Status of wild Atlantic salmon in Norway 2018

Norwegian Scientific Advisory Committee for Atlantic Salmon

The status of wild Atlantic salmon in Norway is evaluated annually by the Norwegian Scientific Advisory Committee for Atlantic Salmon. This is an English summary of the work of the committee, mainly based on the 2018 annual report.

The committee is appointed by the Norwegian Environment Agency and given the assignment to evaluate status of salmon and the relative importance of different threats, give science-based catch advice, and give advice on other issues related to wild salmon management. The advice is only related to biological questions, and not to socio-economic challenges in the salmon management.

Thirteen scientists from seven different institutes/universities are members of the committee: Torbjørn Forseth (leader), Bjørn T. Barlaup, Sigurd Einum, Bengt Finstad, Peder Fiske, Morten Falkegård, Åse Helen Garseth, Atle Hindar, Tor Atle Mo, Eva B. Thorstad, Kjell Rong Utne, Asbjørn Vøllestad and Vidar Wennevik. The committee is an independent body, and the members do not represent the institutions where they are employed when serving on the committee.

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Main findings of the 2018 annual report

The abundance of wild Atlantic salmon has declined. The number returning from the ocean to Norway each year is now less than half of the level thirty years ago. In 2017, about 530 000 salmon were estimated to return, which was an increase from 2016, but still on a low level. The declined abundance has reduced, and in some cases eliminated, the harvestable surplus available for fisheries.

Due to the decline of Atlantic salmon, fisheries have been greatly reduced. Annual catches in the sea and rivers are reduced from 1500 to 500-600 tonnes during the last 30 years. The reduced exploitation has more than compensated for the decline, and the number of salmon spawning in the rivers has increased during recent years. In 2017, there were enough spawners in most rivers, which means that the natural capacity of the rivers to produce salmon juveniles was utilized. Hence, salmon populations are not restricted by lack of spawners, with a few exceptions.

Reduced salmon populations are caused both by human impacts and a general and large-scale reduction in survival at sea. Populations in middle and western Norway are most severely reduced.

Escaped farmed salmon, salmon lice and infections from salmon farming are the greatest anthropogenic threats to Norwegian wild salmon. The proportion escaped farmed salmon in the rivers is reduced in recent years, and the risk of further loss of wild salmon due to escaped farmed salmon is reduced from very high to high. The knowledge of infections from salmon farming is poor.

Hydropower production, other habitat alterations, acid rain and introduced pink salmon are also major anthropogenic threats to wild salmon, but the risk of further loss is smaller than for the threats related to salmon farming. Hydropower production and other habitat alterations significantly impact wild salmon, but the negative impact will likely not expand in the future. However, there is large potential for further mitigation measures. Due to liming of rivers and reduced emissions, the risk of increased negative impacts due to acid rain is small. Salmon populations in southern Norway have increased due to the comprehensive liming programs.

The threat to wild salmon from the introduced parasite *Gyrodactylus salaris* is now greatly reduced. Number of rivers with known occurrence of the parasite has been reduced from fifty to seven, due to successful eradication measures. Wild salmon have been re-established in rivers where the parasite has been eradicated. The risk of further spreading is reduced.

Sea trout populations are greatly reduced in large parts of the country (western and middle Norway and several rivers in northern Norway), but stable in eastern and southern Norway. Agriculture, other habitat alterations and salmon lice seem at present to be the most serious threats to sea trout.

The 2017 annual report is published in Norwegian: https://brage.bibsys.no/xmlui/handle/11250/2503390

Extended summary

Catches and pre-fishery abundance

In 2017, the total reported catch in sea and river fisheries was 172 000 Atlantic salmon (*Salmo salar*), equaling 666 metric tons. In addition, 25 900 salmon (116 metric tons) were reported caught and released (26% of the river catches).

The number of wild Atlantic salmon returning from the ocean to Norway each year (pre-fishery abundance) is significantly reduced since the 1980s (**figure 1**). The pre-fishery abundance was more than halved from 1983-1986 to 2014-2017 (54% reduction). The pre-fishery abundance was estimated at about 530 000 wild salmon in 2017, which was higher than in 2016 (470 000 salmon).

