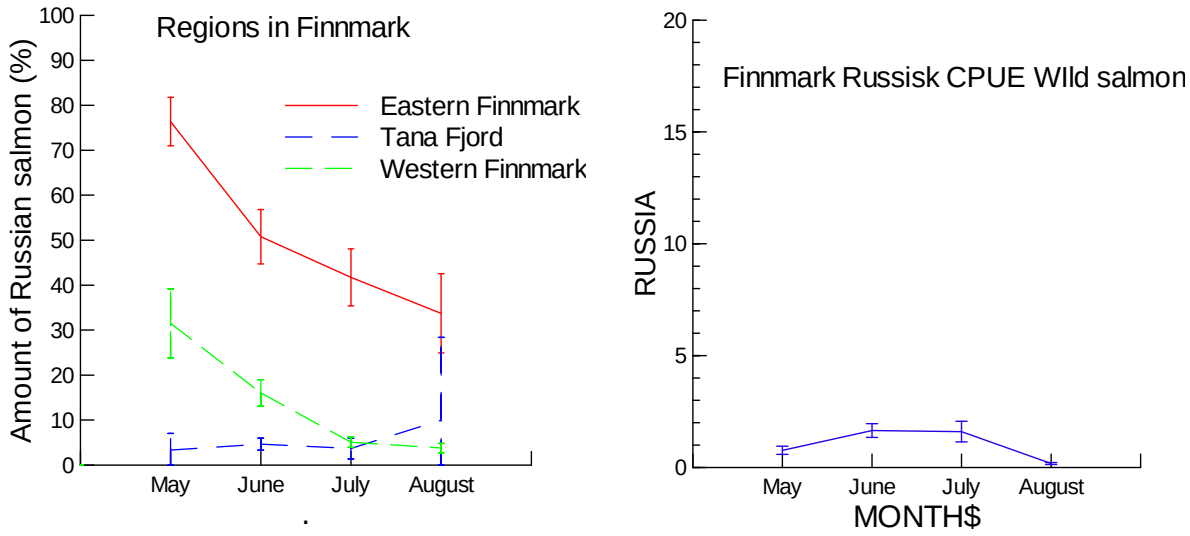


***Figure 5**. Amount (CPUE) of Russian salmon captured in Eastern Finnmark, Tana Fjord and Western Finnmark in 2011 and 2012 (left) and in Nordland and Troms county (right) in 2011 and 2012.*

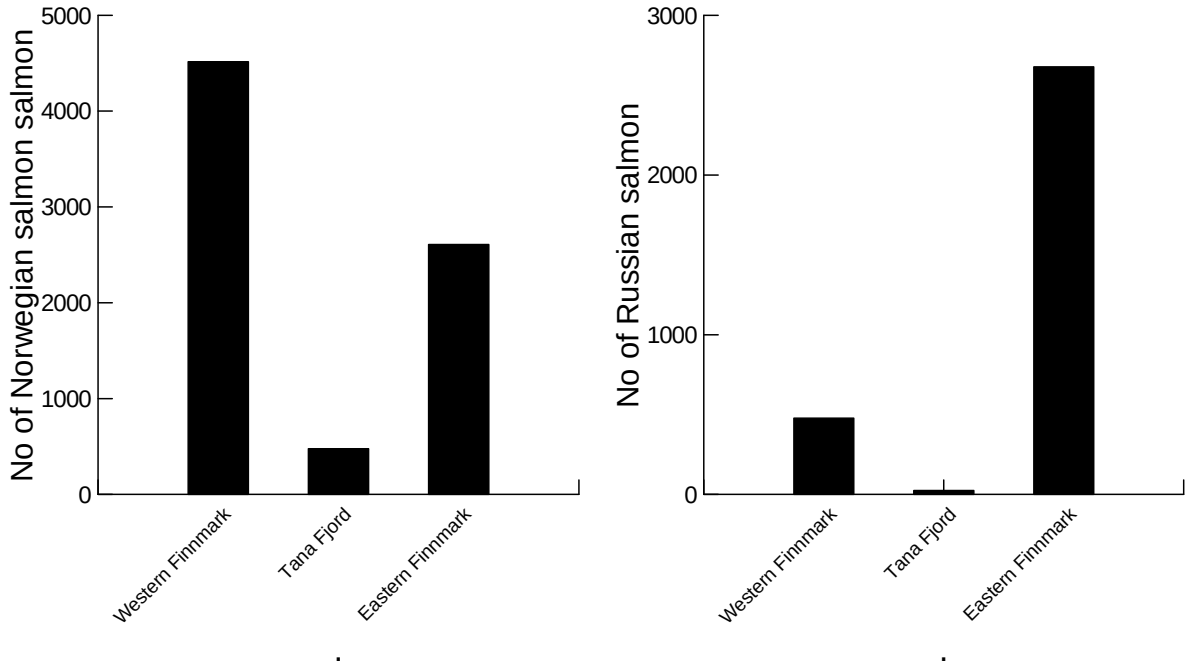


***Figure 6**. Total number of Norwegian (left) and Russian salmon (right) captured in coastal areas in 2011 and 2012 in Western Finnmark, Tana Fjord and Eastern Finnmark.*

3.3 Coastal exploitation and management regions

The Norwegian salmon management regime is currently based on a system of regions defined by Jensen et al. (2006). The basic tenet of this regional classification is that the outer coastal fisheries are expected to exploit salmon from stocks covering a large area, while the fjord fisheries are expected to exploit salmon from local stocks, located within the fjord. With this background, the different regions receive separate status assessments and exploitation advice from the Scientific Advisory Committee for Atlantic Salmon Management in Norway, and the separate advice have resulted in contrasting regulatory measures in the different regions.

3.3.1 Catch patterns in outer vs. inner regions

In general, there was a higher stock diversity in the outer region-catches compared with inner regions (**Table 4**). The main exception was the *Inner Varanger*-region which had a higher stock diversity than the other inner regions and also a higher stock diversity than the northern coast of the Varanger peninsula.

The local contribution to the catches in each region, defined as the proportion of the catch in a region that belonged to stocks located within that region, was generally much higher in inner vs. outer regions (**Table 4**). Exceptions to this pattern were *Inner Nordland* and *Inner Varanger*, both of which had a high catch proportion of stocks from other regions. Among the outer regions, there was a particularly high proportion of local catch in *Outer Nordland* and the eastern part of *Outer Finnmark*.

Finally, the catch in most outer regions consisted of a relatively high proportion of salmon from the inner region situated on the inside of each outer region (**Table 4**). The exception was *Outer Nordland* where only a few salmon from stocks in *Inner Nordland* were caught.

Table 4*. Stock diversity and percentage local stocks in the salmon catch of the project fishermen in 2011 and 2012. The original regions defined by Jensen et al. (2006) are given in rows without italics while new region-definitions suggested by the Kolarctic-dataset are provided in rows with italics.*

	Number of stocks	% local stocks	% salmon from inside inner region
Outer regions			
Outer Nordland	72	47 %	1 %
Outer Troms	105	6 %	27 %
Outer Finnmark (whole)	134	18 %	47 %
Outer Finnmark (west)	*103*	*0 %*	*39 %*
Outer Finnmark (middle)	*102*	*15 %*	*21 %*
Outer Finnmark (east)	*49*	*34 %*	*30 %*
Inner regions			
Inner Nordland	55	3 %	
Inner Troms	47	79 %	
Fjords in West-Finnmark	31	83 %	
Porsangerfjord	23	69 %	
Tanafjord	44	78 %	
Inner Varanger	77	24 %	
Varangerfjord	*107*	*24 %*	

Based on **Table 4**, the catches in most management regions, both outer and inner, followed the expected patterns of high diversity and low local catch in outer regions and low diversity and high local catch in inner regions. We will therefore largely follow the Norwegian management region classification in the following presentation of results, with two exceptions:

1) The outer coastal area of Finnmark is currently a long region spanning the whole outer coast of Finnmark from Troms to Russia. There are, however, differences in the catch composition from west to east, and to clearly show these patterns, we divide the outer coastal region into three separate regions in this report. These three outer coastal regions cover the western, middle and eastern part of Finnmark. Each of these outer coastal areas have a large proportion of salmon belonging to the inside neighbouring inner region.

2) The Varangerfjord is a special case in the current region classification, diverging from the other fjords. Most of the fjord is currently classified as part of the outer coast of Finnmark, while the innermost area of the fjord and the small fjord arms on the southern side are classified as an inner region (called *Inner Varanger*). The high stock diversity and low representation of local stocks in these inner areas demonstrate that the region catch clearly follows a pattern defined for outer regions. The salmon catch in the inner areas had clear similarities to the catch in the outer Varanger areas, but were substantially different from the catch elsewhere on the outer Finnmark coast (e.g. on the northern side of the Varanger peninsula). To accommodate this, we present the Varanger catch in a *Varangerfjord*-region consisting of the municipalities Vadsø, Nesseby and Sør-Varanger.

3.3.2 Total catch rate in management regions

The highest total catch rate was observed in *Inner Troms* (up to 21.8 salmon per day per gear in weeks 26-27), followed by *Outer Troms* (up to 11.5 salmon per day per gear in weeks 26-27) and *Varanger* (up to 10.2-10.3 salmon per day per gear in weeks 26-29) (**Figure 7)**. Most of the other regions had maximum catch rates at around 6-7 salmon per day per gear. Lowest catch rates were observed in Nordland, up to 4.67 salmon per day per gear in *Inner Nordland* in weeks 26-27.

The highest catch rates in the two Nordland-regions were observed in weeks 24-27. Further north, in Troms and western Finnmark, the highest rates were observed in weeks 24-29. In middle Finnmark and *Porsanger*, the highest rates were observed later, in weeks 26-31. In eastern Finnmark, including *Tanafjord* and *Varangerfjord*, the highest rates were observed in weeks 26-29.

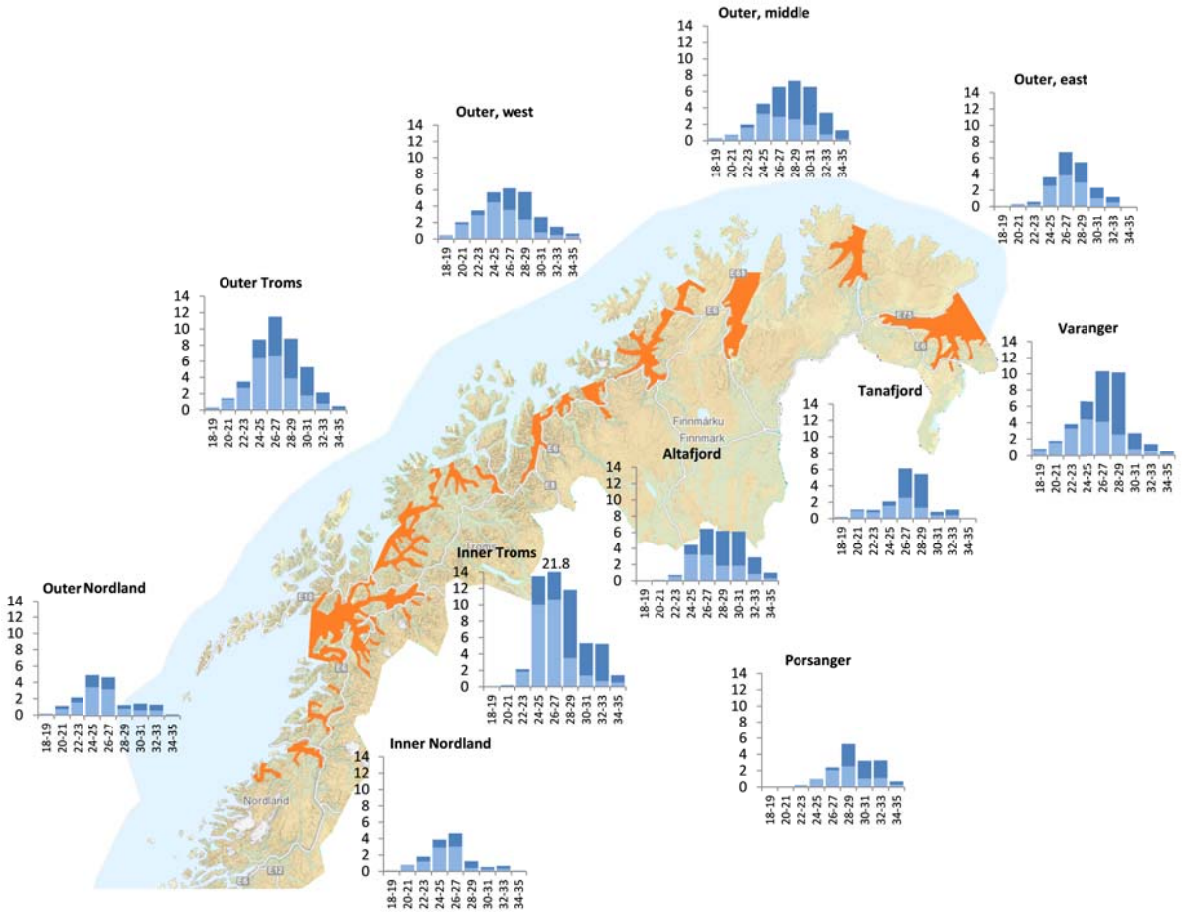
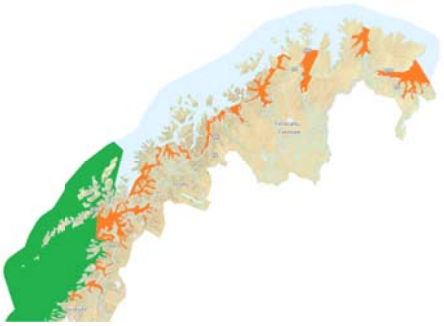


Figure 7*. Regional total catch of salmon, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.3 Regional composition of catch within regions

3.3.3.1 Outer Nordland

In the original classification of Jensen et al. (2006), Nordland county is divided into a northern and southern outer coastal region. The northern coastal region (*Lofoten and Vesterålen*) has around 30 small and 6 larger salmon stocks. The southern outer coastal region (*Nordland south of Vestfjord*) has only a few salmon stocks (under 10). In this report, we treat these two outer coastal regions together.



The project-fishermen in this area reported catches in weeks 19 to 35. The highest catches were seen in weeks 23 to 27, varying between 3.87 and 5.29 salmon per day per gear in these weeks.

The coastal catch in the *Outer Nordland* region was dominated by local stocks (**Figure 8**), with the highest catches in weeks 23-27 (June to early July). In this period, catch per day per gear reached a maximum value of 2.93 salmon in week 24.

In addition to the *Outer Nordland*-stocks, there was a notable fraction of Russian stocks in the *Outer Nordland*-catch, especially in the weeks 21-25 with a maximum of 1.20 salmon per day per gear in week 25. The rest of the *Outer Nordland*-catch mainly consisted of stocks from Troms, with a catch of 1.21 *Inner Troms*-salmon per day per gear as the maximum catch in week 27.

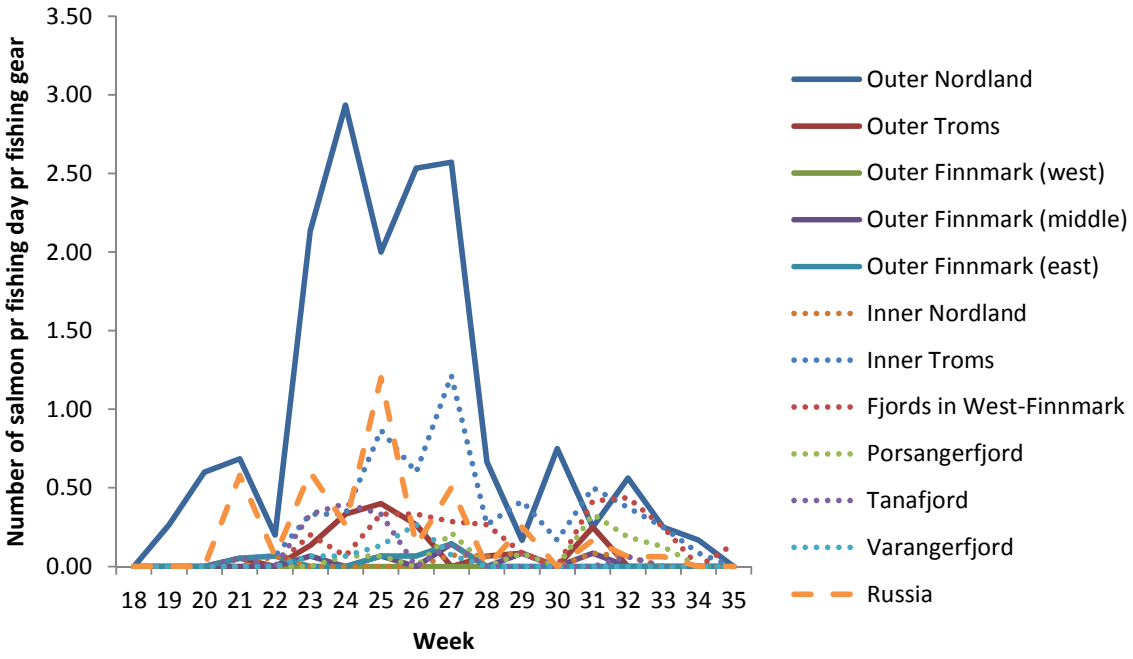
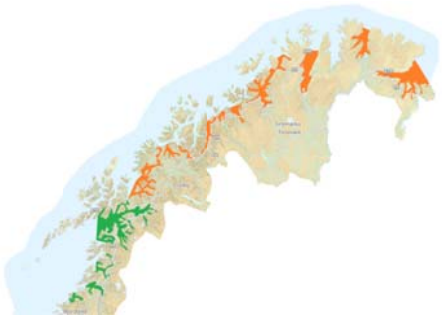


***Figure 8**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Outer Nordland *region.*

3.3.3.2 Inner Nordland

Similarly to *Outer Nordland*, the inner parts of Nordland are also divided into two regions in Jensen et al. (2006). The northern inner Nordland region, *Ofoten and Inner Salten*, has some small stocks and one large significant stock (Beiarelva). The southern inner Nordland region (*Helgeland*) has historically had several larger stocks but these have been severely depleted due to *Gyrodactylus salaris*. In this report, we are treating these two regions as one single *Inner Nordland*-region.



Compared with the *Outer Nordland*-region, there was a slightly lower catch per day per gear in the *Inner Nordland*-region. Highest catches were seen in weeks 23 to 27, varying from 3.33 salmon per day per gear in week 23 to 4.78 salmon per day per gear in week 26.

Interestingly, the coastal catch in the *Inner Nordland*-region showed a much higher geographical distribution than the outer coastal catch. Whereas the outer coastal catch had a high fraction of local stocks, almost no local salmon were found in the *Inner Nordland* catch (**Figure 9**).

The highest catch rate was seen for salmon from *Inner Troms* in weeks 26 and 27 with 1.67 and 2.0 salmon per day per gear, respectively. Similarly to the *Outer Nordland*-catch, there was a relatively high incidence of Russian stocks in the *Inner Nordland*-catch, especially in week 20-27. Highest catch of Russian salmon was 1.44 salmon per day per gear in week 23. Another significant region represented in the *Inner Nordland*-catch was *Outer Nordland* with catch rates up to 1.22 salmon per day per gear in week 24).

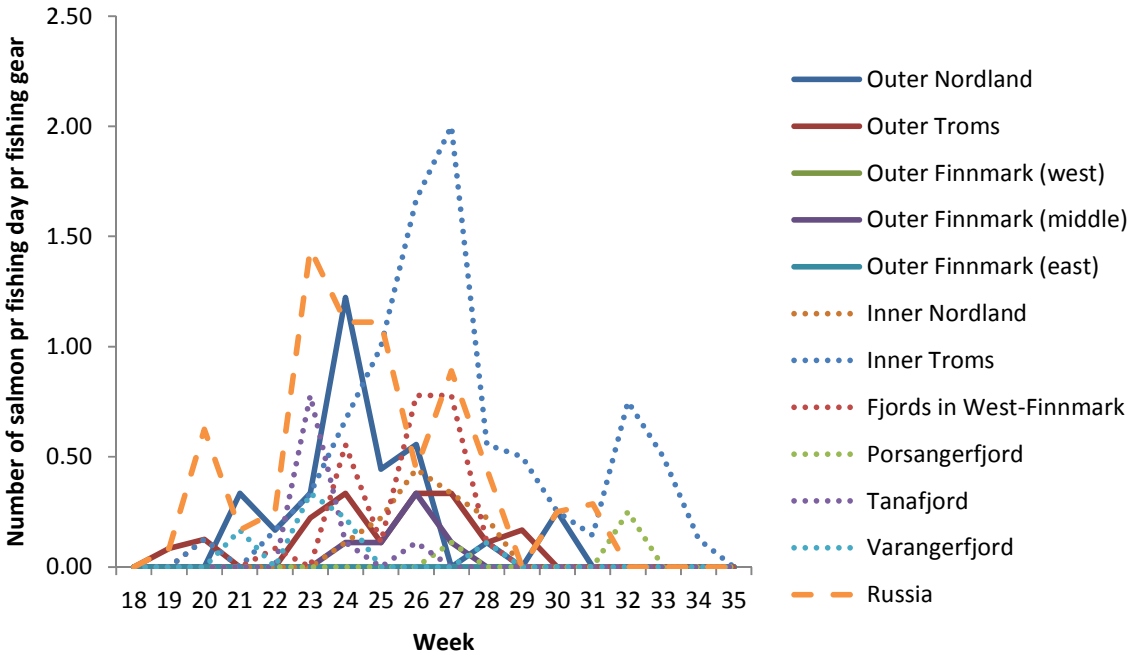
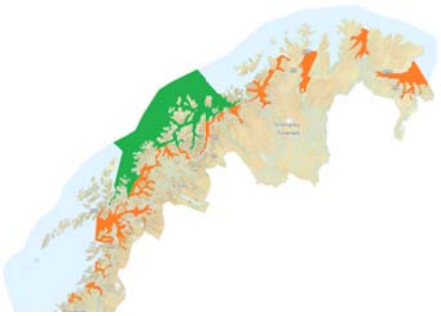


***Figure 9**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Inner Nordland *region.*

3.3.3.3 Outer Troms

There are 13-14 small local salmon stocks in the outer coastal region of Troms. All larger salmon stocks in Troms are therefore localized in the *Inner Troms* region.



Highest catches in *Outer Troms* were seen in weeks 23-31, varying from 4.54 salmon per day per gear in week 30 to 11.73 salmon per day per gear in week 26.

The outer coastal catch in Troms was dominated by salmon from two nearby regions: *Fjords in West-Finnmark* and *Inner Troms* (**Figure 10**). The highest catches were seen in weeks 25 to 29, up to 4.09 salmon per day per gear belonging to *Fjords in West-Finnmark* in week 27 and 2.70 salmon per day per gear belonging to *Inner Troms* in week 25. *Tanafjord*-salmon were caught up to 1.55 salmon per day per gear in week 26.

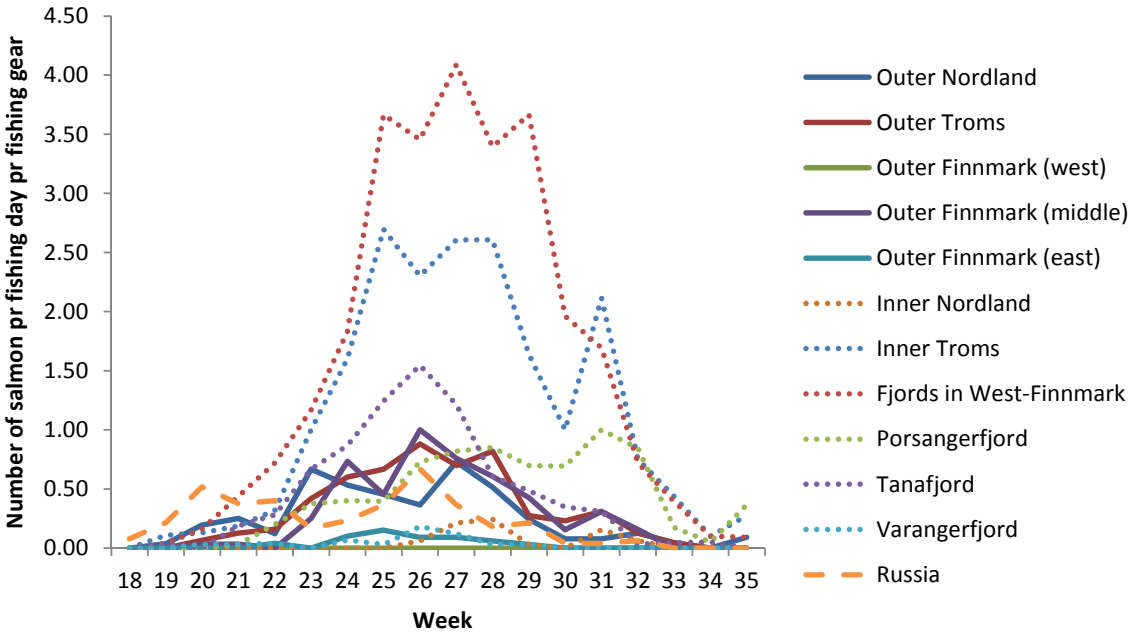
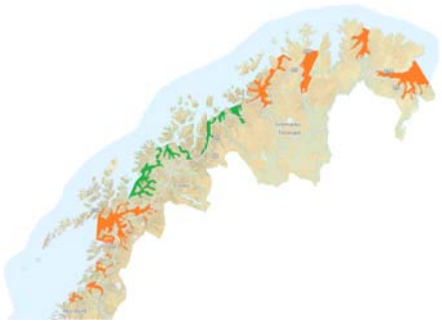


***Figure 10**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Outer Troms *region.*

3.3.3.4 Inner Troms

There are over 20 salmon stocks in the inner parts of Troms. There are two major salmon rivers in the area (Målselva and Reisaelva). Two stocks are infected with *Gyrodactylus salaris* (Skibotnelva and Signaldalselva). Most of the remaining stocks are small.



Of all regions studied in this project, the catch rates seen in *Inner Troms* were the highest. The highest total catches were seen in weeks 24 to 28, varying from 11.87 salmon per day per gear in week 25 to 23.53 salmon per day per gear in week 27.

Stocks from *Inner Troms* totally dominated the catches in this region with catch rates up to 17.27 and 18.53 salmon per day per gear in weeks 26 and 27, respectively (**Figure 11**). The majority of these salmon belonged to the river Målselva and was caught in Malangen.

The only other region that was observed in any significant number in the coastal catches in *Inner Troms* was *Fjords in West-Finnmark*. These salmon were mainly caught in rates up to 3.53 salmon per day per gear in week 27 in the northern part of Troms.

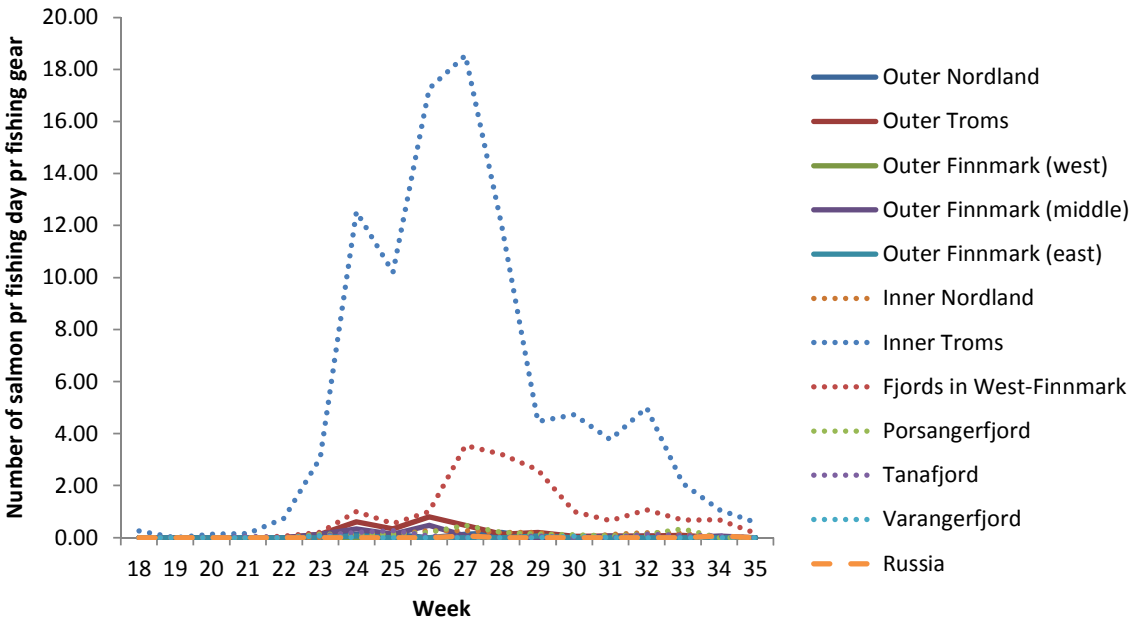
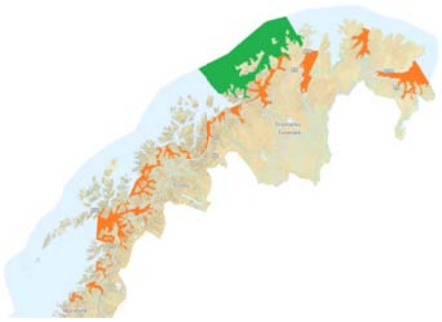


***Figure 11**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Inner Troms *region.*

3.3.3.5 Outer Finnmark (west)



The western part of *Outer Finnmark*, from Loppa in the west to Måsøy in the east, is a coastline dominated by islands with just a few small rivers and, consequently, only a few very small salmon stocks.

The highest catch rates in this region were seen in weeks 22-29, up to 7.46 salmon per day per gear in week 27.

In week 21 and 22, most salmon caught in this region were from Russian stocks with a catch rate up to 3.26 salmon per day per gear in week 22 (**Figure 12**). Later in the season, the salmon catch in this region was dominated by salmon from the inner *Fjords in West-Finnmark*-region with catches up to 3.77 and 3.58 in weeks 27 and 28, respectively.

Other significant regions represented in the catch in Western Finnmark were the *Tanafjord*, up to 1.67 salmon per day per gear in week 24, the *Porsangerfjord*, up to 1.04 salmon per day per gear in week 27, and *Inner Troms*, up to 0.85 salmon per day per gear in week 27 (**Figure 12**).

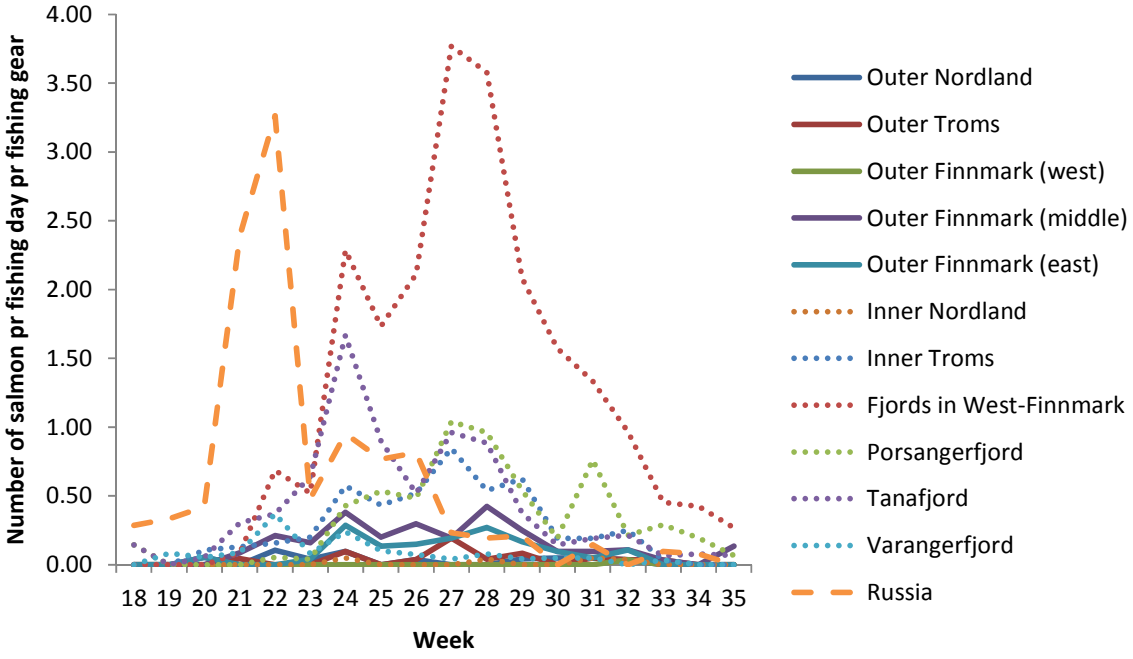
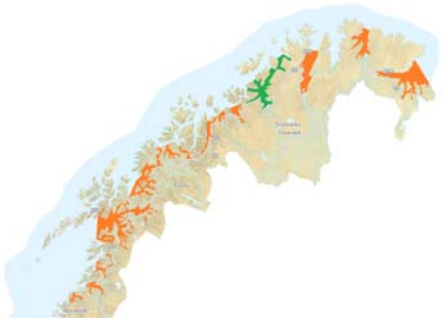


***Figure 12**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Outer Finnmark (west) *region.*

3.3.3.6 Fjords in West-Finnmark (Altafjord)



The inner *fjords in West-Finnmark*, consisting of the Alta and Kvalsund municipalities, have five small and two large salmon stocks (Altaelva and Repparfjordelva).

The most efficient salmon fishery in this region was in the weeks 24-32, with total catch rates up to 8.50 salmon per day per gear in week 27 and 8.17 salmon in week 30.

The salmon catch in the *Fjords in West-Finnmark*-region was dominated by local stocks, and stocks from other regions were represented only in very small numbers (**Figure 13**). The highest catch rates were 7.33 and 7.25 salmon per day per gear seen in weeks 27 and 30, respectively.

