# Status of wild Atlantic salmon in Norway

**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 annual report of 2017.

The committee is appointed by the Norwegian Environment Agency. The mission of the committee is to evaluate status of salmon and the relative importance of different threat factors, give science-based catch advice and give advice on other subjects related to wild salmon management. The committee only gives advice related to biological questions, and do not consider socio-economic challenges in the management of salmon.

Current members of the committee are 13 scientists from seven different institutes/universities: 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 2017 annual report

Numbers of wild Atlantic salmon returning from the ocean to Norway (pre-fishery abundance) has been low during the last 10 years. In 2016, about 470 000 Atlantic salmon returned from the ocean, which is less than half of the numbers returning during the 1980s. In the vast majority of the populations, there are currently sufficient numbers of spawning females to attain the spawning targets (conservation limits), because exploitation has been strongly reduced to compensate for the decline. However, reduced wild salmon abundance has reduced the harvestable surplus of salmon available for marine and river fisheries.

A major reason for reduced salmon populations is the general and large-scale reduction in survival at sea. In addition, human impact factors contribute significantly to the reductions on a local and regional level. Salmon populations in Middle and Western Norway have been most severely reduced. When populations reach their spawning targets but do not have the expected harvestable surplus according to current ocean survival conditions, they are likely negatively impacted by local or regional human impact factors (other than exploitation).

The committee has identified escaped farmed salmon as the greatest threat to Norwegian wild salmon. Genetic changes due to farmed salmon introgression - because escaped farmed salmon have spawned with wild salmon in the rivers - are documented in many rivers. Such genetic changes may be irreversible. Several studies indicate that wild and farmed salmon hybrids are less adapted to life in nature. Large-scale experiments in natural rivers have shown that genetic introgression from farmed salmon can result in reduced production and survival, and thus reduced adult returns to the rivers. A new study has also shown that gene flow from escaped farmed salmon alters the life history of wild salmon in Norwegian rivers. Individuals with high levels of introgression had altered age and size at maturation, and the proportion of large salmon that had been at sea for more than two years was reduced among these fish.

Salmon lice are identified as the second largest threat to Norwegian salmon. In this report, the committee estimated the likely effect of salmon lice on the population level in an analysis that - for the first time - covered the entire country. The annual loss of wild salmon to Norwegian rivers due to salmon lice was estimated at 50 000 adult salmon for the years 2010-2014. This corresponds to an annual loss of 10% of wild salmon due to salmon lice, on a national level (*i.e.*, 10% of the total pre-fishery abundance). Other infections related to fish farming may also be a major threat to Norwegian salmon, but the knowledge level of this impact factor is poor.

The introduced parasite *Gyrodactylus salaris*, freshwater acidifiation (due to deposition of long-range transported air pollutants) and overexploitation have also had a large negative impacts on Norwegian Atlantic salmon in the past. Due to mitigation measures, these impacts are strongly reduced. After the introduction of management based on conservation limits in 2009, overexploitation was strongly reduced and is no longer considered a major impact factor. Hydropower regulation and other habitat alterations affect many wild salmon population, but the likelihood of causing further losses of Atlantic salmon is low. However, the potential for further mitigation measures is large for hydropower regulation and other habitat alterations.

The 2017 annual report is published in Norwegian: https://brage.bibsys.no/xmlui/handle/11250/2446896

## Extended summary

**Catches and pre-fishery abundance**
In 2016, the total reported catch in sea and river fisheries was 154 000 salmon (612 metric tons). In addition, 25 200 salmon (117 metric tons) were reported caught and released (21% 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**). In the early 1980s, the pre-fishery abundance was more than one million salmon, whereas the average during the last five years was 478 000 salmon. Hence, the pre-fishery abundance was more than halved from 1983-1986 to 2013-2016 (55% reduction). The pre-fishery abundance was estimated at about 470 000 wild salmon in 2016. Pre-fishery abundance and catches in numbers were lower in 2016 than in 2015, but the catches in mass was larger (pre-fishery abundance was 522 000 salmon and the catches 162 700 salmon with a total mass of 583 metric tons in 2015).