The main decline has been among the small salmon (body mass < 3 kg). The pre-fishery abundance of small salmon has declined from high levels in the mid-1980s and been at a low level during the last years, except a temporal increase around year 2000. Small salmon have usually stayed at sea for one winter, but during 2007-2017, 10-29% of the small salmon had stayed for two or more winters at sea. This means that the pre-fishery abundance of one-sea-winter salmon after 2006 is even lower than indicated by the estimates of small salmon. For Norway as a whole, the abundance of larger salmon (body mass > 3 kg) has not changed after the late 1980s, but there were more large salmon during the mid-1980s.

The temporal changes in the salmon pre-fishery abundance differ among regions. Since 1989, when the offshore drift net fishery was banned, the abundance including all size classes has declined in Middle and Western Norway, and slightly increased in southern and northern Norway (when the Tana watercourse is excluded). The abundance of small salmon has declined in all parts of the country (compared to the period 1989-1993), but to the greatest extent in middle Norway and the smallest extent in northern Norway. The pre-fishery abundance of salmon larger than 3 kg has decreased in Middle Norway and to a varying extent increased in the rest of the country.

The Tana watercourse has had a marked decline in the pre-fishery abundance, in contrast to the rest of Northern Norway, with a 67% reduction in the pre-fishery abundance since 1989. Both small and large salmon have been reduced. This watercourse is shared between Norway and Finland, and overexploitation is the only known impact factor. A new agreement between Norway and Finland was signed in 2017, and exploitation will be reduced.

Marine survival

Monitoring in the River Imsa shows that the marine survival of Atlantic salmon has been low during the last 20-25 years compared to in the 1970s and 1980s, like in other international monitoring rivers. Results from the Rivers Drammenselva and Imsa showed that the smolts leaving the rivers during 2006-2008 had a particularly low marine survival. The data series from the Drammenselva was terminated in 2008. The marine survival of the smolts that left the River Imsa after 2008 has slightly increased, but the survival remains low. In the best years during the 1980s, the survival of salmon from the River Imsa was 17% from they left the river as smolts until they returned after one year in the ocean. For the salmon that left the Imsa during 2009-2015, the survival was only 1-4%. Knowledge of variation in sea survival for salmon from different regions has been poor due to few monitored rivers, but efforts to monitor sea survival are increasing.

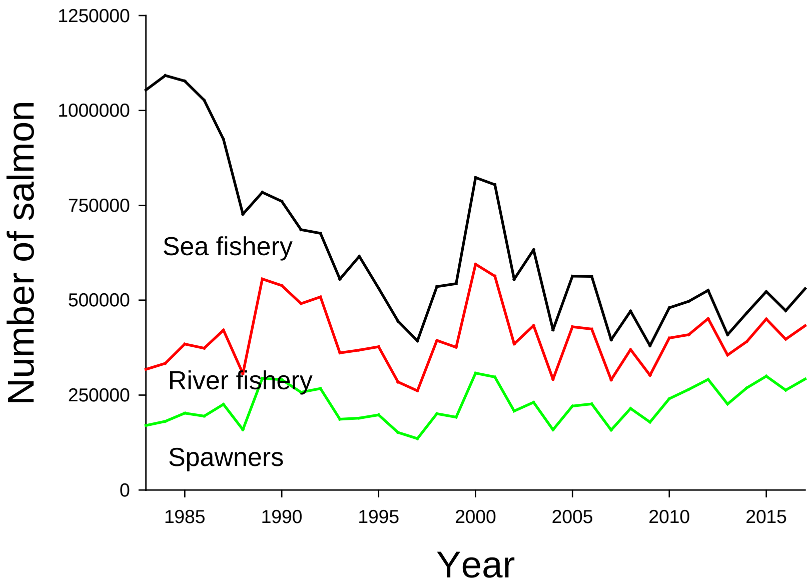

Figure 1. *Estimated number of wild salmon returning from the ocean towards Norwegian rivers (pre-fishery abundance, black line), number of wild salmon entering the rivers (red line, i.e., the number left after catches in sea fisheries), and the number of wild salmon left for the spawning populations (green line, i.e., the number left after catches in sea and river fisheries) during the period 1983-2017.*

Attainment of spawning targets

In the 2018 report, attainment of spawning targets (conservation limits) and exploitation were evaluated for 195 salmon rivers for the period 2014-2017. The management target of a population is attained when the average probability of reaching the spawning target over a four-year period is minimum 75%. The scientific foundation for management according to spawning targets and management targets for Norwegian rivers is described by Forseth et al. (2013). For each river, the harvestable surplus was also estimated - as the pre-fishery female abundance minus the spawning target - expressed in percentage of the spawning targets.

