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Oslo, Norway, 30 May 2023

Environmental impact from salmon farming

Compilation of information on the effects of escaped farmed salmon and salmon lice on wild Atlantic salmon, and on other environmental impacts from fish farming.

The information is compiled for ESA by Norwegian Salmon Rivers, The Norwegian Association of Hunters and Anglers, Norwegian Friends of the Earth and Sabima (May 2023).

In addition to the information hereby submitted, we also underline that ESA may use previously submitted information on aquaculture from our organisations, i.e. the letter of concern (May 2014), the complaint (Nov 2015) and the letter of information regarding the RBMPs for 2016-2021 (Jan 2019).

Introduction

According to the 2022 report on the status of Norwegian wild Atlantic salmon[i] it was estimated that about 403 000 wild Atlantic salmon (S*almo salar - hereafter referred to as either "Atlantic salmon" if wild, or "farmed salmon" if derived from aquaculture*) were set on returning to the Norwegian rivers from the ocean in 2021. This is the lowest number ever recorded and should be compared to the production of 1 558 000 metric tons of farmed salmon in 2022, which equals about 450 million farmed salmon, at any time, in fish farms along the Norwegian coast.[1]

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[i] Annual reports on the status of Norwegian wild Atlantic salmon are presented by the Norwegian Scientific Advisory Committee for Atlantic Salmon. "*The committee is appointed by the Norwegian Environment Agency to evaluate status of salmon and importance of different threats, and to give science-based catch advice and advice on other issues related to wild salmon management*." (From the English summary of the 2022 report[1b])

The year-round ubiquity of innumerous hosts, provided by the fish farms, is the explanation why salmon louse (*Lepeophtheirus salmonis*) plagues Norwegian coastal waters. Atlantic salmon has finally been included as a quality element in the River Basin Management Plans (RBMPs). It is important to note that Atlantic salmon migrates between the rivers and the ocean, whilst the Sea trout (*Salmo trutta trutta*) migrates between the rivers and the fjords, meaning that the trout, unlike *Atlantic* salmon, not only passes through the belt of salmon lice along the coast, but remains in it for their entire saltwater phase. Salmon lice therefore is an even greater threat to Sea trout than *Atlantic* salmon, according to the Institute of Marine Research[2, 3].

Salmon lice and escaped farmed salmon - impact on wild Atlantic salmon and Sea trout

The number of Atlantic salmon returning from the ocean to the coast of Norway each year is now less than half of the level recorded in the 1980s (Figure 1). The reasons for the decline of Atlantic salmon are impacts of human activities such as hydropower and physical and chemical derogation of habitats. However, the biggest and unstabilized threat is escaped farmed salmon, salmon lice and infections related to salmon farming, according to the Norwegian Scientific Advisory Committee for Atlantic Salmon[1]. This Advisory Committee states that the present mitigation measures are insufficient to stabilize and reduce the threat against wild salmon from salmon lice induced mortality and genetic hybridization with escaped farmed salmon.

