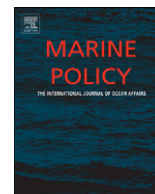




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Wild and farmed salmon in Norway—A review

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ABSTRACT

The Salmon industry in Norway includes three sectors, namely sea and river fishing for wild salmon, and salmon farming, or aquaculture. The three sectors provide different social, economic and cultural benefits to society, but also face many problems and challenges. They have different interests, practices, traditions and audiences, and are also administered by different authorities and regulated under varying management regimes and legislations. On the one hand, they complement each other in terms of product supply, employment creation and income; on the other hand, they face conflicts over management objectives and strategies. This paper provides an overview of the salmon sectors associated with their status, challenges and management regimes. It further analyzes their interests and conflicts over economic contribution and management. Finally, some potential solutions are suggested in an attempt to solve these conflicts.

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1. Introduction

Norway is blessed with a long coastline and rich marine resources. Throughout history, Norwegians have made a living by harvesting the sea through fishing, whaling and sealing. Among these activities, Atlantic salmon (*Salmo salar* L.) fishing has long held significant social, cultural and economic importance for Norwegians. Salmon was traditionally harvested as an important food source. Compared to the harvesting of other fish species, like cod, the salmon catch has been rather modest. However, it has become the prized fish species for fishermen, particularly for recreational anglers who fish salmon in the rivers [1].

The great number of salmon rivers in Norway offers the world's largest spawning ground for wild Atlantic salmon. However, the once abundant salmon resources have suffered a substantial decline in recent years. The catch from the sea is now almost half the level from the 1970s although the catch from the rivers remains relatively stable. Today, the sea fishing of salmon is a way of life, or undertaken as subsistence livelihood rather than for its commercial values. In contrast, recreational fishing in rivers yields greater social and economic values because of the vast number of anglers involved, and the substantial direct and indirect expenses used on fishing. It is reported that around 80,000 adult Norwegians enjoy this fishing annually [2]. Additionally, since the British upper-class

discovered this adventure in the middle of 1800s, thousands of foreign tourists have also been attracted to Norway for river salmon fishing. It is estimated that about 35,000 foreign anglers fished salmon in Norway in 2003 [3]. In the sea, on the other hand, only around 1100 fishermen take part in salmon fishing (Statistics Norway).

Since the 1970s, the emergence of salmon farming has changed the dynamics of salmon sectors as well as the whole seafood industry both in Norway and worldwide. Salmon farming in Norway started as a means to rebuild the livelihoods of rural fishing communities facing depressed economies due to declining wild fisheries in the late 1960s and the beginning of the 1970s ([4,5]). However, in a few decades salmon farming has dramatically expanded to the extent that farmed salmon has replaced wild salmon in production and markets. Norway has become the world's largest producer of farmed salmon, and farmed salmon is now the fourth biggest export commodity (behind oil, gas and metals; Statistics Norway). On the other hand, it seems clear that salmon farming is the main threat to the viability of wild salmon due to spread of diseases, escapees, environmental pollution, etc. (e.g., [6–10]).

Salmon sea fishing (or commercial fishing), river recreational fishing and farming have different stake holders, practices, traditions and management objectives and strategies. They are also managed by different governmental agencies. The Ministry of Environment is responsible for the wild salmon stocks and escaped farmed salmon, while the Ministry of Fisheries and Coastal Affairs is in charge of the salmon farming industry. These primary agencies have established and implemented a number of regulations and

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policies in response to the various issues that have emerged over time. However, conflicts over objectives and policies have arisen within the conservation, recreation and growth of the salmon aquaculture sector. There are conflicts between salmon farming and salmon fishing, but also within the wild salmon fisheries, i.e., fishing in the sea versus river recreational fishing.

The goal of this paper is to present an overview of salmon fishing and farming in Norway with an emphasis on management issues associated with objectives and strategies of salmon sectors. The paper is organized as follows: Section 2 presents an overview of wild salmon fisheries and salmon farming. In Section 3 the management of these sectors is first described and then the evolution of management systems and conflicts between them are discussed. The problems and challenges associated with each sector are also depicted. Section 4 concludes the paper and indicates some potential solutions.