The management targets for the period 2013-2016 were attained, or likely attained, for 91% of the populations, when the uncertainty in both the spawning targets and the estimated attainment of the spawning targets were considered (**figure 2**). This is the best results regarding attainment of the management targets since the first evaluation was done in 2009 (**figure 2**). The number and proportion of populations reaching the management targets have increased markedly from 2006-2009 to 2014-2017 (**figure 2**). This increase in proportion of populations reaching the spawning targets is largely due to stricter regulations of fisheries causing reduced exploitation rates but is also due to increased pre-fishery abundance of multi-sea-winter salmon (salmon larger than 3 kg) during some years in southern and western Norway.

Exploitation

An important principle in Norwegian legislation, which forms the basis for salmon management, is that both conservation and harvestable surplus of salmon should be ensured. The aim of the Salmon and Freshwater Fish Act is to ensure that populations and their habitats are managed such that diversity and productivity are conserved. Further, populations should be managed to ensure increased yields, to the benefit of fisheries stakeholders and recreational fishers. Similar principles are embedded in the Nature Diversity Act (see section on the quality norm below).

Annual declared catches in the sea and rivers have been reduced from about 1500 metric tons during the 1980s to 500-600 metric tons during the last years. In 1983-1988, more than 60% of the salmon returning from the ocean to the Norwegian coast (pre-fishery abundance) were caught in the sea (**figure 3**). When the drift net fishery was banned from 1989, the exploitation was reduced. The sea fisheries have been further reduced after the 1990s. In 2017, 18% of the salmon returning to the coast were caught in the sea.

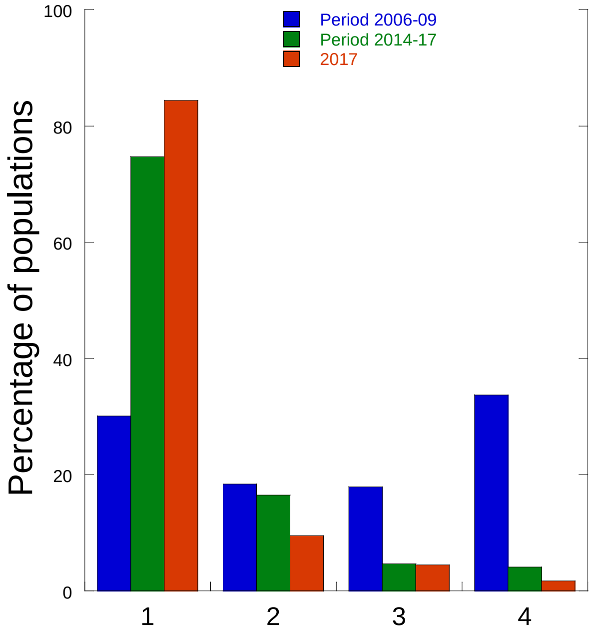

***Figure 2**. Proportion (%) of the evaluated salmon rivers in category 1: the management target is attained, category 2: there is a risk that the management target is not attained, category 3: the management target is likely not attained, and category 4: the management target is far from being attained. Data are given for the periods 2006-2009 and 2014-2017, as well as for 2017 only.*

The proportion of the salmon returning to the coast caught in the rivers has been reduced from 2011. In 2017, 26% of the salmon returning to the coast were caught in the rivers. Of those salmon entering the rivers (after marine exploitation), exploitation has been markedly reduced from 1983-1988 to 2017 (**figure 3**). On average, 47% of the salmon entering the rivers were killed in fisheries until 2005, whereas in 2017, 32% were killed. However, exploitation rates vary among rivers, and many rivers now have very low exploitation rates, and the fishing has been closed in many rivers after 1982 due to reduced populations.