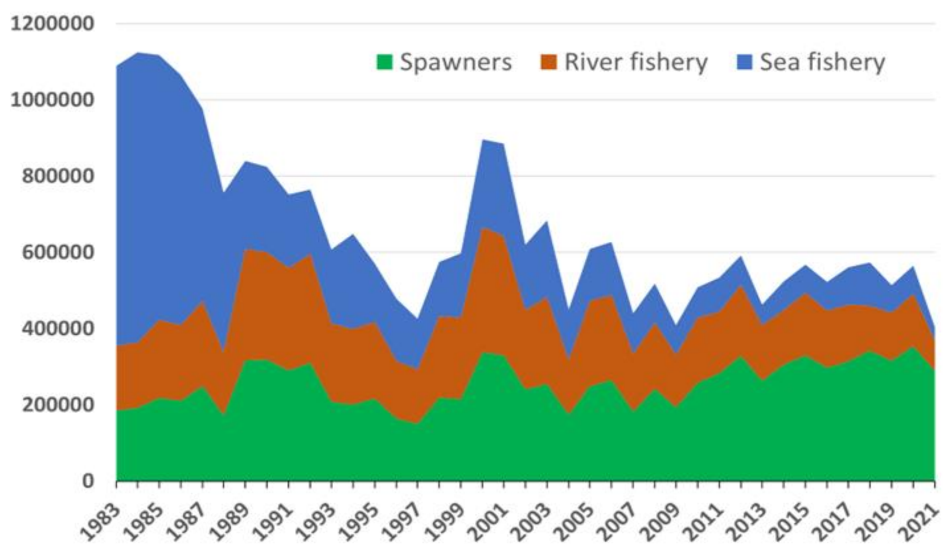

Figure 1 *from the report Status of wild Atlantic salmon in Norway 2022, by the Norwegian Scientific Advisory Committee for Atlantic Salmon[1]:* ***Estimated number of wild salmon returning from the ocean towards Norwegian rivers each year, divided in number of fish caught in the sea fisheries, number of fish caught in the rivers during angling, and the number of fish left for spawning in the rivers during the period 1983-2021.***

Climate change, invasive species like the Pink salmon (or humpback salmon) (*Oncorhynchus gorbuscha*) and the ectoparasite *Gyrodactylus salaris,* are also cumulatively and significantly impacting Atlantic salmon populations. The cumulative threat picture increases the need to mitigate the well documented threat posed by the salmon aquaculture industry.

Escaped farmed salmon

In 2021, 1 558 000 metric tons of farmed salmon were produced in Norway. According to the official statistics of escaped farmed salmon, reported by the companies, the mean annual number of escaped farmed salmon during the last 10 years was 139 000 salmon. Studies by the Institute of Marine Research indicate that the actual numbers of escapes during 2005-2011 were 2-4 times higher than the reported numbers[4]. Since then, no updated estimates have been made for this discrepancy between reported and actual escaped farmed salmon[5].

According to the 2022 annual report from the Scientific Advisory Committee for Atlantic Salmon, the proportion of escaped farmed salmon in angling catches in monitored rivers during the summer has averaged 3-9% in most years since 1989. The proportion of escaped farmed salmon has been larger during monitoring in the autumn shortly before spawning than in the angling catches in the summer, likely because the escaped farmed salmon tend to enter the rivers later in the season than the wild salmon. In the last ten years, the proportion of escaped farmed salmon in rivers during autumn monitoring has varied between 3,4% and 18,0%. While the proportion has declined during the last ten years, new studies show that there is widespread genetic hybridization of escaped farmed salmon in the Norwegian Atlantic salmon population. Indications of genetic hybridization from escaped farmed salmon in the wild population was found in two thirds (150 of 239) of the screened rivers, of which 68 populations were severely impacted (28% of the screened populations)[6]. Another study showed how gene flow from escaped farmed salmon has altered the life history of wild Atlantic salmon in Norwegian rivers; individuals with high levels of hybridization from farmed fish had altered age and size at maturation[7].

Although continually substantiated, the understanding of potential negative effects of escapees has been solid for long and we refer to the Commission Staff Working document On the application of the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) in relation to aquaculture, from 18 may 2016[8], which says *"From the point of view of the ecosystem, the potential effects of escapees from aquaculture are well documented, studied and modelled although conclusions are often disputed. Escapees of non-indigenous species may alter the structure and functions of marine ecosystems by habitat modification and competition for food and space with indigenous organisms. This has the effect of reducing their abundance, biomass and spatial distribution. Farmed indigenous species are often selectively bred for many generations and may therefore differ genetically to wild populations; this raises concerns for the fitness and productivity of wild populations if interbreeding with escapees occurs."*

The scientific evidence that incidence of escaped farmed salmon will negatively affect Norwegian wild salmon, both ecologically and genetically, has grown in recent years.

Even though the proportion of escaped farmed salmon has decreased in monitored rivers, the Advisory Committee states[1] that 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 significantly genetically impacted by hybridization with farmed salmon, and the continued addition of escaped farmed salmon challenges the recovery of the natural genetic composition of wild populations. According to the Advisory Committee, the official goal of protecting the genetic integrity and variation of Atlantic salmon populations cannot be met with current levels of escaped farmed salmon in the populations. In addition to changing the Atlantic salmon populations genetically, hybridization between wild and escaped farmed salmon is also shown to reduce salmon production and survival.

Salmon lice

The number of Atlantic salmon returning to the rivers each year is significantly reduced due to mortality caused by salmon lice (figure 2). This reduction threatens Atlantic salmon populations in the most impacted areas and has significantly reduced the harvestable surplus for angling and marine fisheries over large parts of the country. In 2010-2014, the Advisory Committee estimated that 50 000 fewer Atlantic salmon returned from the ocean to Norwegian rivers each year due to the impacts of salmon lice. For 2018, the estimated reduction was 29 000 Atlantic salmon due to salmon lice, and in 2019 a reduction of 39 000 Atlantic salmon was estimated.