The main decline has been among the small salmon (salmon of body mass < 3 kg, predominately one-sea-winter). The pre-fishery abundance of small salmon has gradually declined from high levels in the mid-1980s, except a temporal increase around year 2000. Small salmon are usually salmon that have stayed at sea for one winter (one-sea-winter salmon), but during 2007-2016, 13-29% of the small salmon had stayed 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 pre-fishery abundance of larger salmon (salmon of body mass > 3 kg) has not changed significantly from the 1980s.

The temporal changes in pre-fishery abundance differ among regions. Since 1989, when the offshore drift net fishery was banned, the pre-fishery abundance including all size classes has declined in Middle and Western Norway, been stable in Northern Norway (when the Tana watercourse is excluded) and increased in Southern Norway. The abundance of small salmon has been reduced in all parts of the country (compared to the period 1989-1993). 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 reduction of the pre-fishery abundance compared to the rest of Northern Norway, with a 59% reduction in the pre-fishery abundance since 1989 (1989-1993 compared to 2013-2016). 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, similar to 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 River Drammen 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. From 2006, the survival of two-sea-winter salmon has been at the same level as, or larger than, the one-sea-winter salmon, which indicates that some of the salmon have delayed their maturation.

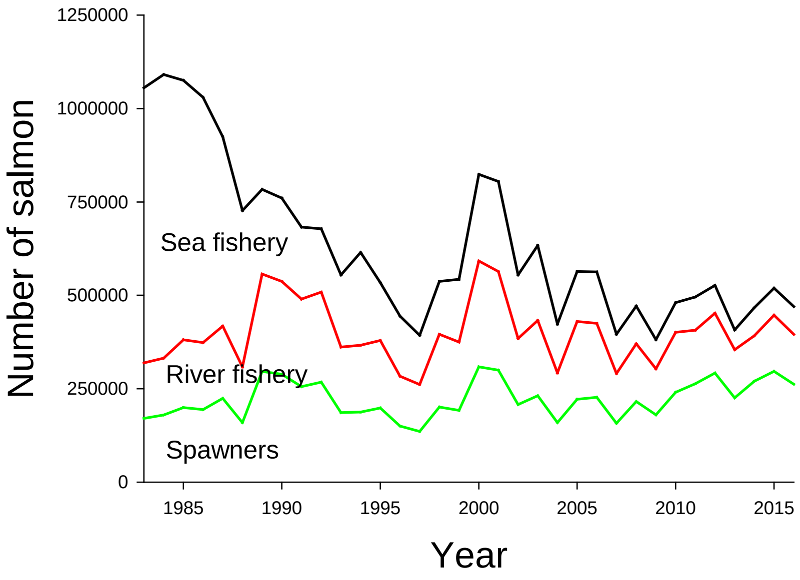


***Figure 1.*** *Estimated number of wild salmon returning from the ocean towards Norwegian rivers (pre-fishery abundance, black line), number of wild salmon entering the rivers (red line, i.e., the number left after catches in sea fisheries), and the number of wild salmon left for the spawning populations (green line, i.e., the number left after catches in sea and river fisheries) during the period 1983-2016.*

**Attainment of spawning targets**

In the 2017 report, attainment of spawning targets (conservation limits) and exploitation in 190 salmon rivers for the period 2013-2016 were evaluated. 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 and procedures for management according to spawning targets and management targets for Norwegian rivers are 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 84% 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 one of 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 2013-2016 (**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 is 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) was 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, and in 2016, 16% of the salmon returning to the coast was caught in the sea.

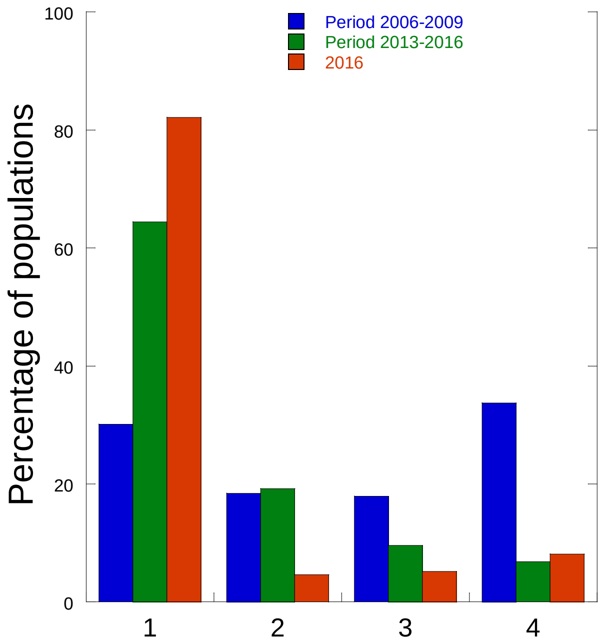


***Figure 2**. Proportion (%) of the evaluated salmon rivers in category 1: the management target is attained, category 2: there is a risk that the management target is not attained, category 3: the management target is likely not attained, and category 4: the management target is far from being attained. Data are given for the periods 2006-2009 and 2013-2016, as well as for 2016 only.*