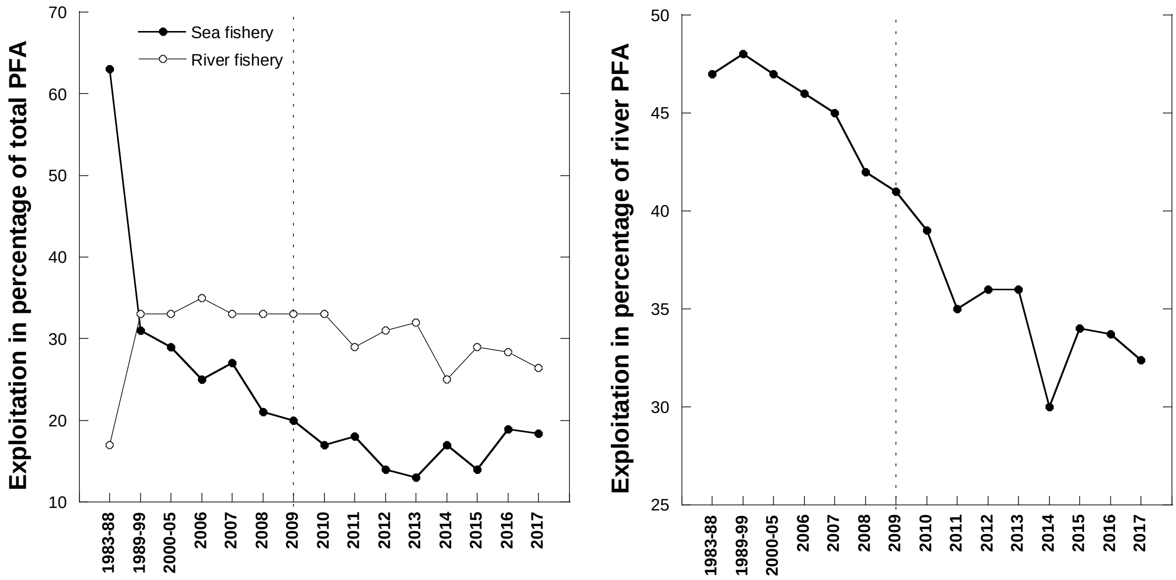

***Figure 3.** Left graph: Exploitation of salmon given as percentage of the pre-fishery abundance (Total PFA, in numbers) for the periods 1983-88, 1989-99 and 2000-05 (averages) and thereafter as annual values. Right graph: Exploitation of salmon in the rivers given as the proportion of salmon entering the rivers (those left after exploitation in sea fisheries, River PFA) for the same periods and years. Hatched line indicates the year when management based on spawning targets was introduced. Note the different scale on the y-axes.*

Reduced exploitation has resulted in an increased number of salmon spawning in the rivers during the last years. In 2017, there was likely a larger number of spawners in the rivers than most other years since 1983 (**figure 1**). The proportion of salmon that were not killed in fisheries but allowed to become a part of the spawning populations, was less than 20% when the drift net fisheries took place (1983-88). This proportion increased to more than 30% during 1989-99, and to 57% during 2014-2017.

Escaped farmed salmon

In 2017, 1 220 000 metric tons of farmed Atlantic salmon were produced in Norway. It was reported that 15 000 farmed salmon escaped from fish farms. The mean annual number of escaped salmon reported during the last 10 years was 183 500 salmon. The actual number of escaped farmed salmon are potentially 2-4 times higher than the reported numbers, according to studies by the Institute of Marine Research during 2005-2011.

The proportion of escaped farmed salmon in angling catches in monitored rivers in summer has been on average 3-9% in most years after 1989 (**figure 4**). In 2017, the average was 2.8%. The proportion of escaped farmed salmon has been larger during monitoring of the rivers in the autumn shortly before spawning, likely because the escaped farmed salmon tend to enter the rivers later in the season than the wild salmon, often towards the end or after the angling season. The proportion escaped farmed salmon in the monitored rivers in the autumn was on average 3.8% in 2017 (**figure 4**). In comparison, the average proportion was greater than 20% in the years 1989-1998. In the last twelve years, the proportion has varied between 4% and 18%. From 2006, there has been a weak decline in the proportion of escaped farmed salmon in the autumn close to the spawning season.

New studies have shown that there is widespread genetic introgression of escaped farmed salmon in Norwegian wild salmon. Significant genetic contributions from farmed salmon (introgression) has been found in wild salmon in 61 of 175 studied rivers. Further, there were indications of genetic introgression from farmed salmon in wild salmon in 54 additional rivers. Hence, in only one third of the rivers, no indication of genetic introgression from escaped farmed salmon were found (60 of 175). It should be noted that all wild salmon examined in these studies were salmon produced naturally in the rivers. Another new study has shown how gene flow from escaped farmed salmon have altered the life history of wild Atlantic salmon in Norwegian rivers; individuals with high levels of introgression from farmed fish had altered age and size at maturation.