The impact of salmon lice is most severe in western and middle Norway (see figure 4 in the Advisory Committee report[1]). In 2019, the areas severely impacted in western and middle Norway had increased. Many Atlantic salmon populations in these areas have been heavily impacted by salmon lice for many years and are now in a very poor state. Several threats impact these populations, including escaped farmed salmon, but heavy salmon lice burdens are probably the reason that they are not able to recover.

The Advisory Committee concludes that an increased number of populations are endangered by salmon lice, and that there is a high risk that more populations will be endangered. Sufficient mitigation measures to improve the situation are not implemented, and the production of farmed salmon is increasing.

In addition, a new article published in the journal Proceedings of the Royal Society B. shows that previous estimates of mortality on Atlantic salmon from salmon lice derived from the salmon aquaculture industry are likely underestimated[9]. It turns out that the widely used method for assessing the degree of impact from salmon lice, does not capture the whole picture in terms of lice impact.

Furthermore, it has probably been underestimated because salmon lice are becoming increasingly resistant to treatments. In addition, the salmon may be partially negatively physiologically affected by the medication.

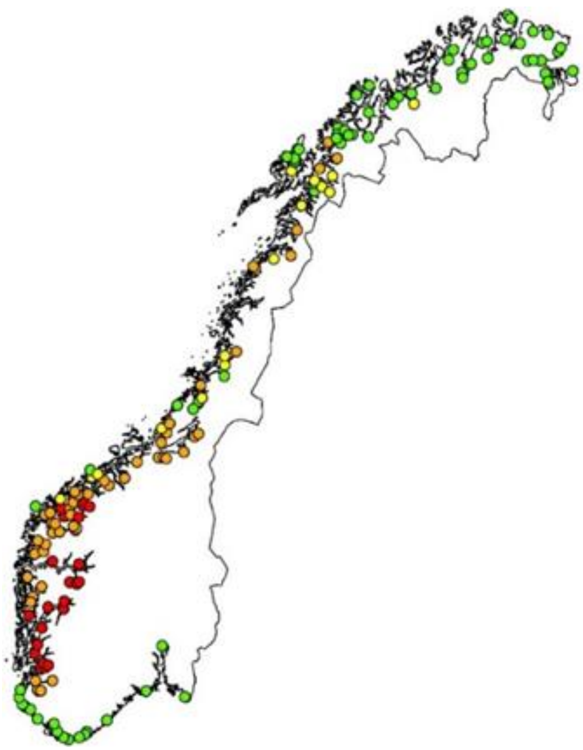

Figure 4 *from the report Status of wild Atlantic salmon in Norway 2022, by the Norwegian Scientific Advisory Committee for Atlantic Salmon[1]:* ***Estimated impacts of salmon lice on the abundance of adult Atlantic salmon returning from the ocean for spawning in 167 rivers in 2019. Green symbols: < 5 % reduction in number of returning spawners. Yellow: 5.0-9.9 % reduction. Orange: 10-30 % reduction. Red: > 30 % reduction***

Major threats to Norwegian wild salmon

The Advisory Committee has developed a classification system to rank different anthropogenic impacts to Atlantic salmon (figure 5, in the Advisory Committee report: Status of wild Atlantic salmon in Norway 2022). Assessments according to this system are updated annually by the Advisory Committee.

Norway is a member of The North Atlantic Salmon Conservation Organization (NASCO), established by the Convention for the Conservation of Salmon in the North Atlantic Ocean, in 1984. In Norway's *Annual Progress Report on Actions taken under the Implementation Plan for the Calendar Year 2022*[10] we find in the summary:

"In 2021, the pre-fishery abundance was estimated at about 403 000 wild salmon, lower 2021 than ever recorded before (time series starting in 1980). Efforts to map sea survival are increasing by the establishment of new monitoring rivers, and so far, results show that sea survival vary significantly among rivers and years. The management targets for the period 2018-2021 were attained, or likely attained, for 93% of the populations. This is among the best results regarding attainment of the management targets since the first evaluation was done in 2009. In two thirds (150) of the 239 screened rivers, there were indications of genetic introgression from escaped farmed salmon in the wild population, of which 68 populations were severely impacted. The number of salmon returning to the rivers each year is reduced due to mortality caused by salmon lice. This reduction threatens salmon populations in the most impacted areas, and has significantly reduced the harvestable surplus".

