Kolarctic CBC – Project KO4178; Conserving our Atlantic salmon as a sustainable resource for people in the North; fisheries and conservation in the context of growing threats and a changing environment.

Environmental impact from fish farming on northern salmon populations in the KolArctic area

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Report XXII. Environmental impact from fish farming on northern salmon populations in the KolArctic area

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Abstract

Aquaculture of Atlantic salmon is a growing industry, with an increasing proportion of the production taking place in northern areas. As climate change may increase sea temperatures further this development is expected to continue, and it will be associated with an increased environmental impact on the northern ecosystems in general, and on wild salmon populations. One impact with negative consequences for wild salmon populations is interbreeding with escaped farmed salmon. As a part of the previous Kolarctic Salmon project, and the present CoASal project, the proportion of escaped salmon in the coastal fishery catches was registered and verified by scale analysis. The data collected shows how escaped farmed fish are distributed in the different areas, and how it has varied over time. The results are the most comprehensive data sets existing in Norway for the marine distribution of escaped famed salmon.

Key words:
Atlantic salmon, aquaculture, genetic introgression, salmo salaris, Troms, Finnmark, Målselva, coastal fishery, escaped salmon

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Development of the farming industry

Atlantic salmon farming is a growing industry in Norway. Since 2005 production has more than doubled, and there are plans for further expansion (see figure 1). There are environmental costs associated with this industry, and the awareness is increasing regarding potential negative effects on wild conspecifics, and other anadromous salmonids. The Norwegian Scientific Advisory Committee for Atlantic Salmon (VRL) has designated sea lice infections and escaped farmed salmon has the two biggest threats to the wild salmon populations (Forseth et al. 2017). The density of fish farms, and the environmental impact of this industry is highest in western and middle Norway, but production is increasing also in northern areas. The proportion of the aquaculture production of Atlantic salmon in the two northernmost counties has increased from 34 % in 2005 to 47 % in 2021 (fig. 1), and there is reason to believe that much of the planned expansion of the industry will take place in the north. As climate change and warmer seas may increase environmental load and stress on fish in southern Norway, the industry may choose to move production northwards. There is also a developing salmon farming industry in Russia, close to the Norwegian border. Though production varies between years, and at present is on a lower scale than Norwegian production, the industry is growing (fig. 2).

