How to capture the role of nature to design effective instruments that ensure sustainability?

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Abstract

We present the case of the ecosystem services generated by the Norwegian populations of wild Atlantic salmon (*Salmo salar*), likely the most significant 'piece of biodiversity' in Norway's history, and whose degradation has been almost impossible to halt. The main anthropogenic drivers of its degradation are two of the most important economic sectors in Norway, food production (aquaculture) and the production of renewable energy (hydropower).

We first present critical aspects of the biology of wild salmon that need to be protected to maintain population integrity and survival, highlighting the challenges to management/ stewardship responsibilities and liability. We then present how ecosystem services from the salmon populations have changed in time and how they interact, for instance biomass production (food) and opportunities for outdoor recreation and nature-based tourism, highlighting the challenge of accounting for these services independently.

We further present the case of provisioning services "genetic resources" which underpin the world's leader in salmon farming, and one of Norway's major industries. Genetic resources for the major selection program for the aquaculture industry were collected 50 years ago from 40 Norwegian rivers, and some of this variation is maintained as cryopreserved sperm. For wild Atlantic salmon, 450 natural populations and their adaptations to a variety of rivers from 58 to 71 degrees North constitute the main resource of genetic diversity. However, aquaculture practices currently pose serious challenges to the wild salmon's genetic integrity and population viability through interbreeding of escaped farmed salmon with wild salmon and increased burden by parasites and other disease agents.

We also present the resource rent estimates prior to the introduction of a resource rent tax on salmon aquaculture. Since 2012 the aquaculture industry in Norway has enjoyed enormous profits with a return to capital far above other comparable industries. The purpose of the tax was to redistribute some of these profits for the public good in Norway. The taxation process was characterized by deep disagreements about who should receive rents (e.g. between the coastal municipalities and the state), and extreme levels of lobbying from the sector, which resulted in exceptions for all farms below a certain size and a lower tax rate than in the initial proposal.

Finally, we refer to recent literature discussing the insufficient incentives for environmental innovation in the aquaculture industry. Environmental innovation in the industry could lead to better protection of wild salmon. However, the proposed resource rent taxation is designed to be neutral and, hence, will not increase the incentives for environmental innovation. To increase both the level of environmental innovation the government needs to introduce new instruments. At the end of the paper, we briefly discuss new instruments like a nature use tax, dedicated research, and development subsidies including closed containment of aquaculture facilities.

The paper is intended as an exploratory paper with a case study that can provide insights on the following topics addressed in the conference:

- Natural capital (the biophysical stock).
- Monetary values connected to ecosystem services.
- Baselines and counterfactuals (monitoring ecosystem services over time).

Introduction

Background

Since its inception in 1993, the United Nations Convention on Biological Diversity (CBD) contains two national-level obligations of signatory countries aiming at the long-term maintenance of life supporting systems, i.e. to conserve and to sustainably use biological diversity (Secretariat of the Convention on Biodiveristy[1]). These commitments have triggered biodiversity conservation actions worldwide, but results along the three decades of its implementation have been mixed.

In the 10th Meeting of the Conference of Parties (COP10) in Nagoya, 2010, signatory parties agreed in developing national biodiversity strategies and action plans (NBSAP) that would address a set of biodiversity conservation, and sustainable use goals and targets. These were formulated as the Aichi Targets[2] and became the core roadmap to support actions for the period 2011-2020. The evaluation of the Aichi Targets by the Global Assessment report of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES) showed that progress could be documented for a few targets, while for most targets there had been poor or moderate achievements (IPBES 2019, figure 6, p. 23). Further, the achieved targets were those that can be considered as areas of action of the "biodiversity conservation sector" typically reducing environmental pressures by, for instance, setting up new protected areas. Most of the targets that required a deeper engagement with society showed limited progress.

The Millennium Ecosystem Assessment (MA), a precursor of the IPBES, highlighted the need for mainstreaming the value of nature to society, and provided a conceptual framework, i.e. ecosystem services, about how ecosystem properties and ecological functions support society and human well-being (MA 2005). The MA triggered a huge interest in interdisciplinary work that brought together disciplines such as ecology, economy, social sciences and geography with the aim to operationalize the ecosystem services framework into decision-making. We understand the development of the System of Environmental Economic Accounting – Ecosystem Accounting (SEEA EA) as one outcome of such efforts.

A core tenet of the ecosystem services framework is that the acknowledgement and assessment of the benefits from ecosystems to society will lead to design legitimate policies that affect economic decision-making in the direction to protect nature (de Groot et al. 2010). The "Cascade-model" of ecosystem services provides a conceptual framework establishing these linkages where ecosystem structures and functions are explicitly connected to societal benefits (Haines-Young and Potschin 2018), which provides, in turn, the theoretical underpinning of the logic chain in the SEEA EA. Hence, formally connecting condition accounts, ecosystem services supply and use and their economic value is viewed as a key source of quantitative information to support national-level policy design and monitoring to ensure the protection and sustainable use of nature.

In this study, we use the case of Atlantic salmon (*Salmo salar*) in Norway to show the kind of data available today for ecosystem accounting and identify current gaps and limitations of the SEEA EA framework in its capacity to inform and design policies aiming to halt the degradation of a cornerstone species in Norwegian culture and economy.