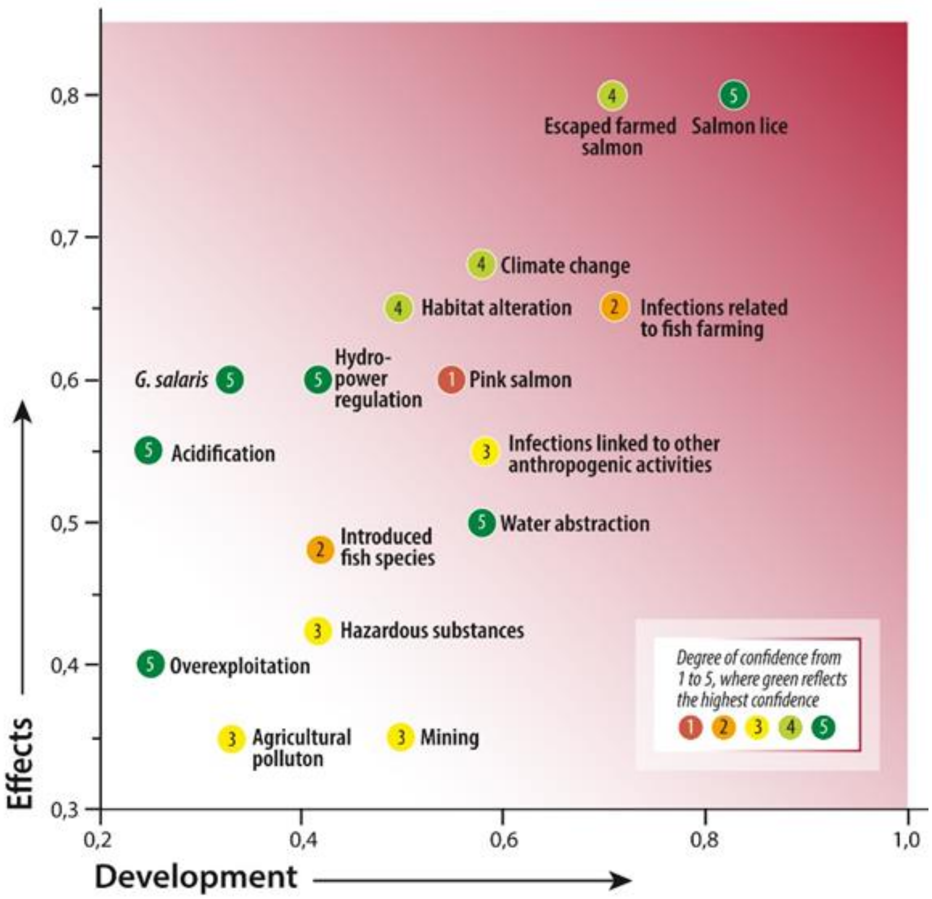

Figure 5 *from the report Status of wild Atlantic salmon in Norway 2022, by the Norwegian Scientific Advisory Committee for Atlantic Salmon*[1]*:* ***Ranking of 16 impact factors considered in 2021, according to their effects on wild Atlantic salmon populations, and the likelihood of a further negative development. Confidence for the assessment of effect by each threat is indicated by the colour of the markers, where green indicates the highest confidence level and red the lowest.***

It is also well documented that salmon lice from the salmon aquaculture industry damage other anadromous species, such as sea trout (*Salmo trutta* L.). A report from the Institute of Marine Research estimates that in western Norway more than 50% of sea trout are infected with harmful or lethal amounts of salmon lice[11]. It has also recently been documented that salmon lice can cause reduced growth in sea trout[12].

Assessment of the impact from the salmon farming industry

The negative impact from escaped farmed salmon and coupled with the unnatural abundance of salmon lice due to salmon aquaculture has been identified for the last decade as the largest threats to Atlantic salmon populations by far (figure 5, in the Advisory Committee report). This must be reduced or eliminated in order to fulfil the objectives in the Water Framework Directive. Escaped farmed salmon and salmon lice are by the Advisory Committee regarded as expanding population threats, which means they affect Atlantic salmon to the extent that their populations may be critically endangered or lost, and are likely to cause even further reductions. Salmon lice constitutes the greatest risk of causing further losses in the future, and current mitigation measures are insufficient to hinder expansion of negative impacts in the future.