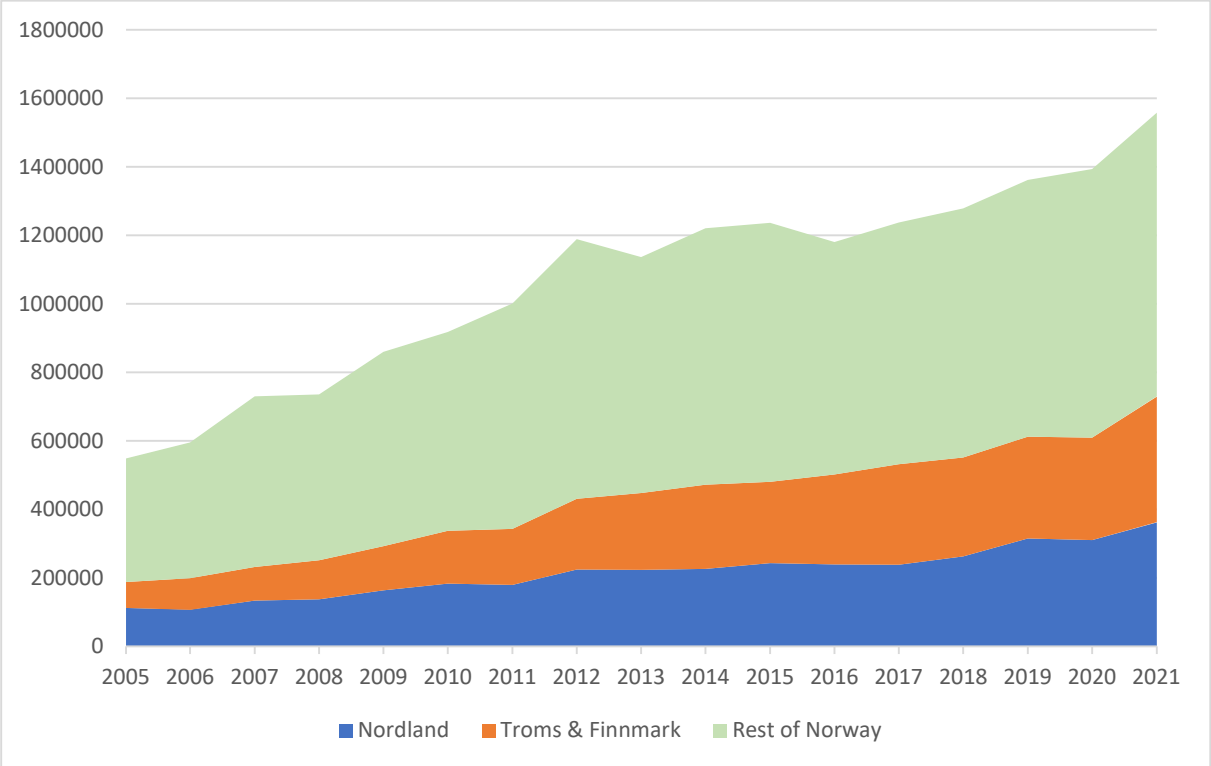

Figure 1 Aquaculture production of Atlantic salmon in Norway 2005-2021. Production in the two northernmost counties, and the rest of Norway is displayed in different colors (data from the Directorate of Fisheries, www.fiskeridir.no).