The proportion of the salmon returning to the coast caught in the rivers has been reduced from 2011. In 2016, 28% of the salmon returning to the coast was caught in the rivers. Of those salmon entering the rivers (after marine exploitation), exploitation has been markedly reduced from 1983-1988 to 2016 (**figure 3**). On average, 47% of the salmon were killed in fisheries until 2005, whereas in 2015 and 2016, 34% 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.

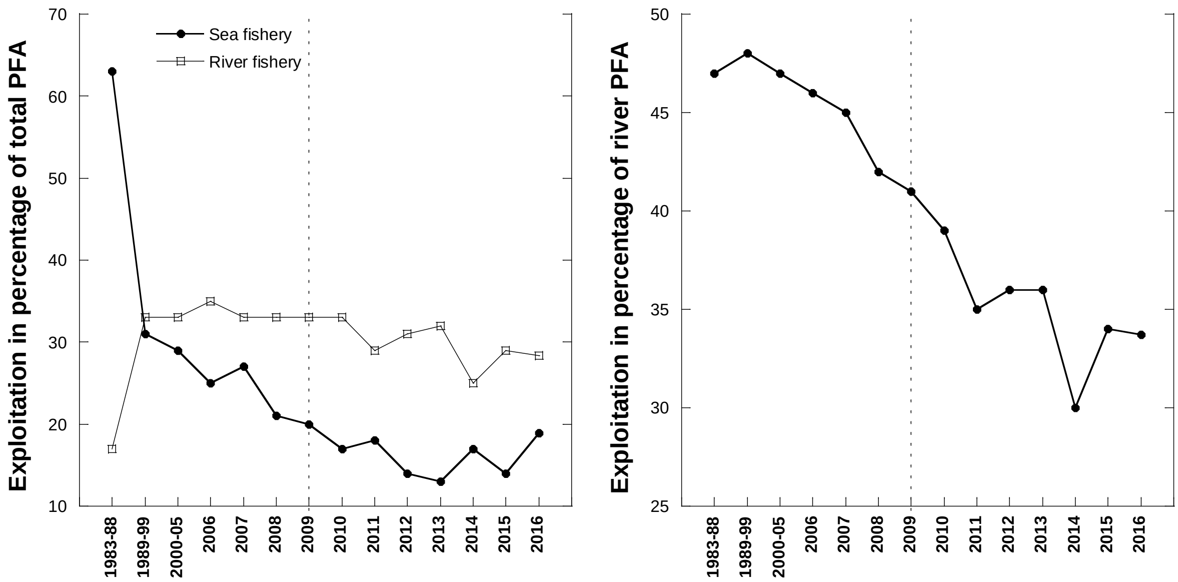


***Figure 3**. Left graph: Exploitation of salmon given as percentage of the pre-fishery abundance (Total PFA, in numbers) for the periods 1983-88, 1989-99 and 2000-05 (averages) and thereafter as annual values. Right graph: Exploitation of salmon in the rivers given as the proportion of salmon entering 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 2016, 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 in the rivers, 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 2014-2016.

**Escaped farmed salmon**

In 2016, 1 180 000 metric tons of farmed Atlantic salmon were produced in Norway. It was reported that 131 000 farmed salmon escaped from fish farms. The mean annual number of escaped salmon reported during the last 10 years was 212 000 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 2016, the average was 4.1%. The proportion of escaped farmed salmon has been larger during monitoring of the rivers in the autumn shortly before spawning than during the angling in the summer, likely because the escaped farmed salmon tend to enter the rivers later in the season than the wild salmon, and often towards the end or after the angling season. The proportion escaped farmed salmon in the monitored rivers in the autumn was on average 6.6% in 2016 (**figure 4**). In comparison, the average proportion was greater than 20% in the years 1989-1998. In the last seventeen years, the proportion has varied between 6% and 18%. From 2006, there has been a weak decline in the proportion of escaped farmed salmon during monitoring in the autumn.