Inorganic pollution – Copper (Cu)

The main source of copper from aquaculture is its use as antifoulant on the fish cages/nets. There is also copper in feed spills and faeces. The Institute of Marine Research has compiled available knowledge on the release of copper from fish farming[13]. The report states that there is little knowledge of how much copper that "bleeds" into the water through ionization and there is no monitoring of copper in the water column. This study however showed that the copper releases are large enough for the researchers to expect negative effects on organisms in the vicinity of the fish farms. The Institute of Marine Research has also begun to look at the environmental effects on mussels (Bivalvia sp)[14].

The Institute of Marine Research found that leaked copper can give a substantial contribution to the total copper concentration in a fjord system. Levels depend on water circulation etc in the fjord. Monitoring showed significant increase in copper levels in the remote zone (>1 km from the nearest fish farm) in about a third of the sites monitored. The Institute of Marine Research has concluded that "*Copper from fish farming, probably has a negative impact on the environment*"[15].

-1,000 tonnes or more of environmentally harmful copper is released from the salmon farms every year. In comparison, a mesh washing plant on land is only allowed to discharge two kilograms per year. We are worried, says researcher at the Institute of Marine Research, Bjørn Einar Grøsvik[16] (our translation).

Regarding the use of copper as antifouling agent on the net pens, the Norwegian Environment Agency writes on its website (our translation): "The pollution control authorities expect that aquaculture companies follow up on emissions of copper and the environmental impact this has"[17].

Organic pollution

The annual *Risk report on Norwegian fish farming 2023*[18], by the Institute of Marine Research, looks at production mortality and environmental effects. The report presents an overview for each of the administrative «areas of production». This latest report concludes that there is a lack of knowledge due to limited monitoring data and research, and thus difficult to say anything about the possible effects on vulnerable habitats of, for example, nutrient salts, particulate organic matter, copper or delousing chemicals.

The risk report points out challenges for each production area. As an example, for "production area no 3", the report says (our translation): "*This will result in emissions of 2 016 kg of dissolved nitrogen and 274 kg of dissolved phosphorus per km² annually. This production area has the highest annual emissions of dissolved nutrient salts along the Norwegian coast. This production area thus has the highest estimated increase in phytoplankton production due to emissions from fish farming (21%) in Norway."*

Aquaculture is by far the largest source, produced by human activity, to the coastal waters. Aquaculture is also a large source of nitrogen, compared with agriculture and natural runoff. This is clearly illustrated in the graph below:

Phosphorus input to coastal waters from different sources

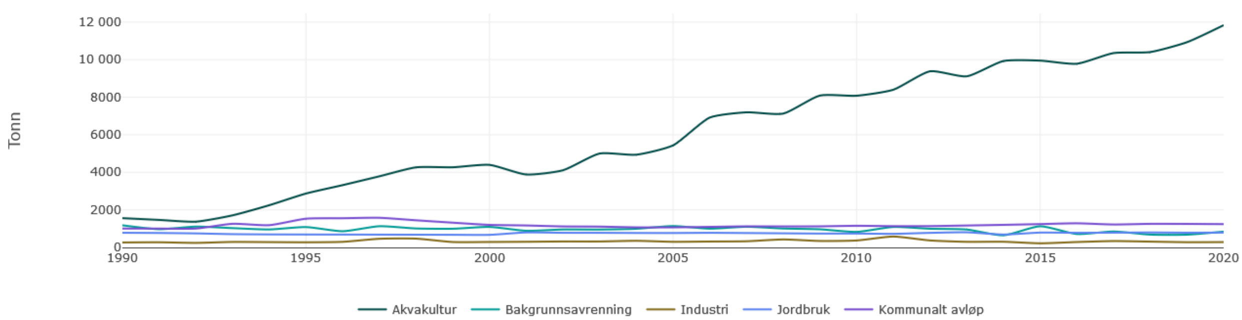

Figure: Graph of phosphorus input from different sources: aquaculture (darkgreen line, now well above 10 000 tonnes), background runoff, industry, agriculture and urban (municipal) waste water, from Miljostatus.no[19].

There are various ways of estimating how much phosphorus and nitrogen (nutrient salts) are released from a fish farm. The methods referred to by the Environment Agency shows that a production of 780 tonnes of salmon is comparable to how much nutrient salts would be released into coastal waters if a town of 7 800-11 700 people piped their effluent strait into the sea.