2. Overview of salmon sectors

2.1. Wild salmon fishery

Atlantic salmon is distributed on both sides of the North Atlantic Ocean, and there are three main geographically distinct populations: the West Atlantic Salmon (North America), the East Atlantic Salmon (Europe) and the Baltic salmon (Baltic Sea). In addition, some also consider the salmon in the Barents Sea as a fourth population (e.g., [1]). The Norwegian stock is East Atlantic Salmon, and in the north, spawning salmon may be from the Barents Sea as well [1].

Atlantic salmon is an anadromous species, that is, it migrates between freshwater and seawater during its life cycle. The spawning and juvenile rearing takes place in rivers and streams, and the main growth takes place in the sea. The juveniles spend 1–4 years in freshwater, migrate to the sea where they spend 1–3 winters and then return to their natal (parent) rivers or streams to spawn. The fishing activities take place during the spawning migration where it is first harvested in the fjords and inlets, and then in the rivers; the fish surviving fishing spawns, however, only a small fraction (about 10%) of the spawners will be part of the next year's stock [11]. See Fig. 1.

As already indicated, wild salmon has long had significant social, economic and cultural importance for Norwegians. It was originally an important food source but is today the prized fish for recreational anglers. However, the wild salmon has suffered a slow and

steady decline in abundance during the last few decades. Some stocks have reached historically low levels, some are designated as endangered, and some have already gone extinct [12]. Norwegian catch statistics clearly show salmon fisheries have declined through time, with a particularly sharp decline in sea fishing (Fig. 2). The current total catch is nearly half of the catch in the 1970s (~ averaged 1500 tonnes in 1970s, and dropped to ~800 tonnes in 2000s). Furthermore, the number of fishermen and fishing gear for sea fishing has also shown declining trends (from 2023 to 1089) while the number of recreational fishers (about 80,000) seems to have remained stable in the same time period (1997–2008, Statistics Norway). The decline in fish abundance is caused by a combination of factors associated with human activities including overexploitation, habitat destruction, salmon aquaculture and as well as changes in the natural environment (e.g., [10,13]). A number of management strategies and regulations have been put in place to curb such decline. Currently, of the ~650 salmon rivers, 400 establish self-reproducing salmon stocks, which makes Norway the world's largest spawning ground for Atlantic salmon.

All salmon sea fishing today takes place within the Norwegian 12 nautical mile zone when the salmon migrates back to its parent river. Salmon in the sea are caught by wedge-shaped seines (or bag-nets) and bend-nets in the fjord and inlets, and by fishing rods in the rivers. Sea fishing was traditionally of the regulated open-access type,

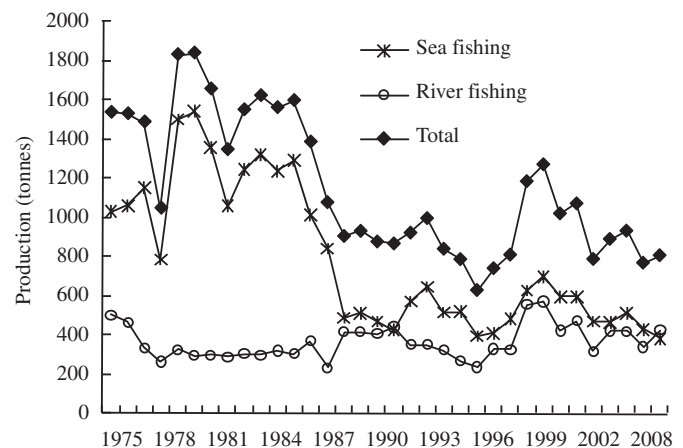


Fig. 2. Catch of wild salmon from sea and river fishing, 1975–2008. Source: Statistics Norway.