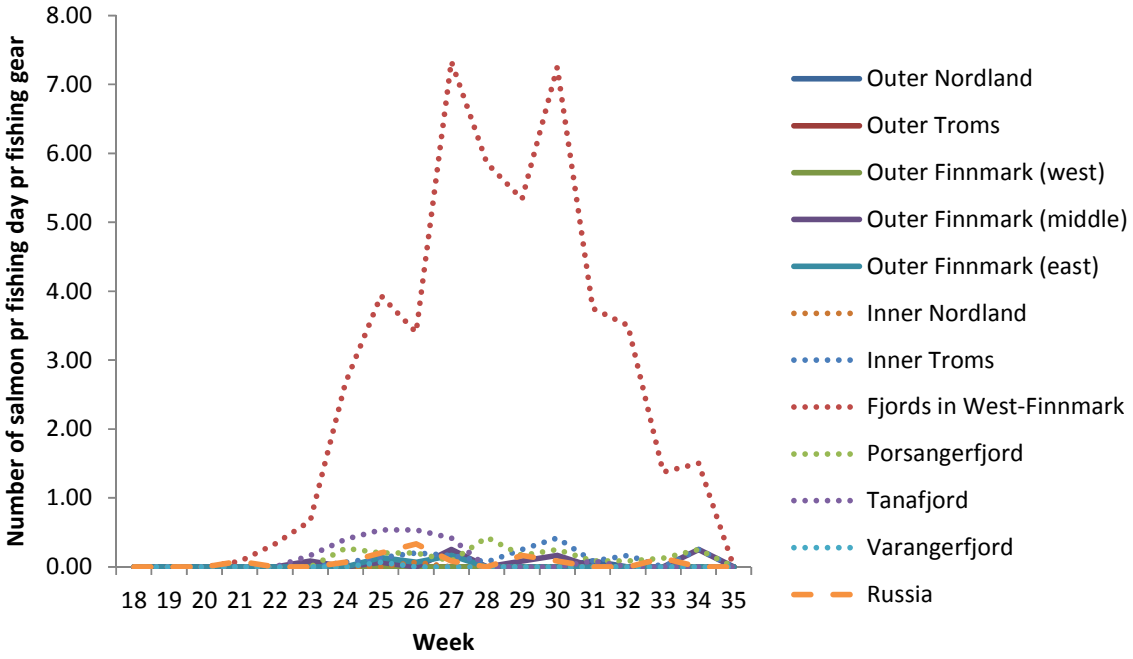
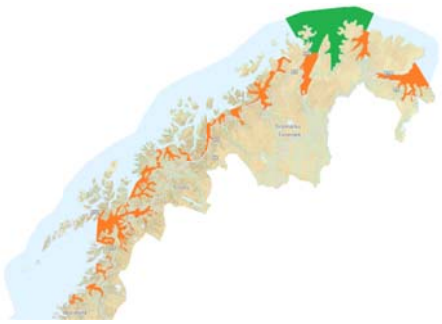


***Figure 13**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Fjords in West-Finnmark *region.*

3.3.3.7 Outer Finnmark (middle)



The middle part of *Outer Finnmark*, defined as the area from Nordkapp in the west to the outer half of Gamvik in the east, is an area with a few relatively small salmon rivers. The most significant are Veidneselva, Storelva, Sandfjordelva and Risfjordelva.

There was high catch diversity in this middle part of Finnmark, indicating that the area around Nordkapp is a point where fishermen are exploiting salmon migrating both eastwards and westwards.

The highest total catch rates in the middle part of *Outer Finnmark* were found in weeks 25-31, with 7.56 salmon per day per gear in week 28 as the highest rate.

Salmon belonging to stocks from the *Porsangerfjord* had the highest catch values in this region, up to 2.07 and 2.39 salmon per day per gear in weeks 30 and 31, respectively (**Figure 14**). Other regions with significant catch rates in the middle part of *Outer Finnmark* were *Fjords in West-Finnmark* (up to 1.56 salmon per day per gear in week 27), local salmon from *Outer Finnmark (middle)* (up to 1.50 salmon per day per gear in week 28), salmon from *Inner Troms* (up to 1.23 salmon per day per gear in week 26), *Tanafjord* (up to 1.10 salmon per day per gear in week 27), Outer Finnmark (east) (up to 0.87 salmon per day per gear in week 27) and Russian stocks (up to 0.85 salmon per day per gear in week 27).

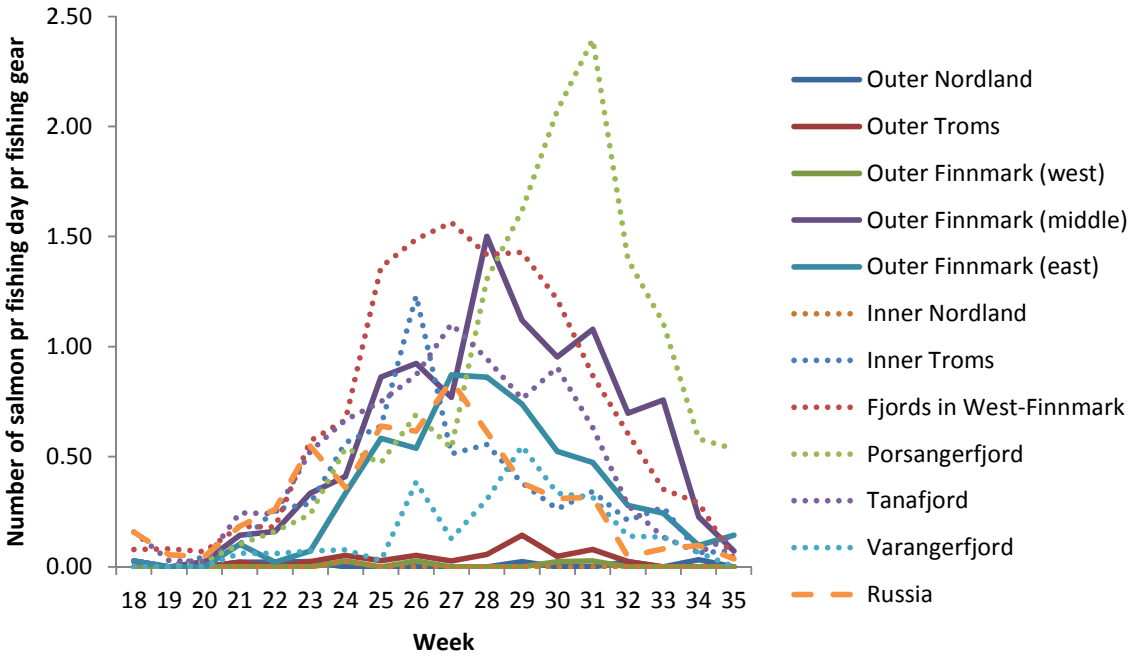
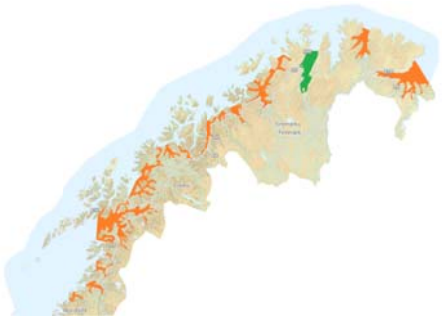


***Figure 14**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Outer Finnmark (middle) *region.*

3.3.3.8 Porsangerfjord

There are four salmon stocks in the *Porsangerfjord*, of which one is very small while the other three are relatively large stocks (Lakselva, Stabburselva and Børselva).



The highest total catch rates in the *Porsangerfjord*-region were seen in weeks 28-32, up to 5.89 salmon per day per gear in week 28 and 5.58 salmon per day per gear in week 31.

The salmon catch in *Porsangerfjord* was dominated by local stocks, with catch rates up to 4.17 salmon per day per gear in week 31 and 3.56 salmon per day per gear in week 28 (**Figure 15**). The only other notable region present in the *Porsangerfjord*-catch was *Fjords in West-Finnmark*, with catch rates up to 1.11 and 1.08 salmon per day per gear in weeks 28 and 29, respectively.

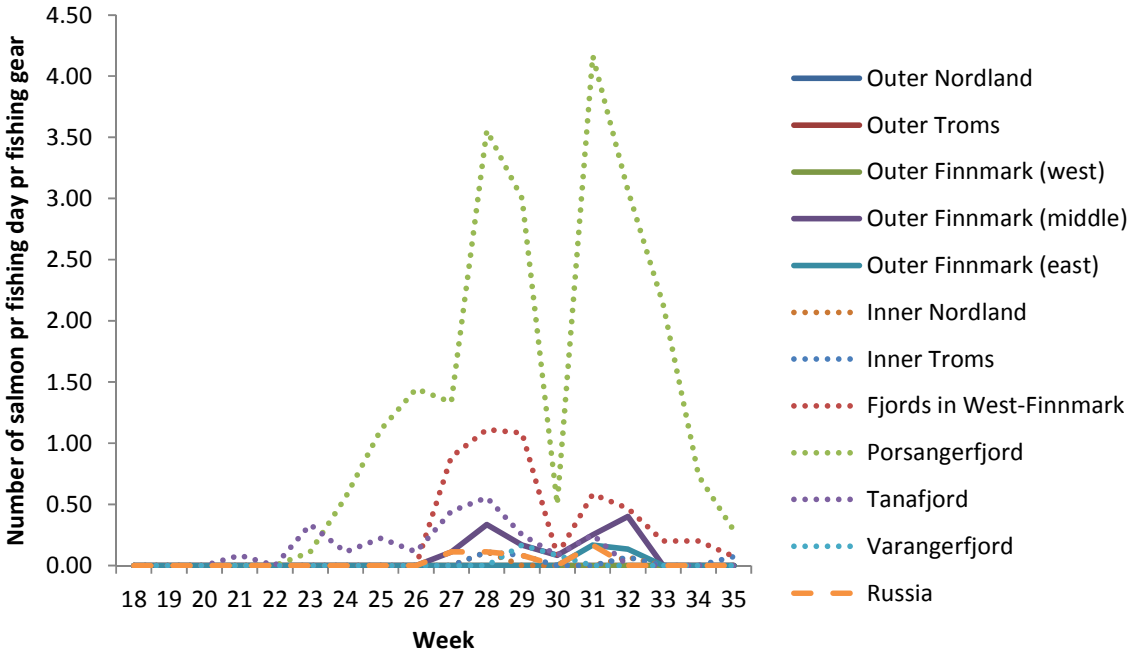
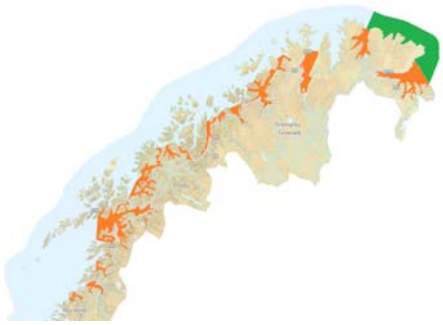


***Figure 15**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Porsangerfjord *region.*

3.3.3.9 Outer Finnmark (east)

This region is the outer part of the Varanger peninsula, defined from the outer part of Berlevåg in the west to the whole of Vardø in the east. There are three major salmon rivers in this region (Kongsfjordelva, Syltefjordelva and Komagelva) and one small stock (Sandfjordelva).



Highest total catch in the eastern part of *outer Finnmark* was in weeks 25-29, up to 8.53 salmon per day per gear in week 26.

The coastal catch in this eastern part of *outer Finnmark* were dominated by salmon from local stocks and salmon belonging to the inside *Tanafjord*-region (**Figure 16**). The highest catch rates were seen in week 26 for salmon from both regions, up to 3.40 salmon per day per gear from local stocks and 3.00 salmon per day per gear from *Tanafjord*-stocks.

Other notable regions represented in the catch from the northern coastline of the Varanger peninsula were *Varangerfjord*-stocks, up to 1.15 salmon per day per gear in week 29, and Russian salmon, up to 0.60 salmon per day per gear in weeks 26 and 28.

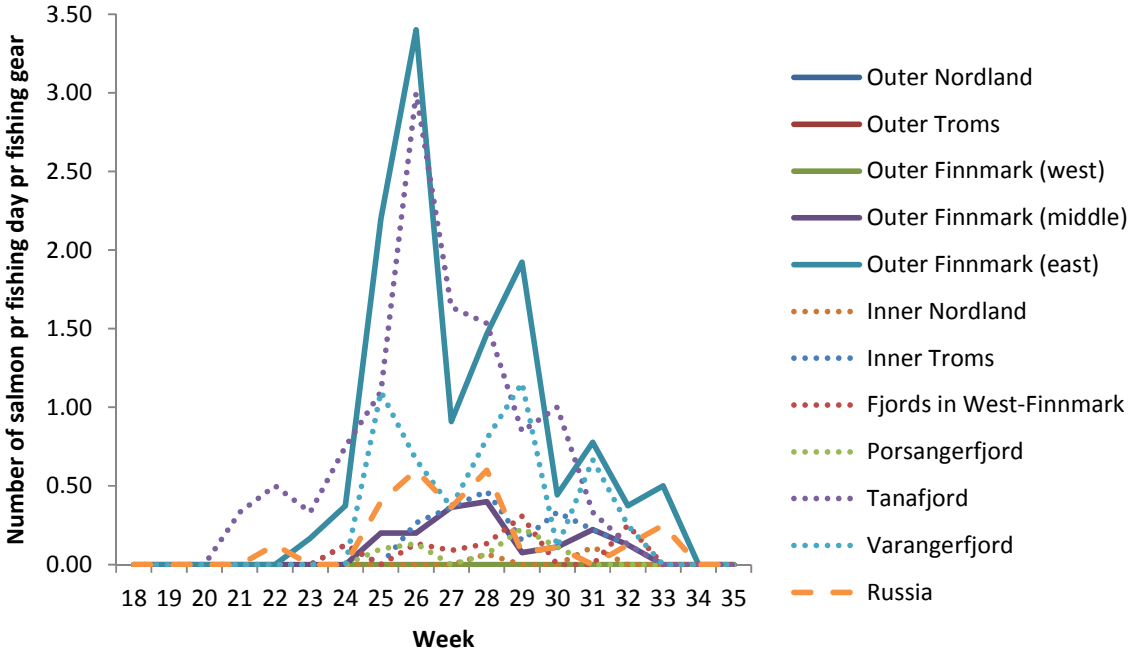


***Figure 16**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Outer Finnmark (east) *region.*

3.3.3.10 Tanafjord

There are two salmon rivers in this region, one medium-sized (Langfjordelva) and then the very large Tana river system, the latter of which likely has over 20 separate stocks and is the dominant salmon-producing river system in Norway.

The highest catch rates in the *Tanafjord*-region were seen in weeks 26-29, up to 7.33 salmon per day per gear in week 29.

The *Tanafjord*-catch was dominated by local stocks throughout the sampling period, with catch rates up to 4.87 and 4.89 salmon per day per gear in weeks 29 and 27, respectively (**Figure 17**).

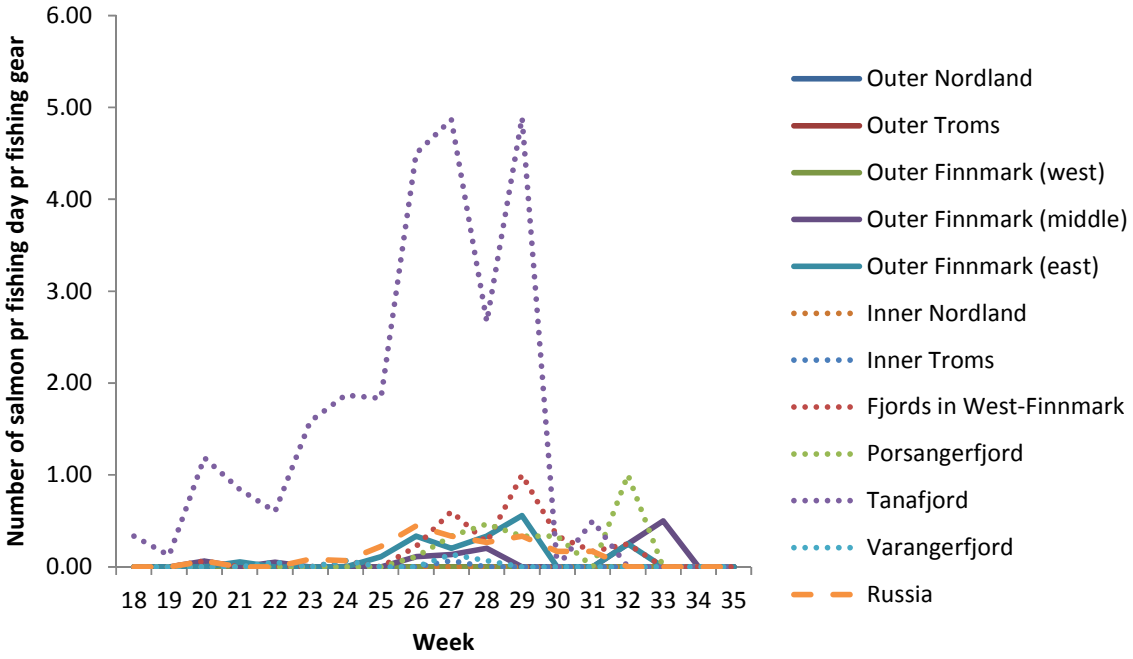


***Figure 17**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Tanafjord *region.*

3.3.3.11 Varangerfjord

In the original region classification by Jensen et al. (2006), only parts of the Varangerfjord were treated as an inner region. These parts were the innermost part (Nesseby municipality) and the inside areas of Sør-Varanger on the southern side of the Varangerfjord. There are only small differences in the catch composition of the fishermen in these innermost areas and the fishermen on the outside of Sør-Varanger and in the Vadsø municipality. We therefore include all these areas in a *Varangerfjord* region in the analyses of this report. There is one large-, five medium- and five small-sized salmon stocks in this extended *Varangerfjord*-region.

Highest total catch rates were seen in weeks 25-29, up to 12.58 and 12.34 salmon per day per gear in week 27 and 28, respectively.

Russian stocks dominated the catch in *Varangerfjord*, with catch rates up to 6.19 salmon per day per gear in week 27 (**Figure 18**). Local stocks were caught at rates up to 2.86 salmon per day per gear in week 27, while salmon from the *Tanafjord* were caught in rates up to 1.61 salmon per day per gear in week 28.

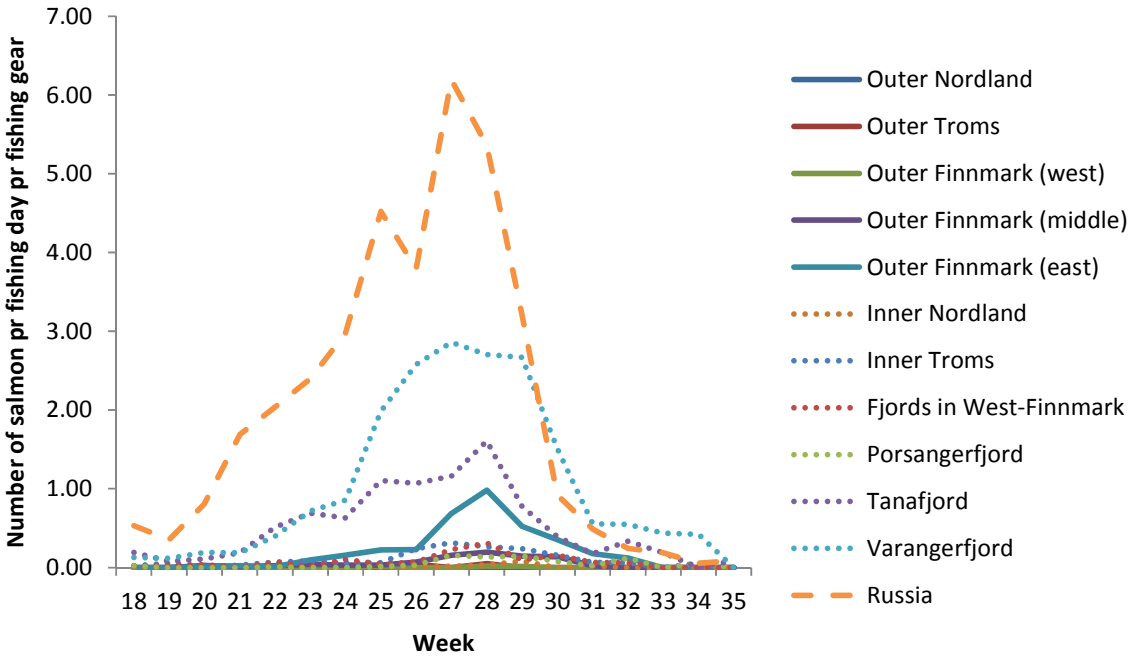


***Figure 18**. Number of salmon from stocks located in the different regions caught per day per fishing gear from week 18 to week 35 in the* Varangerfjord *region.*

3.3.4 Where are salmon from the different regions caught?

3.3.4.1 Outer Nordland

Salmon from stocks in *Outer Nordland* are primarily exploited locally in the *Outer Nordland*-region in weeks 24-27 with catch rates up to 2.5 salmon per day per gear (**Figure 19**)**.** There is also some exploitation in the *Outer Troms*-region and *Inner Nordland*, and then a few fish in southern parts of *Inner Troms*.

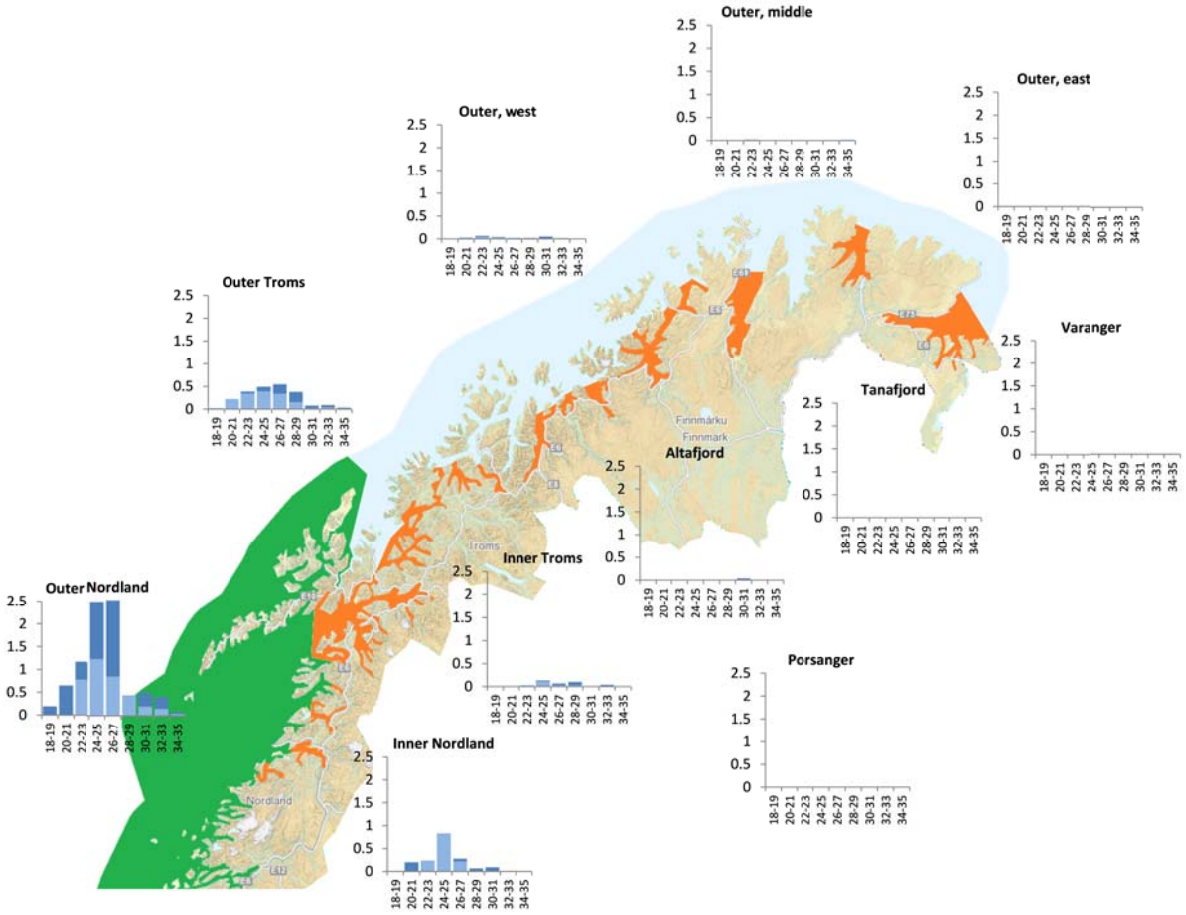


Figure 19*. Regional catch of salmon from the* Outer Nordland*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.2 Inner Nordland

Salmon from stocks belonging to the *Inner Nordland*-region were only sporadically found in the project data (**Figure 20**). The few salmon from this region that were caught were mostly found in *Inner* and *Outer Nordland* and *Inner* and *Outer Troms*. This indicates that salmon from *Inner Nordland*-stocks likely mostly migrates from the south and therefore escapes the project fishermen that were fishing only in the northernmost part of the region.

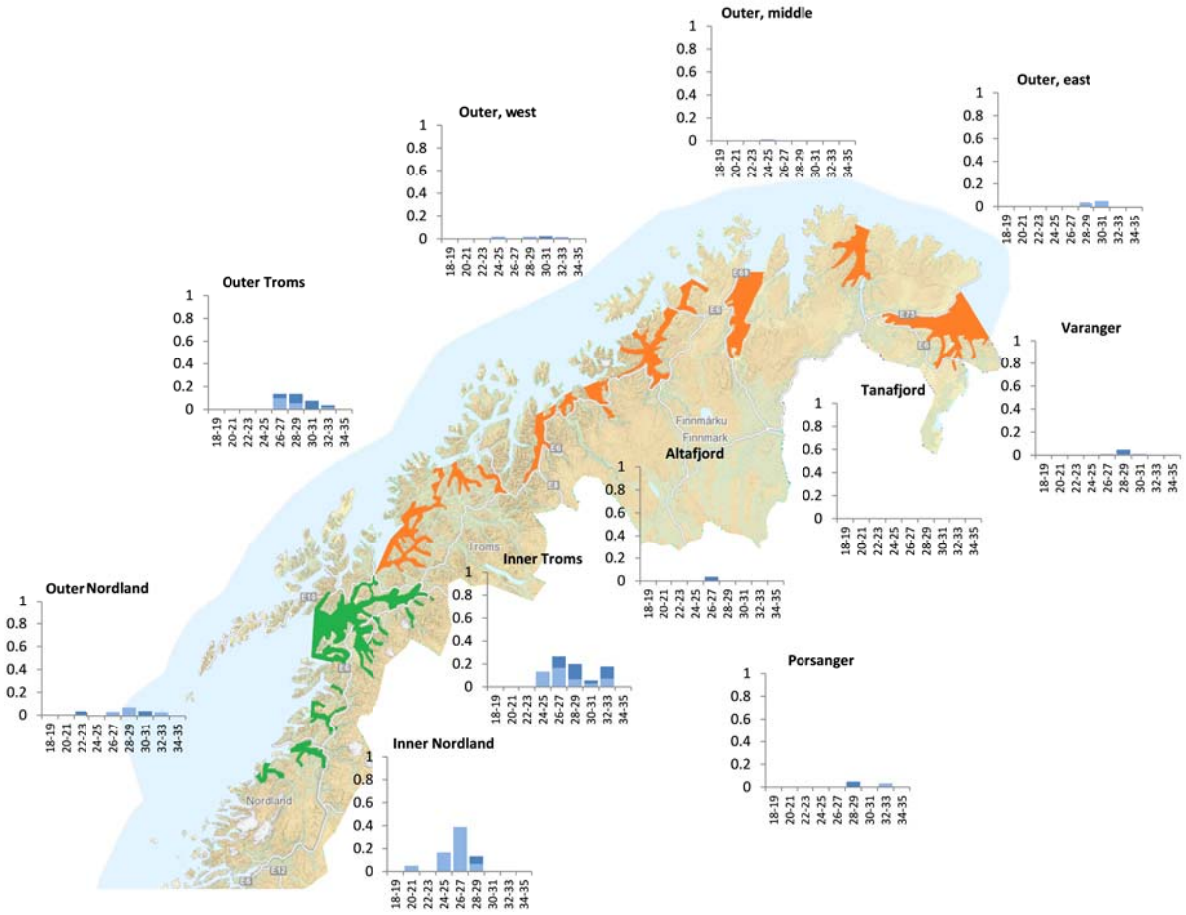


***Figure 20**. Regional catch of salmon from the* Inner Nordland*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.3 Outer Troms

Salmon from stocks belonging to the *Outer Troms*-region were caught mainly in four regions, albeit in relatively low numbers (**Figure 21**). Highest catch rates were found locally in *Outer Troms*, up to 0.65 and 0.64 salmon per day per gear in weeks 26-27 and 28-29, respectively. The three other regions were *Inner Nordland* (up to 0.61 salmon per day per gear in weeks 26-27), *Inner Troms* (up to 0.43 salmon per day per gear in weeks 26-27 and 28-29), and *Outer Nordland* (up to 0.43 salmon per day per gear in weeks 24-25).

Very few salmon from *Outer Troms* were caught in Finnmark, and the catch pattern seen in **Figure 21** indicates that salmon from stocks in the *Outer Troms*-region approach their respective home rivers from the west and south.

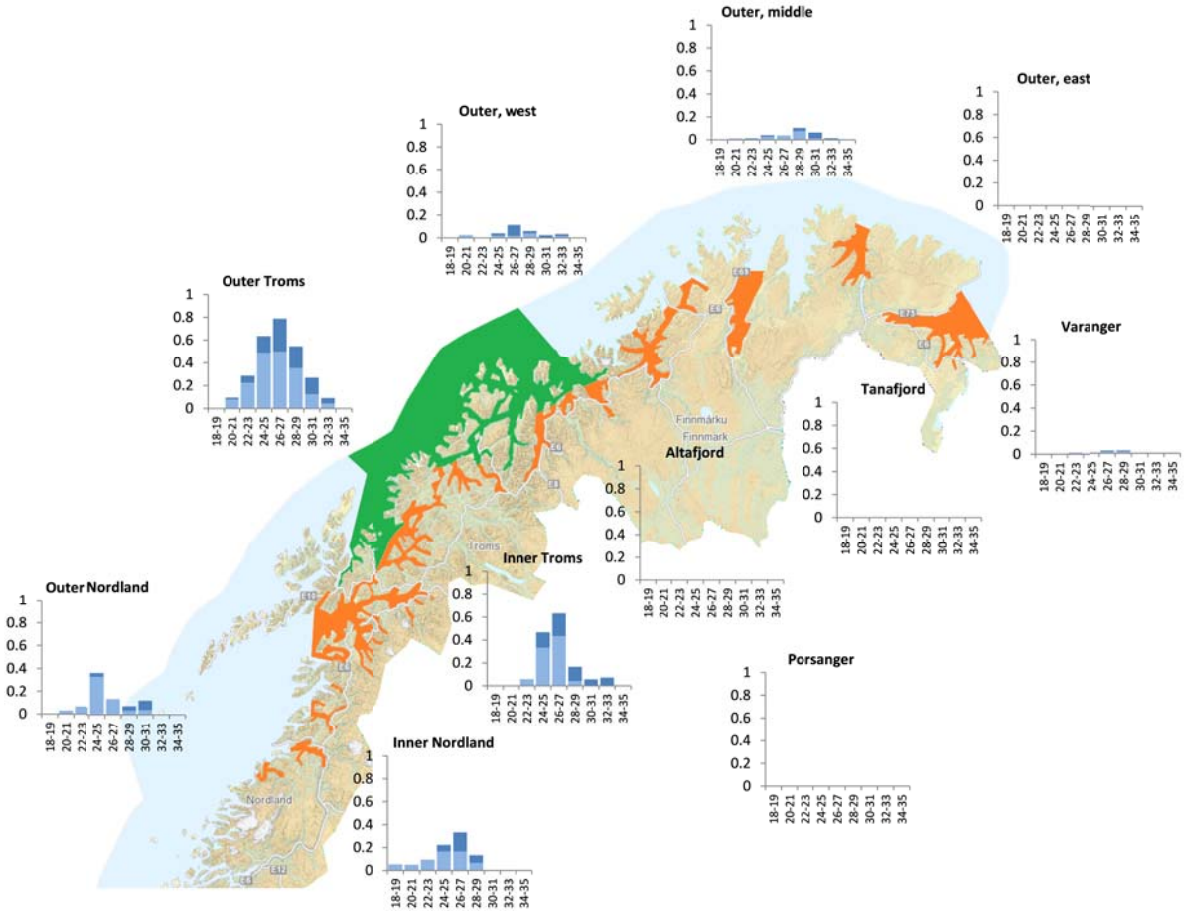


Figure 21. *Regional catch of salmon from the* Outer Troms*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.4 Inner Troms

The highest catch rates of salmon from the *Inner Troms*-region were by far seen locally in Inner Troms with up to 17.9 salmon per day per gear in weeks 26-27 (**Figure 22**). Other regions had significantly lower catch rates. Second-highest rates were found in *Outer Troms,* up to 2.45 salmon per day per gear in weeks 26-27. Some salmon from *Inner Troms* were also caught to the south (up to 1.83 salmon per day per gear in *Inner Nordland* in weeks 26-27 and 0.9 salmon per day per gear in *Outer Nordland* in weeks 26-27) and north (up to 0.68 and 0.87 salmon per day per gear in *Outer Finnmark (west)* and *Outer Finnmark (middle)*, respectively, in weeks 26-27).

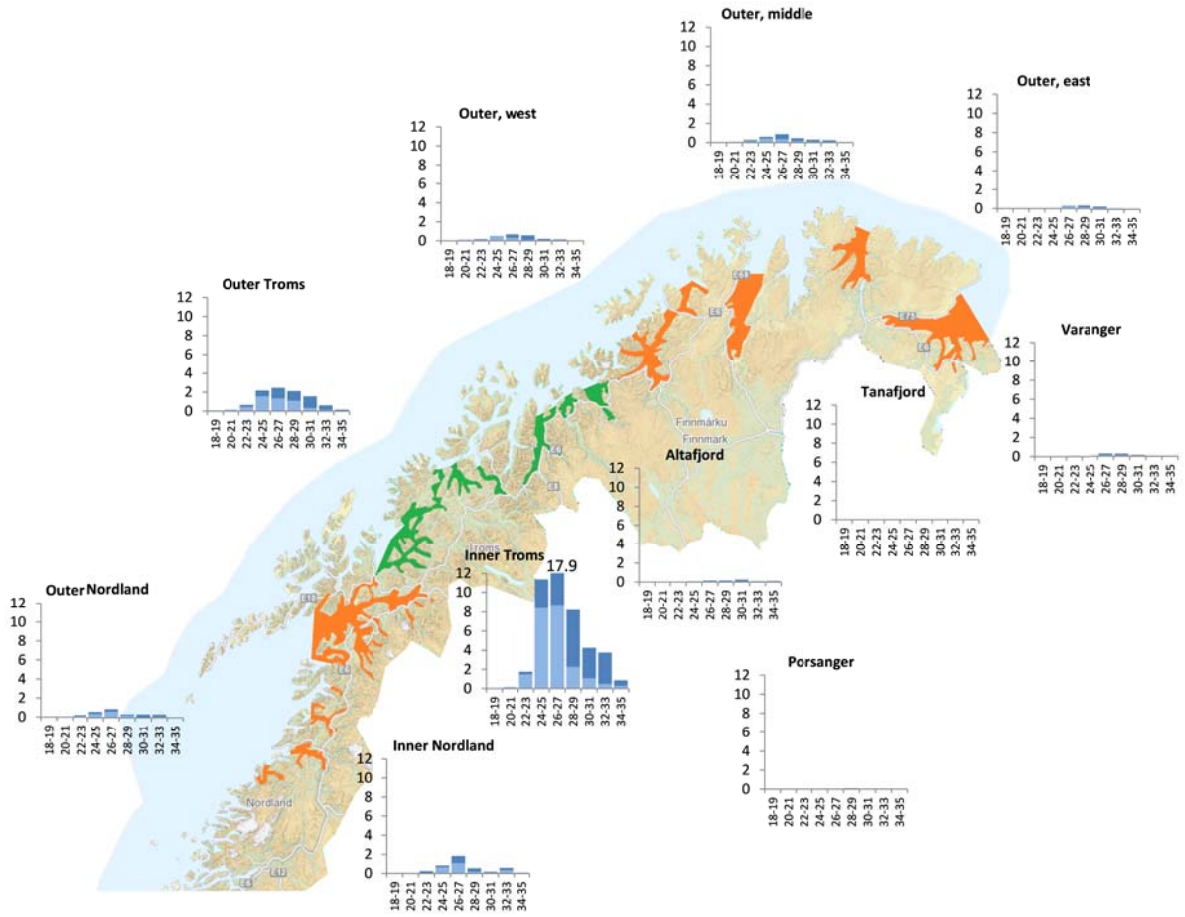


Figure 22*. Regional catch of salmon from the* Inner Troms*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.5 Outer Finnmark (west)

There are only a few relatively small rivers in this region, and accordingly also only a few very small salmon stocks. This is reflected in the catch pattern of salmon from this region (**Figure 23**).