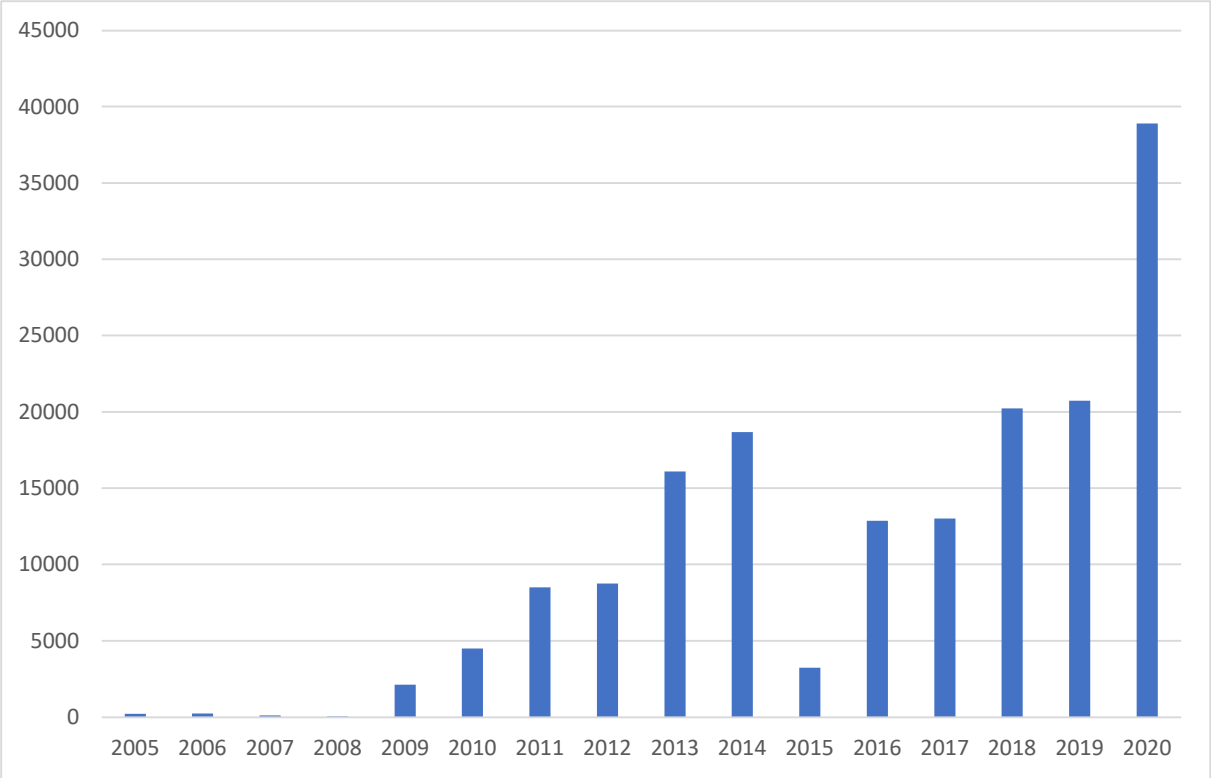

Figure 2 Russian aquaculture production of Atlantic salmon 2005-2020 (ICES 2021).

The potential geographic scale of impacts from aquaculture on wild populations of salmon is large. Salmon aquaculture in northern Norway have the potential to have an impact on wild salmon populations in Russia, and vice versa. In evaluating potential risks, it is therefore important to consider the question of scale. The scale on which different threats operate varies; from local effects impacting the environment directly around the fish farm (such as eutrophication, heavy metal pollution etc.), to more long ranging effects such as the spread of escaped farmed salmon.

Monitoring of escaped farmed fish and risk for negative impacts

In some countries with extensive aquaculture production impacts from fish farming on the marine environment, including wild salmonids, are assessed in various ways. In Norway an evaluation and risk assessment of the fish farming industry is published annually by the Institute of Marine Research (Grefsrud et al. 2022). The report categorizes the different threats, and risk diagrams per salmon production area are published for some of the factors. Among these factors are infections from sea lice, transmission of infectious diseases, and genetic introgression of farmed salmon into wild populations. An example of the risk assessment from genetic introgression from escaped farmed fish from aquaculture production areas in counties Troms and Finnmark is shown in figure 3. The evaluation of risk shows a close association with farming intensity and gradually decreases towards the eastern part of Finnmark where farming intensity is lower.

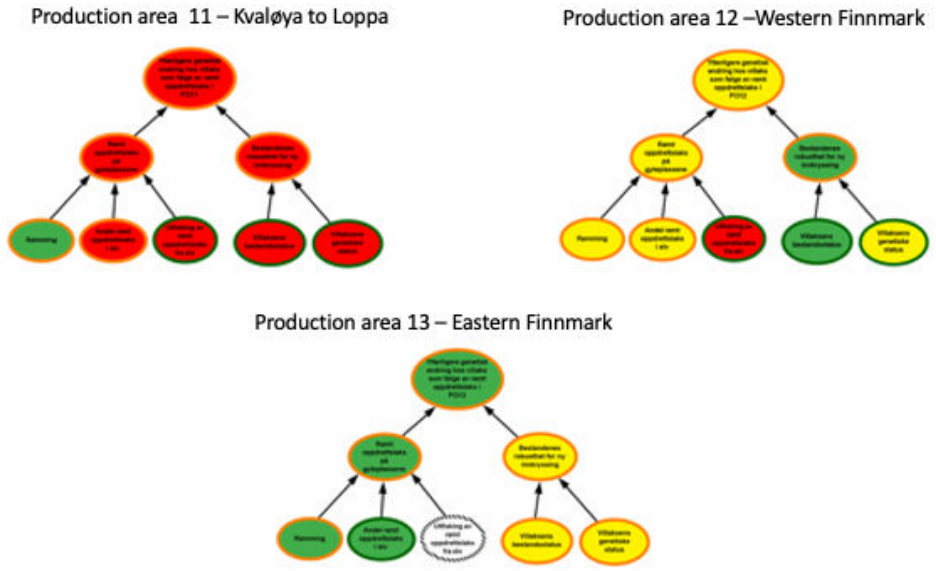

Figure 3 Risk assessment of further genetic introgression from escaped aquaculture salmon on wild populations in northern rivers. (From Grefsrud et al. 2022)