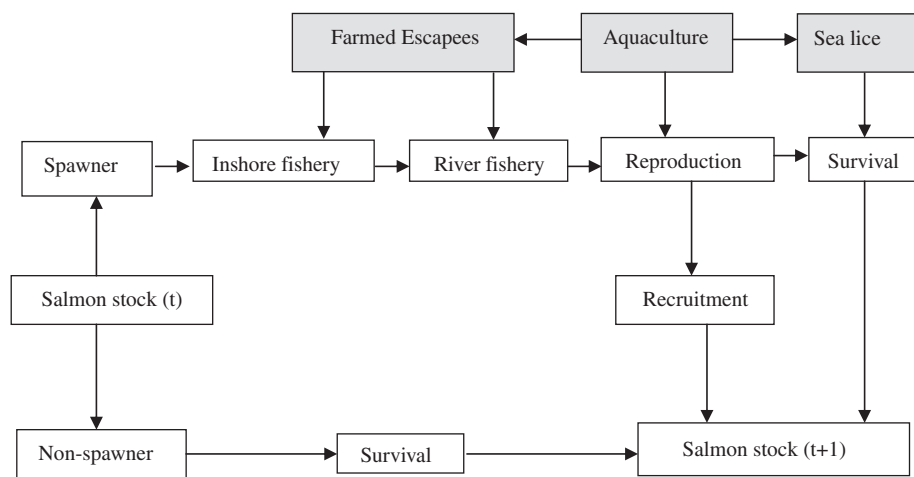


Fig. 1. Schematic diagram of wild salmon life cycle. The shaded boxes indicate the interaction from the farmed sector.

meaning anybody who was privileged to a fishing ground could fish during the season. However, to secure healthy sustainable wild stocks restrictions on sea fishing were required. A license system was imposed on drift net fishing in 1979. The salmon stocks, however, continued to decline, and drift net fishing was completely forbidden in 1989 [1]. In the same period, fishing activity with bend nets and bag nets in the fjords and inlets was also restricted because of a reduction in the fishing season. These restrictions have been further tightened during the last few years.

Sea fishing plays a minor role economically as this fishery, in most cases, is an economic side activity (for e.g., farmers) only for the meat value. The river fishing is for sport, leisure and personal consumption, and significantly more important economically. The largest benefit derived from river recreational fishing is the spending by the anglers. The main components of their expenses are fishing permits and other expenses associated with the fishing trips. Many studies have shown that these fisheries related to expenses (accommodation, fishing equipment, etc.) are on average higher than the direct payment to the landowner for the fishing permit (e.g., [14]). In summary, river fishing is an important economic activity in many river valleys with an economic value estimated to NOK 1.3 billion per year (Norges Skogeierforbund 2004).

2.2. Salmon farming

Salmon farming started in the late 1960s as a government-supported activity to strengthen the livelihood of rural fishing communities facing depressed economies due to declining wild fisheries (e.g., [4,5,15]). During the 1970s, many breakthroughs with respect to biological and technological bottlenecks, such as smolt rearing and development of dry feed, fundamentally advanced salmon aquaculture [16]. The real large scale commercial operation, however, took off in the 1980s. Since then, salmon aquaculture has experienced remarkable growth as a result of expanded new cultured locations, improved productivity, enhanced husbandry practices and management and growing global markets (e.g., [17,18,19]). In just over four decades, the Norwegian yearly farmed salmon production has increased from less than 500 tonnes in the early 1970s to 743 thousand tonnes in 2008 with a farmgate (or first-hand) value of over NOK 15 billion (See Fig. 3) according to the Statistics Norway (<http://www.ssb.no/english/subjects/10/05/>).

Norwegian salmon aquaculture has gradually undergone a number of structural and technical changes, and it has expanded, intensified and diversified through time. In the beginning, salmon

farms were small local family businesses scattered along the sheltered inlets, and with products targeting local markets ([4,15]). Later, due to high profitability and prospects of further expansion, the local small-scale farms were merged and restructured into big multinational companies. This industrial restructuring process has gradually carried on through further capital concentration and vertical integration, where the initial demand from the home market was overtaken by exports. Today, the Norwegian farm industry is a world leader in the globalisation of international seafood market.