The scientific evidence that incidence of escaped farmed salmon will negatively affect Norwegian wild salmon, both ecologically and genetically, is strengthened during recent years. Even though the proportion of escaped farmed salmon has decreased in monitored rivers, the proportions are still so high in many rivers that more extensive measures are required to reduce the negative impacts. Many salmon populations are already genetically impacted by farmed salmon introgression, and continued addition of new escaped farmed salmon challenge the recovery of the natural genetic composition of wild populations. The official goal of protecting the genetic integrity and variation of wild Atlantic salmon populations cannot be met with current levels of escaped farmed salmon in the population, including the levels recorded during monitoring in 2017. In addition to changing the populations genetically, hybridization between wild and escaped farmed salmon is also shown to reduce salmon production and survival.

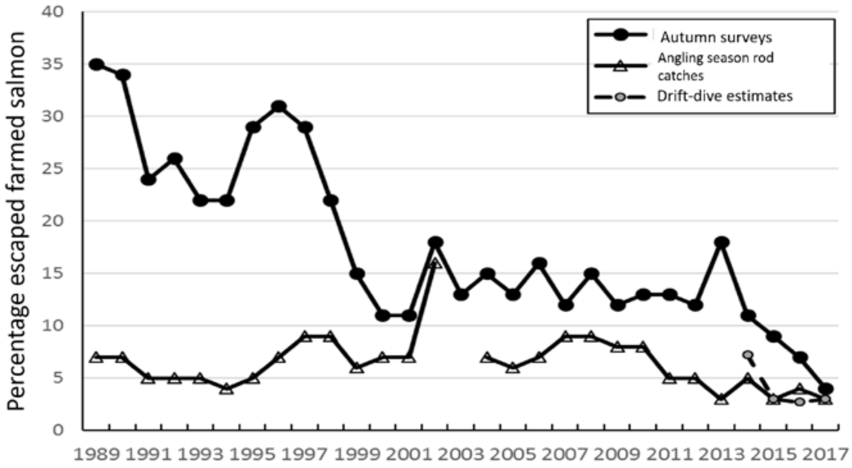

***Figure 4**. Incidence of escaped farmed salmon in samples collected during the angling season, and in monitoring immediately before spawning in the autumn during the period 1989-2017. In recent years, drift-dive estimates are also included in monitoring. Data are given as average proportion of escaped farmed salmon in monitored rivers.*

Pink salmon

The natural distribution area of pink salmon (*Oncorhynchus gorbuscha*) is in the Pacific Ocean. Eggs were transported from Sakhalin in the Pacific Ocean to hatcheries around the White Sea in Russia during 1956-1979, and fry were released in rivers draining to the Barents Sea and White Sea. This resulted in significant catches if pink salmon, particularly in the White Sea. Pink salmon invaded several rivers, including in the county of Finnmark in northern Norway. Pink salmon from these releases only occasionally resulted in self-reproducing pink salmon in nature, maybe because pink salmon from Sakhalin were not well adapted to the environmental conditions in the north.

During the 1980s, eggs from the River Ola, which is further north than Sakhalin in Pacific Russia, were transported to the hatcheries at the White Sea. This resulted in self-reproducing pink salmon in several rivers in northwest Russia, and likely also in some Norwegian rivers close to the Russian border. The last hatchery releases were made in 2001. Hence, pink salmon returning to the rivers after this must have originated from spawning in the rivers. In Norway, pink salmon have occurred mainly in rivers in eastern Finnmark, where pink salmon have been recorded almost every year. A few individual pink salmon have also been recorded in Southern Norway.

In 2017, a large and unexpected invasion of pink salmon was recorded. Almost 6500 pink salmon were reported caught in the sea and in 271 rivers along the entire coastline in Norway. These are minimum numbers, because an official reporting system is lacking. In some rivers, hatching was observed from late autumn 2017. Juveniles were recorded in several rivers in the winter and spring 2018. Most of the recordings of juveniles were from Finnmark. The monitoring elsewhere was limited.

The knowledge of the effects of pink salmon is limited, and it is not known to which extent they may negatively impact local Atlantic salmon, sea trout (*Salmo trutta*) and Arctic char (*Salvelinus alpinus*) populations. Even though pink salmon spawn earlier than the local salmonids, they may be aggressive towards other fishes, which can be disturbed or scared away from holding pools and spawning sites. If pink salmon occur in large numbers, angling for Atlantic salmon and other fishes may also be negatively impacted. After hatching, pink salmon may start feeding in the river, before moving to sea, which is shown in studies on the Kola peninsula in Russia. Similar observations were done in some Norwegian rivers in the spring 2018. Pink salmon juveniles may therefore compete with juveniles of other salmonids during a few weeks in the spring. Also, it cannot be excluded that pink salmon may impact growth and feeding of other salmonids in the sea, if they occur in large numbers. This has so far not been studied. Pink salmon may spread diseases to new areas, but also this has not been studied. Pink salmon die after spawning, and the decay of dead fish adds nutrients to the rivers, which can potentially alter river ecosystems.