Every year, the proportion of escaped salmon is estimated for between 200-250 salmon rivers in Norway (Wennevik et al. 2022). The estimates are based on analysis of scale samples collected from rod fisheries in the sports fishing season, research fisheries in autumn, closer to the spawning season, and drift diving counts in many rivers. Often data from several of these data collections are available for a river, and an expert group assesses the data available and classify the proportion of farmed escapees in the population as low (<4%), medium (4-10%) or high (>10%) (see Glover et al. 2019 for a description of the monitoring program). Many of the rivers in northernmost Norway are included in the monitoring program. In total 61 rivers in Troms & Finnmark county have been evaluated at least once since the since the beginning of the monitoring program in 2014. The average classification of the rivers into the three categories with regards to proportion of escaped farmed salmon over this time period is shown in figure 4. The location of the rivers is shown on a map in fig. 5. Both figure 4 and the map demonstrates that the proportion of escaped farmed salmon in the rivers appear to be higher in the western part of the county, while numbers of escapees are low in most rivers in eastern Troms & Finnmark. Despite this observation, published estimates of genetic introgression of farmed salmon into wild populations show that some of the eastern populations are also affected (Diserud et al. 2020).

Genetic introgression and impacts on wild populations

Introgression of genetic variants from farmed fish is a cumulative process, and although studies show that selection inflicts greater mortality on hybrids between farmed and wild salmon, this comes at a cost for the productivity of the population, and reduces the potential production of the river. If farmed fish continue to escape, the problem will persist and perhaps increase. Reduced fitness of offspring from interbreeding between farmed and wild salmon

has been demonstrated in a number of experiments in Ireland (McGinnity et al. 2003), in the Ims river in Rogaland county (Fleming et al. 2000) and in Guddalselva in Vestland county (Skaala et al. 2019). Further follow up studies have clarified the mechanisms by which these fitness differences arise (Solberg et al. 2013a, 2013b, 2020). A review of the knowledge status of the effects of introgression was published by Glover et al. (2017). Recently, two studies investigating a large number of populations has demonstrated how the level of introgression in a population is correlated with life history changes (Bolstad et al. 2017, 2021). Such changes as a result from introgression, may be presumed to be less than optimal, as it may push populations away from their local adaptation optimums for these life history traits. Perhaps even more worrisome, is that the northern populations belong to a different phylogenetic group than the rivers which were used as the foundation for farmed fish breeding lines (Wennevik et al. 2019), and the effects of introgression may be expected to be more severe.