Hence, the economic development has followed the typical pattern of 'home spun' growth [20], see also [21]. The industry is today a highly capitalized, vertically integrated and export-oriented enterprise ([18,19]) owned and controlled by only a few multinational companies such as Marine Harvest, Cermaq, SalMar, Lerøy Seafood Group and Grieg Seafood. According to Statistics Norway from 1994 to 2008 the number of companies has declined by 60%, but the number of licenses has increased by 28%; and on average, one company holds five licenses at present. Licenses are related to the concession system (more details below). In addition, Norwegian salmon companies have also expanded abroad and established farming in countries such as Canada in the 1970s and Chile in the 1980s.

Today, the salmon industry is an important part of the Norwegian economy, especially in creating employment opportunities (direct as well as indirect) in select rural coastal communities. In addition, as already mentioned, farmed fish has become the fourth largest export commodity after oil, gas and metals. The first-hand value of salmon aquaculture has exceeded that of traditional fisheries. However, in terms of its contribution to the Norwegian GDP, it is insignificant. For example, in 2008 fish farming's share of GDP in Norway is less than 0.3% (Statistics Norway).

2.3. Interaction between wild and farmed salmon sectors

The Norwegian wild and farmed salmon sectors intersect closely in production, especially since the environmental effects brought about by salmon aquaculture, such as escapees and sea lice infections on wild salmon stocks, have intensified with the rapid expansion of salmon aquaculture. The major negative environmental and biological effects associated with salmon aquaculture on wild salmon include disease and parasite transfer and spread, particularly sea lice infestation and interbreeding (e.g., [6–10,22]). As already indicated these effects are displayed at different life stages of wild salmon (see Fig. 1) and are potentially significant because the wild and farmed fish may share the same habitat or ecosystem. For instance, it is estimated that farmed salmon consists of an average of 14–36% of the spawning populations in Norwegian rivers, even up to 80% of the spawning populations in some rivers ([23,24]). Studies show that interbreeding between farmed and wild salmon causes changes in genotypes and the loss of genetic variations in wild salmon populations [25], and also cause the depression in the fitness and productivity of wild salmon ([10,13]). Consequently, the cumulative fitness reduction and productivity depression resulting from the repeated intrusion of escapees may potentially wipe out wild salmon populations, especially vulnerable ones [10]. In the long run, this may be a worry for the aquaculture sector since the farmed salmon broodstock (i.e., sexually mature fish) originate from wild stocks which are selected from the various salmon rivers. Then they are gradually domesticated through genetic modifications for fast growth and other economically important traits [10]. At the end, the farmed fish are genetically different from their wild counterparts. Such selected broodstock fish can be used up to about 10 generations, and a new selection cycle will then start again. Hence, the wild

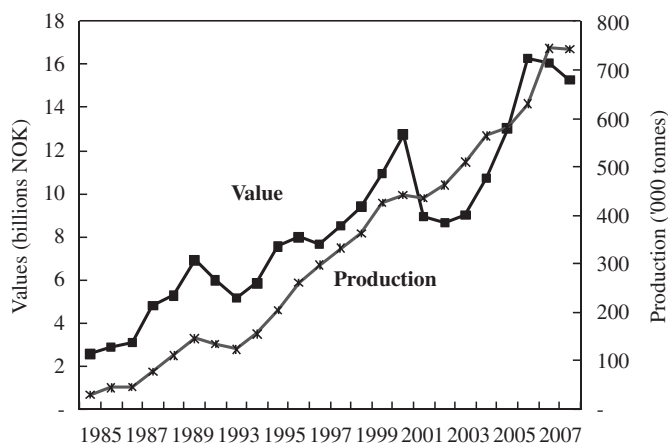


Fig. 3. Production and first-hand values of farmed salmon in Norway, 1985–2008. Source: Statistics Norway.

stock gene pool may turn out to be crucial to develop future farmed stocks.

Disease and parasite problems are another association between salmon farms and wild stocks since these are infective and epidemic, and they can be spread and transferred to the environment and other biotic resources. For example, there is a positive relationship between farmed production and sea lice production [26], and the high concentrations of sea lice have contributed to the decline of some wild salmon stocks in Norwegian rivers ([27,28]). Salmon lice is mainly a problem for the post-smolt on their out-migration journey to the ocean as they may get heavily infected by sea lice from the fish farms before they reach their offshore habitat.