Recording of catches and observations of pink salmon have so far been restricted. We recommend introducing a mandatory reporting system for pink salmon in the sea and river fisheries, and to establish a simple recording system. There is also need for more knowledge on the impacts of pink salmon on Atlantic salmon, sea trout and Arctic char, as a basis for threat analyses and development of mitigation measures.

Major threats to Norwegian wild salmon

The committee has developed a semi-quantitative 2D classification system to rank different anthropogenic impacts to Norwegian Atlantic salmon populations (also published by Forseth et al. 2017). The first dimension, the effect axis, describes the effect of each impact factor on the populations, and ranges from factors that cause loss in adult returns, to factors that threaten population viability and genetic integrity. The second dimension, the development axis, describes the likelihood for further reductions in population size or loss of additional populations in the future.

Combined, these axes form a continuous classification system in which the impact factors can be categorized into four major groups (**figure 5**):

(i) Expanding population threats—factors affecting populations to the extent that populations may be critically endangered or lost in nature and that have a high likelihood of causing even further reductions. Current mitigation measures are unable to hinder expansion of negative impacts in the future.

(ii) Stabilized population threats—factors that have contributed to populations becoming critically endangered or lost in nature, but that have a low likelihood of causing further reductions than they do already today. Mitigation measures taken can hinder expansion of negative impacts in the future.

(iii) Expanding loss factors—factors that cause loss in number of returning adults, and that have a high likelihood of causing further loss, but not to the extent that populations become threatened. Mitigation measures taken are unable to hinder expansion of negative impacts in the future.

(iv) Stabilized loss factors—factors that cause loss in number of returning adults, but not to the extent that populations become threatened, and that have a low likelihood of causing further loss. Mitigation measures taken can hinder expansion of negative impacts in the future.

Assessments according to this system are updated annually by the committee. Escaped farmed salmon, salmon lice and infections related to fish farming were identified as the largest population threats to wild salmon (**figure 5**). Escaped farmed salmon have the greatest negative impact, whereas salmon lice have the greatest risk of expansion of negative impacts in the future. The risk of causing further loss due to escaped farmed salmon is reduced compared to earlier assessments due to the potential for effective mitigation measures. Infections related to fish farming were also identified as a threat that can significantly impact salmon, and with a large likelihood of causing further reductions and losses in the future. However, knowledge of the impacts of infections related to fish farming is poor, and the uncertainty of the projected development of this impact factor is high. More knowledge on this impact factor is needed.