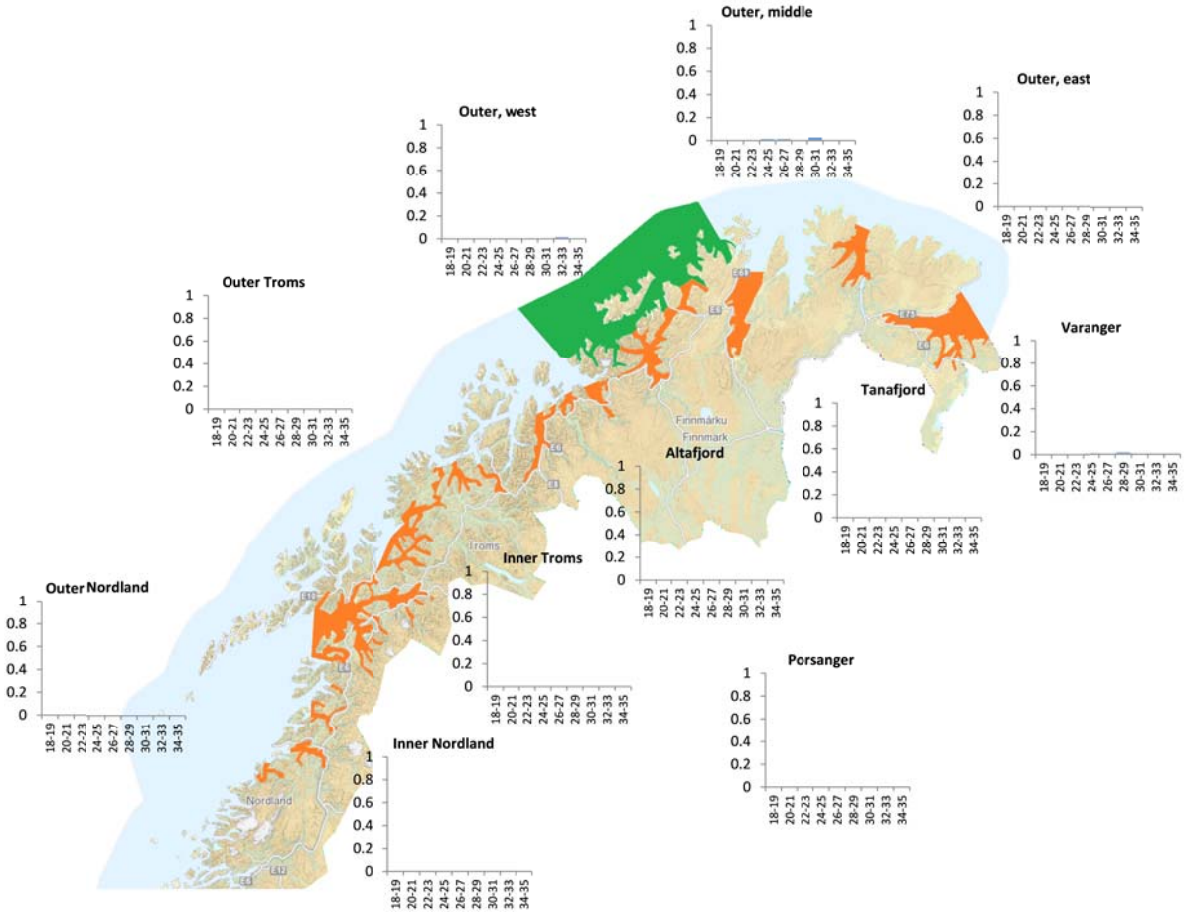


***Figure 23**. Regional catch of salmon from the* Outer Finnmark (west)*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.6 Fjords in West-Finnmark (Altafjord)

There are two large stocks (Alta and Repparfjord) and several smaller stocks in the *Fjords in West-Finnmark*-region. The main coastal catches of salmon from this region were taken locally, with rates over 5 salmon per day per gear in weeks 26-31 (**Figure 24**). The maximum catch rate was 5.62 salmon per day per gear in weeks 28-29.

Salmon from this region were further exploited in significant numbers along the outer coast of Finnmark and Troms. The highest catch rates were 3.77 salmon per day per gear in weeks 26-27 in *Outer Troms*, 2.92 salmon per day per gear in *Outer Finnmark (west)* and 1.53 salmon per day per gear in *Outer Finnmark (middle)*. High rates were also seen in *Inner Troms*, up to 2.9 salmon per day per gear in weeks 28-29. Only a few salmon from the *Fjords in West-Finnmark*-region were observed in catches in Nordland and in the eastern part of Finnmark.

The regional catch pattern seen in **Figure 24** indicates that salmon from the *Fjords in West-Finnmark*-region mainly migrates towards the region from the west and north.

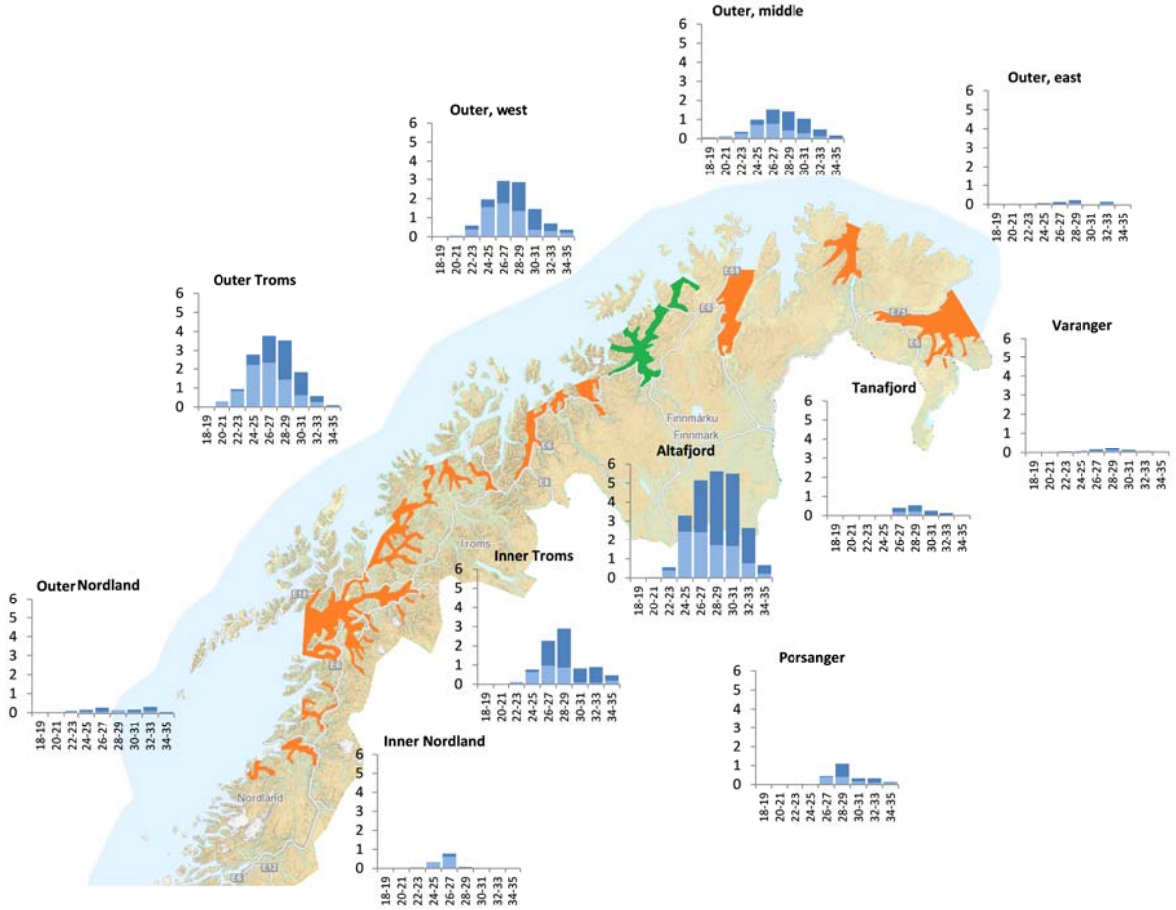


***Figure 24**. Regional catch of salmon from the* Fjords in West-Finnmark *(Altafjord)-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.7 Outer Finnmark (middle)

There are several small- and middle-sized salmon rivers in the *Outer Finnmark (middle)*-region. Most of the stocks in these rivers are dominated by grilse.

The highest catch rates were observed locally in the middle part of *Outer Finnmark* (**Figure 25**), with rates up 1.29 salmon per day per gear in weeks 28-29. Other regions with significant catch rates were *Outer Troms* (up to 0.88 salmon per day per gear in weeks 26-27), *Outer Finnmark (west)* (up to 0.34 salmon per day per gear in weeks 28-29) and *Outer Finnmark (east)* (up to 0.27 salmon per day per gear in weeks 26-27).

The observed catch pattern indicates that salmon from stocks in this region migrates from the west, north and east (**Figure 25**).

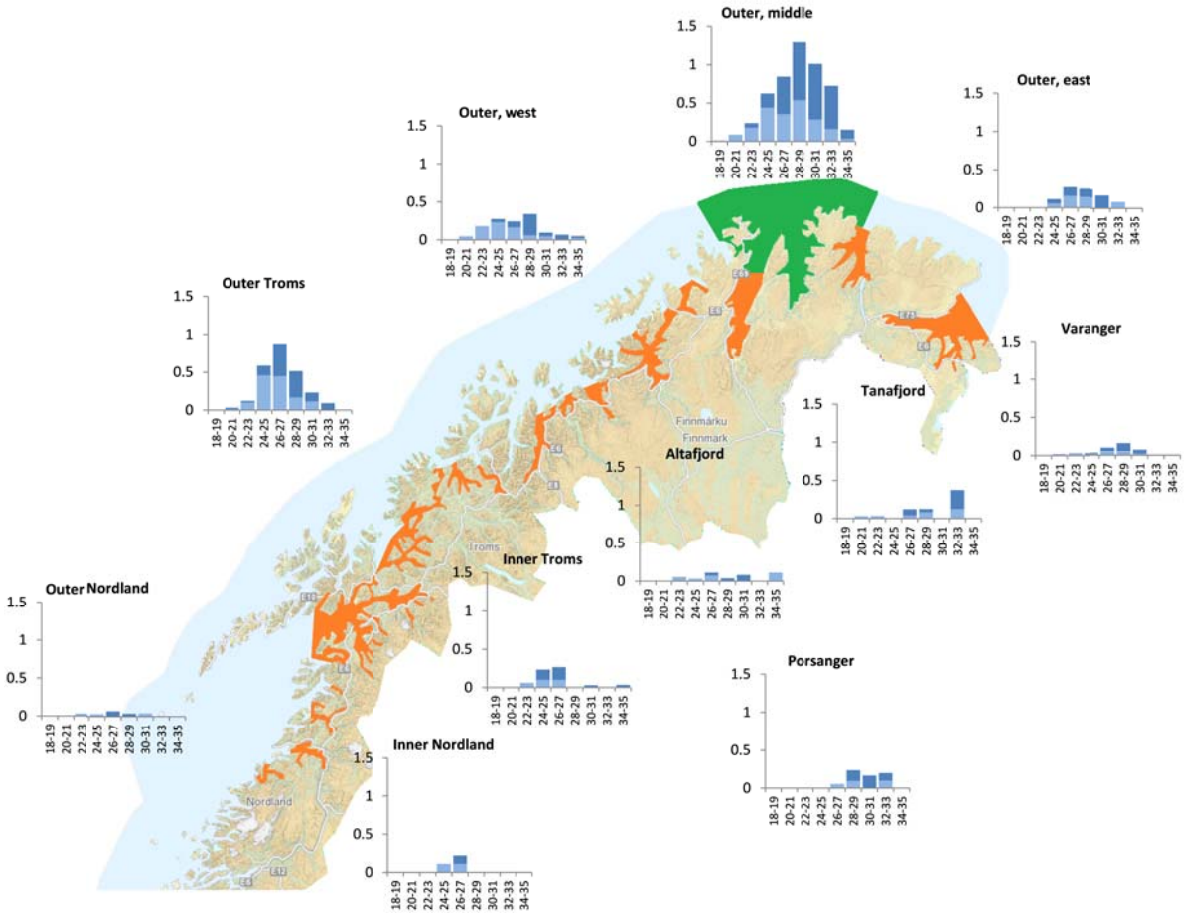


***Figure 25**. Regional catch of salmon from the* Outer Finnmark (middle)*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.8 Porsangerfjord

There are three major salmon stocks in the *Porsangerfjord* (Stabburselva, Lakselva, Børselva) and one very small stock (Billefjord).

Most of the coastal exploitation of salmon from this region was observed locally, up to 3.24 salmon per day per gear in weeks 28-29 (**Figure 26**). The remaining exploitation was in outer coastal areas of Finnmark (2.23 salmon per day per gear in weeks 30-31 in middle Finnmark and 0.75-0.76 salmon per day per gear in western Finnmark in weeks 26-29) and Troms (0.85 salmon per day per gear in weeks 30-31).

The observed catch pattern indicates a western and northern migration route for salmon belonging to the *Porsangerfjord*.

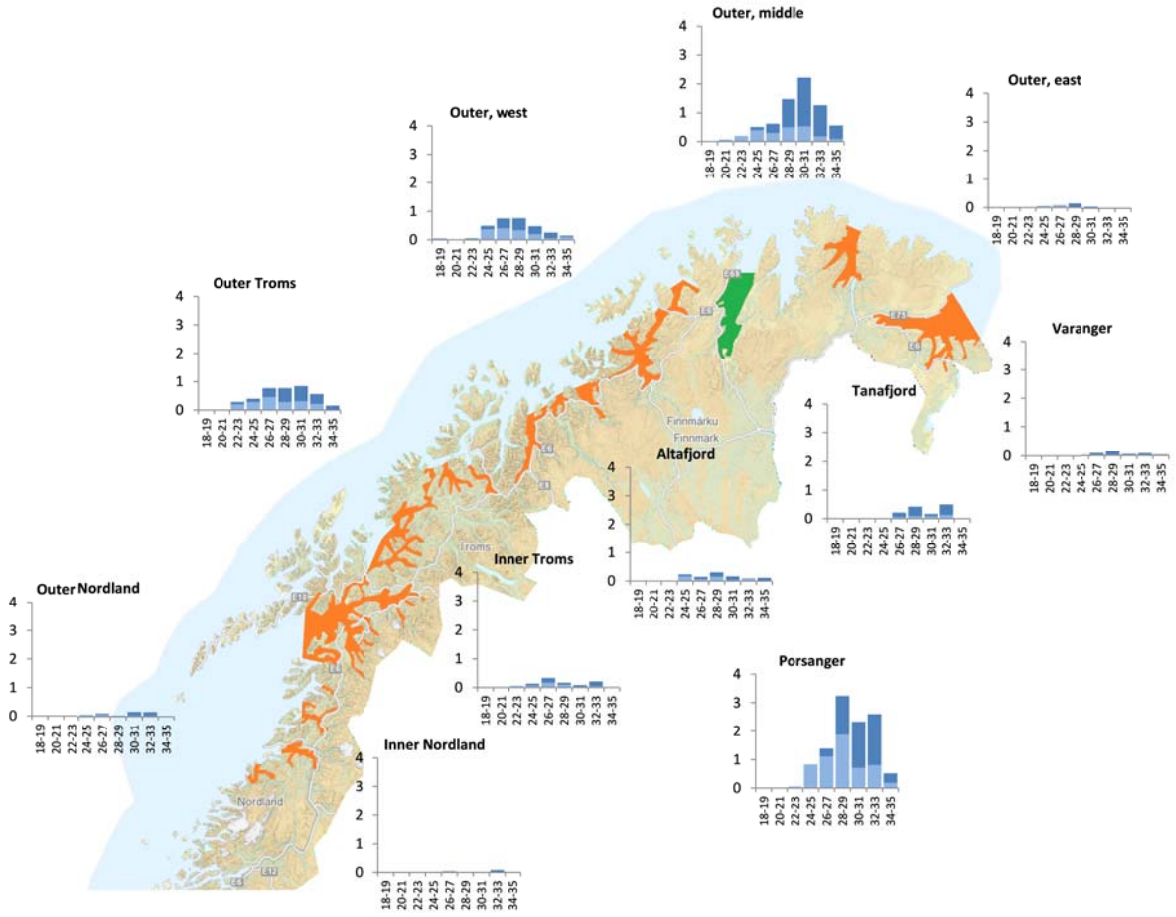


***Figure 26**. Regional catch of salmon from the* Porsangerfjord*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.9 Outer Finnmark (east)

There are four salmon stocks in the eastern part of *Outer Finnmark*. Three of these are medium-sized (Kongsfjord, Syltefjord, Komag), while the fourth is small (Sandfjord). The latter is missing from the genetic baseline and therefore not identified in the coastal catch.

The majority of the catch was observed locally along the eastern part of the outer coastline of Finnmark (**Figure 27**), with rates up to 2.35 salmon per day per gear in weeks 26-27. In addition, salmon from stocks in this area were exploited to the west in the middle part of *Outer Finnmark*, up to 0.79 salmon per day per gear in weeks 28-29, and to the east in the *Varangerfjord*, up to 0.75 salmon per day per gear in weeks 28-29.

The catch pattern indicates migration both from northwest and east.

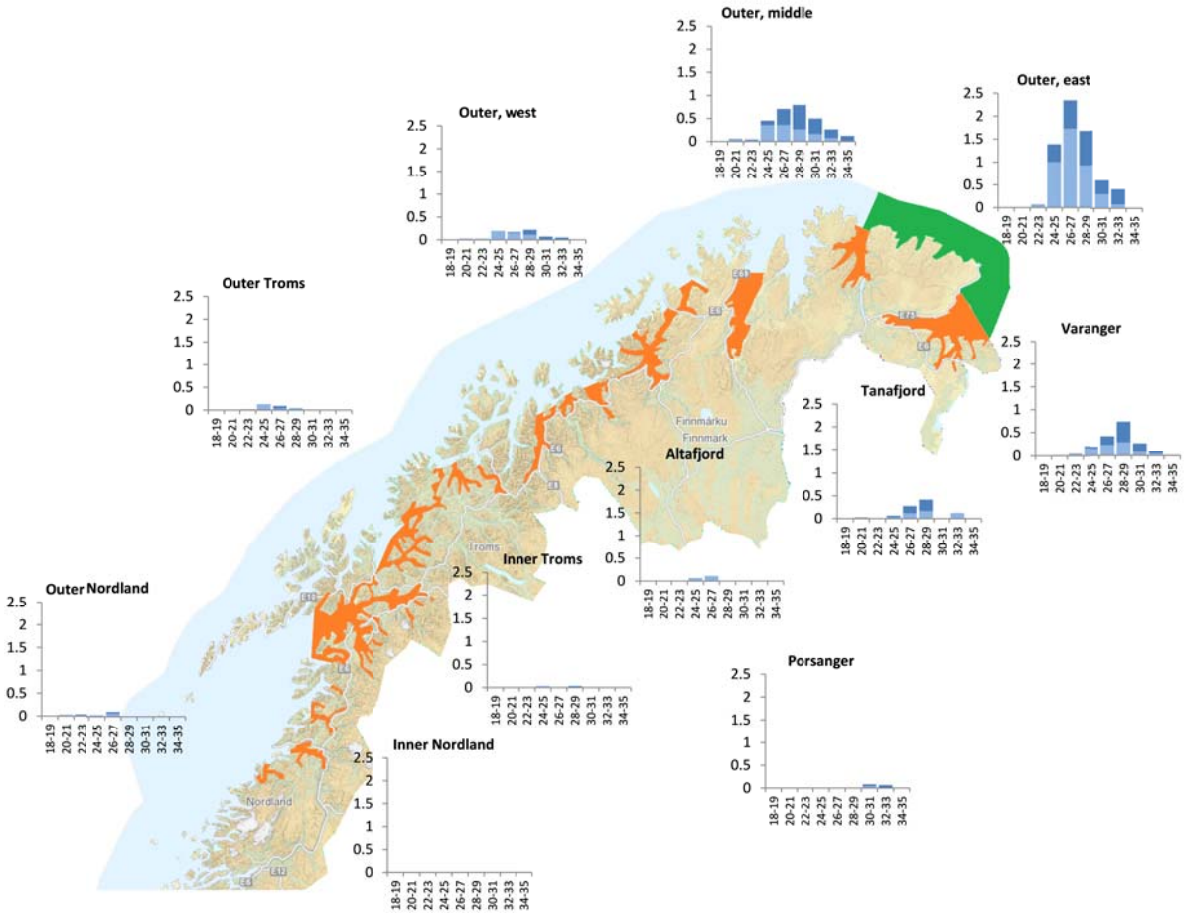


***Figure 27**. Regional catch of salmon from the* Outer Finnmark (east)*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.10 Tanafjord

The *Tanafjord*-region has two salmon rivers, one medium-sized (Langfjord/Laggo) and then the large Tana river system which is home to a multitude of large-, middle- and small-sized stocks.

Highest catch levels of salmon from this region were observed locally in the *Tanafjord*, up to 4.67 salmon per day per gear in weeks 26-27 (**Figure 28**). Significant catches were also observed in outer regions, such as *Outer Finnmark (east)* (up to 2.42 salmon per day per gear in weeks 26-27), *Outer Finnmark (middle)* (up to 0.99 salmon per day per gear in weeks 26-27), *Outer Finnmark (west)* (up to 1.22 salmon per day per gear in weeks 24-25) and *Outer Troms* (up to 1.38 salmon per day per gear in weeks 26-27).

The catch pattern indicates migration from all directions (west, north and east).

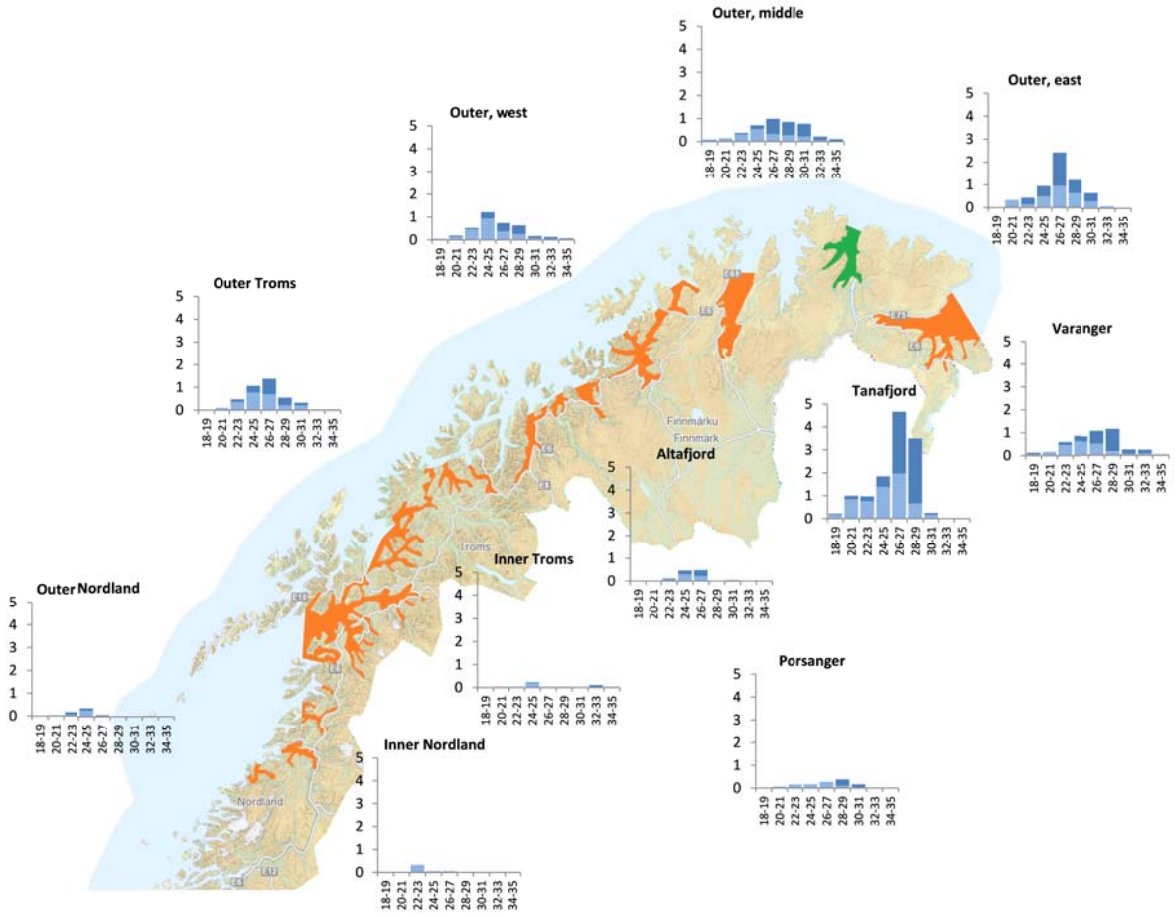


***Figure 28**. Regional catch of salmon from the* Tanafjord*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.11 Varangerfjord

There are several salmon stocks in this region, both along the northern coast (Skallelv, Vestre Jakobselv, Bergebyelv), fjord bottom (Vesterelv) and southern side (Nyelv, Klokkerelv, Munkelv, Neiden, Sandneselv, Karpelv and Grense Jakobselv).

The highest catch rates of stocks belonging to the *Varangerfjord* were observed locally, up to 3.3 salmon per day per gear in weeks 26-27 (**Figure 29**). Apart from the local catch, stocks from *Varangerfjord* were exploited in the eastern part of Outer Finnmark, up to 1.25 salmon per day per gear in weeks 28-29.

The observed catch pattern indicates a northern and eastern migration route for salmon from the *Varangerfjord* region.

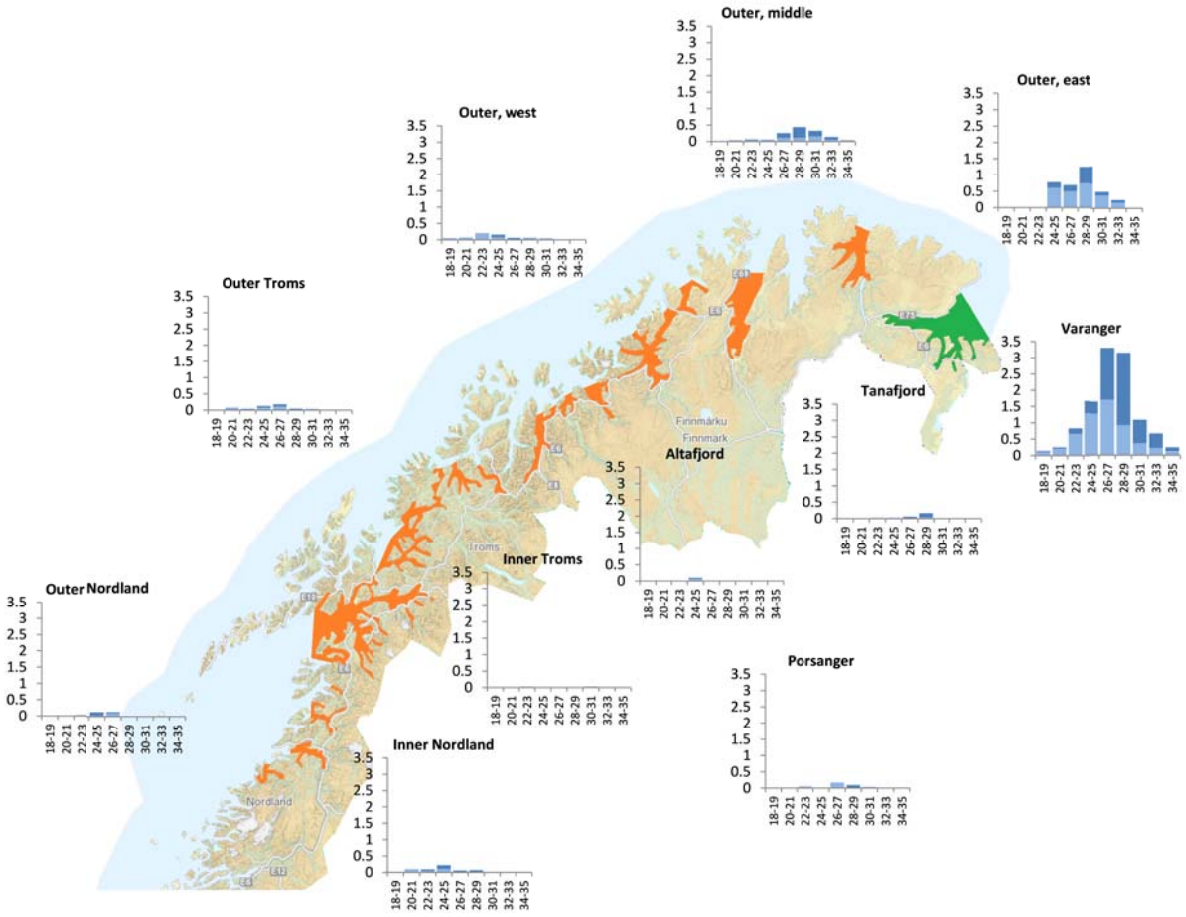


***Figure 29**. Regional catch of salmon from the* Varangerfjord-*region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.3.4.12 Russian stocks

Russian stocks were mainly exploited in the *Varangerfjord* region, with catch rates up to 4.86 salmon per day per gear in weeks 26-27 (**Figure 30**). Outside of the *Varangerfjord*, Russian stocks were exploited in smaller numbers in the outer coastal regions of Finnmark (up to 1.68 salmon per day per gear in *Outer Finnmark (west)* in weeks 22-23), *Outer Troms* (up to 0.52 salmon per day per gear in weeks 26-27) and Nordland (0.73 salmon per day per gear in weeks 24-25 in *Outer Nordland* and 1.11 salmon per day per gear in weeks 24-25 in *Inner Nordland*).

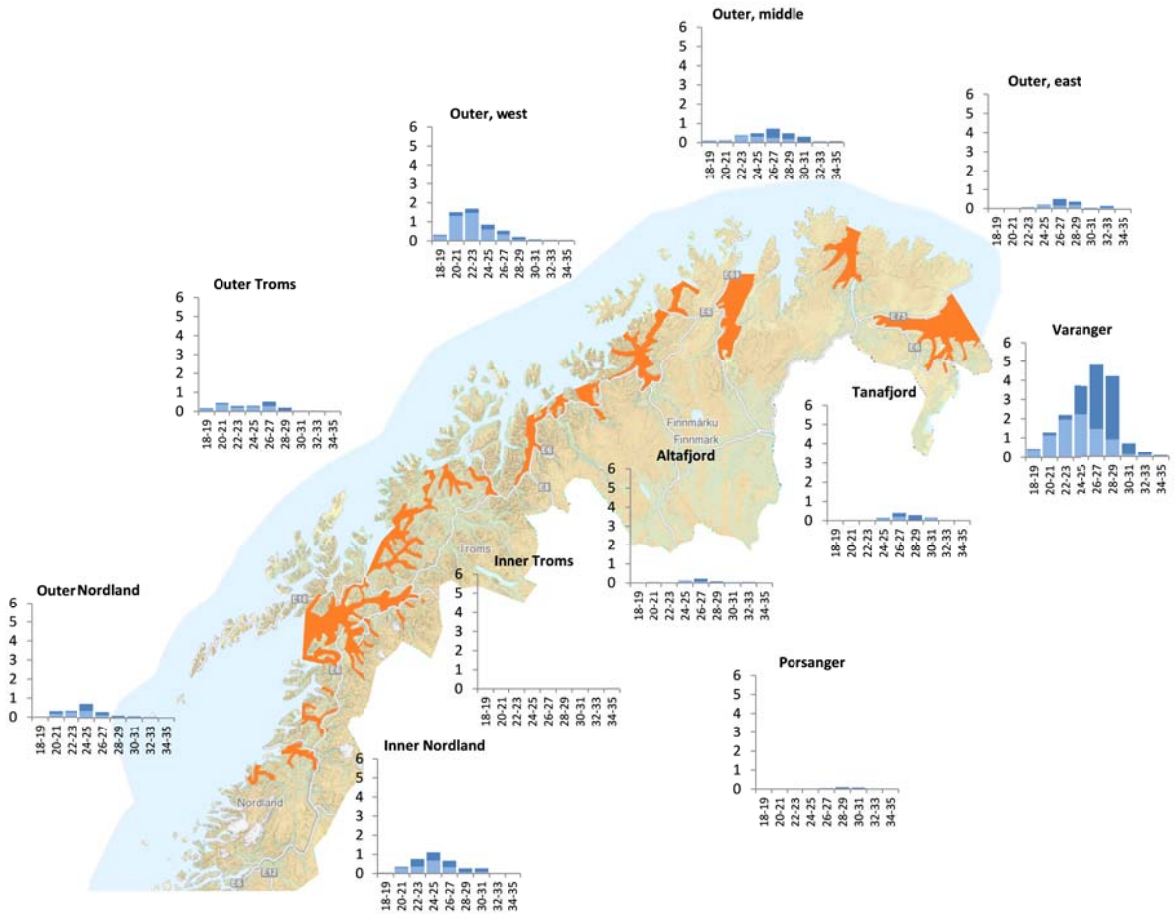


***Figure 30**. Regional catch of Russian salmon, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

3.4 Sustainable management: coastal catch, riverine catch and spawning stock size

At its core, salmon fisheries management really is allocation. Every year a number of salmon from a stock undertakes their spawning migration from the oceanic feeding grounds towards their home river. This number is called the pre-fishery abundance (PFA) of a stock. Management then becomes a process of allocating a proportion of the PFA to the coastal fishermen and a proportion to riverine fishermen. The remaining survivors are allowed to survive to spawning.