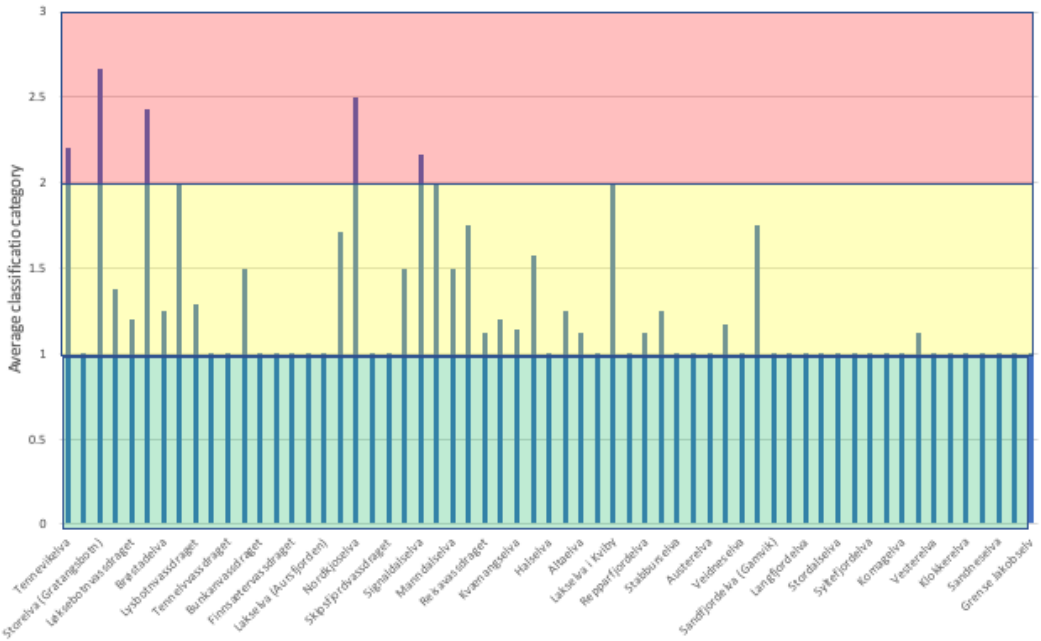

Figure 4 Average classification of rivers in Troms & Finnmark into categories 1-3 (low-medium-high) with regards to proportion of escaped farmed salmon in the period 2014-2021 in the national monitoring program (Wennevik et al. 2022).

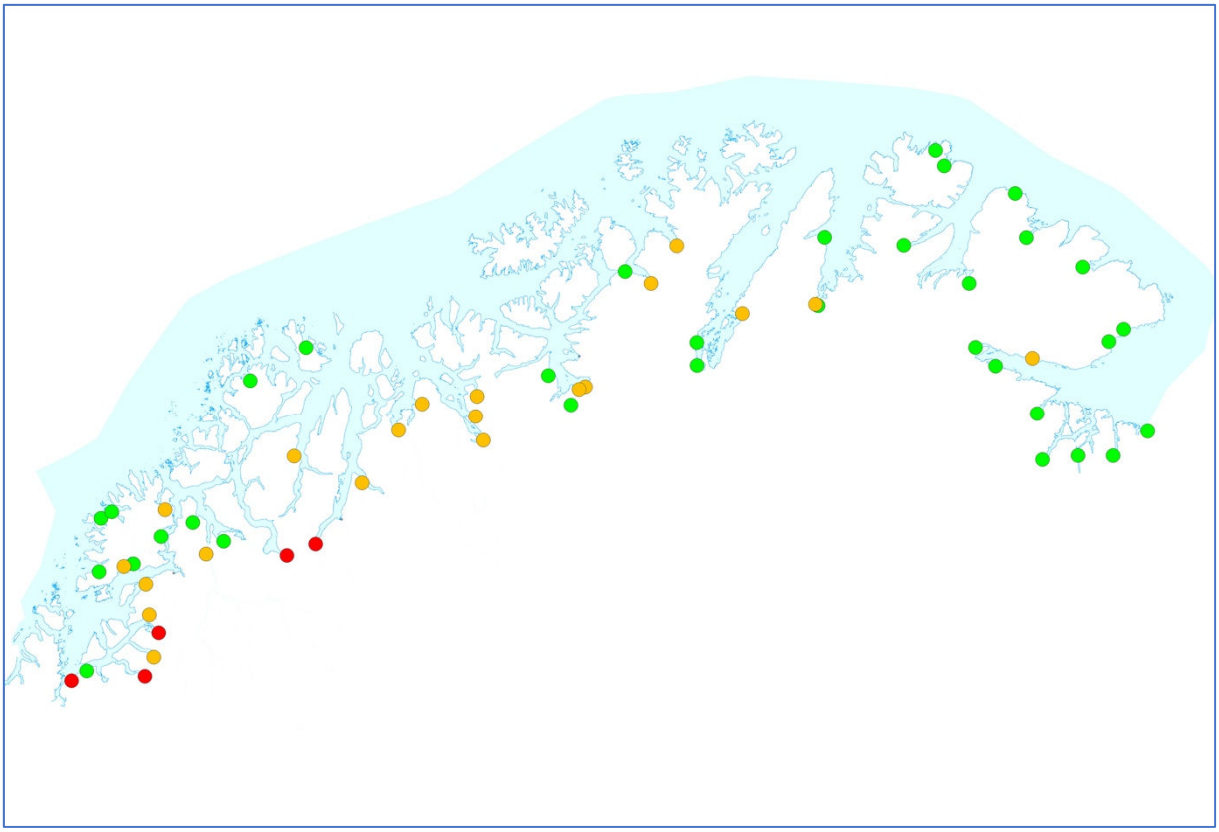

Figure 5 Map the location of the monitored rivers in the national monitoring program. Colours are according to the average classification shown in figure 4 (Data from Wennevik et al. 2022).