Clearly, these ecological influences have a direct negative economic effect on fishing activities, especially in recreational fishery in the rivers. Results from Ref. [29] indicate that the anglers' willingness-to-pay are reduced by about 60% and 85% when the shares of escaped farmed salmon in the recreational catch increase from 0% to 50% and 100%, respectively. On the other hand, escapees may under some circumstances mean that more fish are available for fishermen and anglers if the combined stock of escaped farmed and wild salmon is considered. Thus, the loss from harvesting less wild salmon are to some extent compensated by the gain from harvesting more farmed escapees. In some cases, the total direct economic benefit from harvesting both escapees and wild may even be higher than pre-invasion value ([30,31]). However, note that this is the case when all non-use values of having wild Atlantic salmon stocks, such as existence values, are completely neglected.

Moreover, the economics of interbreeding problem between wild and farmed salmon show mixed results when considering only harvest value compared to the situation where the combined value of harvest and stock is considered [32]. This study indicates that the economic benefits in terms of only harvest value may decline compared to the scenario without escapees given the same fishing mortalities. This is because the escaped fish has a declining economic value for the recreational anglers with a higher proportion of escaped fish in the spawning population (see also above). In a situation where the wild salmon stock value included as well (e.g., intrinsic value) as the simulations indicate more profound negative external effects and hence a larger social loss due to the escapees.

3. Management of salmon sectors

3.1. Wild salmon fishery

Wild salmon fishery and salmon aquaculture have different institutional structures, management objectives and regulations. They are also managed by different authorities. The Ministry of Environment has the overall responsibility for wild salmon stocks, but the Directorate for Nature Management directs the management plans and advisory activities. The management objective for wild salmon stocks and fisheries today is *to conserve and restore salmon spawning stocks and to ensure the genetic diversity and natural productivity as well as to secure a sustainable harvest* [2].

Earlier, the management of the salmon stocks was basically related to the fishing activity, the management now is (as the above citation indicates) much more multi-faceted (see also [1]). The main management strategy today is to meet certain spawning targets for individual rivers. So far, spawning targets have been established in 180 important salmon rivers representing 80–90% of the total catch. Salmon fisheries are managed through a system of gear restrictions, closed seasons and closed areas. A fishing permit is required to fish in the fjords and inlets, and is distributed among those who possess fishing rights due to the specific landowner structure [1]. The rivers are owned by the landowners or associate landowner organizations that are given the authorized rights by the

State through the Directorate for Nature Management to sell fishing licenses to anglers. The cost of a fishing license varies based on the type of license (daily, weekly, monthly or seasonal), and the location and natural condition of a fishing site. In the most expensive river, the Alta river in the Northern part of Norway, the peak price was NOK 200 000 per day in 2007 while it may cost only NOK 50 in rivers with smaller sized salmon.

While only stationary gears such as wedge-shaped seines/bag nets and bend nets in the fjords and inlets currently are allowed for sea fishing, only fishing rods are permitted in the rivers (with some few exceptions). The fishing seasons and days vary depending on geographical area, time and state of stocks. In some areas, fishing may be open for some few days or completely shut down. If the spawning target is not met in a specific river or region, the fishing can be completely closed. For instance, in 2008 sea fishing was only open up to 34 days and about 50 rivers were totally closed for fishing. The river fishing is generally open for three months from June 1st to August 31st while the fishing season in the sea is shorter. Since 2008, Norwegian authorities have introduced a delayed start-up of all bag-net fishing throughout the Norwegian coast—up to six weeks in fjord areas. The delayed start enables early returning salmon, especially large three sea-winter fish (meaning salmon that have been in the sea for three winters before returning to their spawning river—home river) to reach their rivers without obstacles. There are more stringent regulations imposed on the heavily exploited areas such as the west coast. In most rivers, day and/or seasonal quotas are introduced to support the netting restrictions in the sea.