For each stock, we have defined a management target in the form of a spawning target that defines the minimum number of females that should survive to spawn in order for the river to fulfill its production potential. The PFA minus the spawning target then provides us with the number of salmon that constitutes the sustainable exploitable surplus. Ideally, the coastal and riverine exploitation should not exceed this sustainable surplus.

Using a combination of spawning stock estimates, river catch statistics, coastal catch statistics and the stock-identified coastal data from the Kolarctic-Salmon project, we can estimate the pre-fishery abundances (PFAs) of different stocks in the area. Using the PFA-estimates, we can then calculate the proportion of the PFA that were caught in coastal and riverine fisheries, and the proportion that survived to spawning, given the current coastal and river management regimes.

The Kolarctic-Salmon project data further allows us to estimate the effects of changing the coastal fisheries regulations, e.g. estimate the effect of increasing or decreasing the length of the fishing season either at the beginning or at the end of the current season. This is, however, outside the scope of the current report.

In the following, some stock-specific examples of resource allocation are provided from the years 2011 and 2012. All regions, except *Inner Nordland* and *Outer Finnmark (west)*, are present with examples.

In the previous chapter, we used genetic stock assignment pooled to a regional level when presenting the results. In this chapter, we use genetic stock assignment to individual rivers. This introduces a new level of uncertainty. The genetic stock assignment is probability-based, with an individual salmon receiving a probability-value depending on how well the salmon fits the various rivers in the genetic baseline. Then, depending on the coverage of baseline rivers and quality of the baselines, this probability might be high or low. Of the river examples below, the quality of the assignment mostly looks good with a high number of samples with high probabilities. The assignments are weaker for some of the examples, however, especially the rivers Lysbotn, Laukhelle, Repparfjord and Storelv. A thorough discussion on this problem can be found in the genetics report (Vähä *et al*. 2014).

3.4.1 Roksdal (Outer Nordland)

This is a relatively productive salmon river located on the island Andøya, in the northernmost part of the *Outer Nordland*-region. It is a well-monitored river with video counting of ascending salmon and good-quality catch statistics, meaning that the spawning stock size can be estimated fairly accurately.

Salmon from the River Roksdal were caught in three regions. The main catch was locally in the *Outer Nordland*-region, up to 0.57 salmon per day per gear in weeks 24-25 (**Figure 31**). Some Roksdal-salmon were also caught in *Outer Troms* (up to 0.2 salmon per day per gear in weeks 26-27) and *Inner Nordland* (up to 0.14 salmon per day per gear in weeks 22-23).

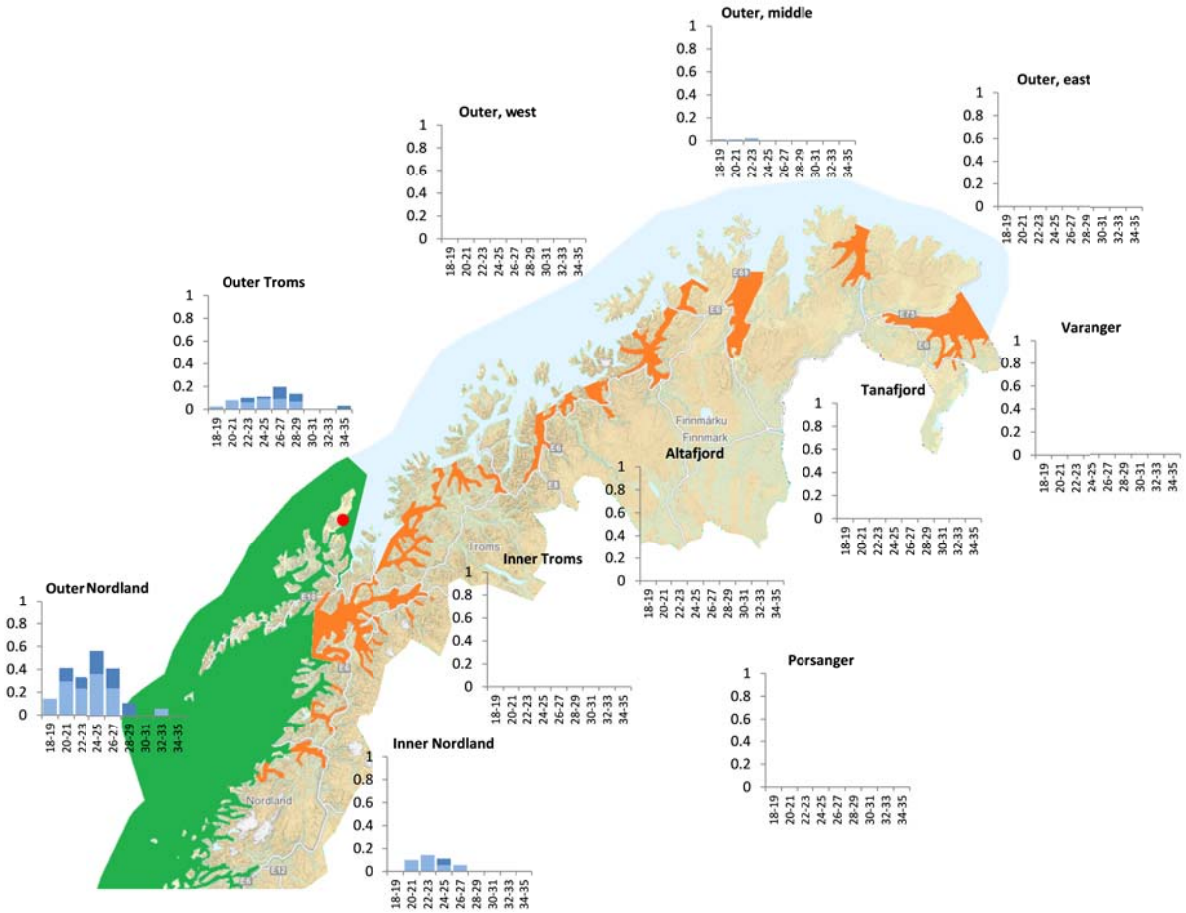


***Figure 31**. Regional catch of salmon from the river Roksdal (red circle) in the* Outer Nordland-*region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Roksdal-salmon was very low, at 3 and 1 % of the total pre-fishery abundance (PFA) in 2011 and 2012, respectively (**Figure 32**). River exploitation was higher but also very variable, being at 14 % of the total PFA in 2011 and 30 % in 2012. The river Roksdal fishery closes completely when certain conditions are met, e.g. low water levels, and such conditions shortened the 2011-season considerably and caused the very low riverine exploitation rate in that particular year.

The spawning target of River Roksdal has been estimated to be 1 087 kg (female biomass). Both in 2011 and 2012, the estimated spawning stock size exceeded the spawning target by a solid margin (**Figure 32**), indicating room for a higher rate of exploitation for this stock in these two particular years.

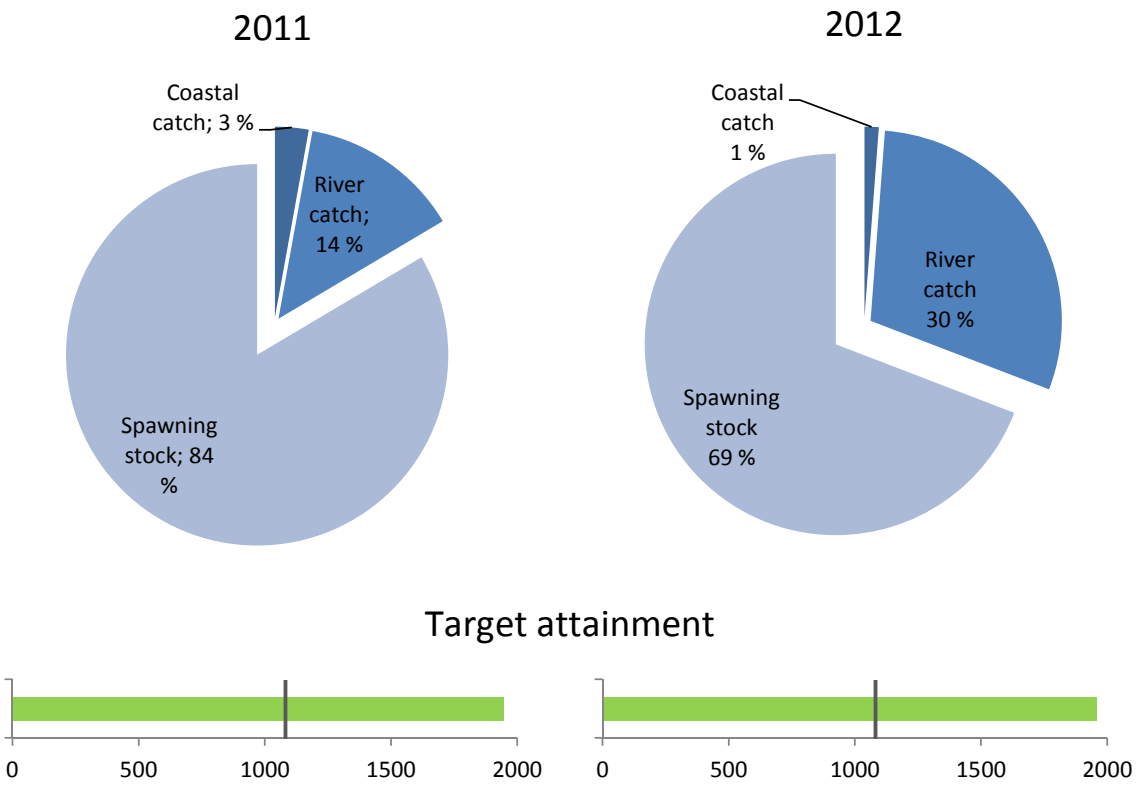


***Figure 32**. Upper part: The estimated pre-fishery abundance of Roksdal-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.2 Lysbotn (Outer Troms)

This is a relatively small river system on the northern side of Senja in the *Outer Troms*-region. The river has sizeable stocks of both anadromous trout and charr in addition to salmon.

Salmon from Lysbotn were mainly caught locally in the *Outer Troms*-region, with rates up to 0.48 salmon per day per gear in weeks 24-25 (**Figure 33**). Smaller catches were recorded in *Inner Troms* (up to 0.27 salmon per day per gear in weeks 26-27) and *Outer Nordland* (0.20 salmon per day per gear).

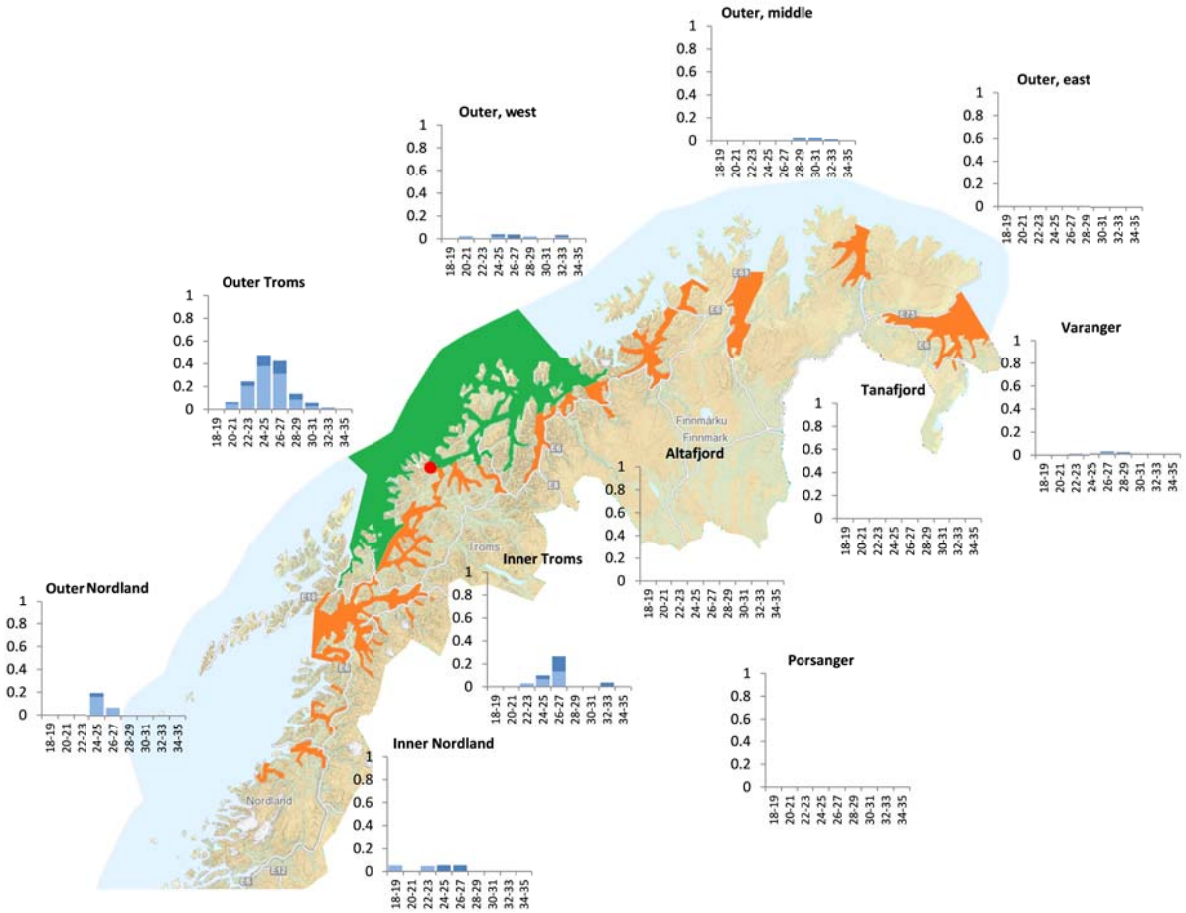


***Figure 33**. Regional catch of salmon from the river Lysbotn (red circle) in the* Outer Troms*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Lysbotn-salmon was relatively low, at 4 and 10 % of the total pre-fishery abundance (PFA) in 2001 and 2012, respectively (**Figure 34**). River exploitation was higher, at 24 and 27 % in 2011 and 2012, respectively. 63 to 72 % of the PFA survived to spawning.

The spawning target of river Lysbotn is 336 kg (female biomass). The estimated spawning stock exceeded the spawning target in both 2011 and 2012 (**Figure 34**).

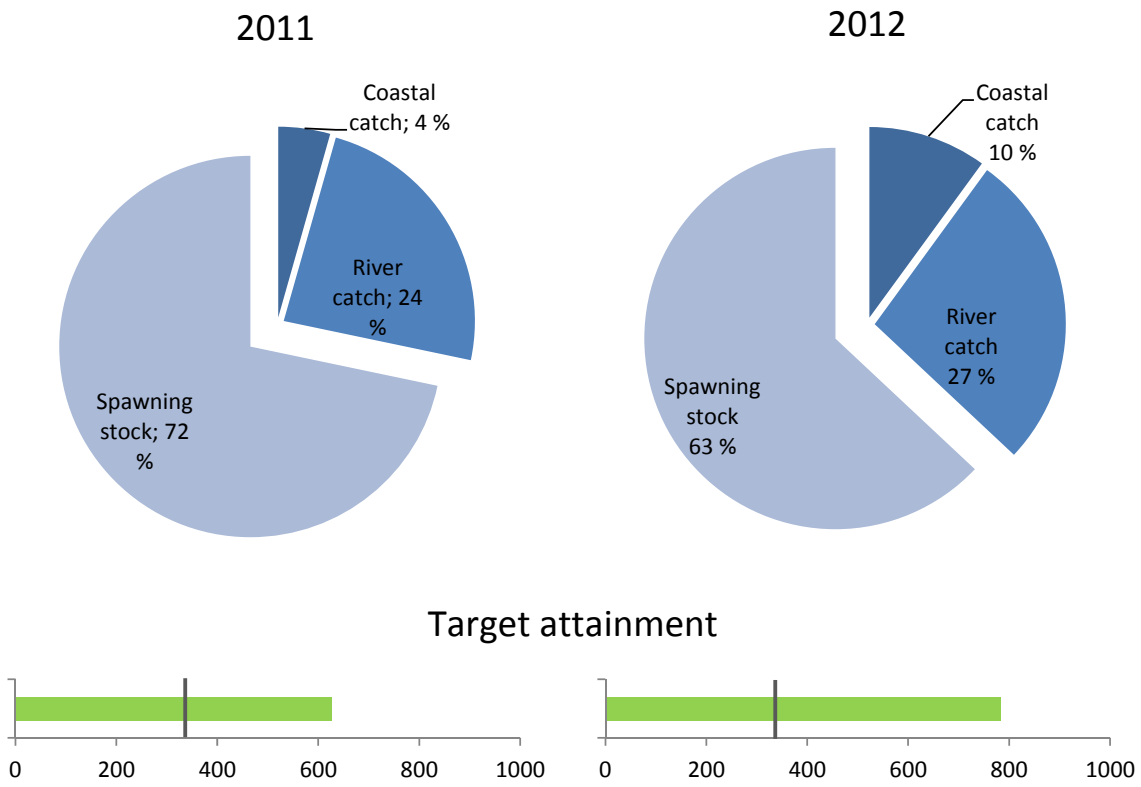


***Figure 34**. Upper part: The estimated pre-fishery abundance of Lysbotn-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.3 Laukhelle (Inner Troms)

This is a medium-sized river located on the eastern side of the island Senja, inside the *Inner Troms*-region. It is a well-monitored river with video counting of ascending salmon. Despite this, it is difficult to accurately estimate the spawning stock size in Laukhelle due to the large number of farmed salmon ascending the river each year.

Wild salmon from Laukhelle were caught mostly in three regions (**Figure 35**). The highest catch rate was seen in *Inner Nordland* at 0.39 salmon per day per gear in weeks 26-27. The other two regions with significant catches of Laukhelle-salmon were the *Outer Troms*-region with catch rates up to 0.21 salmon per day per gear and *Inner Troms* with rates up to 0.17 salmon per day per gear.

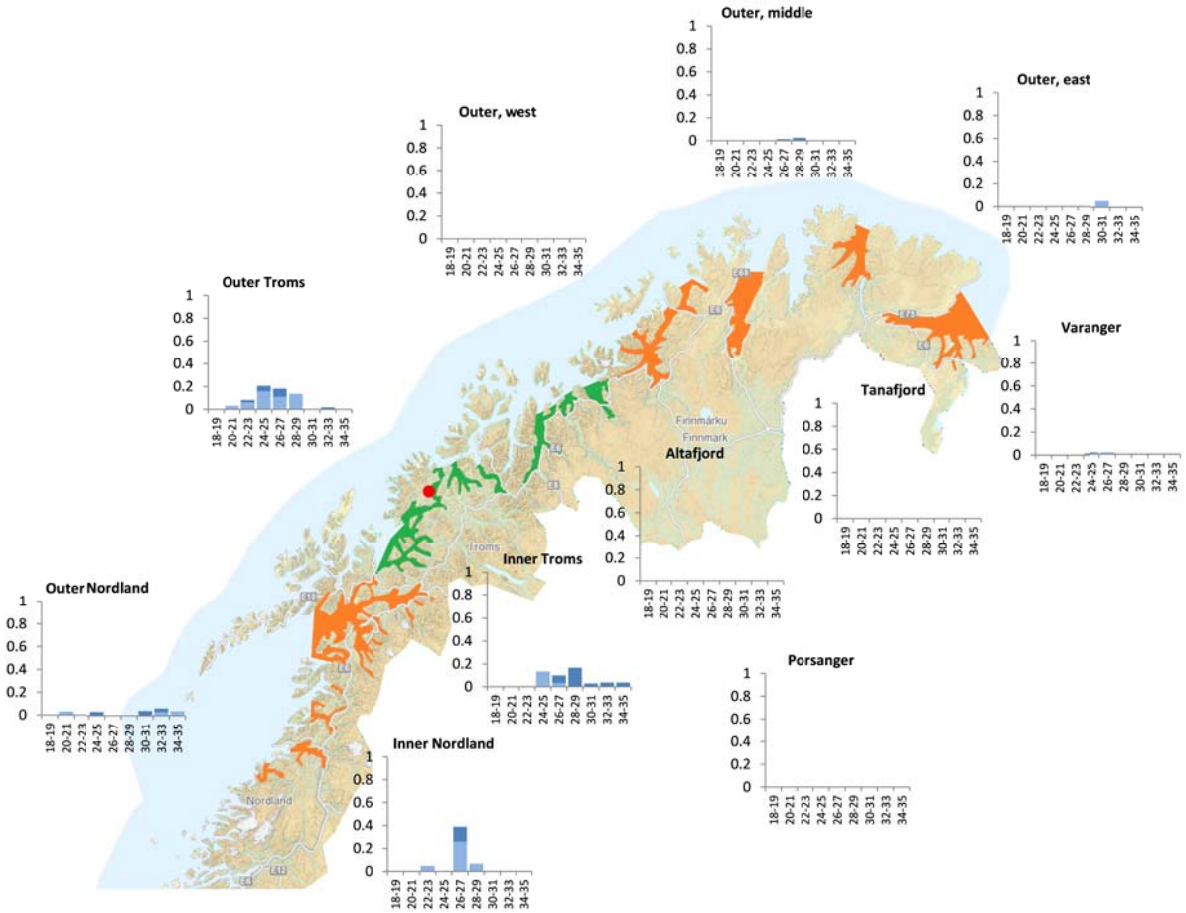


***Figure 35**. Regional catch of salmon from the river Laukhelle (red circle) in the* Inner Troms*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Laukhelle-salmon was variable, at 16 % of the pre-fishery abundance (PFA) in 2011 and 5 % in 2012 (**Figure 36**). River exploitation was at 17-19 %.

The spawning target of river Laukhelle is 1 055 kg (female biomass). This target was clearly missed in 2011 with an estimated spawning stock size under 50 % of the spawning target (**Figure 36**), meaning that all exploitation this year, both coastal and riverine, was unsustainable overexploitation. The stock situation improved in 2012 with an estimated target attainment of just over 100 %.

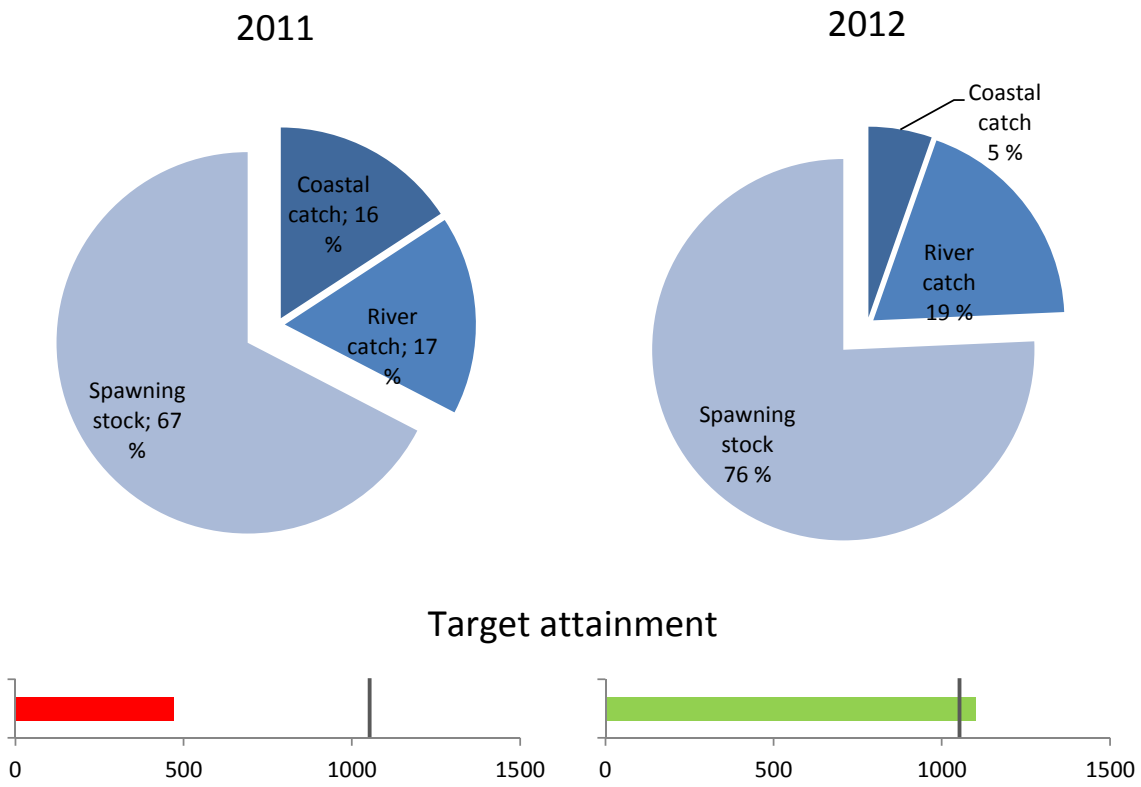


***Figure 36**. Upper part: The estimated pre-fishery abundance of Laukhelle-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.4 Målselv (Inner Troms)

This is the main salmon river in southern Troms, located in the innermost part of the Malangen fjord. It is a long river with a major water fall that salmon are able to pass with the help of a fish ladder. The catch statistic is good, and with the help of video counting in the fish ladder the spawning stock size can be estimated fairly accurately.

Salmon from Målselv were caught in two regions. Very high catch rates were observed in *Inner Troms*, up to 14.9 salmon per day per gear in weeks 26-27 (**Figure 37**). In *Outer Troms*, Målselv-salmon were caught up to 0.65-0.67 salmon per day per gear in weeks 26-31.

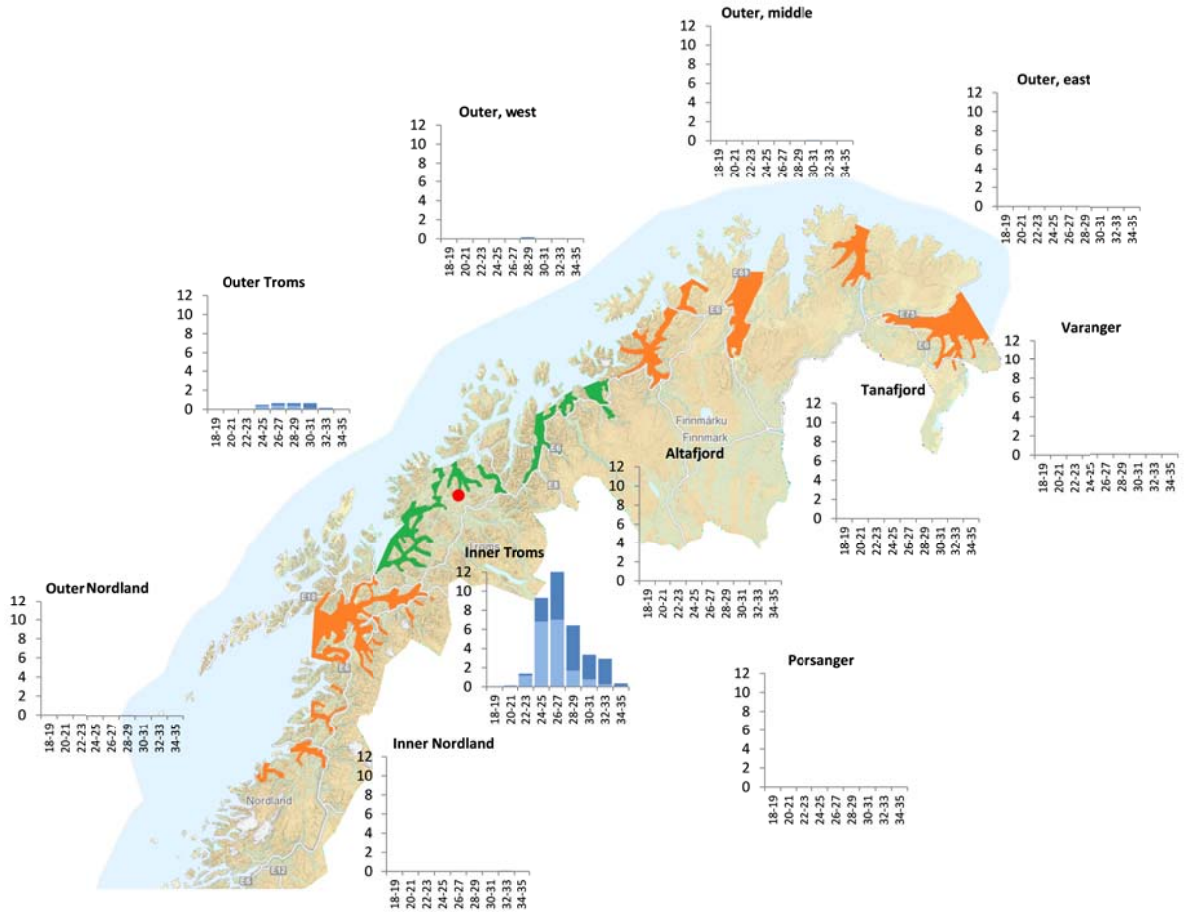


***Figure 37**. Regional catch of salmon from the river Målselv (red circle) in the* Inner Troms*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Målselv-salmon was 23 and 18 % of the total pre-fishery abundance (PFA) in 2011 and 2012, respectively (**Figure 38**). River exploitation of the PFA was higher, at 29-31 %.

The spawning target of river Målselv is 5 362 kg (female biomass). Estimated spawning stock exceeded the spawning target by a solid margin on both 2011 and (especially) 2012 (**Figure 38**), indicating room for a higher rate of exploitation for this stock in these two particular years.

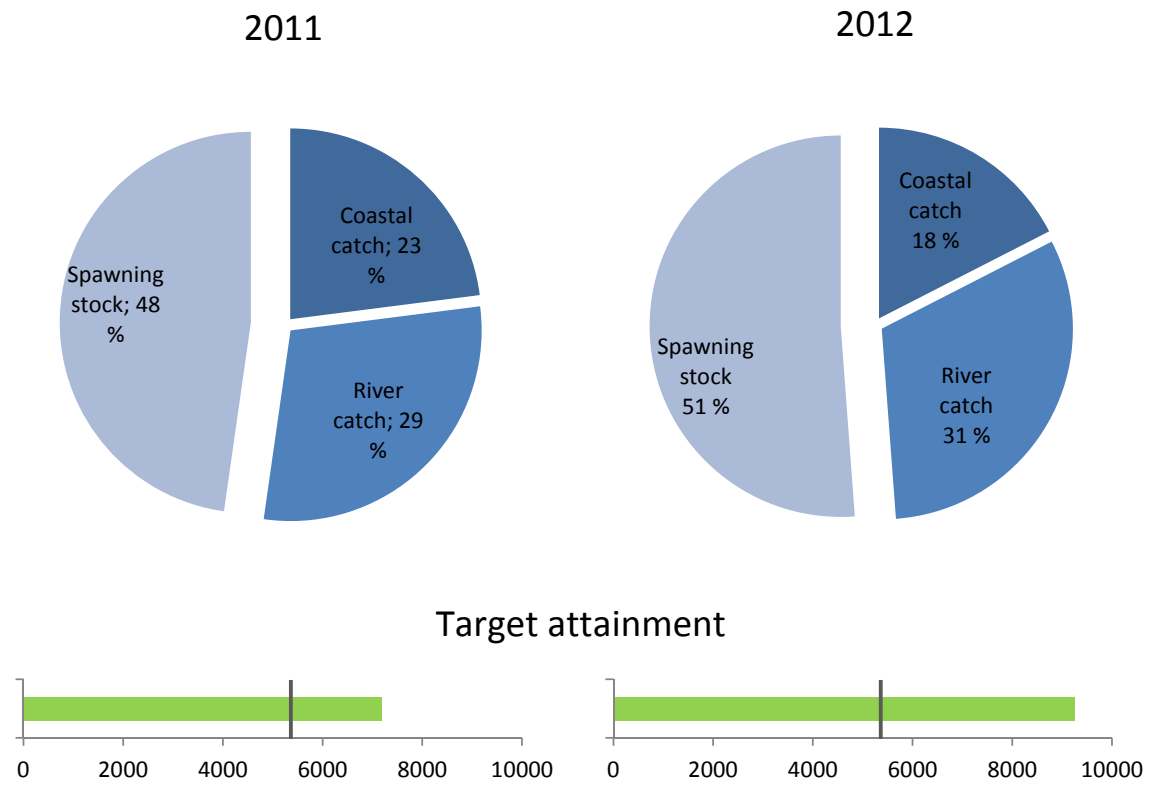


***Figure 38**. Upper part: The estimated pre-fishery abundance of Målselv-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.5 Reisa (Inner Troms)

This is the major salmon river in the northern part of Troms. It is a river that has had a positive catch development in the last decade, going from an average annual catch of slightly over 400 salmon in the years before 2004 up to an average of over 1 100 salmon in the years since.

Salmon from the river Reisa were captured mainly in three regions. The highest catch rates were observed in *Outer Troms*, up to 0.4 salmon per day per gear in weeks 30-31 (**Figure 39**). The other regions were *Inner Troms* (up to 0.33 salmon per day per gear in weeks 24-25) and *Outer Finnmark (west)* (up to 0.34 salmon per day per gear in weeks 28-29).