Though there is now a reasonably good coverage of the proportion of escaped farmed salmon in rivers, the availability of data describing the marine distribution of escaped salmon is more limited. For many regions of Norway such information does not exist, as the coastal fisheries for salmon have been terminated. The data collected during the CoASal project, and also the previous Kolarctic Salmon project are in effect the most comprehensive investigations of marine distribution of escaped farmed salmon in Norway in recent years. In the Kolarctic Salmon project and the CoASal project combined, the occurrence of escaped farmed salmon in coastal catches in the years 2008-2012 and 2020-2021 have been investigated in from 8 to 20 different fishing regions in different years. The proportion of escaped farmed salmon is illustrated in figs. 6 and 7 below.

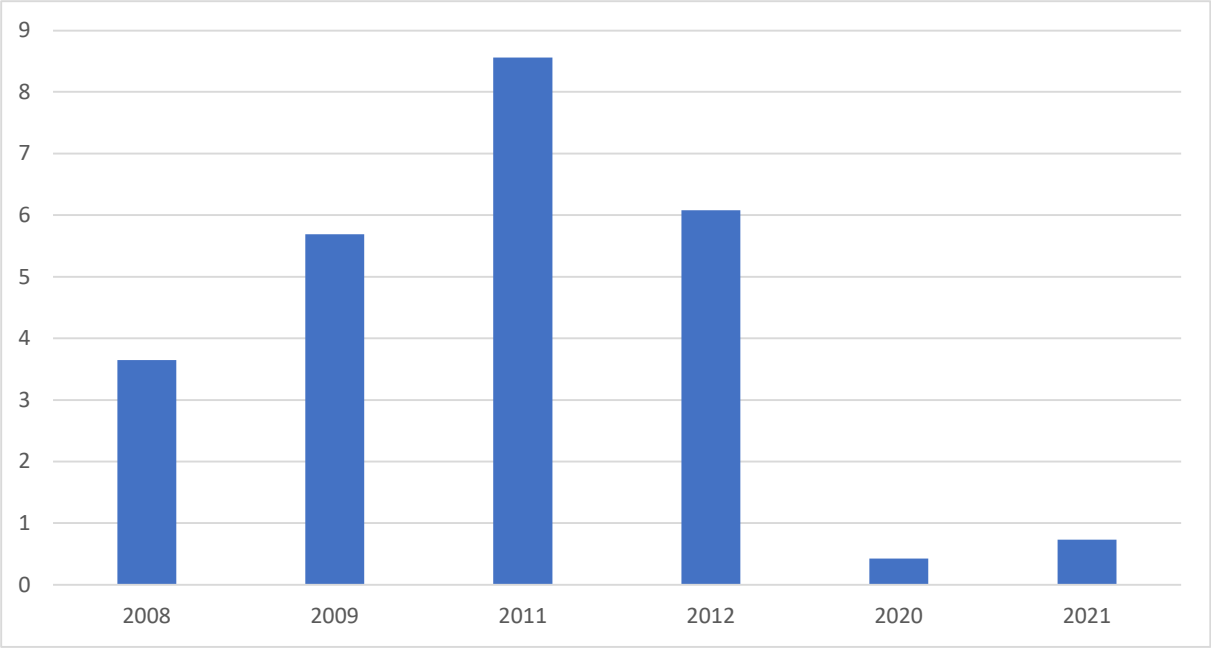

Figure 6 Overall percentage escaped in coastal catches 2008-2021. Note that the sampling period was extended beyond the normal fishing season in the earlier period.