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 populations in 61 of 175 studied rivers. Further, there were indications of genetic introgression from escaped 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 fish 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 mitigation 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 aim to protect 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 2016. In addition to changing the populations genetically, hybridization between wild and escaped farmed salmon is also shown to reduce salmon production and survival.

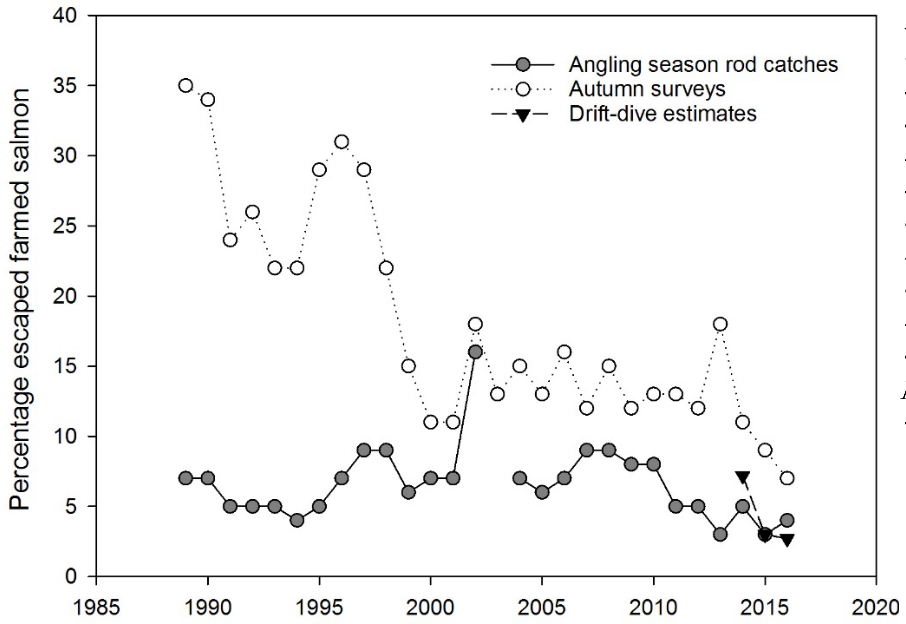


***Figure 4****. Incidence of escaped farmed salmon in samples collected during the angling season, and in monitoring immediately before spawning in the autumn during the period 1989-2016. In recent years drift-dive estimates are also included in monitoring. Data are given as average proportion of escaped farmed salmon in monitored rivers.*

**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 are able to 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 are able to hinder expansion of negative impacts in the future.

Escaped farmed salmon, salmon lice, the introduced parasite *Gyrodactylus salaris*, freshwater acidification, infections related to fish farming, hydropower regulation and other habitat alterations were identified as population threats (**figure 5**). Of these, escaped farmed salmon and salmon lice were identified as expanding population threats, affecting populations to the extent that they may be critically endangered and lost, with a large likelihood of causing further reductions and losses in the future.

Infections related to fish farming was also identified as a threat that can significantly impact salmon, and with a large likelihood of causing further reductions and losses in the future. Compared to the other population threats, 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 particular impact factor is needed.