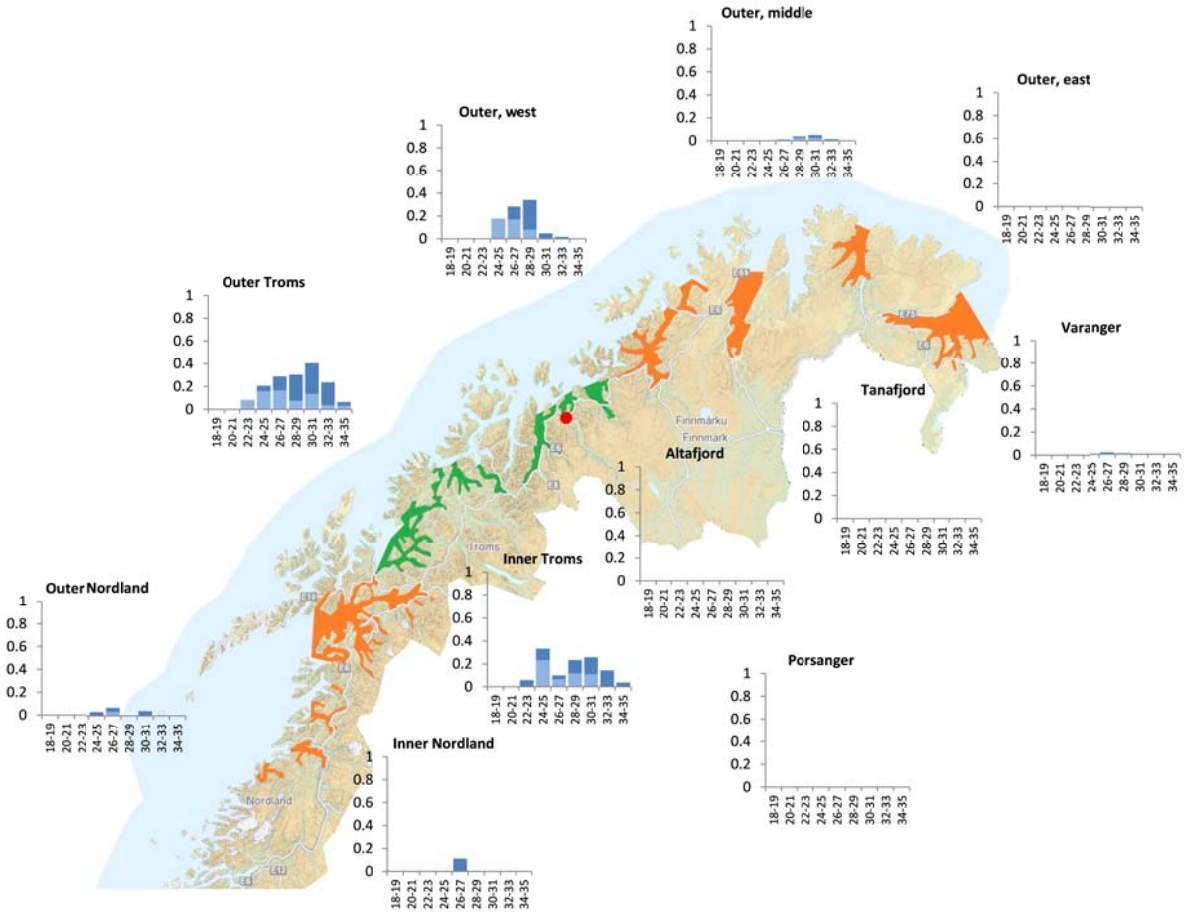


***Figure 39**. Regional catch of salmon from the river Reisa (red circle) in the* Inner Troms*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Reisa-salmon was relatively low, at 11 and 15 % of the total pre-fishery abundance (PFA) in 2011 and 2012, respectively (**Figure 40**). Riverine exploitation was higher at 30-33 %. In 2011 and 2012, the estimated spawning stock was at 55-56 % of the PFA.

The spawning target in Reisa is set to 3 652 kg (female biomass). The estimated spawning stock was above the target in both 2011 and 2012, meaning that the exploitation of Reisa-salmon was sustainable in both years.

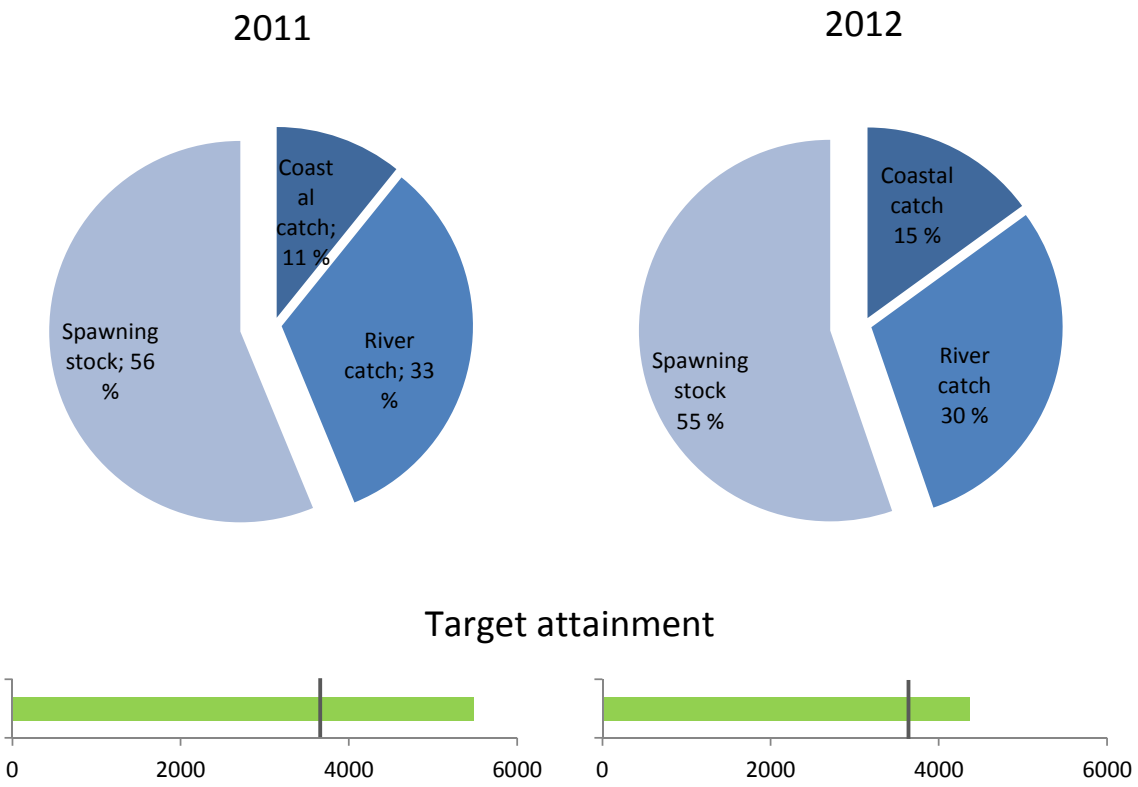


***Figure 40**. Upper part: The estimated pre-fishery abundance of Reisa-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

The percentage seen in **Figure 40** above is surprisingly low compared with e.g. the coastal catch-proportion seen for the river Målselva in southern Troms (**Figure 38**). Looking at the stock-identified data set however, it is clear that there are similarities in the baseline-material for Reisaelva and the neighbouring rivers Rotsundelva and Kvænangselva. Using the production potential of these three rivers as a basis for the expected number of stock-identified samples, both the latter becomes highly overrepresented in the stock-identified data set while Reisaelva in comparison is strongly underrepresented. If we pool the stock-identified samples from these three rivers and redistribute the samples proportionally according to the three rivers relative production potential, we get an extended catch pattern with increased catch rates and a broadened exploitation into more regions (**Figure 41**). The highest redistributed catch rates were again observed in *Outer Troms*, at 0.63 salmon per day per gear in weeks 24-25. In addition to *Outer Troms*, the redistributed catch numbers show substantial catches in *Inner Troms* (up to 0.3 salmon per day per gear in weeks 24-27), *Outer Finnmark (west)* (0.36 salmon per day per gear in weeks 26-27) and *Outer Finnmark (middle)* (up to 0.41 salmon per day per gear in weeks 26-27).

The coastal catch-proportion for Reisa-salmon increased substantially from 11-15 % (**Figure 40**) to 23-26 % with the redistributed catch numbers (**Figure 42**).

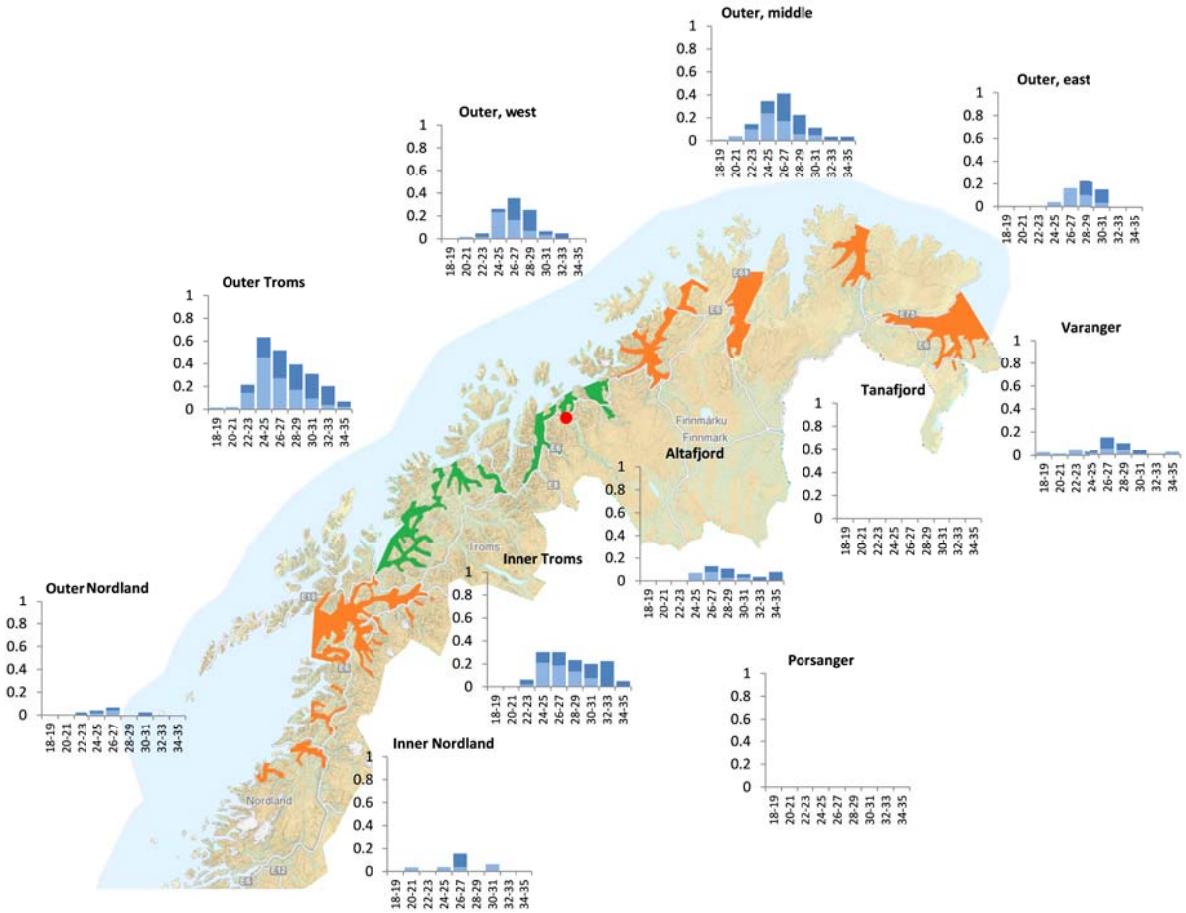


***Figure 41**. Regional catch of salmon from redistributed stock-identified catch numbers based on relative production potential between Reisa (red circle) and neighbouring stocks in the* Inner Troms*-region, given as number of salmon per day per fishing gear over two-week-periods.*

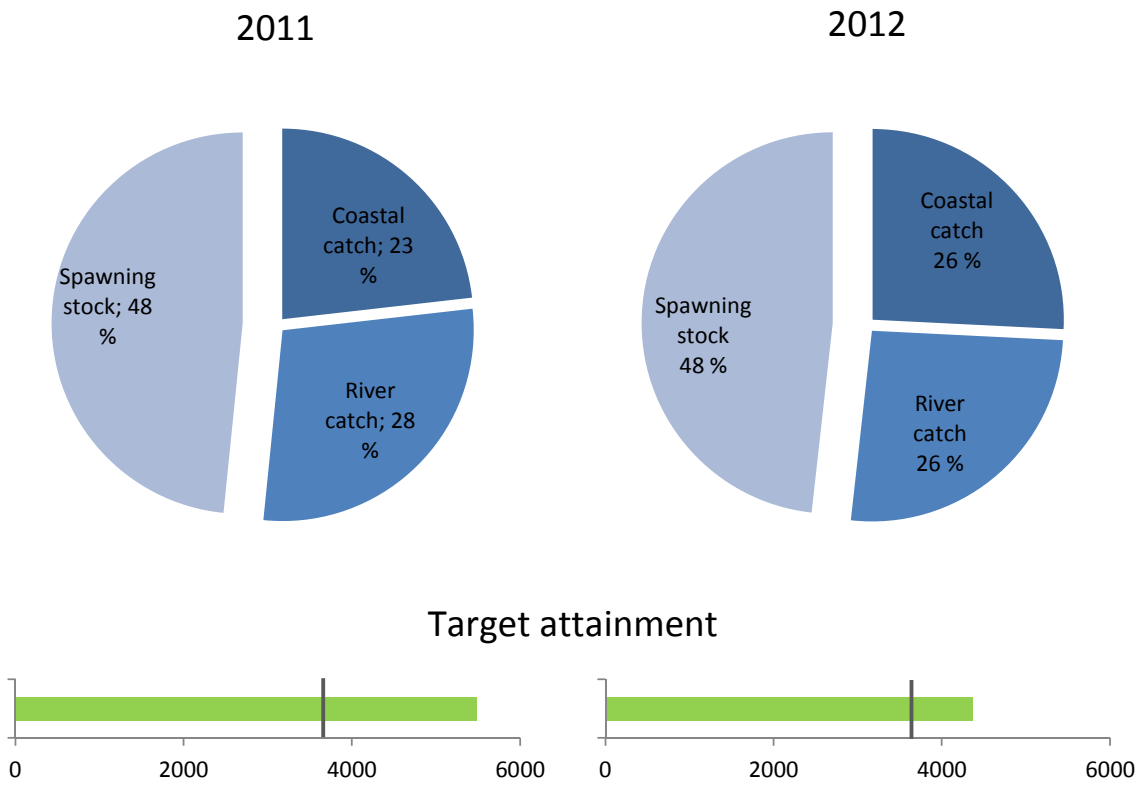


***Figure 42**. Upper part: The estimated pre-fishery abundance of Reisa-salmon in 2011 and 2012, from redistributed stock-identified catch numbers based on relative production potential between Reisa and neighbouring stocks, separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.6 Altaelva (Fjords in West-Finnmark)

The river Alta is a large river flowing from the south into the innermost part of the Altafjord in the *Fjords in West-Finnmark*-region. This is a highly productive river with a large average salmon size. Most spawners are multi-sea-winter (MSW) salmon.

The highest catch rates of Alta-salmon were observed locally in the Altafjord, up to 5.54 salmon per day per gear in weeks 28-29, 5.42 in weeks 30-31 and 4.93 in weeks 26-27 (**Figure 43**). Alta-salmon was also caught outside in *Outer Finnmark (west)* (up to 1.88 salmon per day per gear in weeks 28-29), to the west in *Outer Troms* (up to 2.14 salmon per day per gear in weeks 28-29) and *Inner Troms* (up to 1.9 salmon per day per gear in weeks 28-29), and then also to the east in *Outer Finnmark (middle)* (up to 0.58 salmon per day per gear in weeks 28-29).

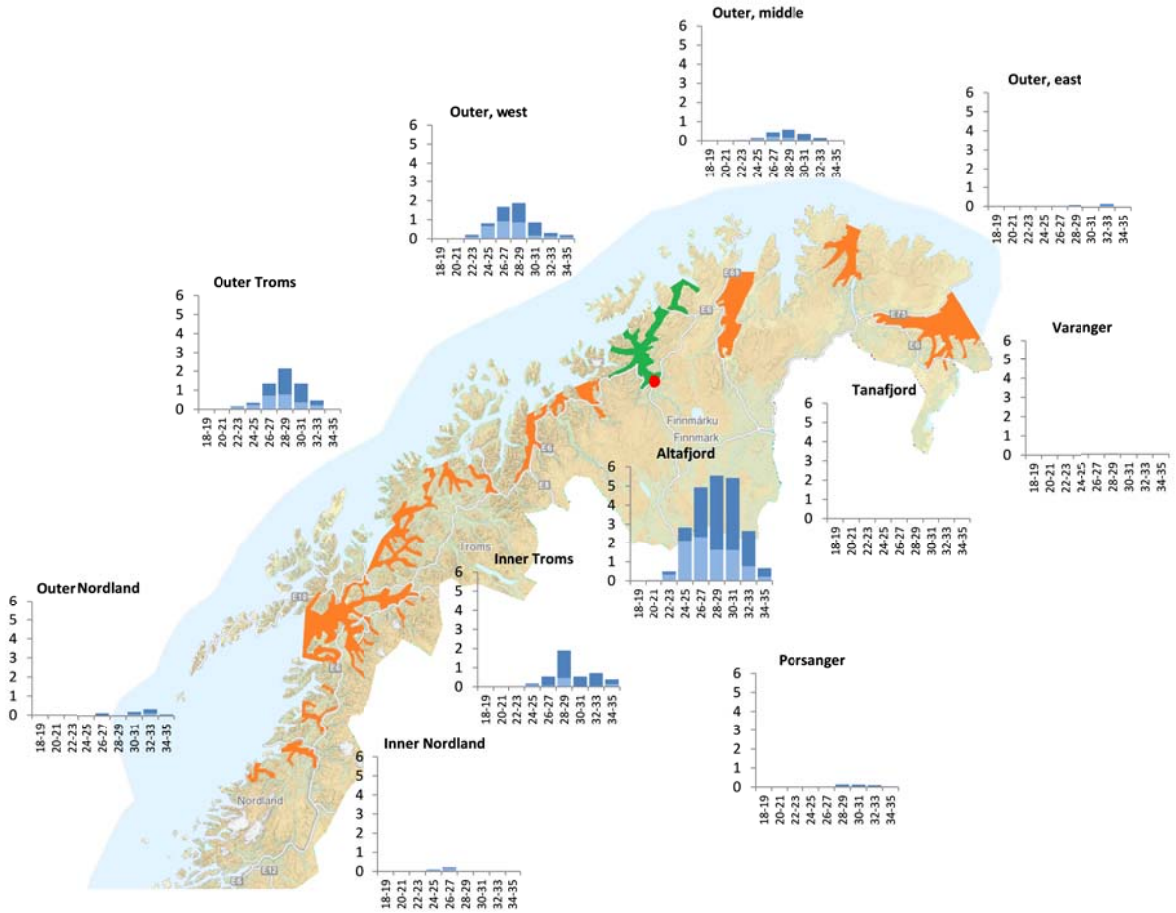


***Figure 43**. Regional catch of salmon from the river Alta (red circle) in the* Fjords in West-Finnmark-*region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Alta-salmon was relatively high, at 49 and 42 % in 2011 and 2012, respectively (**Figure 44**). The riverine exploitation was lower, at 17 and 20 % in the two years. In total, this meant that 33 to 38 % of the PFA survived to spawning.

The spawning target of river Alta has been set to 12 130 kg (female biomass). Despite the high total exploitation, the estimated spawning stock exceeded the target in both 2011 and 2012. Target attainment was just over 100 % in 2011 and well over 300 % in 2012.

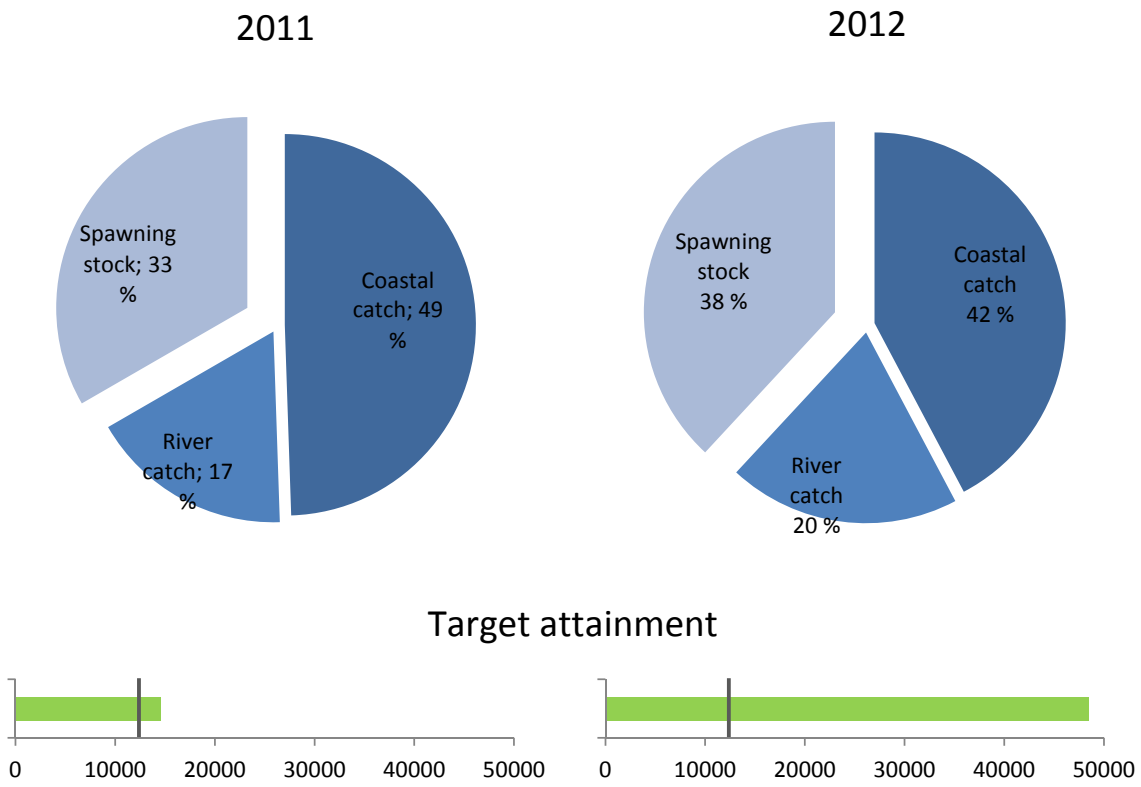


***Figure 44**. Upper part: The estimated pre-fishery abundance of Alta-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.7 Repparfjordelva (Fjords in West-Finnmark)

This is the second large river in the *Fjords in West-Finnmark*-region, located in Kvalsund to the east of Alta. It is one of many rivers in the north with a positive salmon stock development in the last 10-15 years.

The highest catch rates of Repparfjord-salmon were observed in the *Outer Troms*-region, up to 2.05 salmon per day per gear in weeks 26-27, followed by 1.3 salmon per day per gear in weeks 26-27 in the *Inner Troms*-region, 1.21 salmon per day per gear in weeks 26-27 in the *Outer Finnmark (west)*-region and 1.04 salmon per day per gear in weeks 26-27 in the *Outer Finnmark (middle)*-region (**Figure 45**). This indicates a migratory pattern with most Repparfjord-salmon coming from west-southwest and only a few coming from the north and east.

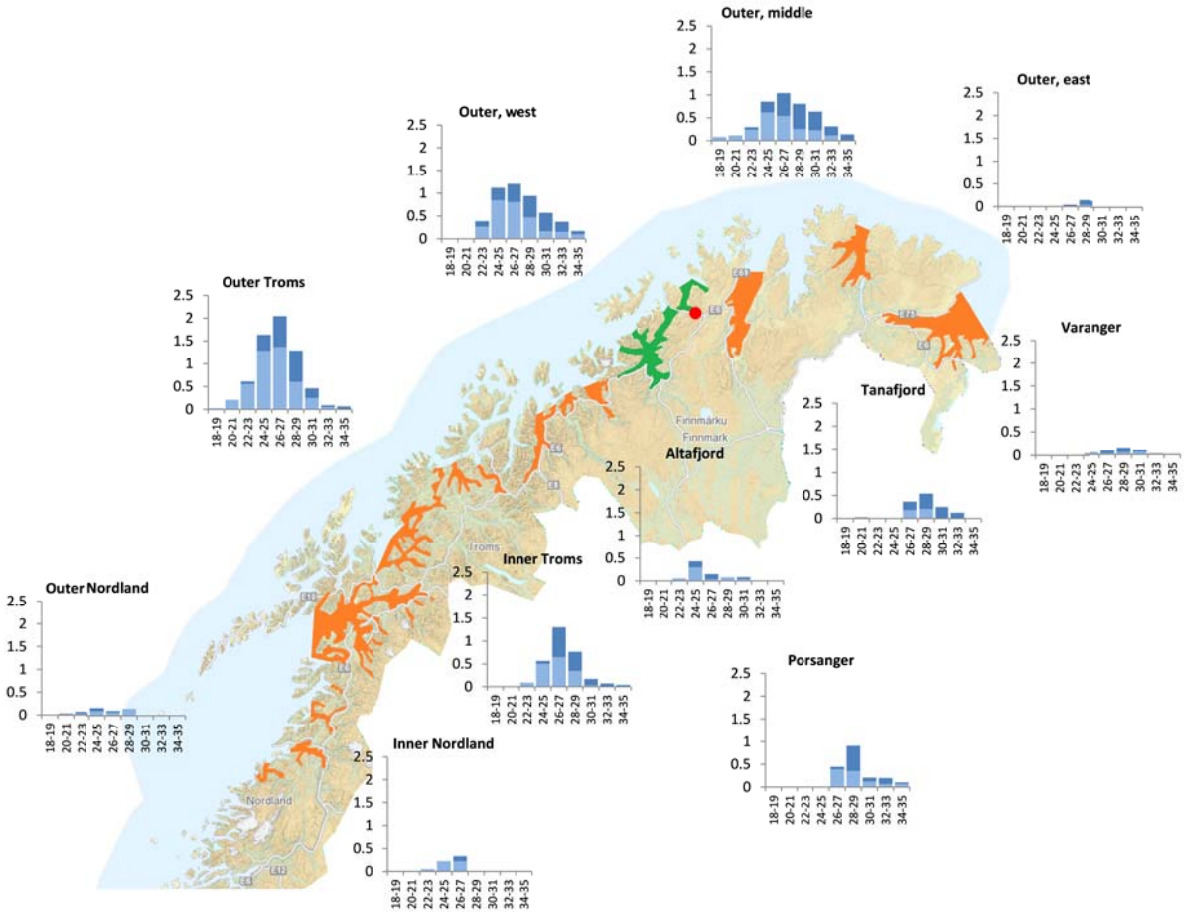


***Figure 45**. Regional catch of salmon from the river Repparfjordelva (red circle) in the* Fjords in West-Finnmark*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Repparfjord-salmon was relatively high**,** at 28 and 32 % in 2011 and 2012, respectively (**Figure 46**). River exploitation was at the same level, estimated at 27 and 29 %.

The spawning target of Repparfjord has been set to 3 301 kg (female biomass). Both in 2011 and 2012, the estimated spawning stock size exceeded the spawning target (**Figure 46**), indicating a sustainable level of exploitation in both years.

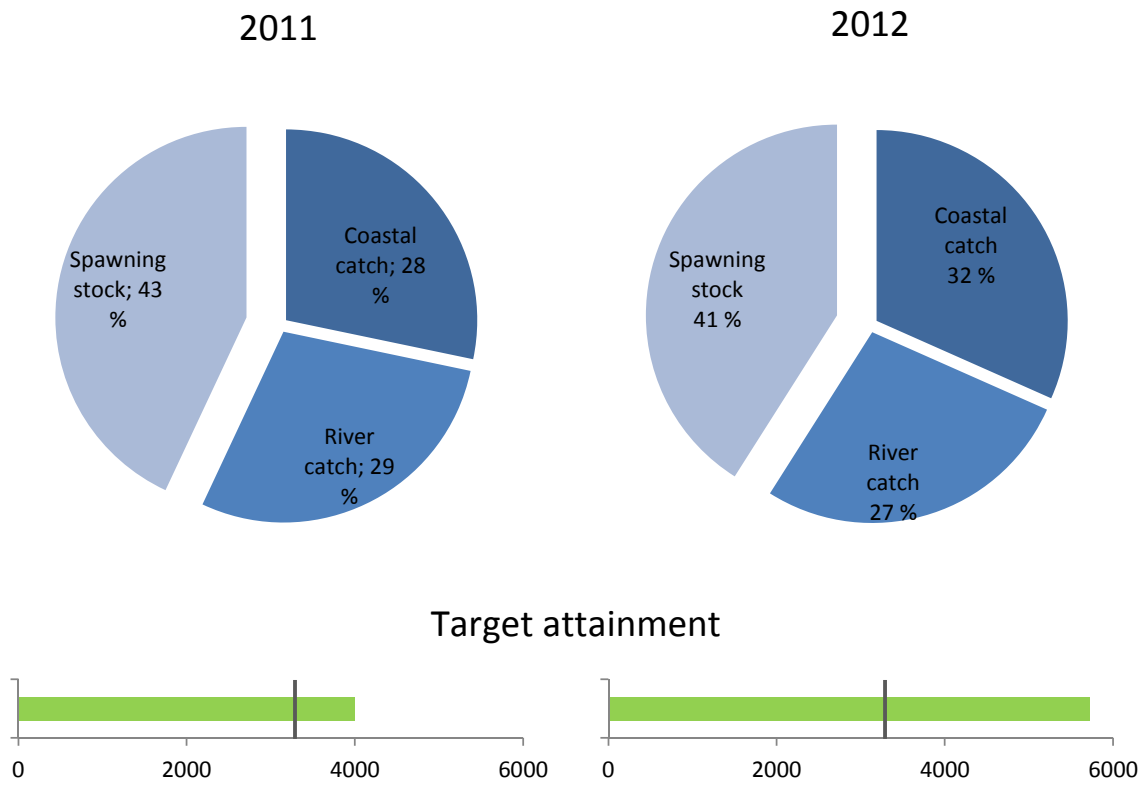


***Figure 46**. Upper part: The estimated pre-fishery abundance of Repparfjord-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.8 Lakselva (Porsangerfjord)

This is one of three large salmon rivers in the *Porsangerfjord*. The river Lakselva is located in the innermost part of the *Porsangerfjord*, and has a stock with a large proportion of MSW-salmon. A significant proportion of the stock therefore is of a size that is positively selected by the mesh sizes used in the coastal fisheries.

The highest catch rates of Lakselva-salmon were recorded locally in the *Porsangerfjord*, up to 2.67 salmon per day per gear in weeks 28-29 (**Figure 47**). Second-highest catch rates were seen in the *Outer Finnmark (middle)*-region, up to 1.74 salmon per day per gear in weeks 30-31. Other regions with substantial catches of Repparfjord-salmon were *Outer Finnmark (west)* (up to 0.48 salmon per day per gear) and *Outer Troms* (up to 0.67 salmon per day per gear). The observed exploitation pattern of Lakselva-salmon thus indicates a predominantly western migration route.

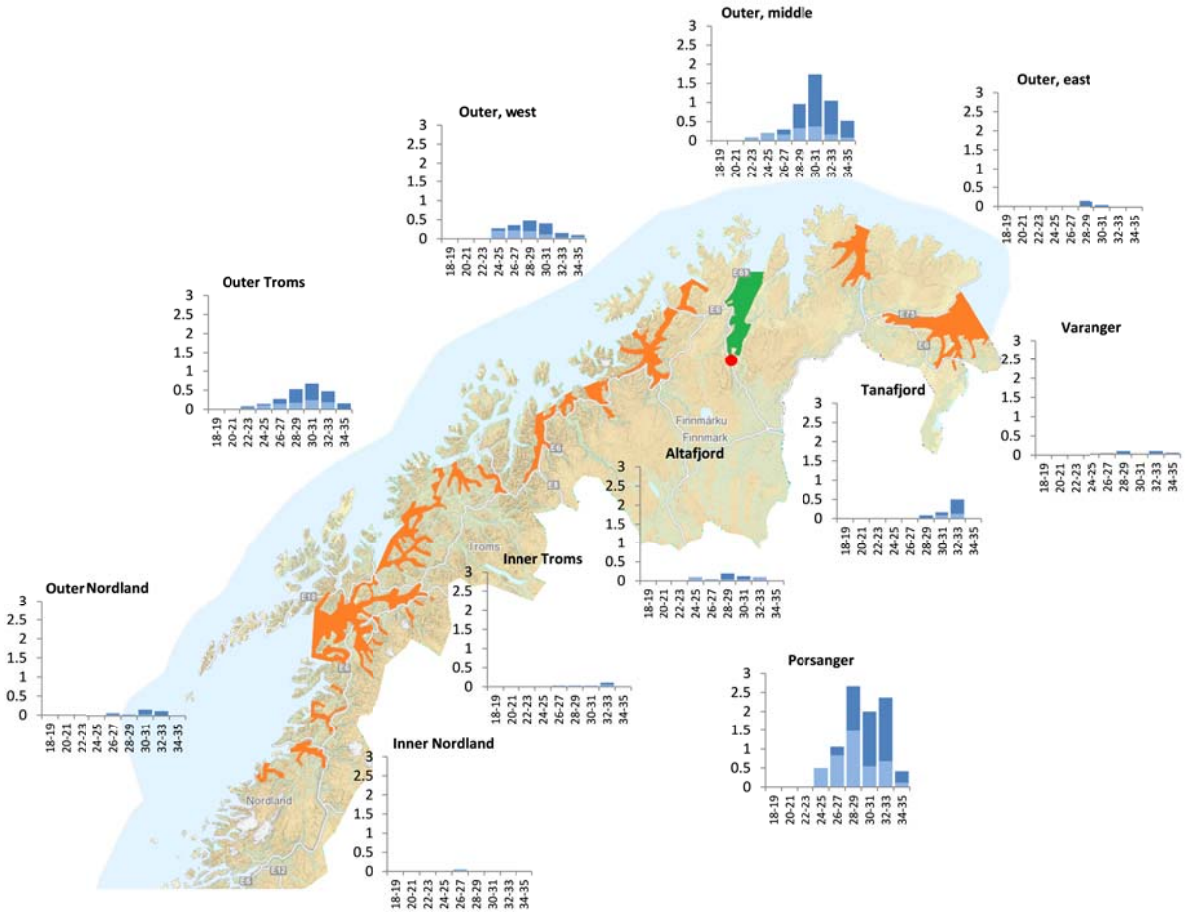


Figure 47*. Regional catch of salmon from the river Lakselv (red circle) in the* Porsangerfjord*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Lakselva-salmon was relatively high, at 28 and 33 % in 2011 and 2012, respectively (**Figure 48**). River exploitation was lower at 23 % in both years.

The spawning target of river Lakselva has been estimated to be 3 424 kg (female biomass). Both in 2011 and 2012, the estimated spawning stock size exceeded the spawning target by a solid margin (**Figure 48**), indicating that exploitation in both years was sustainable.