In addition to all these regulation measures, there are some additional programs that have been developed on a volunteer basis in order to reduce fishing effort. For example, in the Trondheim fjord a voluntary net fishing buy-out program was introduced in 2005 by the landowners in an attempt to reduce the exploitation by bag nets in the area. The river landowners are willing to pay the sea fishermen for not setting their nets, at a cost of about NOK 70/kg. The side-payment to each sea fisherman is determined based on their average catch for the last five years [33]. In addition, there are strong voices from recreational anglers, river owners and some NGOs that the sea-netting fishery should be completely shut down or a complete buy-out should be put in place. Such measures would regulate the number of sea fishermen and number of bend and bag nets further. Strict catch and release regimes in the rivers may be legalized in the future although it is a controversial issue in Norway because it contradicts the commonly held view that Norwegians fish for eating, not for playing [14].

In order to protect wild salmon stocks in some rivers from the potential effects associated with salmon farming, 'protection zones'—currently 37 national watercourses and 21 national salmon fjords have been established along the coastline. These watercourses and fjords have strict restrictions on salmon aquaculture. For instance, aquaculture is prohibited if there is a risk for transmission of diseases and pathogens from farmed fish or escapees from netcages [5].

3.2. Salmon farming

Salmon aquaculture is governed by the Ministry of Fisheries and Coastal Affairs, and is primarily administered by the Directorate of Fisheries. In addition, the Norwegian Food Safety Authority is responsible for the animal health, food safety and quality. The management objective for salmon aquaculture is to *"promote profitability and competitiveness of the aquaculture industry within the framework of a sustainable development and contributing to the creation of value on the coast"* (Ministry of Fisheries and Coastal Affairs 2009). The major legislation is the Aquaculture Act, which has been modified

through time with emerging issues. The current Act has four specific focus areas including (1) growth and innovation; (2) efficiency improvement and user friendliness; (3) environmental issues and (4) relationship to other user interests in the coastal zone. The Aquaculture Act as an instrument is facilitated by a series of guidelines, regulations, management planning and monitoring procedures. They target special issues and problems such as siting/licensing and operation facilities including waste management, escape prevention, fish health and use of chemicals and drugs.

In order to establish a fish farm in Norway, a company needs a license issued by the government. These licenses were given away almost for free until 2002. However, since 1991, the licenses were allowed to be sold in the market. Thomesen [34] estimated the average value of a license to be NOK 28.5 million, even up to NOK 40–50 million. The price for new licenses issued by the government is still much lower, and in 2008, a new license for producing 780 tonnes of salmon per year was sold for an one-time payment of NOK 8 million [35].

In order to ensure regional development and secure local ownership, the farming licenses were allocated according to a strict regional allocation regime through 1970s and early 1980s. The “owner–operator” license system was introduced; meaning licenses had to be given the local residents who were the owners and operators of the farms. Further, only one license was issued to each owner. On top of the ownership, other measures such as limitation on farm size (cage volume) and the number of farms and locations were also implemented in order to avoid overproduction [21]. During that period, the licenses were granted to applicants who were mainly locals employed in fishing and agriculture. With the technological advancement and the high demand on the world market, an expansion was called for. The policy was shifted from a focus on the regional development to promoting a profitable industry competing in the world market. Therefore, in 1985 the owner–operator licensing system was relaxed, and a more market oriented licensing system was established; there were no strict rules on the ownerships [35]. In other words, one owner could have multiple licenses and farm sites at any locations. There was further liberalization on capacity in the 2000s, meaning the maximum licensed volume by a single company could be up to 35% of the total national capacity [35]. However, there are still regulations entailed in Northern Norway to balance regional development. Moreover, in the last several years the environmental problems due to rapid expansion of salmon aquaculture has shifted the policy to environmental protection ([5,35]).

In addition, the Food Safety Act (2005) regulates health and food safety issues related to the operation of farm facilities such as the use of feed and drugs, and food safety measurement. At present, environmental problems such as diseases, parasites and escapees have intensified and are persistent (see also above). Thus, the associated regulations have been increasingly modified and developed. These problems can be minimized to some extent, but it seems almost impossible to eliminate them given current farming technology and practice. Moreover, the farmed sector has been very profitable, but does not pay either resource rent or compensation for the environmental damages brought about by farming activities. Therefore, it could be argued that more stringent regulations are needed to reduce these problems.