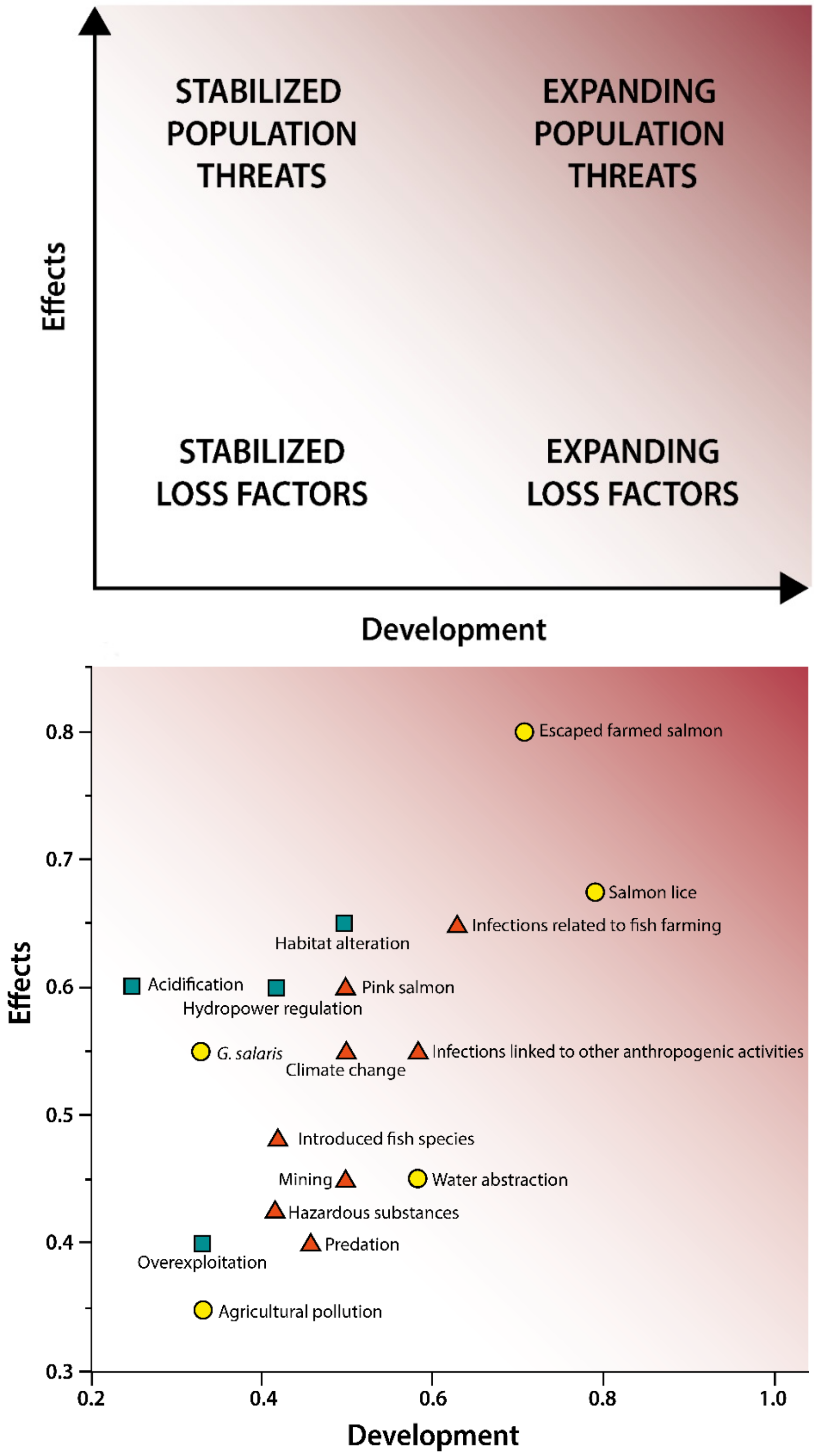

Figure 5*. Upper graph: The classification system developed to rank different anthropogenic impacts to Norwegian Atlantic salmon populations along the effect and development axes. The four major impact categories are indicated, but the system is continuous. Background coloring indicate severity of impacts, with dark as the most severe.*
Lower graph: Location within the classification system of the 17 impact factors considered in 2018. For illustration, the knowledge on each impact factor and the uncertainty of future development is indicated by the color of the markers. Green squares = Extensive knowledge and small uncertainty, yellow circles = moderate knowledge and moderate uncertainty, and red triangles = poor knowledge and high uncertainty.

Hydropower production, other habitat alterations, acid rain and introduced pink salmon were also identified as threats to wild salmon, but with a lower risk of causing further loss of wild salmon in the future than the threats related to salmon farming (**figure 5**). Hydropower production and other habitat alterations significantly impact wild salmon, but the negative impact will likely not increase in the future. However, the potential for further mitigation measures is large. Due to large-scale liming of rivers and reduced emissions, the risk of increased negative impacts due to acid rain is low. Salmon populations in southern Norway have increased due to the comprehensive liming programs.

The threat to wild salmon from the introduced parasite *Gyrodactylus salaris* is greatly reduced, because successful eradication programs have been in operation, strongly reducing the number of rivers infected with the parasite, and the salmon populations have been re-established from live gene banks. Number of rivers with known occurrence of the parasite has been reduced from fifty to seven, due to the eradication measures.

Other impacts were identified as less influential, either as stabilized or expanding factors that cause loss in terms of number of returning adults, but not to the extent that populations become threatened. Management based on population specific reference points (conservation limits) has reduced exploitation, and overexploitation was no longer regarded an important impact factor.

Classification system for sea trout populations
A system was developed for classification of sea trout populations into five categories, from poor to very good status. Spawning targets have not been developed for sea trout, and the knowledge of population sizes is poorer than for Atlantic salmon. Based on present knowledge, it is difficult to classify status by use of local population data. The system is therefore based on a combination of classification of impact factors, use of a statistical model developed for this purpose, use of local data where they exist, evaluation of exploitation rates, and comments from local managers. Sea trout populations will be classified by using this system later in 2018.