The Norwegian institute for water research (NIVA) has mapped effects of high input of nutrient salts on ecosystems in the Oslofjord and other sites along the coast and warn of continued eutrophication[20]. When interviewed by the Norwegian broadcasting channel, Eli Rinde, researcher at NIVA, warns that the observed signs of excessive growth of filamentous algae at several sites along the coast may be related to the input of nutrient salts from aquaculture[21]. A clear indication of poor environmental status of large areas of the important shallow coastal waters, is that sugar kelp forests are now on the list of endangered types of nature, listed as endangered (EN)[22].

Aquaculture and the environmental status of coastal waters and rivers

Norway has not updated the guidelines in line with the recommendations in Staff Working Document on the WFD and aquaculture of 18 May 2016[8].

In the 2022 Norwegian conference on water environment, an annual event hosted by the Norwegian water authorities, there was a parallel session on salmon aquaculture and the WFD. The Ministry of Trade, Industry and Fisheries and the Ministry of Climate and Environment, had a joint presentation on the theme of aquaculture in the RBMPs[23]. In the presentation, the two ministries declared that, in rivers with high levels of escaped farm fish, the environmental objectives of the WFD will not be reached in the 2022-2027 planning cycle, and that new measures are needed in order to deal with salmon lice and escaped farm salmon.

Investigations and planning as a measure

In their presentation, the two ministries presented their four most important measures for reaching the environmental objectives, slide 14, (our translation):

- Investigate how the Norwegian “traffic light system[24]” affects the work to achieve the goals set in the quality standard for wild Atlantic salmon
- Set a pace to prepare criteria for including sea trout in the traffic light system
- Investigate how the location/distribution of salmon farms can be altered with a view to the protection of river specific populations of Atlantic salmon that are particularly exposed due to the pressure from salmon lice
- Follow up the ongoing work on an integrated and more efficient system for monitoring and removal of escaped farmed fish and future criteria for a general solution to track the escaped fish

These measures are perceived as too vague, and the pace too slow. For instance, when asked about the timeframe for developing a method for including the impact on Sea trout, it was clear that the Ministries had no deadline for this work.

For an up to date summary of publicly available, established knowledge, about the environmental effects of aquaculture, we also refer to another presentation at the national conference on water environment, titled “Risk assessment of Norwegian fish farming — Effects on the environment”, by the Institute of Marine Research[25].

The River Basin competent authorities submitted a summary of input from the public hearing of the RBMPs for 2022-2027 to the group of agencies working with the implementation of the WFD[26]. (This summary from the competent authorities does not list all input in the hearing, just the points that require clarifications or other action from the agencies, or their ministries.) The competent authorities of the river basins explain that there are doubts with regards to the suggested measures and whether they are sufficient to reach the environmental objectives regarding impact of salmon lice and genetic hybridization with escaped farmed salmon, and also whether the authorities have the tools and measures needed. The competent authorities list 14 points regarding impact from aquaculture for which they ask for various types of clarification or point at needed management tools.

Missing transitional waters

Aquaculture, once associated with family driven small enterprises, today an industry of unfathomable turnover and ecological footprint, is no doubt a special Norwegian interest and as neither Norway and no longer the UK (which also has, or had, a certain salmon production) are members of the EU, it might be too much to ask for the WFD and EU Taxonomy to build good regulations and standards that limit negative environmental impact. From the NGO perspective, we see a clear change in that the Directorate of Fisheries no longer works to protect the aquaculture as a Norwegian interest, but now acknowledges the scientific evidence of the various negative impacts of the industry. In terms of the implementation of the WFD, we (the NGOs) consider several years lost and honestly question the possibilities of reaching or sustaining good environmental status along the coast if Norway sticks to the plan of allowing the aquaculture industry grow five times bigger. A remaining weakness from when the WFD was to be implemented, and the authorities wished to keep impact from aquaculture out of the WFD implementation, is the decision to cut out transitional waters as a water type in Norway.

As we explained in our original complaint regarding biological effects of aquaculture[27], submitted in 2015 by us and other NGOs, When the WFD was introduced in Norway, it was decided not to use the category ‘transitional waters’.[28] Instead, Norway uses freshwater influenced categories of coastal water, such as “Fjord influenced by freshwater”, “Fjord heavily influenced by freshwater” and “Specific Water

Bodies". This means that there is no category of water between water bodies categorized as rivers and water bodies categorized as coastal waters.