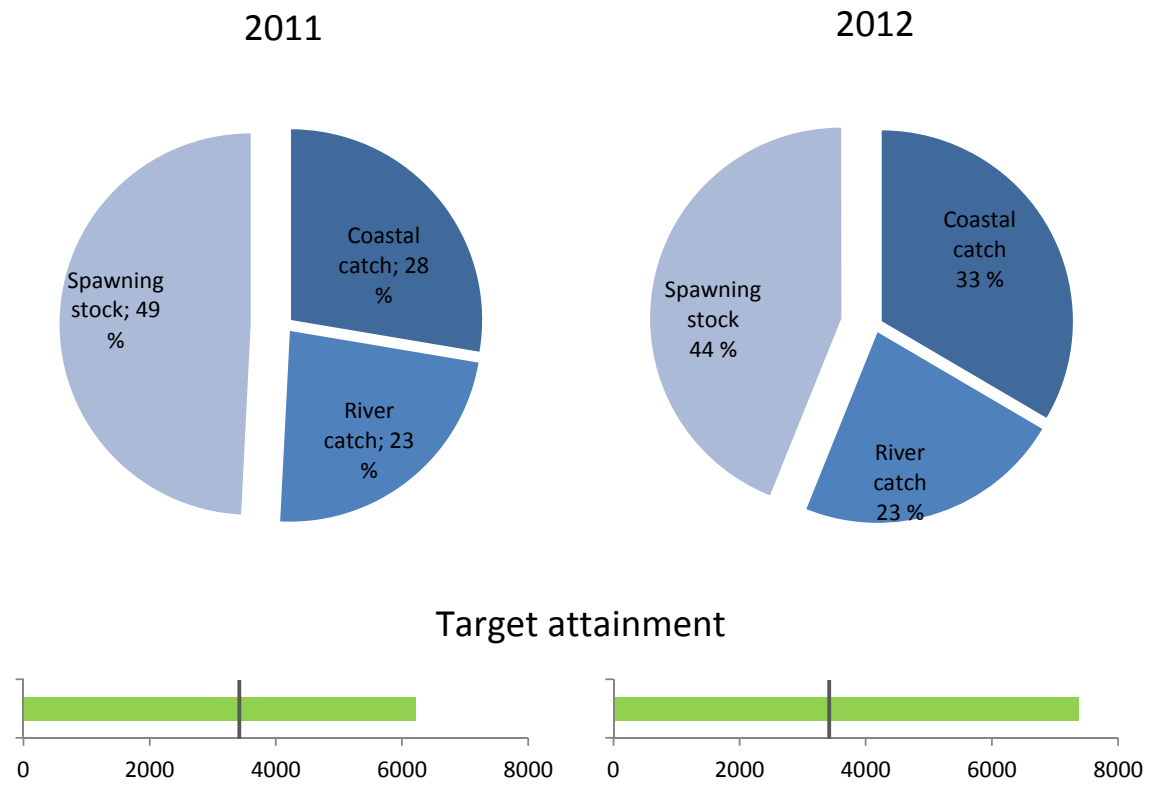


***Figure 48**. Upper part: The estimated pre-fishery abundance of Lakselv-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.9 Storelva (Outer Finnmark, middle)

This medium-sized river is located in the innermost part of Laksefjorden. This fjord is considered a part of the *Outer Finnmark (middle)*-region.

Salmon from Storelva were found in all the sampled regions, with the highest rates observed in *Outer Troms* at 0.39 salmon per day per gear in weeks 26-27 (**Figure 49**). Then followed *Outer Finnmark (middle)* at 0.31 salmon per day per gear in weeks 26-27, *Inner Troms* at 0.27 salmon per day per gear in weeks 26-27, *Outer Finnmark (east)* at 0.27 salmon per day per gear in weeks 26-27 and *Outer Finnmark (west)* at 0.17 salmon per day per gear in weeks 26-27.

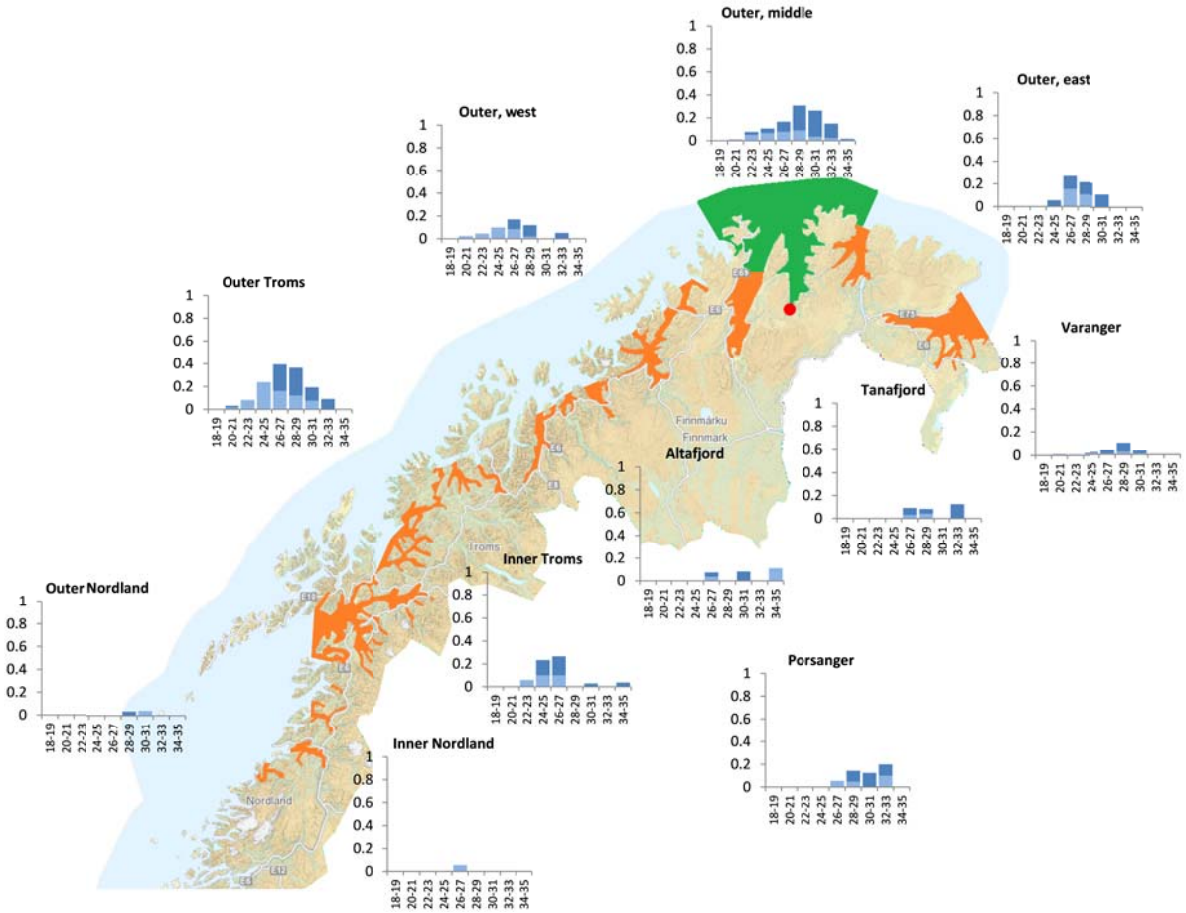


***Figure 49**. Regional catch of salmon from the river Storelv (red circle) in Laksefjord, a part of the* Outer Finnmark (middle)*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Storelva-salmon was relatively high, but also very variable, from 36 % in 2011 down to 20 % in 2012 (**Figure 50**). River exploitation was lower, at 16 to 20 %.

The spawning target of Storelva has been set to 1 241 kg (female biomass). The estimated spawning stock size barely reached the spawning target in 2011 and exceeded the target by a solid margin in 2012 (**Figure 50**). This indicates that the total exploitation in 2011 and 2012 was sustainable, but only barely so in 2011.

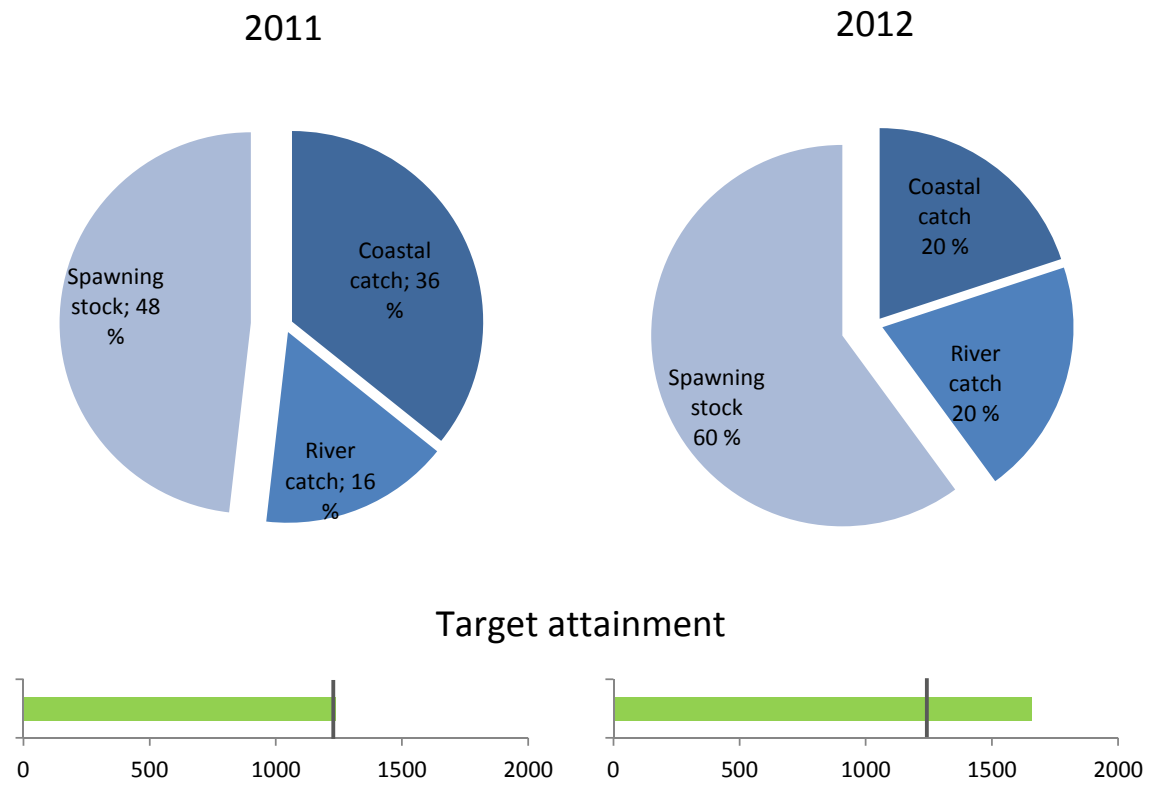


***Figure 50**. Upper part: The estimated pre-fishery abundance of Storelv-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.10 Sandfjordelva (Outer Finnmark, middle)

The river Sandfjordelva is located squarely on the outer coast of Finnmark, in the *Outer Finnmark (middle)*-region. This is a small to medium-sized river dominated by grilse.

The highest catch rates of Sandfjordelva were observed locally in the *Outer Finnmark (middle)*-region, up to 0.26 salmon per day per gear in weeks 24-25 (**Figure 51**). The second-highest rates were recorded in *Outer Finnmark (west)*, up to 0.14 salmon per day per gear in weeks 24-25. Only a few Sandfjord-salmon were found in regions to the east. This indicates that salmon in this river mainly arrives from the west and north.

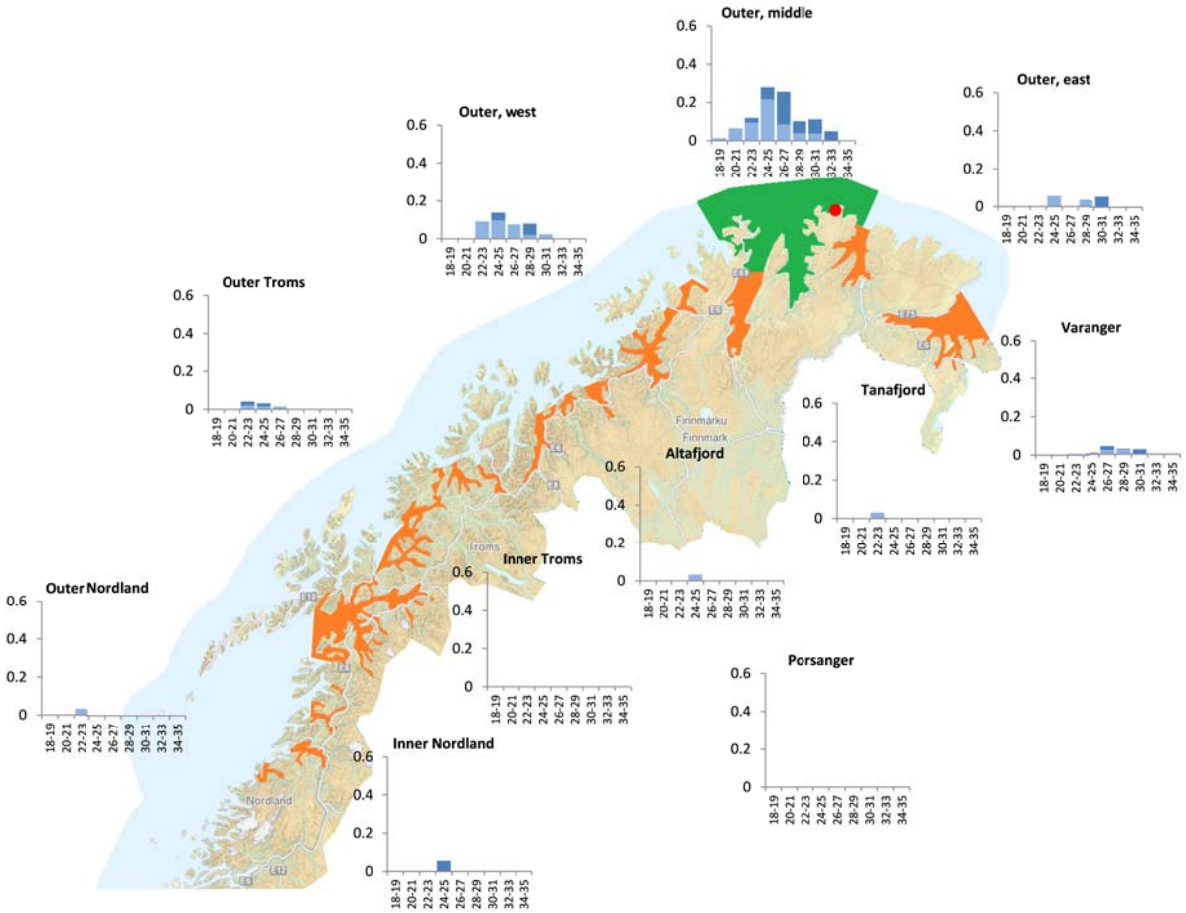


***Figure 51**. Regional catch of salmon from the river Sandfjordelv (red circle) in the* Outer Finnmark (middle)*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Sandfjordelv-salmon was at 22 and 20 % in 2011 and 2012, respectively (**Figure 52**). River exploitation was higher, at 30 and 31 %.

The spawning target of Sandfjordelva has been set to 426 kg (female biomass). The estimated spawning stock size exceeded this target narrowly in 2011 and with a sizeable margin in 2012 (**Figure 52**). This indicates a sustainable total exploitation in both of these years.

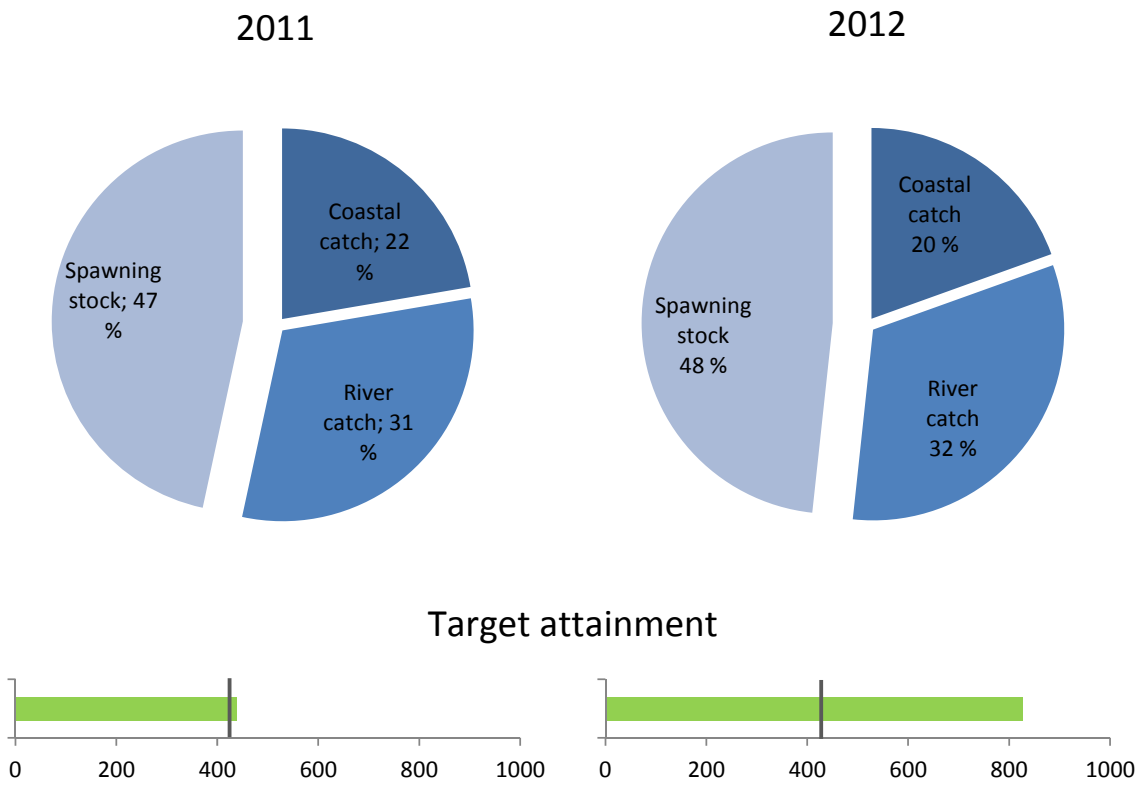


***Figure 52**. Upper part: The estimated pre-fishery abundance of Sandfjord-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.11 Tana (Tanafjord)

This large river system located in the innermost part of the *Tanafjord* contains 20-30 stocks with a total production potential far exceeding the other salmon rivers in northern Norway. The mainstem of Tana forms the border between Norway and Finland and the river is a vital part of the local economy in both countries.

Salmon from Tana were recorded in the coastal catch from all regions in the study area. The highest catch rates were observed locally in the *Tanafjord*, up to 4.45 salmon per day per gear in weeks 26-27 (**Figure 53**). The second-highest rates were found in *Outer Finnmark (east)* with 2.35 salmon per day per gear in weeks 26-27. Significant rates were also found further away in the *Varangerfjord* (1.09 salmon per day per gear in weeks 28-29) and to the west in *Outer Finnmark (middle)* (0.79 salmon per day per gear in weeks 26-27), *Outer Finnmark (west)* (1.22 salmon per day per gear in weeks 24-25) and *Outer Troms* (1.38 salmon per day per gear in weeks 26-27).

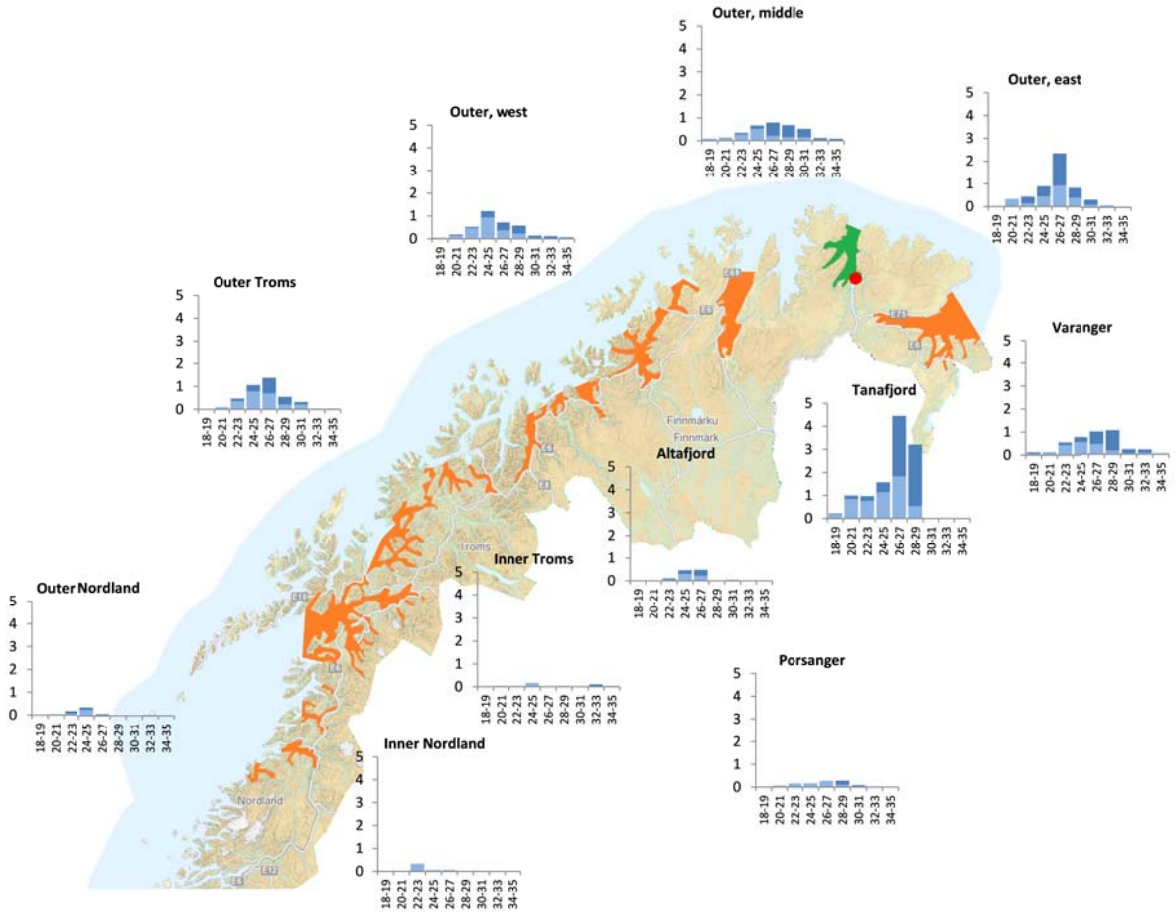


***Figure 53**. Regional catch of salmon from the river Tana (red circle) in the* Tanafjord*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Tana-salmon was surprisingly low, down at 13 and 9 % in 2011 and 2012, respectively (**Figure 54**). River exploitation was substantially higher, up to 57 and 59 % in the two years. Approximately a third of the PFA survived to spawning.

The total spawning target of the Tana river system has been estimated at 60 372 kg. The estimated spawning stock size was well below this target in both 2011 and 2012 (**Figure 54**), indicating that the current exploitation level of Tana-salmon is unsustainably high.

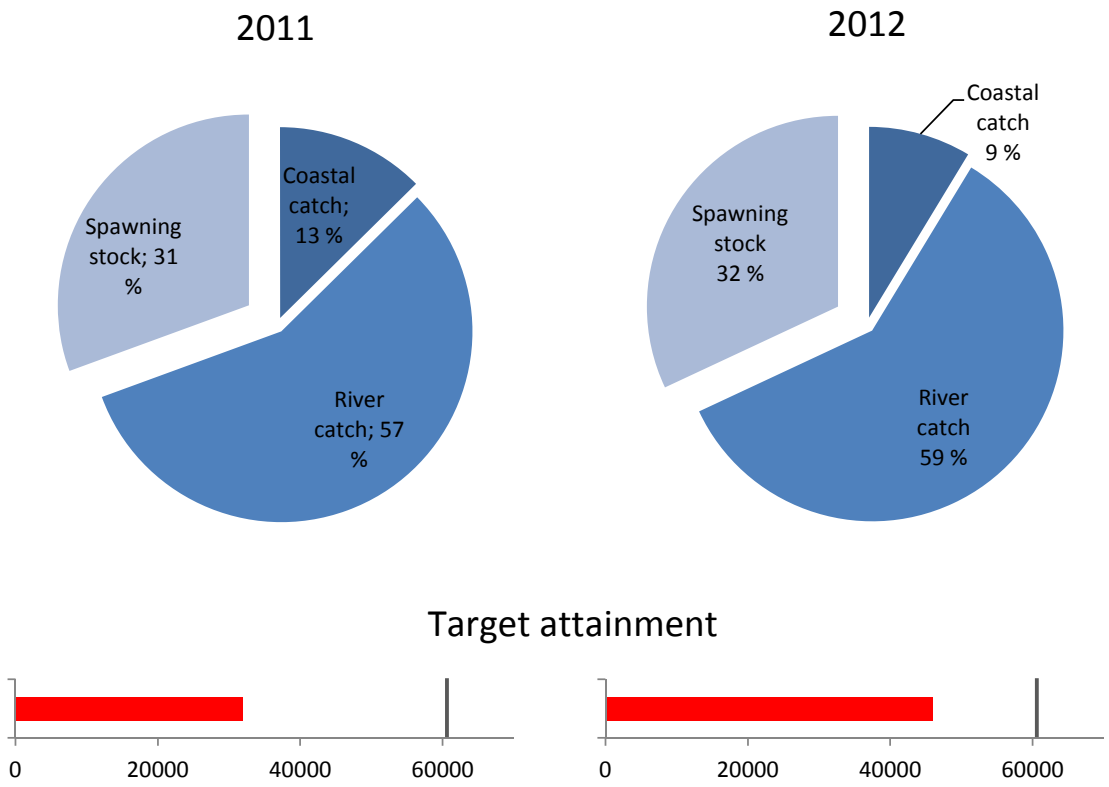


***Figure 54**. Upper part: The estimated pre-fishery abundance of Tana-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.12 Kongsfjordelva (Outer Finnmark, east)

This is a small- to middle-sized river located on the north side of the Varanger peninsula which forms the eastern part of *Outer Finnmark*. This is a regulated river, and the regulation has possible negative effects on the salmon stock.

The catch pattern show that Kongsfjord-salmon were mainly caught in the eastern regions, with the highest catch rates observed locally in the *Outer Finnmark (east)*-region with up to 0.62 salmon per day per gear in weeks 26-27 (**Figure 55**). Second-highest rates were observed in *Outer Finnmark (middle)* with 0.31 salmon per day per gear in weeks 28-29.

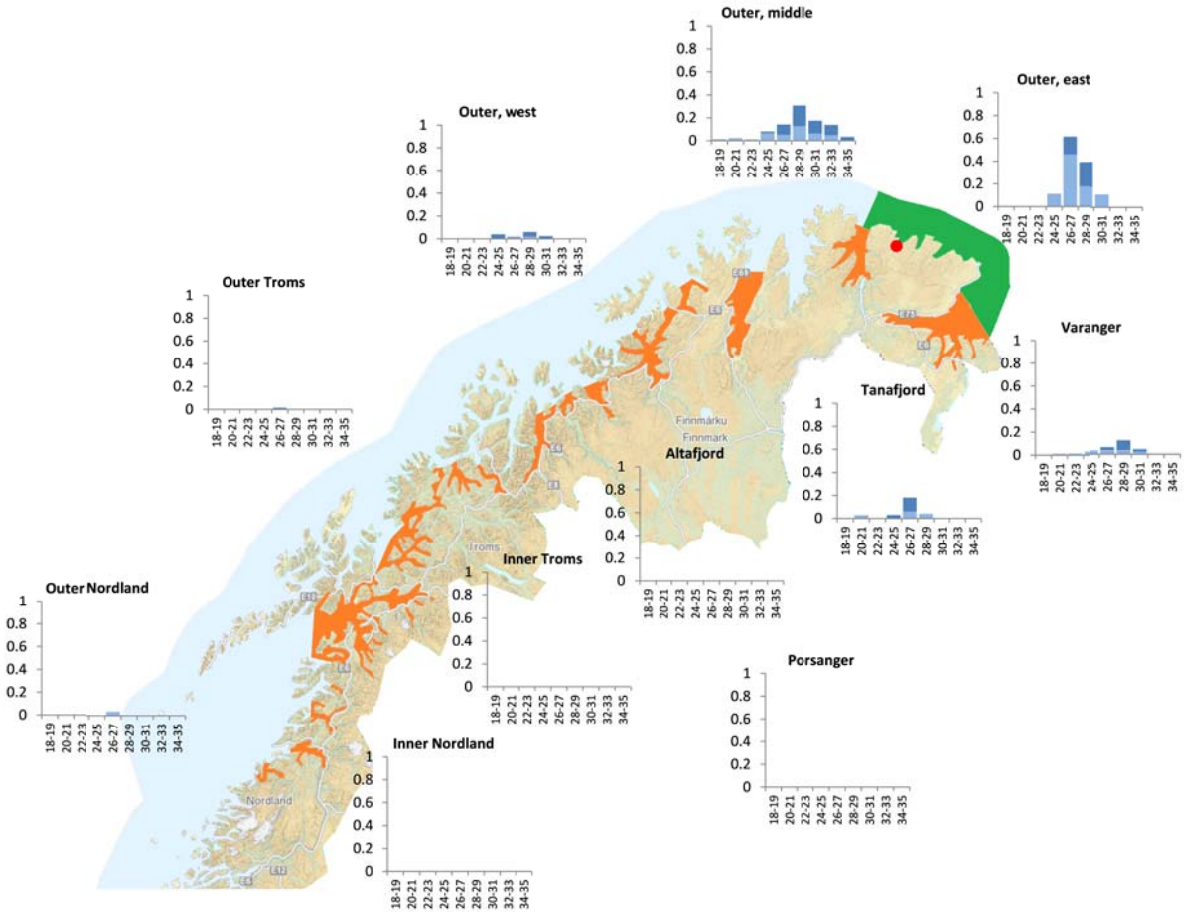


***Figure 55**. Regional catch of salmon from the river Kongsfjordelv (red circle) in the* Outer Finnmark (east)*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Kongsfjord-salmon was variable when comparing 2011 and 2012. In 2011, an estimated 21 % the of total pre-fishery abundance (PFA) was caught in the coastal fisheries, while in 2012, the estimated coastal exploitation was only 10 % of the PFA (**Figure 56**). River exploitation was substantially higher, at 32 % in 2011 and 36 % in 2012.

The spawning target of Kongsfjordelva has been set to 1 102 kg (female biomass). The estimated spawning stock size exceeded this spawning target both in 2011 and 2012 by a relatively solid margin (**Figure 56**). This indicates that the current level of exploitation experienced by the Kongsfjord-salmon is sustainable.

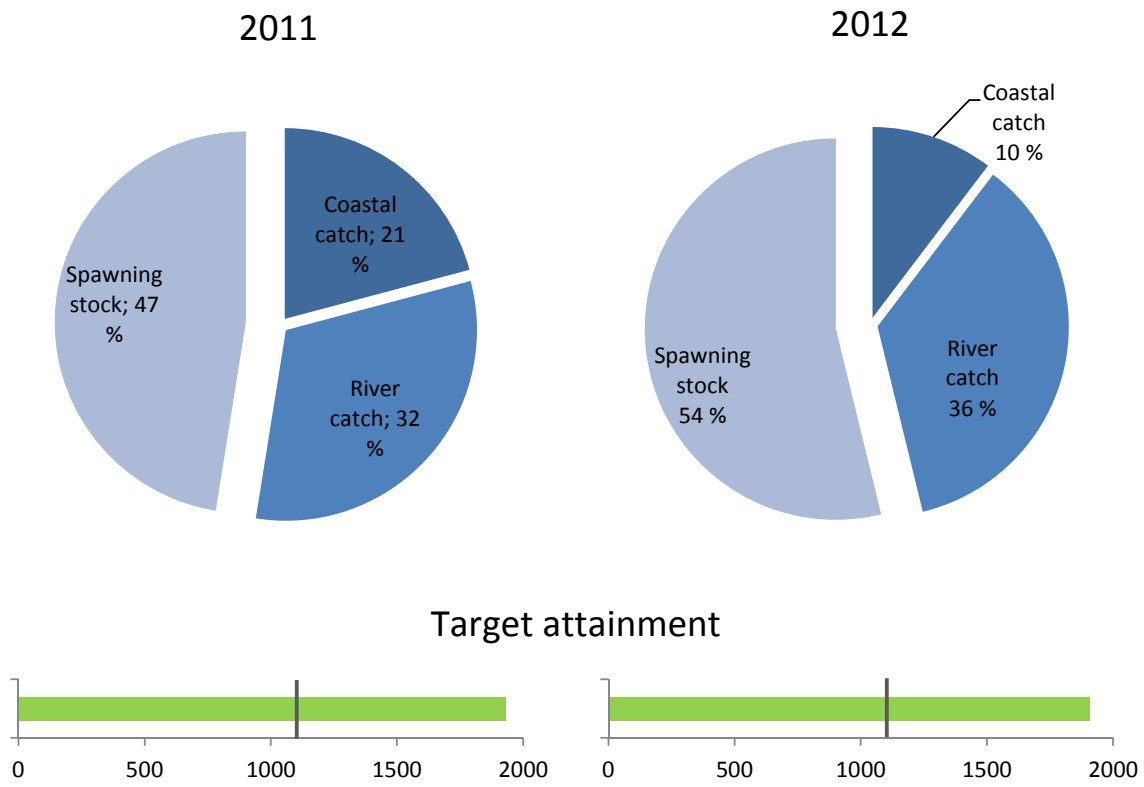


***Figure 56**. Upper part: The estimated pre-fishery abundance of Kongsfjord-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.13 Syltefjordelva (Outer Finnmark, east)

This is a medium-sized river located on the north side of the Varanger peninsula, which forms the *Outer Finnmark (east)*-region. It is one of several rivers in Finnmark with a very positive stock development in the last decade.

The highest catch rates of Syltefjord-salmon were observed locally in the *Outer Finnmark (east)*-region, up to 1.62 salmon per day per gear in weeks 26-27 (**Figure 57**). Notable catch rates were also observed to the west in *Outer Finnmark (middle)* (up to 0.51 salmon per day per gear in weeks 26-27) and eastwards in the *Varangerfjord* (up to 0.29 salmon per day per gear in weeks 28-29).