A statistical model was developed based on the change of population sizes in 69 sea trout rivers and ten different variables, which were eight human impacts, freshwater supply to the fjords, and status of the salmon population in the river. The model showed that a large proportion agriculture area within one kilometre from the river, habitat alterations and salmon lice impacted the sea trout populations negatively. Increased freshwater supply to the fjords impacted populations positively, likely because brackish water to some extent protect the sea trout against salmon lice. There was also a tendency that sea trout populations were in a poorer state where the salmon population was in a good state. Impact factors not included in the model may still impact sea trout. Factors having a strong impact in a few watersheds may not be included in the model. Proportion agriculture area within one kilometre from the river had the strongest negative impact, followed by salmon lice.

The quality norm for Norwegian salmon populations
A quality norm sanctioned by the Nature Diversity Act was adopted by the Norwegian government in 2013. The quality norm is a standard that all salmon populations should attain. The aim is to contribute to the conservation and rebuilding of salmon populations to a size and structure that will ensure diversity and productivity within the species, and that will ensure harvest opportunities.

For a population to attain a good enough standard according to the quality norm, the population must not be genetically impacted by escaped farmed salmon or other anthropogenic activities, it must have a large enough spawning population to reach the spawning target and it must provide a normal harvestable surplus (given the current ocean survival conditions). Hence, population status can only be classified as good when the spawning targets are attained after a normal exploitation of the population. When a population does not have a normal harvestable surplus, this indicates that local or regional human impact factors are negatively impacting them. A population that reaches the spawning target, but where the fishing is highly reduced or closed, does not have a good status. In total, 149 populations have been evaluated according to the norm.

Only 29 populations (20%) attained classification as having a good or very good quality, which is the requirement of the norm. This means that 119 populations (80%) did not meet the requirements of the quality norm. Of these, 42 populations (28%) had moderate quality and 77 populations (52%) had poor or very poor quality. Populations in Rogaland county and in the northern part of Trøndelag county had the best quality, whereas populations in Troms and Hordaland counties and in the southern parts of Trøndelag county had the poorest quality.

Most of the populations reached their spawning targets. The reason that many populations did not attain the quality norm was that they were genetically impacted by escaped farmed salmon (**figure 6**) and/or did not have a normal surplus, indicating that they were impacted by human impacts.

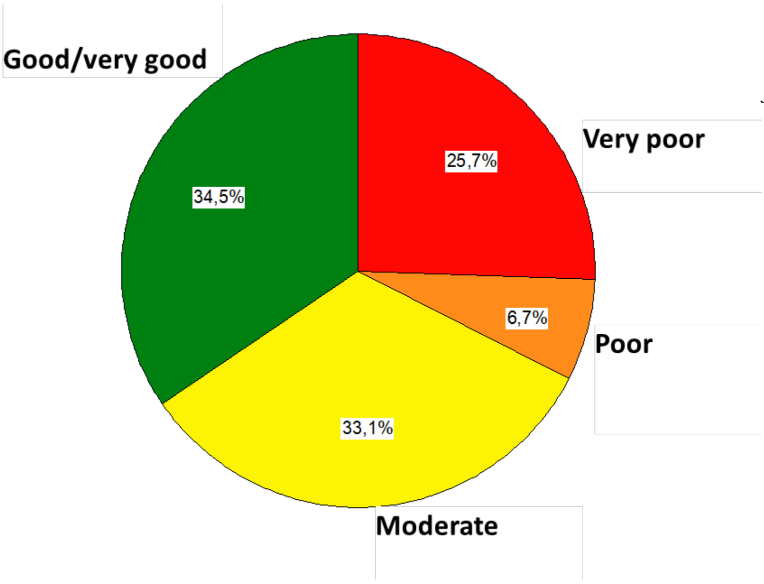

Figure 6. Genetic impact of escaped farmed salmon in Norwegian wild Atlantic salmon populations classified by the quality norm (i.e., genetic introgression). Proportion of populations with no genetic impact is shown in green (good/very good status), with significant genetic impact in red and orange (very poor and poor status) and with indications of genetic impact in yellow (moderate status). The classification is based on genetic analyses of individual salmon born in and collected from the rivers.

The classification of populations according to the quality norm is published in Norwegian: http://hdl.handle.net/11250/2438379

References to scientific publications of work from the Norwegian Scientific Advisory Committee for Atlantic Salmon

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