3.3. Conflicts of management between salmon sectors

As indicated, while the main goal for wild salmon is to conserve and restore the diversity of wild stocks, salmon farming aims to enhance profitability and competitiveness. Policies for wild salmon include eliminating any threats and adverse impacts that may endanger wild salmon stock [1]. On the other hand, the aquaculture

sector hopes to increase productivity and profitability through continuous expansion and intensification. This may amplify the above described environmental effects, such as sea lice infestation and interbreeding on wild salmon stocks, and thus also the negative external effects from the farmed to the wild salmon sector. Farming expansion requires more space in the coastal areas to accommodate more farms and higher production volume, while the wild fishery needs farm-free fjords to restore declining salmon stocks. Clearly, further farming industrial expansion is in conflict with the conservation-oriented motivation of wild salmon stocks. For instance, many of the restrictions imposed, such as farming-free fjords and watercourses to protect the wild stock, may influence the farming sector considerably. It can also be argued that the salmon farming sector has expanded so fast that there may not be enough time and knowledge to respond to these problems effectively.

The reduced catch and restrictions on sea fishing are in direct conflict with sustaining the coastal fisheries. In the meantime, voices from recreational fishing have added pressure to sea fishing since recreational fishing has led to far greater benefits than the sea fishing (meat vs. recreational value). This has resulted in conflicts between commercial fishing in the sea and recreational fishing in the rivers. Hence, management objectives within the wild salmon sectors are difficult to fulfill for sea and river fishing at the same time. Allocating the catch from the sea to the rivers clearly has distributional consequences unless a side payment regime is put in place.

4. Concluding remarks

As discussed above, there are serious conflicts between keeping healthy and viable wild salmon populations and the rapidly expanding farmed salmon sector. The farmed sector has gained strong political support during the last years, and together with the economic power to lobby politicians in the policy-making process, this makes the sector an ever increasing threat to the wild sector. Clearly, the sector does not compensate the wild sector for the imposed negative external costs. It is also a strong argument that the farmed salmon sector should pay a resource rent like the Norwegian oil and hydroelectric power production sectors.

The fact that two different governmental agencies manage these sectors is also a problem because they have different interests, different stakeholders, different traditions and management objectives. The two governmental agencies rely on sectoral approaches with limited cross-sectoral planning and coordination. The Directorate for Nature Management aims to conserve and restore wild salmon stocks, while the Directorate of Fisheries aims to promote profitability of salmon aquaculture. Thus, there is evidence of a lack of adequate coordination between the two governing agencies when launching their management objectives. It has been suggested that both sectors should be planned and managed under the context of the integrated coastal zone management [5], which aims to balance the ecological, social and economic goals of all human induced actions or activities in a collaborative, comprehensive and multidisciplinary manner.

In recent years, some efforts have been made in reconciling the two sectors. For instance, to protect wild salmon stocks from extinction, particularly those mixed and vulnerable stocks, a number of watercourses and fjords where salmon farms are restricted have been established. However, it appears this effort is not nearly enough because the escape and disease problems associated with salmon farming have persisted. In addition, one must take into account that some damage may be irreversible, such as lost salmon stocks. Thus, other measurements and strategies, such as additional watercourses and fjords free of farms, together

with compensation regimes, should be developed. Emphasis should be given to the important salmon spawning grounds, migratory routes and vulnerable stocks. Only by such means can one expect the salmon aquaculture sector to internalize the externalities they impose on other resource users and the environment.

One of the most promising solutions would be the development of closed containment production systems for salmon aquaculture, that is, a transmission from the open net cages to more closed containment facilities. This is already available for small-scale aquaculture production, and pilot projects at a commercial scale have also been conducted in Canada. Investing in such technologies will be costly in the short run for the aquaculture sector, but may turn out beneficial in the long run. In any case, this technology has the potential to solve many of the challenges between the wild and farmed salmon. Since closed containment systems separate farmed fish from wild fish and the environment, it will alleviate or eliminate most of the problems caused by open cage farming such as escapees and spread of diseases and sea lice. As a result, the impact of farming on the wild salmon would be considerably reduced.

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