Norwegian fjords are different from typical estuaries of many large European rivers, and the arguments for cutting out transitional waters were explained in the characterization report from May 2013[29]. The problem with using coastal water types is that fish are not included among the biological quality elements in the classification system for coastal waters[30]. This in turn means that the reported environmental status of fjords, estuaries and other brackish water areas does not reflect the population status of important species such as eel, sea trout and arctic char, which all spend substantial time in the fjords and transitional waters – habitats heavily influenced by aquaculture in Norway.

Related issues

It should be noted that, although not directly related to the WFD, control and management of aquaculture involves several authorities, including the municipalities. The Norwegian Food Safety Authority and the Norwegian Veterinary Institute have roles related to health of domestic animals, in this case health and welfare of fish in aquaculture. The Veterinary Institute report that the total number of farmed salmon that died prior to slaughter was 54 million (15.5 percent) in 2021[31], just to illustrate the situation.

In addition to the farmed fish, they authorities also overlook the use of cleaner fish. Cleaner fish were introduced as a biological control measure to keep numbers of salmon lice down in fish farms. However, in an industry the size of the Norwegian aquaculture, even marginal errors result in gross numbers: 50 million cleaner fish die every year, or 150 000 a day, in Norwegian fish farms[32].

Use of farmed and wild cleaner fish in the production of Atlantic salmon and Rainbow trout, by species.		
	2021	
Species	Number (individuals)	Value in NOK
Lumpfish (Cyclopterus lumpus)	27 655 000	554 750 000
Ballan wrasse (Labrus bergylta)	4 603 000	227 396 000
Goldsinny wrasse (Ctenolabrus rupestris)	6 256 000	124 006 000
Corkwing wrasse (Symphodus melops)	6 940 000	115 198 000
Rock cook (Centrolabrus exoletus)	120 000	1 927 000
Total	45 575 000	1 023 277 000

Table 1: data from the Directorate of Fisheries showing the 2021 numbers of cleaner fish in aquaculture[33]. According to the statistics, numbers have varied from about 26.5 million in 2015 to over 61 million in 2019, with an average of about 46.5 million cleaner fish per year in Norwegian fish farms in the period 2015-2021.

Another issue in salmon farming, which affects the Atlantic salmon although not directly related to the WFD, is the presence and risks associated with various infections and diseases, like the infectious salmon anaemia (ISA)[34], [35].

Concluding remarks

Whereas aquaculture has become an important industry along the Norwegian coast, providing direct and indirect work opportunities for many, the negative environmental effects, and the accumulated pressure on the ecosystems, need to be acknowledged and repaired. It is clearly needed to assess how impacts from this industry are covered by the WFD.

We wish to refer to a notification letter from ESA concerning the complaint regarding aquaculture, dated 21 February 2017.[36] In the letter, ESA writes about the planned assessment of Norway's RBMPs that was to start in 2017. According to the letter, ESA has discussed our complaint with the Commission. The letter says: "*In light of the work that will begin shortly, we have decided to await the results of the assessment of Norway's RBMPs before taking further steps in the case. The project will provide us with an in-depth assessment of the aquaculture issue, as well as further general information on how Directive 2000/60 is being implemented in Norway*."

It is important that the WFD manages to recognize the environmental impact from aquaculture in coastal waters, and anadromous stretches of rivers, such that the environmental status of any given water body reflects the pressure on the ecosystem. As the Norwegian authorities lack sufficient tools to reach the environmental objectives of the WFD, apparent from the summary of input from the public hearing of the RBMPs for 2022-2027 by the River Basin competent authorities as well as the presentation by the Ministry of Trade, Industry and Fisheries and the Ministry of Climate and Environment in the 2022 national conference on water environment, it is important that the WFD work contributes to the prioritization of this topic. As there has still not been a thorough compliance check, and not an in-depth assessment of the aquaculture issue, we kindly ask ESA to proceed with this work.

Best regards,

Christian Steel, Director, The Norwegian Biodiversity Network (Sabima)

Torfinn Evensen, Director, The Norwegian Salmon Rivers (Norske Lakseelver)

Arnodd Håpnes, Head of conservation, Friends of the Earth, Norway (Naturvernforbundet)

Siri Parmann, Chief Advisor, The Norwegian Association of Hunters and Anglers (NJFF)

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