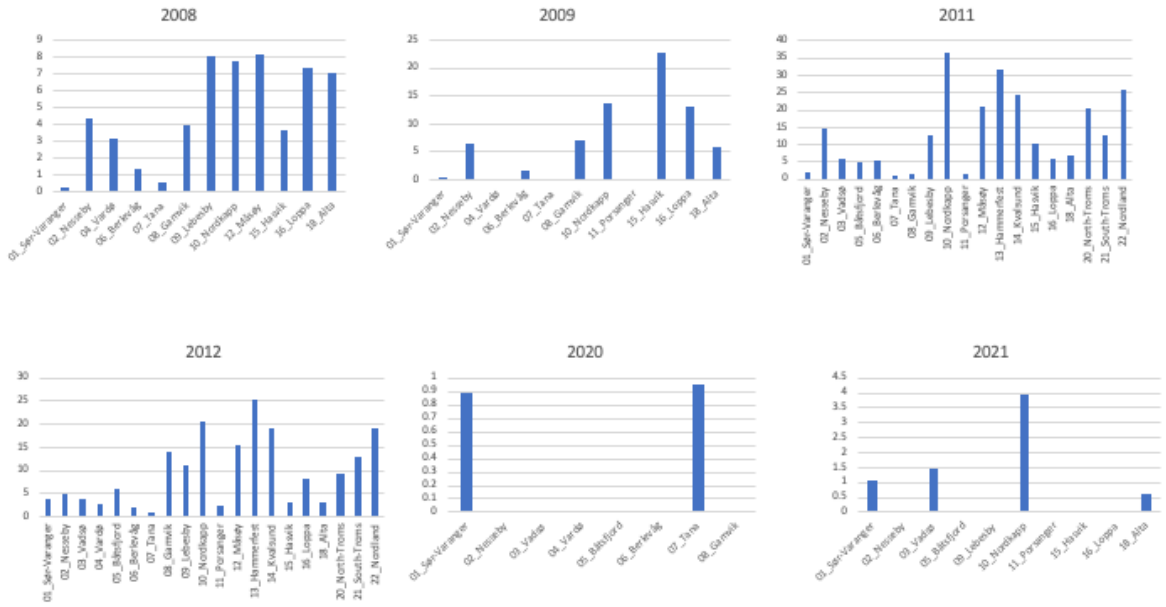

Figure 7 Proportion of escaped farmed salmon in coastal catches in different fishing regions across years 2009-2012 and 2020-2021. Notice that the scale is different in different sub-plots.

As is apparent from figures above, the proportion of escaped farmed salmon was higher in the earlier period than in the two recent years investigated in the CoASal project. But also, it is evident that the highest proportions were recorded in the western part of the investigated area in the Kolarctic Salmon project. In the CoASal project, work was focused on investigations

in Finnmark part of the Troms & Finnmark county, not covering the fishing areas in Troms and Nordland. Nevertheless, the proportions recorded during the CoASal project are lower than those recorded in the same areas during Kolarctic Salmon.

Future outlook

The stated political goal of increasing aquaculture production is likely to have a larger effect on the northern areas in the future. The so called “Traffic Light System” that currently regulates production by evaluating the added mortality inflicted by sea lice infection from fish farms currently has classified the northernmost production areas as “green”, which means that aquaculture production is allowed to increase in these areas. As described in a previous section of this report, aquaculture production in the two northernmost counties is already increasing and constitutes an increasing proportion of salmon aquaculture in Norway. We can expect that this trend will continue.

Also, production in Russia is expected to increase. Along with the increase in production, we may expect the environmental impact to increase. The extent of this increase will depend on the technology used in fish farming, and technical regulations from management authorities. If for instance closed farming systems will be a significant part of further expansion in production, environmental impacts will be different from the open net pen systems that dominates the industry today.

The data sets generated from registrations of escaped farmed salmon in coastal catches during the Kolarctic Salmon and CoASal projects will provide a useful future reference as the fish farming industry continues to expand in the northern areas.

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