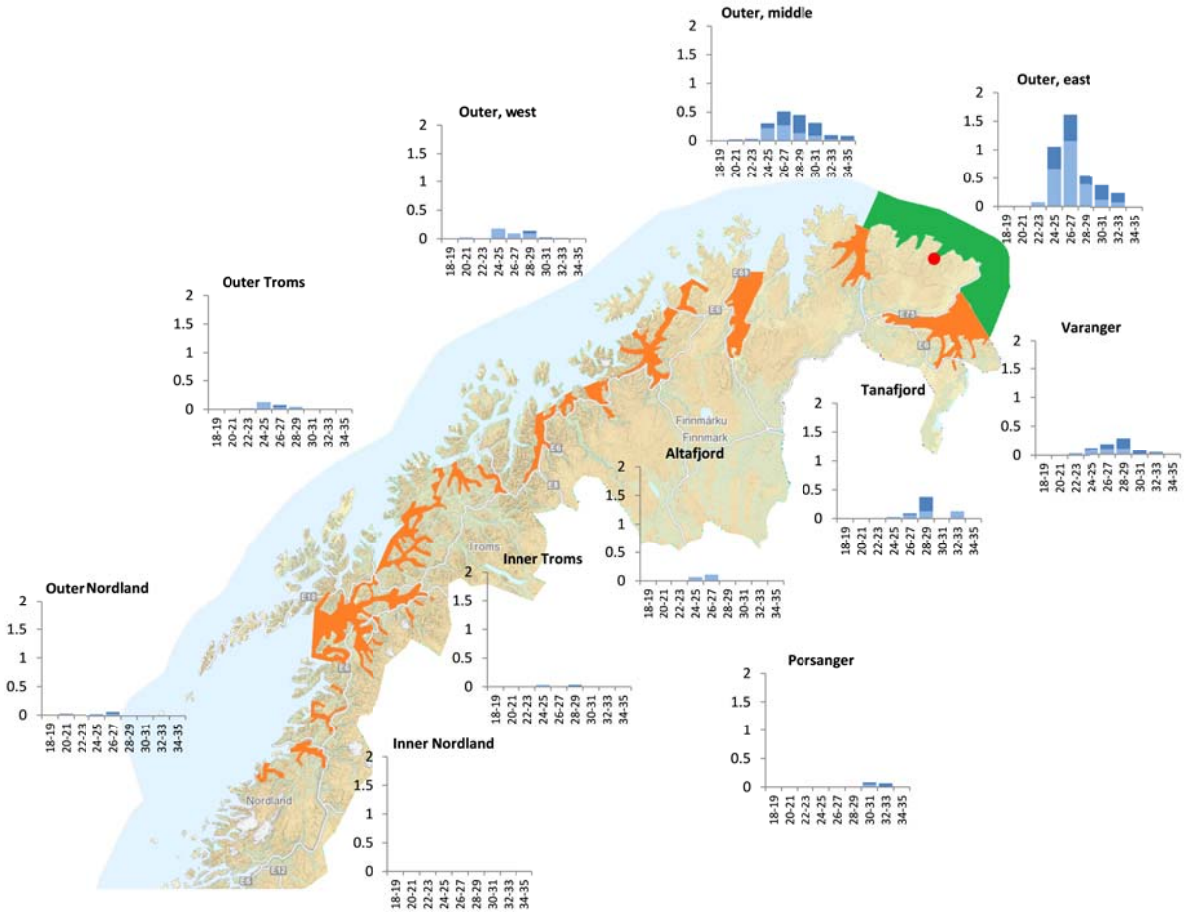


***Figure 57**. Regional catch of salmon from the river Syltefjordelv (red circle) in the* Outer Finnmark (east)*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Syltefjord-salmon was at a medium level, at 20 and 19 % of the total pre-fishery abundance (PFA) in 2011 and 2012, respectively (**Figure 58**). River exploitation was significantly higher, exploiting 32 % of the PFA in both years.

The spawning target in Syltefjordelva has been set to 1 356 kg (female biomass). This target was exceeded almost fourfold by the estimated spawning stock size in 2012, while in 2011 the estimated spawning stock was slightly below the spawning target (**Figure 58**). The 2011-result indicates that while the Syltefjord-stock has been in a positive development, we still might experience a situation in which the salmon stock is overexploited.

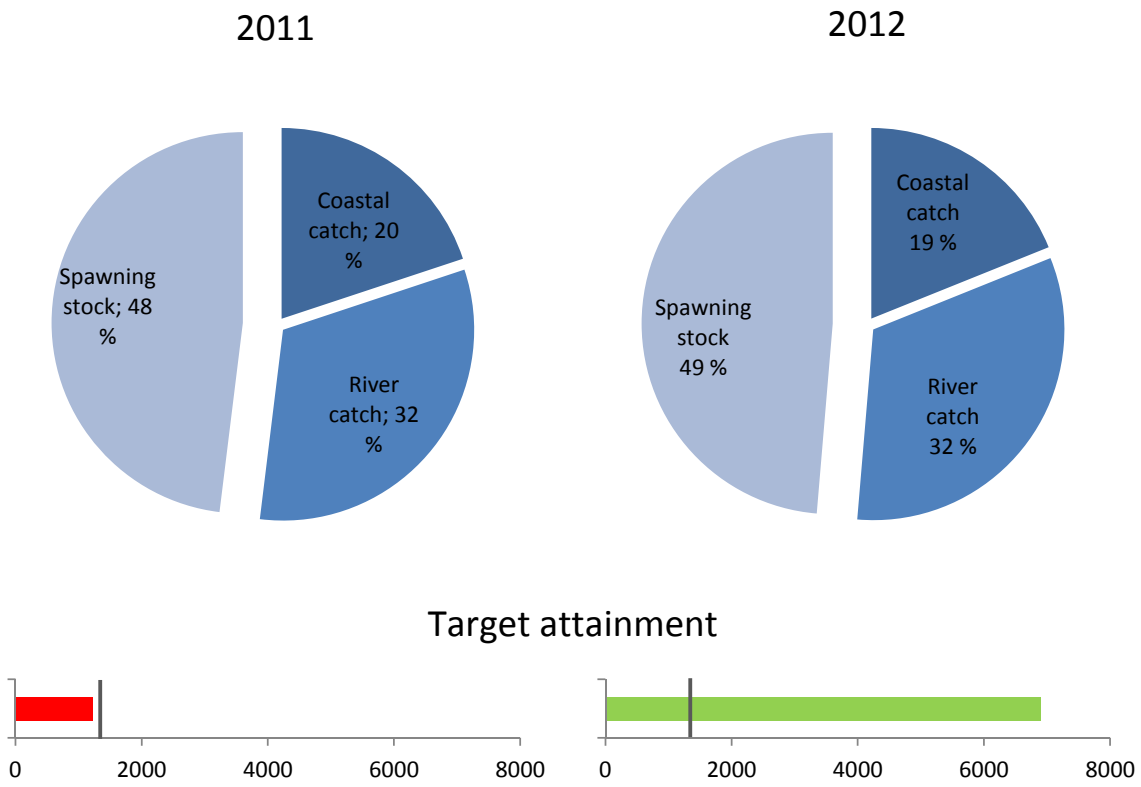


***Figure 58**. Upper part: The estimated pre-fishery abundance of Syltefjord-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.4.14 Vestre Jakobselv (Varangerfjord)

This medium-sized river enters the *Varangerfjord* a few km to the west of Vadsø. It is a river with several waterfalls, but well-functioning fish ladders ensure that a large part of the watershed now contributes to salmon production. The river catch of salmon in Vestre Jakobselv has been steadily increasing in the last 15 years.

The observed catch pattern show that Vestre Jakobselv-salmon were mainly exploited in the outer Finnmark (east)-region, up to 0.50 salmon per day per gear in weeks 28-29, and locally in the *Varangerfjord*-region, up to 0.48 salmon per day per gear in weeks 28-29 (**Figure 59**).

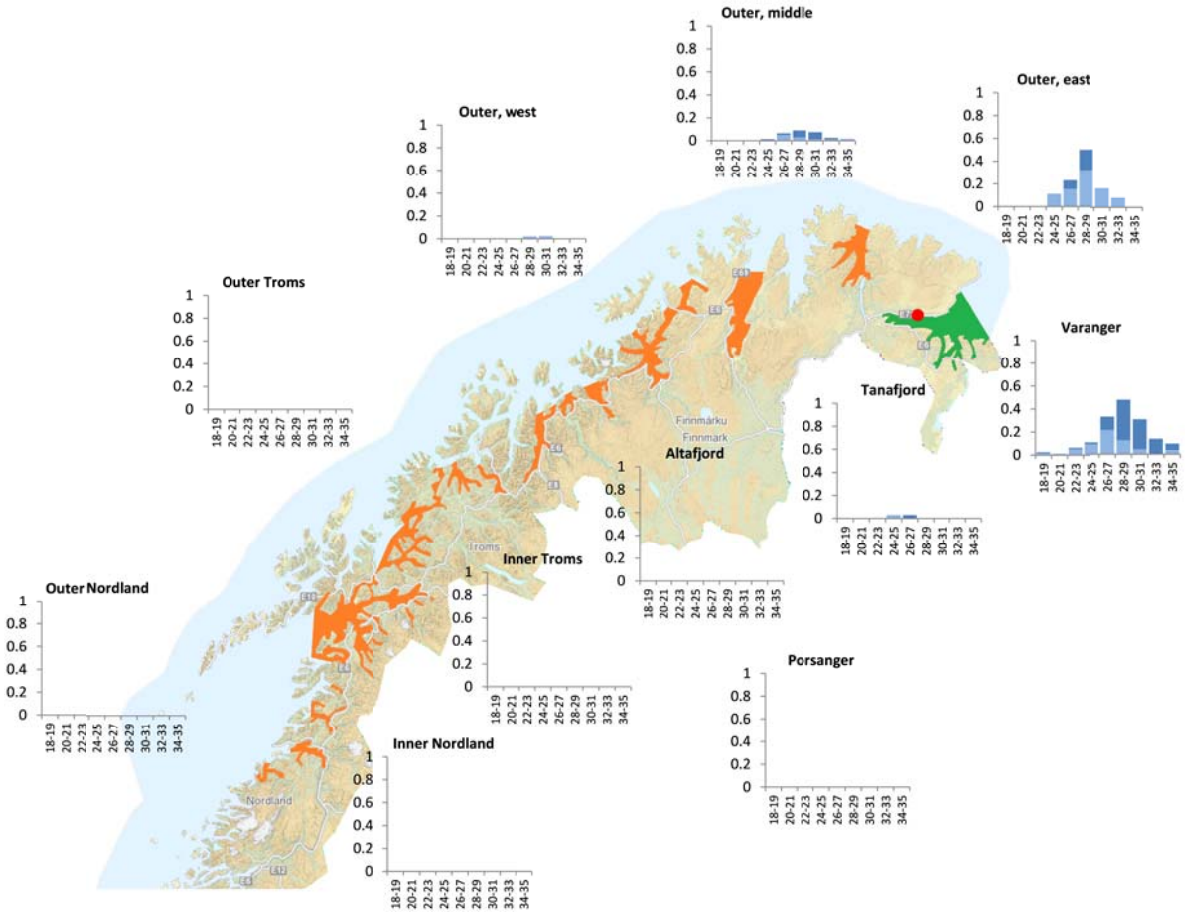


***Figure 59**. Regional catch of salmon from the river Vestre Jakobselv (red circle) in the* Varangerfjord*-region, given as number of salmon per day per fishing gear over two-week-periods. Light blue bars = female salmon catch rate, dark blue = total catch rate.*

The estimated coastal exploitation of Vestre Jakobselv-salmon was very low, at 7 and 5 % of the total pre-fishery abundance (PFA) in 2011 and 2012, respectively (**Figure 60)**. River exploitation was higher, at 37 and 38 % in 2011 and 2012.

The spawning target of Vestre Jakobselv has been set to 1 919 kg (female biomass). This target was exceeded by the estimated spawning stock size in both 2011 and 2012, indicating that the exploitation of salmon from this stock is at a sustainable level.

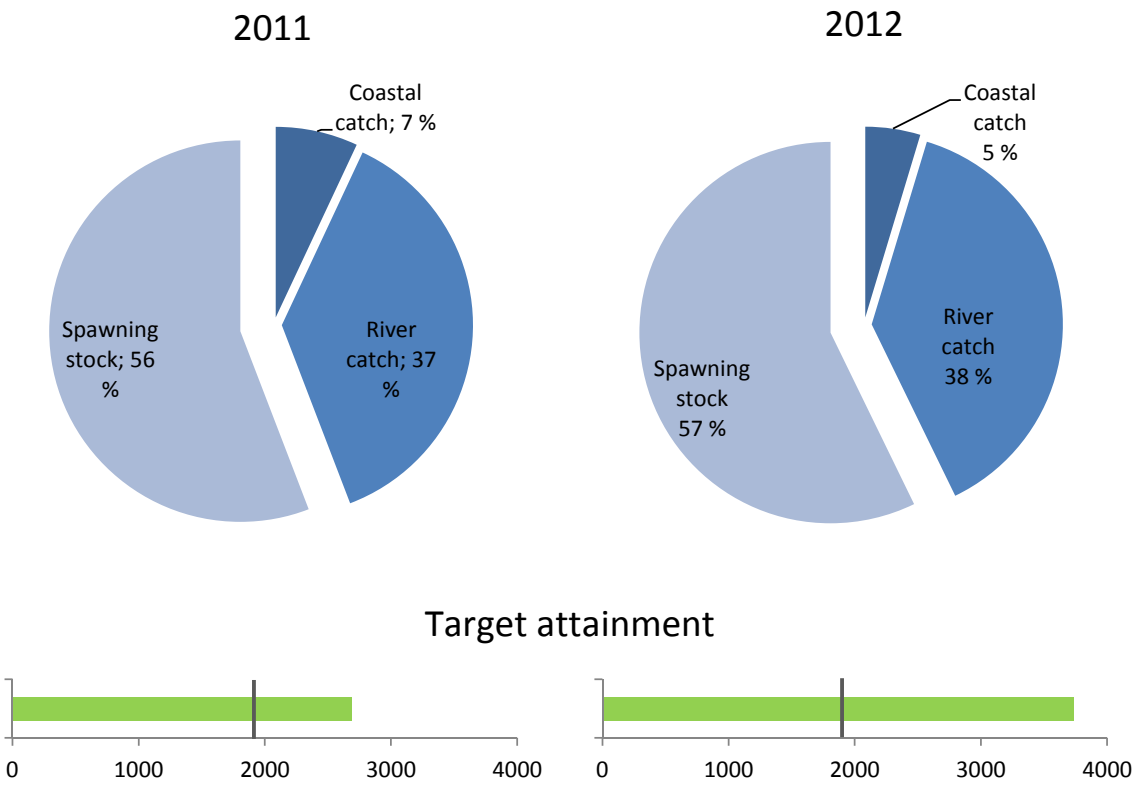


***Figure 60**. Upper part: The estimated pre-fishery abundance of Vestre Jakobselv-salmon in 2011 and 2012 separated into coastal catch (given current coastal regulations in Nordland, Troms and Finnmark), riverine catch and surviving spawning stock (both males and females). Lower part: Spawning target attainment in 2011 and 2012. The estimated spawning stock size (weight kg, female biomass) is shown by horizontal bar, with green colour indicating spawning stock larger than the target and red colour indicating spawning stock smaller than the target. The spawning target is shown as a vertical thick black line.*

3.5 Modelling the probability of capture: four stock-specific examples

While the previous chapters on stock exploitation (chapter 3.3) and sustainable management (chapter 3.4) used pooled regional numbers as the basis for the analyses, the following modelling is based on individual catch records from 2011 and 2012. Four stock-specific examples are shown, with separate models for 1SW- and MSW-salmon.

3.5.1 Målselv (Inner Troms)

Grilse belonging to Målselva start entering the coastal catches in the middle of June (**Figure 61**). High probabilities of catching one 1SW Målselv-salmon per day per gear were observed among fishermen in southern Troms in July and the first half of August.

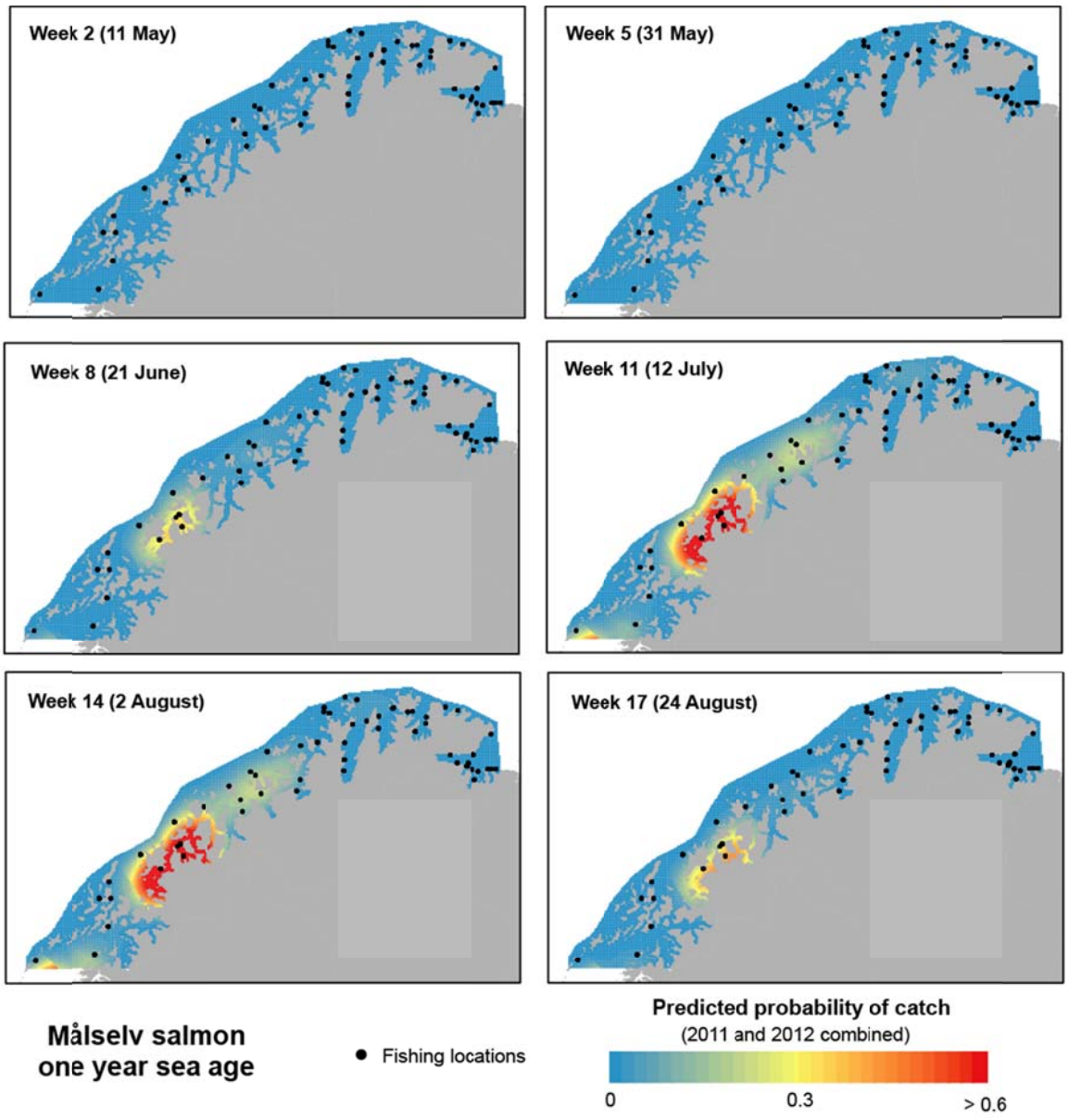


***Figure 61**. The predicted probability of catching one 1SW Målselv-salmon per day per gear along the coast of Nordland, Troms and Finnmark, modelled on the basis of the individual catch of each fisherman in 2011 and 2012. Week numbering starts with week 1 at May 1.*

The migration pattern of 1SW Målselva-salmon in 2011 and 2012 were narrow, with the salmon coming directly from the west, moving around the islands of Senja, Kvaløya and Ringvassøya and then into the Malangen fjord. The same migration pattern can be seen for MSW-salmon from Målselva, but with a slightly longer tail towards the Lofoten in the south (**Figure 62**).

MSW-salmon from Målselva were found in the catches from the beginning of the sampling in early May. By the end of May, catch probabilities increased and were high throughout June, July and early August (**Figure 62**).

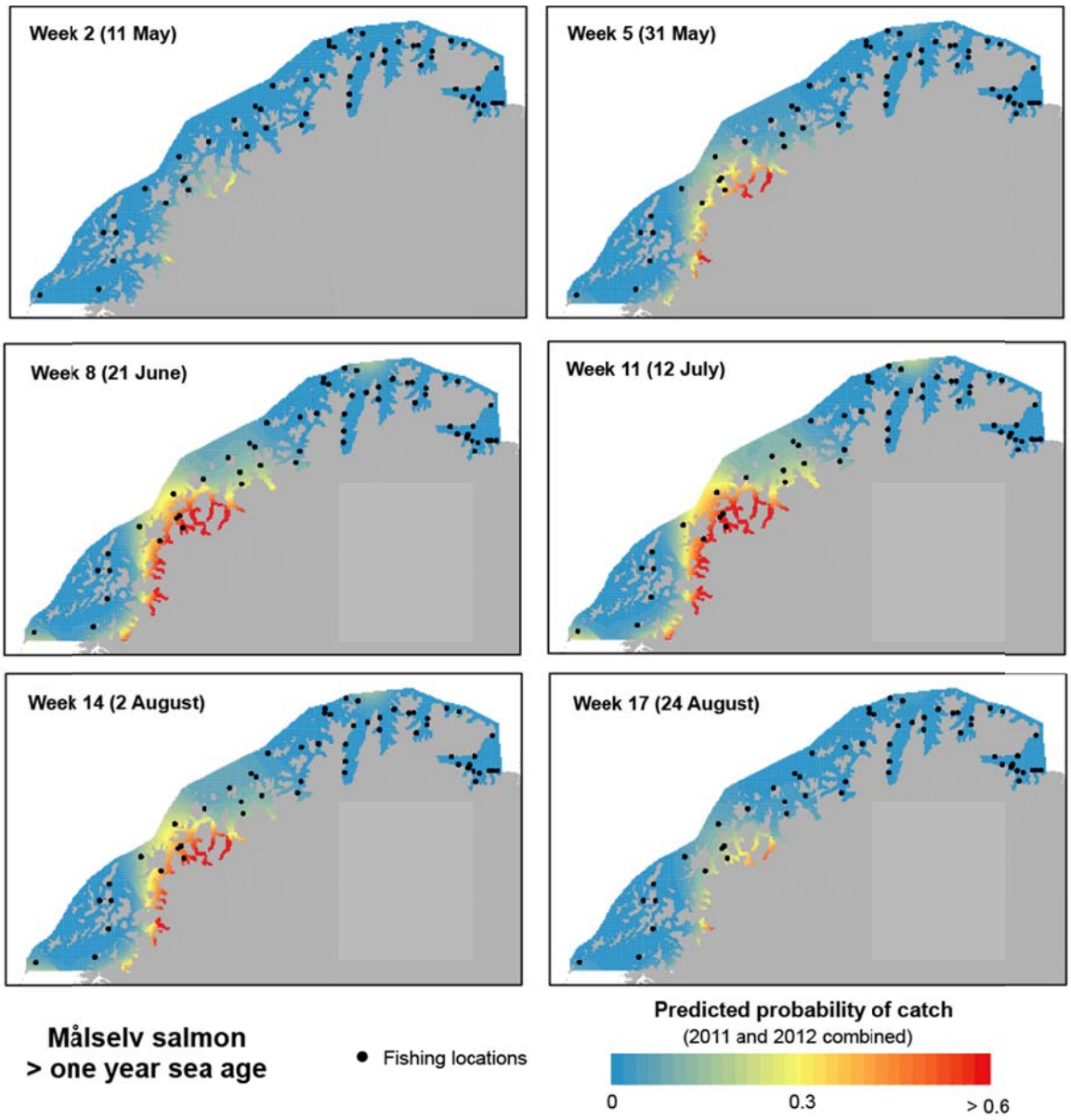


***Figure 62**. The predicted probability of catching one MSW Målselv-salmon per day per gear along the coast of Nordland, Troms and Finnmark, modelled on the basis of the individual catch of each fisherman in 2011 and 2012. Week numbering starts with week 1 at May 1.*

3.5.2 Alta (Fjords in West-Finnmark)

1SW-salmon from River Alta were found in increasing numbers in the coastal catches in early July. High probabilities of catching one 1SW per day per gear were observed in western Finnmark, northern Troms and southern Troms throughout July and until mid-August (**Figure 63**).

The 1SW Alta-salmon were exploited over a broad area, from the southernmost fishermen in Lofoten to the northernmost fishermen around Nordkapp (**Figure 63**). This catch pattern indicates that the majority of the 1SW Alta-salmon moves in towards the coast mainly from the west and northwest.

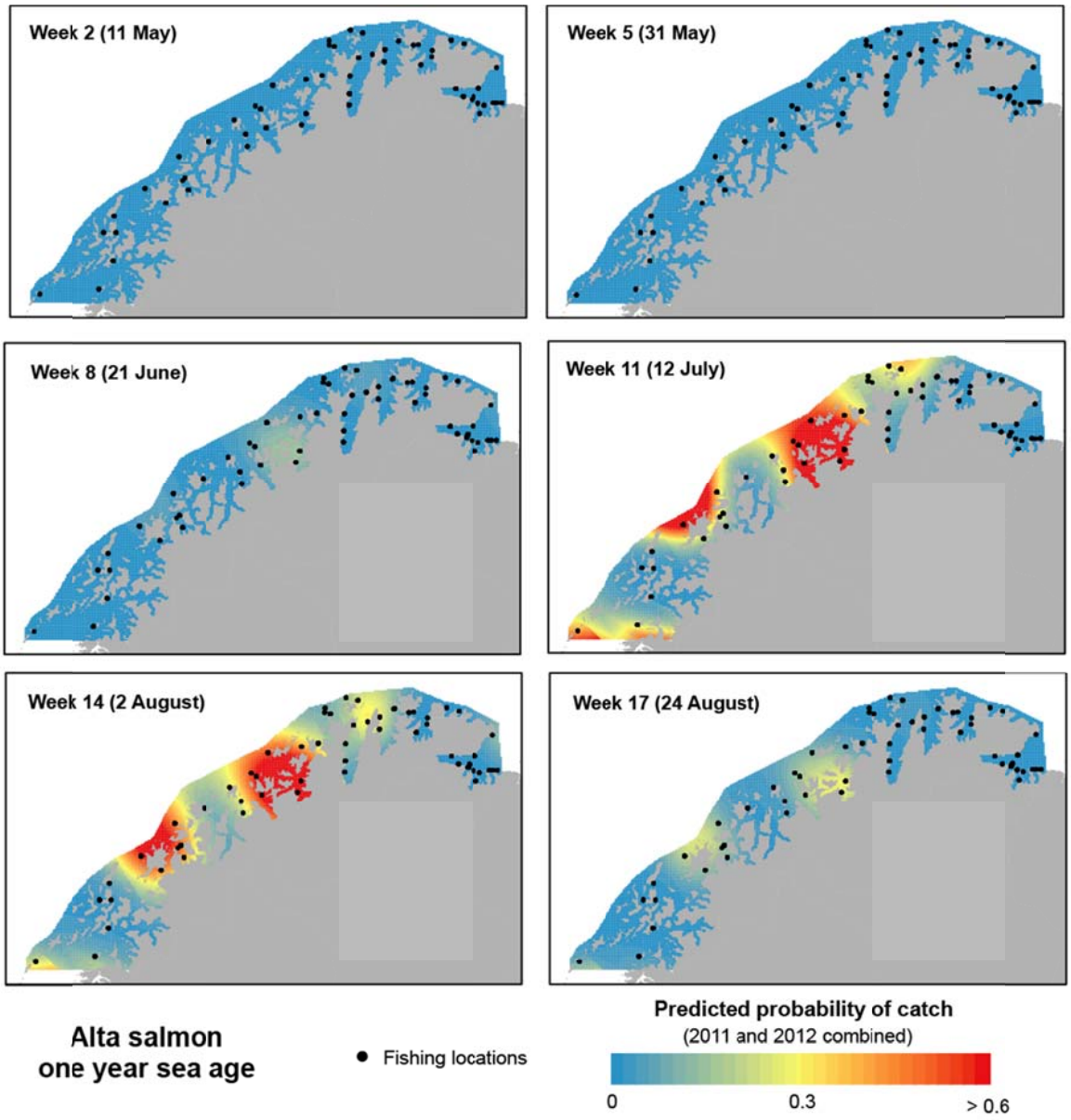


***Figure 63**. The predicted probability of catching one 1SW Alta-salmon per day per gear along the coast of Nordland, Troms and Finnmark, modelled on the basis of the individual catch of each fisherman in 2011 and 2012. Week numbering starts with week 1 at May 1.*

The probability of catching one MSW-salmon from Alta per day per gear was increasing among fishermen in western Finnmark in the last week of May (**Figure 64**). This capture area increased south-westwards in mid-June, with increasing catch probabilities around Senja and all the way south in Lofoten. The probability of catching one MSW Alta-salmon per day per gear was high throughout July and most of August.

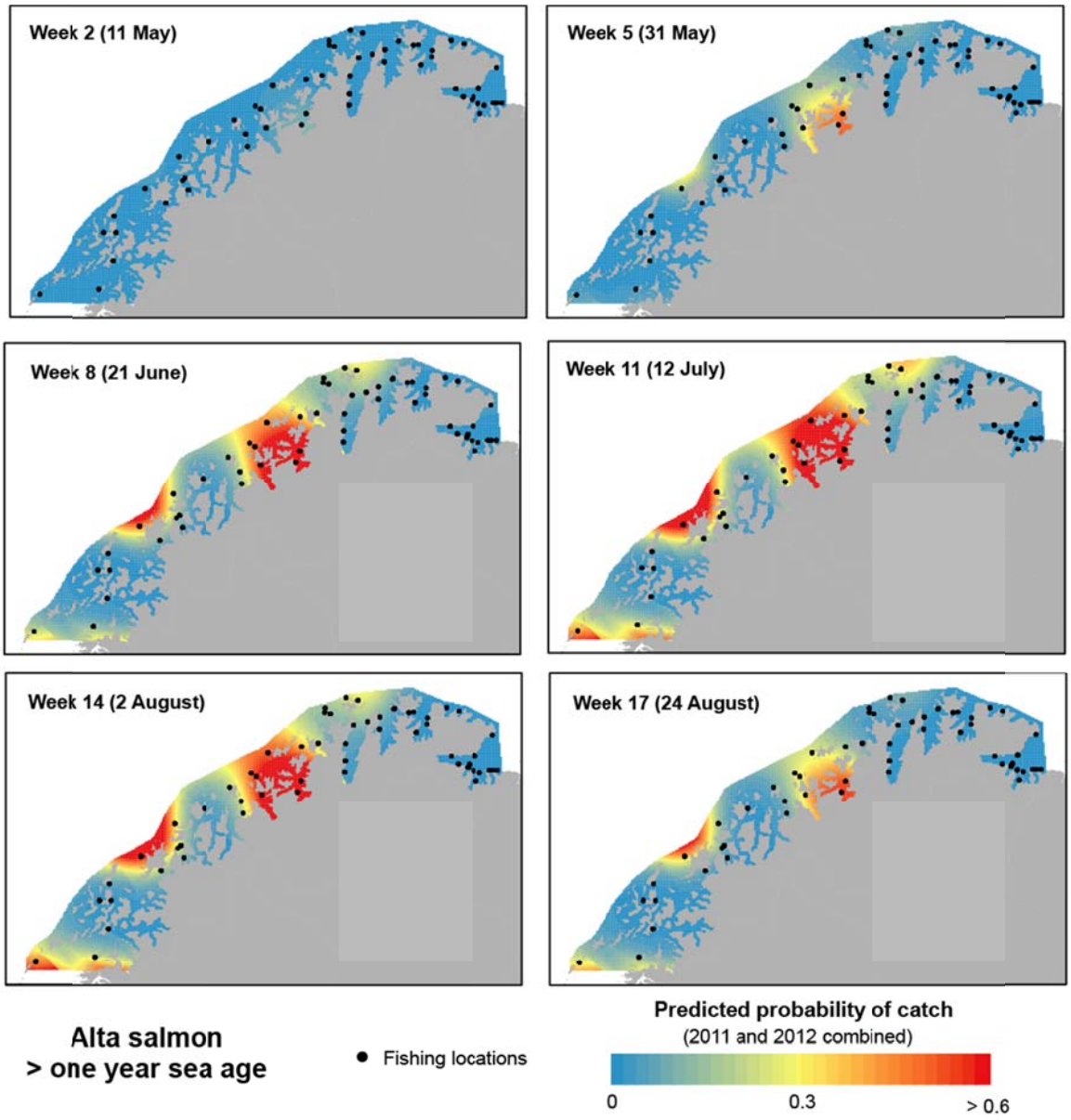


***Figure 64**. The predicted probability of catching one MSW Alta-salmon per day per gear along the coast of Nordland, Troms and Finnmark, modelled on the basis of the individual catch of each fisherman in 2011 and 2012. Week numbering starts with week 1 at May 1.*

3.5.3 Tana (Tanafjord)

The probability of catching one 1MSW Tana-salmon per day per gear started to increase in the coastal catches all the way from Lofoten in the southwest to Varanger in the east in the last half of June (**Figure 65**). The highest probabilities were seen along the outer coast of Troms and Finnmark in mid-July, before tailoring off in early August.

The observed catch pattern indicates a broad migration of 1SW Tana-salmon, with the salmon coming towards the Tanafjord from all directions (west, north and east).