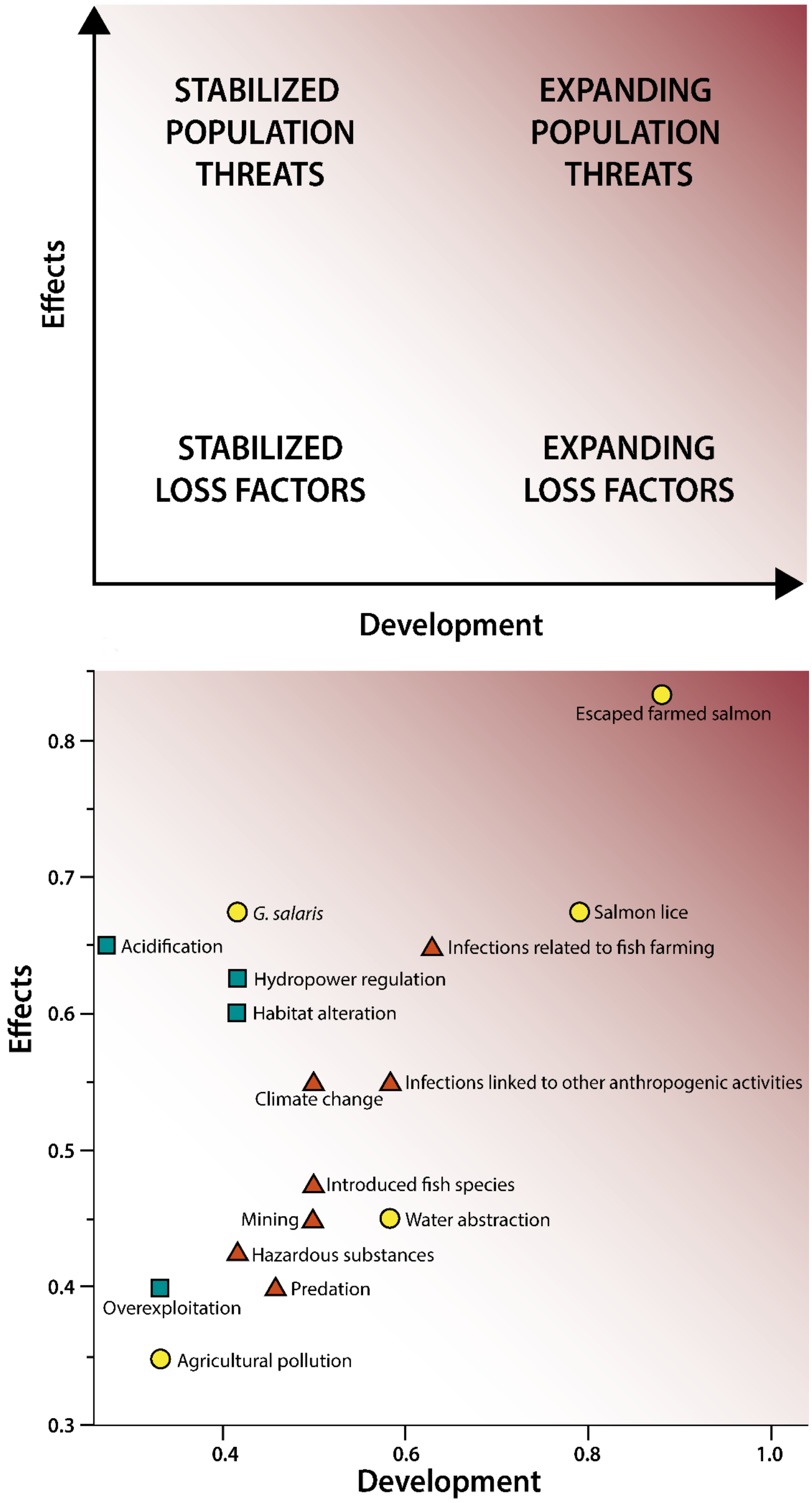


***Figure 5**. Upper graph: The classification system developed to rank different anthropogenic impacts to Norwegian Atlantic salmon populations along the effect and development axes. The four major impact categories are indicated, but the system is continuous. Background coloring indicate severity of impacts, with dark as the most severe.*
*Lower graph Location within the classification system of the 16 impact factors considered in 2015. 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.*

*G. salaris*, freshwater acidification, hydropower regulation and other habitat alterations were identified as stabilized population threats, which have contributed to populations becoming critically endangered or lost, but with a low likelihood of causing further loss. *G. salaris* is more stabilized the last three years than during earlier analyses, 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. These measures have also reduced the risk of transmission to new rivers. Freshwater acidification is the most stabilized among the population threats due to large-scale liming programs. Regarding impacts of hydropower regulation and other habitat alterations, there is a potential for accomplishing further mitigation measures to reduce the impact.

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.

**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 and Nord-Trøndelag counties had the best quality, whereas populations in Sør-Trøndelag, Troms and Hordaland counties 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 and/or did not have a normal surplus, indicating that they were impacted by human impacts.

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**

Forseth, T., Fiske, P., Gjøsæter, H. & Hindar, K. 2013. Reference point based management of Norwegian Atlantic salmon populations. Environmental Conservation 40: 356-366.

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