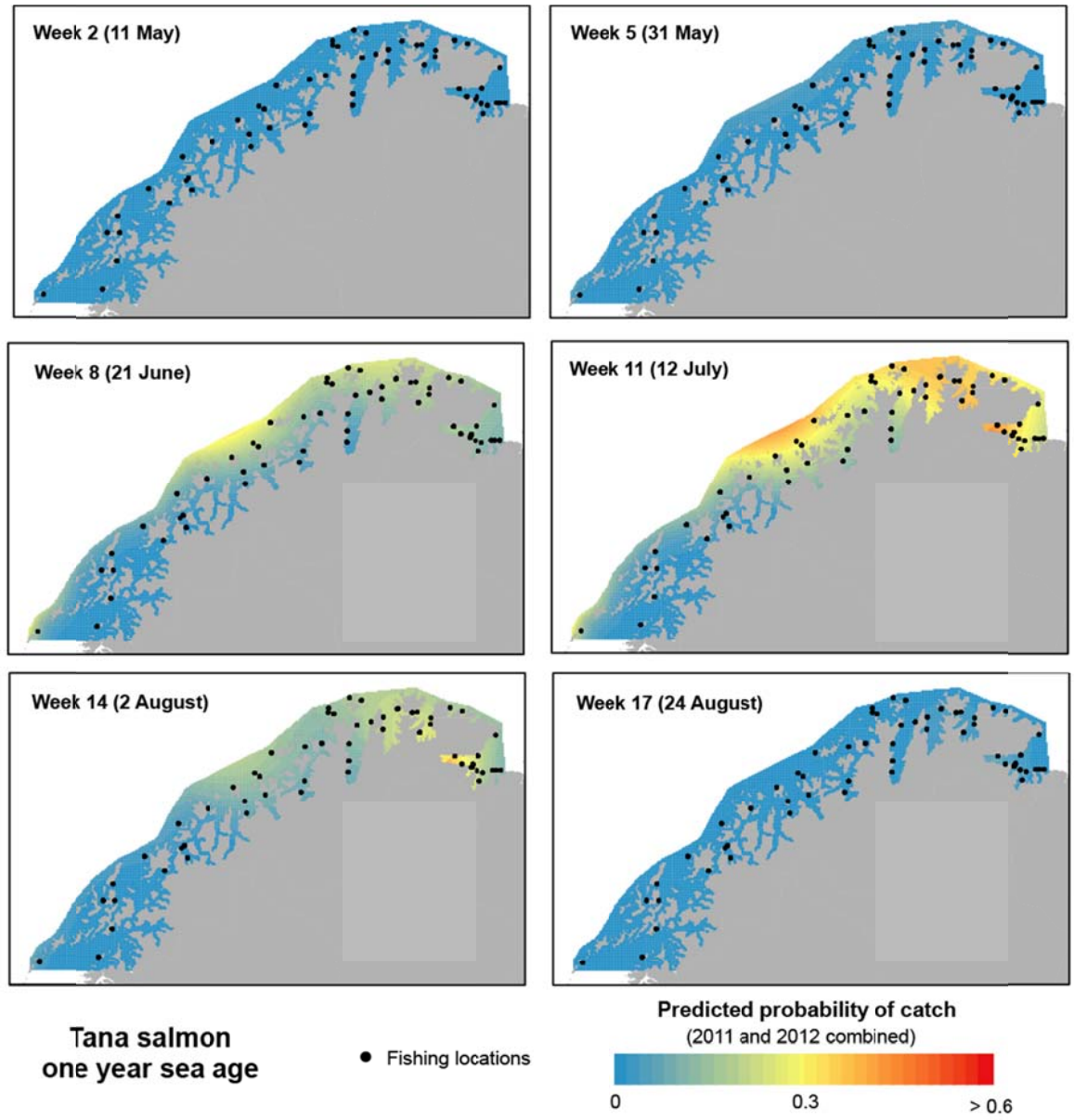


***Figure 65**. The predicted probability of catching one 1SW Tana-salmon per day per gear along the coast of Nordland, Troms and Finnmark, modelled on the basis of the individual catch of each fisherman in 2011 and 2012. Week numbering starts with week 1 at May 1.*

MSW Tana-salmon were found in the coastal catches from Troms and Finnmark from the beginning of May (**Figure 66**). Capture probabilities increased to high levels by the end of May and continued to be high in the outer coastal areas of Troms and Finnmark throughout June and until approximately mid-July. Probabilities then decreased in the last half of July and in August few MSW salmon from Tana were caught anywhere in the project area.

The Tana MSW catch pattern indicates the same broad migration that were seen for 1SW Tana-salmon, with the MSW salmon coming towards the Tanafjord from all directions (west, north and east).

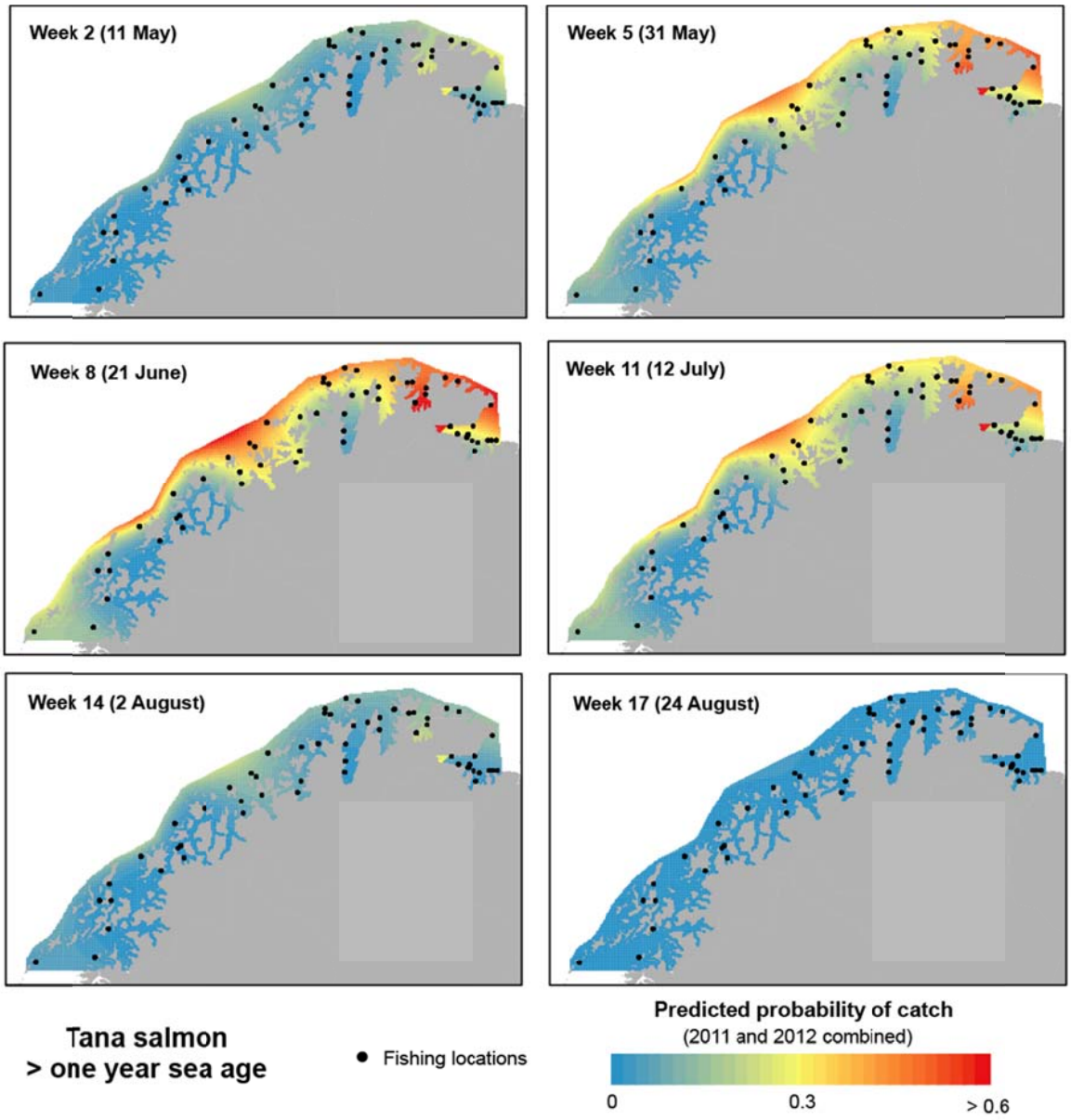


***Figure 66**. The predicted probability of catching one MSW Tana-salmon per day per gear along the coast of Nordland, Troms and Finnmark, modelled on the basis of the individual catch of each fisherman in 2011 and 2012. Week numbering starts with week 1 at May 1.*

3.5.4 Kola River (Russia)

The probability of catching one 1SW salmon from the Kola River was close to zero throughout May and early June (**Figure 67**). From mid-June, the probability increased in the Varangerfjord to high levels in the first half of July. Then the probability in Varangerfjord decreased to low levels in July/August. In addition to the Kola River 1SW salmon caught in Varangerfjord, some salmon were also caught in late June/early July by the fishermen south of Lofoten.

The catch pattern of 1SW demonstrates a predominantly eastern migration route, with the Kola River 1SW salmon present almost exclusively in the coastal catches from Varangerfjord.

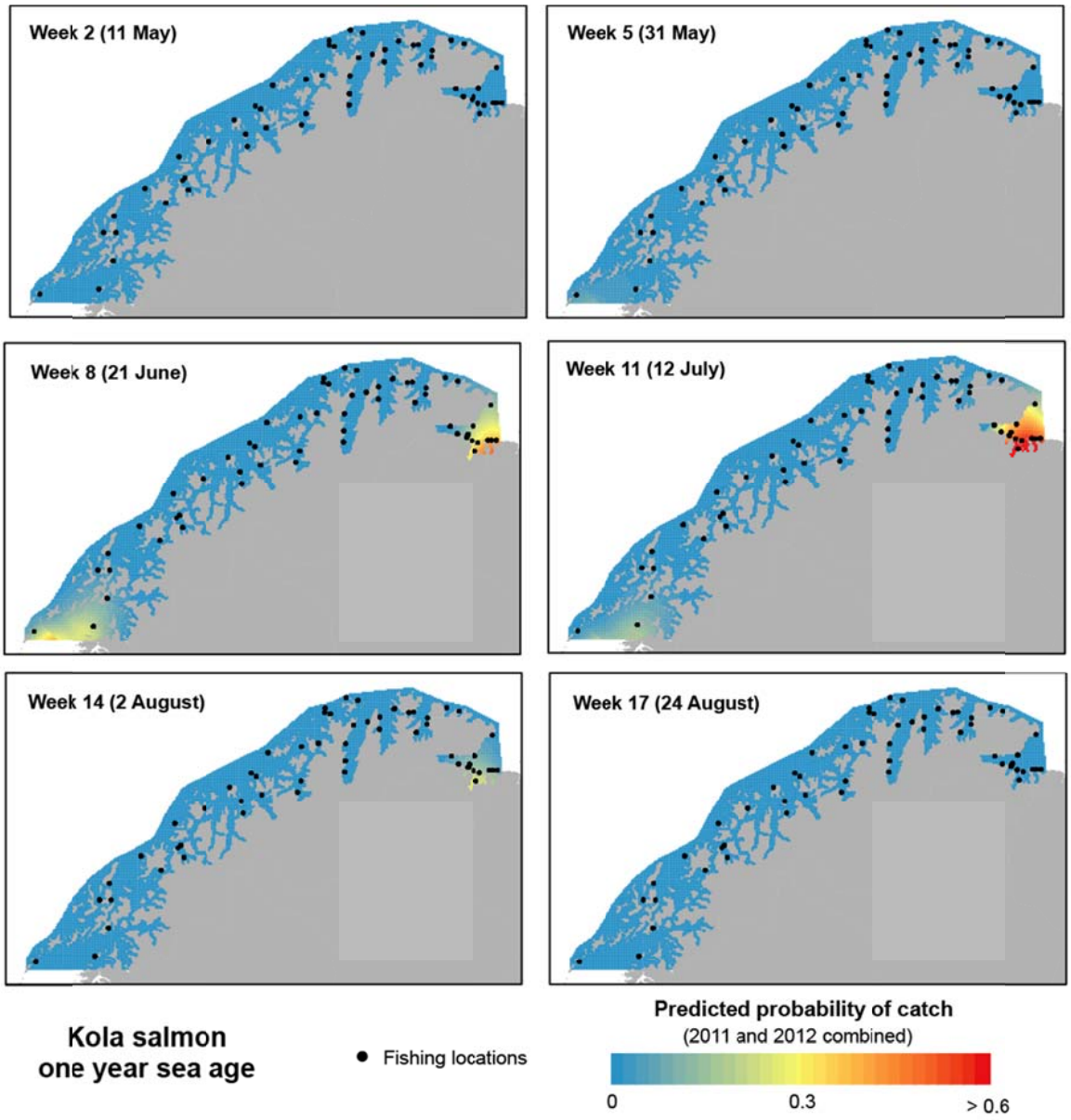


***Figure 67**. The predicted probability of catching one 1SW Kola-salmon per day per gear along the coast of Nordland, Troms and Finnmark, modelled on the basis of the individual catch of each fisherman in 2011 and 2012. Week numbering starts with week 1 at May 1.*

The coastal exploitation pattern of MSW Kola River salmon follows the same geographical pattern as that of the 1SW salmon, with high catch probabilities being observed mostly in the Varangerfjord (**Figure 68**). MSW Kola River salmon were present in the catches in the Varangerfjord from the beginning of May, increasing to high probabilities in late May and throughout June. Catch probabilities tapered off in mid-July and the MSW salmon were absent from catches in August.

In addition to Varangerfjord, Kola River-salmon were found in western Finnmark and south of Lofoten late in May and then in June.

The catch pattern of MSW Kola River-salmon corresponds to that of the 1SW salmon, showing a predominantly eastern distribution with a few fish moving along the coast northeastwards from Nordland.

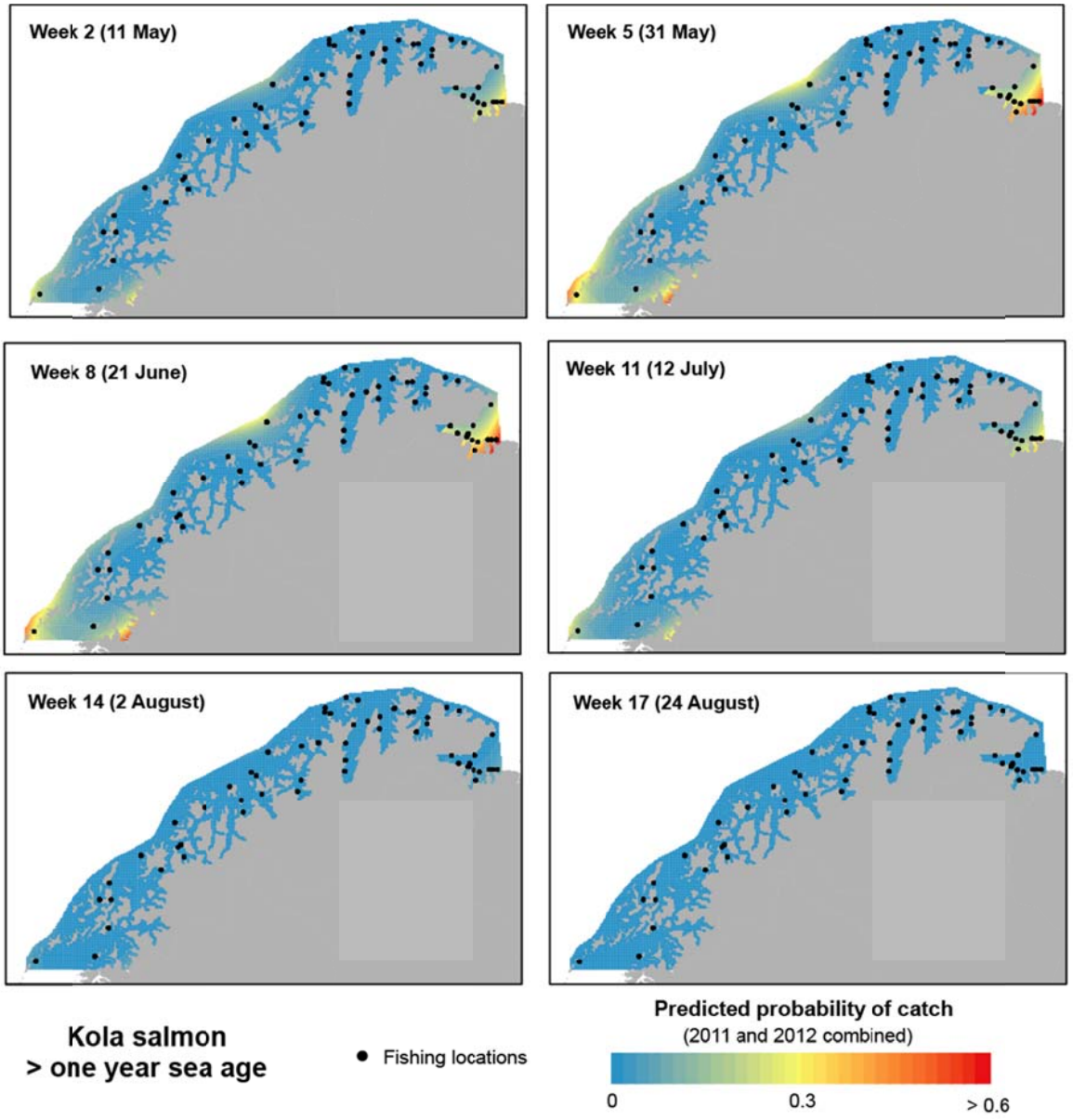


***Figure 68**. The predicted probability of catching one MSW Kola-salmon per day per gear along the coast of Nordland, Troms and Finnmark, modelled on the basis of the individual catch of each fisherman in 2011 and 2012. Week numbering starts with week 1 at May 1.*

3.6 Coastal catch and distance to river mouth

3.6.1 Målselv (Inner Troms)

A box-plot of catch against distance to river shows the very narrow catch pattern of salmon belonging to the river Målselv (**Figure 69**). Both 1SW and MSW Målselv-salmon are predominantly caught in the area closest to the river position along the coastal baseline.

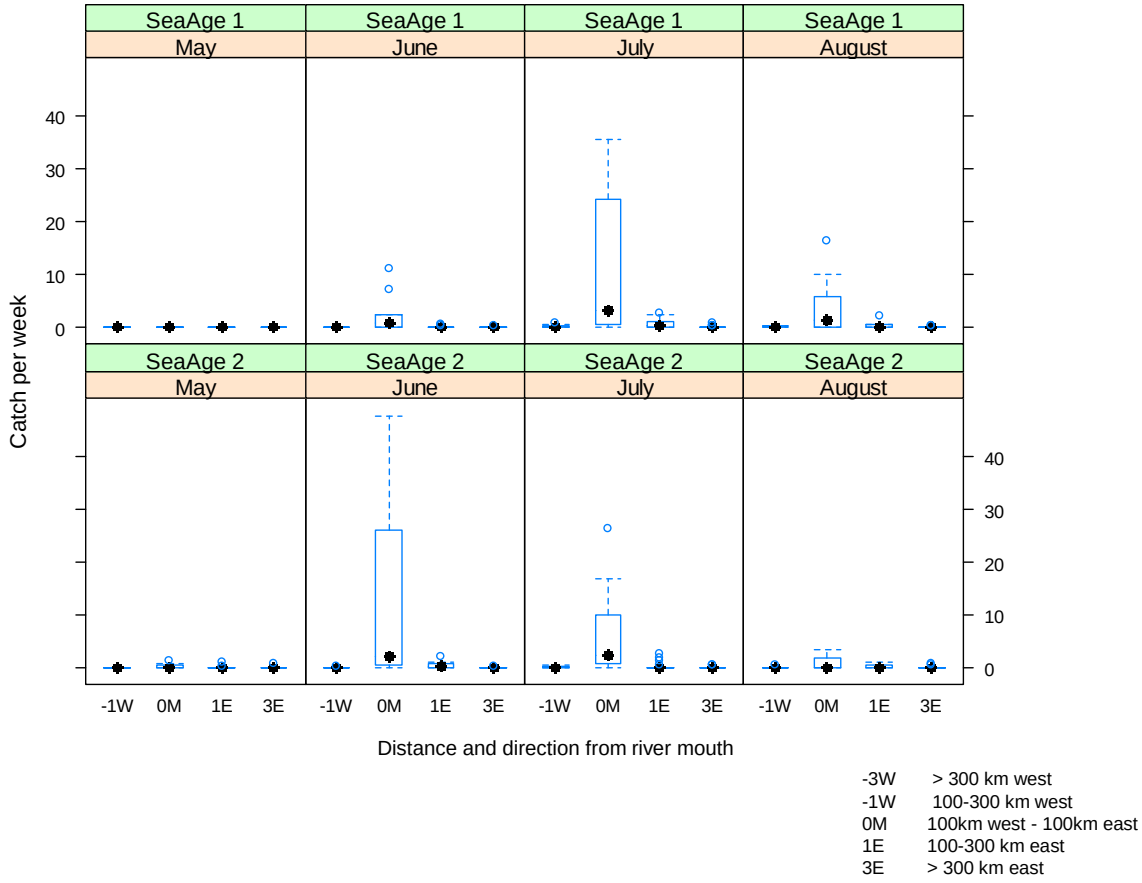


***Figure 69**. Catch per week of Målselv-salmon plotted against distance to river mouth. Distances are to the east or west from the river position along the coastal baseline. Upper panel is 1SW, lower panel is MSW.*

3.6.2 Alta (Fjords in West-Finnmark)

Salmon from the river Alta in western Finnmark show a broader catch pattern than Målselv-salmon. Most of the Alta-salmon were caught close to the Alta river position along the coastal baseline (**Figure 70**). The remaining catch was distributed mostly westwards along the coastal baseline, with some catch of both 1SW and MSW Alta-salmon also to the east.

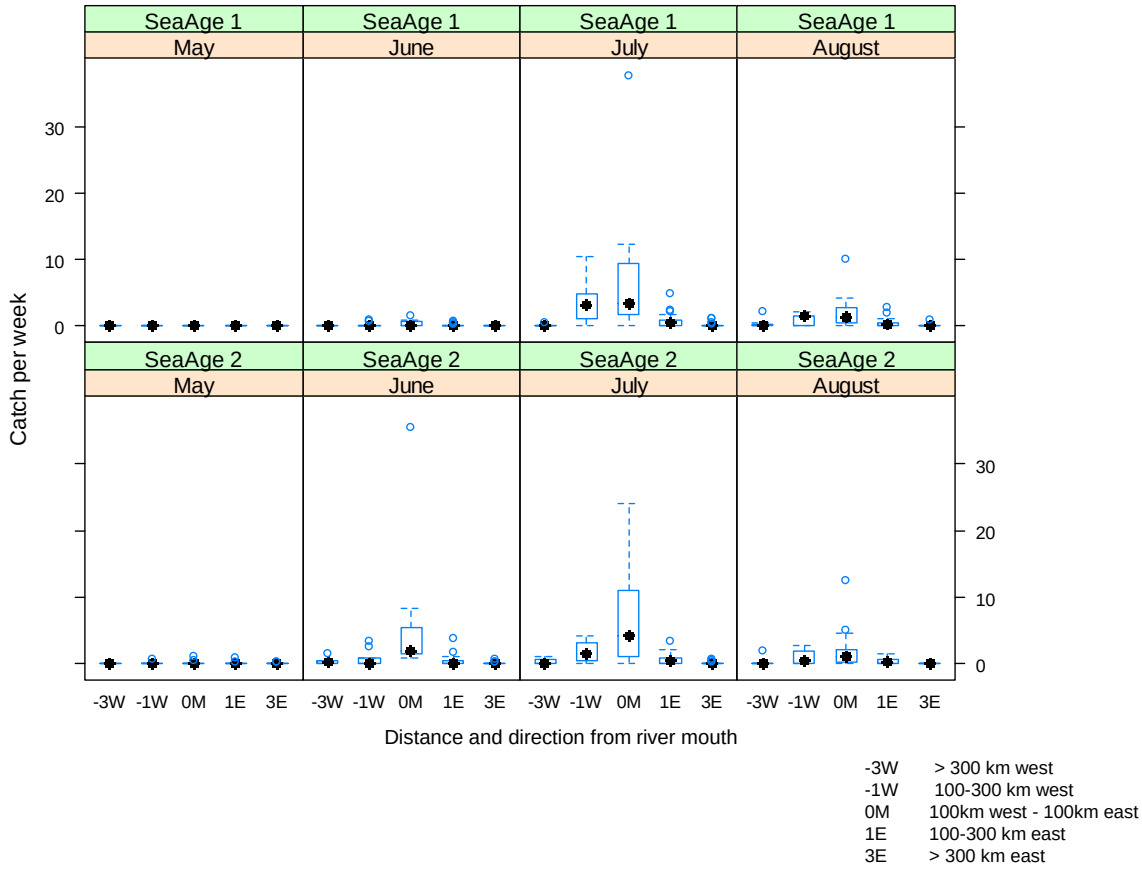


***Figure 70**. Catch per week of Alta-salmon plotted against distance to river mouth. Distances are to the east or west from the river position along the coastal baseline. Upper panel is 1SW, lower panel is MSW.*

3.6.3 Tana (Tanafjord)

The Tana-salmon had a much broader catch pattern than the other two example stocks in this analysis. The highest number of salmon was caught close to the Tana river, mainly in the Tanafjord, but there is a significant catch distribution both eastwards and westwards (**Figure 71**).

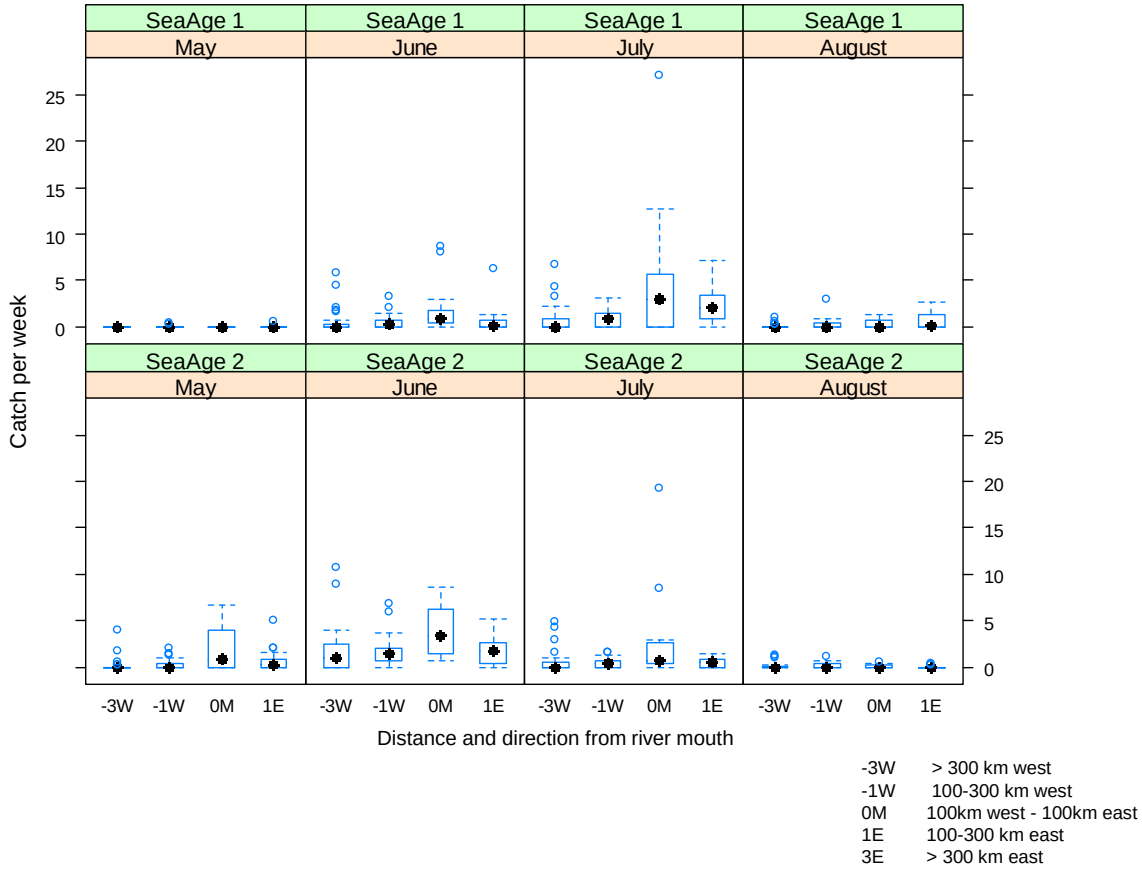


***Figure 71**. Catch per week of Tana-salmon plotted against distance to river mouth. Distances are to the east or west from the river position along the coastal baseline. Upper panel is 1SW, lower panel is MSW.*

4 Concluding discussion

The comprehensive sampling of adult Atlantic salmon along the North-Norwegian coast in 2011 and 2012, summed up to 17 383 wild salmon (74 tons), were conducted through a very close collaboration between scientists and commercial fishermen. To determine the river origin (home river) of the captured salmon, each fish was compared to genetic profiles from nearly 200 river stocks in the Barents Sea area. By combining local, ecological and genetic knowledge the resulting dataset has given us unique and quantitative insight into the spatial and temporal ecological use of the marine coastal environment of the Barents Sea salmon. Of special importance is that the project data set makes it possible to define and quantify the contribution of different salmon stocks to the North-Norwegian coastal salmon fisheries through stock- and region-specific exploitation and migration models.

The catches of wild salmon from the 58 fishermen sampling in 2011 and/or in 2012, varied strongly among sites, season and years. Catch per unit of effort, calculated as the number of salmon captured per day per fishing gear (CPUE) was highest in July (7.6) and lowest in May (1.2), and with an average of 4.1 during the whole season (early May to late August for both years). In general, the largest salmon, i.e. multi-seawinter-salmon (MSW) dominated in early season, while smaller salmon, i.e. one-seawinter-salmon (1SW), was more frequent in late season.

A stock-specific migratory model was developed for the four largest stocks, i.e. Målselv salmon in Troms county, Alta and Tana salmon in Finnmark county and the Kola salmon (Kola peninsula, Russia). All these stocks reached the North-Norwegian coast mainly in June-July, while MSW-salmon in general arrived earlier than 1SW-salmon. The two westernmost stocks, i.e. the Målselv and Alta stock, both seemed to approach the western coast of northern Troms and western Finnmark, more or less directly from the open sea. Thus, for instance the Målselv stock was mostly exploited around islands and coastlines in western Troms and close to the Malangen fjord system. Both MSW and 1SW Målselv salmon seem to reach the coast from the west, but MSW salmon reach the coast ca. one month earlier. Thus, due to the coastal migration pattern of Målselv salmon, most sea fishery exploitation take place in inner part of Troms county, i.e. based on the strong regulations in salmon sea fishery in Troms, a relatively small fraction of the stock is exploited through the formal sea fishery.

In general terms, the Alta stock seem to have a fairly similar migrating patterns as the Målselv stock, i.e. approaching the coast more or less from the west, and the dominant part of the stock is exploited within the Alta fjord. Still, due to their eastward migration pattern, a relatively large fraction of the stock is also exploited by the salmon sea fishery in outer/northern Troms, and also in areas in western Finnmark, i.e. along the coastline west of Alta fjord. Based on the migration model, some of the 1SW salmon enter Alta fjord from the north, being slightly different compared to the MSW Alta stock. Although MSW Alta salmon reach the coast several weeks earlier than 1SW, MSW salmon was quite heavily exploited not only in late May and early June, but also in July and even in August. The Alta stock suffers a very high exploitation rate from the salmon sea fishery, especially within the Alta fjord in July and early August.

Tana salmon, as opposed to Målselv and Alta salmon, was recorded in the coastal catches from all fishing regions in the study area. Although the highest number of salmon (CPUE) was captured in the Tanafjord, the relatively high CPUE-values both in southern Troms, as well as western and eastern Finnmark, plus that the catches were rather high in all areas during the same periods/weeks, strongly suggest that Tana salmon reach the coastal areas both from southwest, west, north and east. Still, the number of Tana salmon in the coastal catches was relatively low, especially in light of the dominating position the Tana river system has in terms of total salmon production potential in northern Norway. As a result of the relatively low coastal catches of Tana

salmon in 2011 and 2012, the estimated proportions of the pre-fishery abundance that were caught in the coastal fisheries were also low (9-13 %) in these particular years. These low estimates are inconsistent with e.g. the Alta coastal estimate of 40-50 %.

There are likely as many as 20-30 reproductively discrete salmon stocks within the Tana river system (J.P. Vähä, unpublished). Many of these are early-migrating stocks that are caught in the Tana main stem as soon as the river fishing season starts (May 20). Some of these salmon had therefore likely passed the outer coastal areas before the coastal sampling commenced. Another possible contributing factor in explaining the low coastal catch of Tana salmon might be that catchability in general is lowest for early migrating salmon and that the efficiency of the coastal fisheries vary between regions, perhaps being naturally low in the Tanafjord. This catchability might be related to how close to the coastal shoreline the salmon is migrating. At times, e.g. early in the season when freshwater runoff is high, the salmon might migrate further away from the shore than later in the season. This might particularly be the case in a fjord such as the Tanafjord. The freshwater runoff from the Tana river is present as a significant surface layer for a long distance from the river mouth, and the presence of this layer might affect the migration behaviour of the salmon, causing the salmon to migrate within or close to the freshwater from the river instead of close to the shore. Such behaviour would decrease the catchability in the coastal fisheries and might explain the relatively low catch levels of Tana salmon in the Tanafjord.

Salmon originating from Russian rivers comprised more than 20 % of the recorded catches. Still, the incidence of Russian salmon in the catches varied strongly within season and among fishing regions, being less than 9 % in the coastal catches from Nordland, Troms, western Finnmark, mid Finnmark and the Tanafjord, while nearly 50 % of all salmon captured in eastern Finnmark, i.e. mostly in Varangerfjord, had Russian origin. Further, the catch of Russian salmon decreased by time within season, and in eastern Finnmark the incidence of Russian salmon decreased from ca. 70 % in May to ca. 20 % in August. Thus, catches of Russian salmon was much higher before the start of formal fishing season in eastern Finnmark, but, still a fairly high amount of the recorded catch in this area consisted of salmon stocks originated from Russian rivers.

Kola salmon, both 1SW and MSW, was most frequently recorded in catches in Eastern Finnmark, i.e. especially in Varangerfjord, but some Kola salmon were also caught in western Finnmark very early in the season. This may indicate that most Kola salmon approached the coast in Eastern Finnmark, whereas some fishes migrated from the west, but fairly far from the North-Norwegian coastal areas. The CPUE-values of MSW Kola salmon in Varangerfjord was highest in June/July, while Kola salmon was more or less absent in catches from early August and onwards.

4.1 Relevance for future management

The dataset accumulated during the Kolarctic salmon-project will provide us with an invaluable management tool in future revisions of both coastal and riverine salmon fisheries regulations. The data, standardized to catch per unit effort, enables the estimation of the effect, both on a region- and stock-specific basis, of proposed regulations. For instance, let's picture a case study with a struggling stock with negative spawning target attainment on an annual basis. Using coastal and riverine catch statistics in combination with the Kolarctic salmon-data, we can estimate pre-fishery abundances and coastal and riverine catch proportions. These proportions can then be used as a basis to make management decisions. Is the coastal proportion relatively high? That might be an argument for reducing the coastal exploitation pressure on this particular stock. Then we can look at the coastal region-specific catch pattern of the example stock. Are there areas and times in particular where we find high levels of exploitation? These areas/periods might then be pinpointed for a more restrictive regulation, and we can use the exploitation model from the project data to

estimate the positive effect (number of salmon spared from the example stock) of these restrictions.

Every salmon fisheries regulation process is a trade-off between the need to restrict exploitation to heighten the probability of 100 % target attainment and the demands of various interest groups towards increasing the exploitation (e.g. by lengthening the fishing season). The Kolarctic salmon-dataset will be an invaluable tool in future processes. Now, for the first time, we can estimate pre-fishery abundances and the relative stock-specific exploitation pressures in coastal areas. And now, we finally have data and models that enable us to estimate the direct effect of various regulation scenarios on specific salmon stocks. This will simplify the selection of regulatory measures and also clarify the communication between managers and interest groups. The importance of this cannot be overstated.

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