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[1] https://www.cbd.int/doc/legal/cbd-en.pdfhttps://www.cbd.int/doc/legal/cbd-en.pdf
[2] https://www.cbd.int/sp/targets

The case of the Norwegian Atlantic salmon.

The life cycle of Atlantic salmon and its relationship to the provision of ecosystem services

The Atlantic salmon (hereafter: salmon) life cycle takes place in both rivers and the sea, which means that salmon are part of both marine and freshwater ecosystems. Salmon begin life in the river and then migrate to the sea to grow before returning to spawn in the river. Some of the adult fish die after spawning, but some survive and migrate to the sea, and some may return to the river one or more times to spawn.

Young salmon live in the river for between one and six years before they become *smolts* and enter the sea. Salmon can be in the sea from one to four years before reaching sexual maturity and returning to the river. The spawning migration of adult salmon from the open sea to the rivers takes place from late spring to early autumn and the spawning occurs in late autumn. It is mainly during this return migration phase that salmon has been the subject of human interest, as salmon has always been an attractive species for fishing, both in fjords and rivers. Periodically, salmon fishing has also taken place in the open sea and there is still sea fishing for salmon along parts of the Norwegian coast.

Salmon largely returns to the same river in which it is born, and in larger river systems also to the to the part of the watercourse it grew up in. Salmon from different rivers are genetically different and salmon populations show adaptations to their local river. This means that salmon living in different rivers of Norway may have different adaptations in traits such as growth rate, spawning time and size at sexual maturity (Barson et al. 2015). Management of salmon in Norway therefore takes place at the population level and the Norwegian authorities aim to safeguard the genetic diversity within the species. This is enshrined in both legislation (the Nature Diversity Act 2009[3], and the Salmon and Inland Fish Act 1992[4]) and in the Quality standard for wild stocks of Atlantic salmon (Quality standard for wild populations of Atlantic salmon (*Salmo salar*) - Lovdata, September 2013[5]).

Pressures on wild Atlantic salmon populations

It is estimated that approximately 80-98% of the smolts that migrate out of the rivers die in the sea and do not return to freshwater. Mortality is particularly high in the first year of life in the sea and many smolts never reach the open sea. Most of this mortality is part of the salmon's natural life cycle and due to natural causes, such as disease and predation. The mortality of salmon at sea is density-independent (Jonsson et al. 1998) meaning that additional anthropogenic causes of mortality are not compensated by reduced natural mortality.

Sea survival over the past 30 years has been generally lower than in the 1960s and 1980s and the decline appears to have occurred over large areas. This may be related to large-scale changes in the ocean with consequences for salmon survival and growth (Vollset et al. 2022). There is limited knowledge about the extent to which large-scale changes in the ocean may be anthropogenic, but according to the Scientific Council for Salmon Management (VRL 2021), there are regional and local impact factors in the ocean that are anthropogenic. Among these, sea lice (*Lepeophtheirus salmonis*) and other disease agents associated with aquaculture are considered the most important, while overfishing used to be a bigger problem before 1990.

Unlike the sea phase, we know a great deal about the life of wild salmon in freshwater. For salmon to be able to complete its life cycle, it is important that migration routes are maintained. This applies to both outmigration of smolts and return migration of mature salmon and involves migration along the coast

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[3] Nature Diversity Act https://www.regjeringen.no/en/dokumenter/nature-diversity-act/id570549/

[4] Laks og innlandsfisk loven https://lovdata.no/dokument/NL/lov/1992-05-15-47

[5] Regulation nr 1109 on quality parameters for wild Atlantic salmon stocks (*Salmo salar*) https://www.fao.org/faolex/results/details/en/c/LEX-FAOC127311/

and through fjord, and in-river migrations which in some rivers can be hundreds of kilometres. Physical interventions in watercourses may reduce the salmon's ability to reach their spawning grounds. Historically, salmon were trapped in rivers and in coastal areas where salmon migrate near land. Today, sea fishing is prohibited in most parts of Norway, and river fishing is strongly regulated and mostly by rod and line only.

The management of wild salmon has mainly focused on rivers, as this is where it has been easiest to implement measures. Many of the human impacts that may threaten wild salmon are also found in freshwater. According to the Scientific Council for Salmon Management, the most important anthropogenic factors affecting wild salmon in freshwater are farmed salmon that escape from net pens (Disserud et al. 2022), watercourse regulation and other habitat changes, the parasite *Gyrodactylus salaris*, invasive pink salmon (*Oncorhynchus gorbuscha*), and poor water quality (involving eutrophication, acidification, and other pollutants) (Forseth et al. 2017; VRL 2021).

Spiritual, artistic and symbolic value associated with salmon in Norway

The value of salmon has been a clear part of Norwegian's cultural history. The salmon has been of great importance to the settlement of Norwegian population as long back as people have lived in the country.

All the provisioning services provided by salmon described below are also closely linked to several categories of cultural ecosystem services. There are far more people than those who are involved in fishing that consider salmon to be an essential part of the Norwegian cultural heritage and a symbol of untouched nature and traditional resource utilisation. Such values are of great importance to people's quality of life.

The significance of salmon throughout Norwegian history can still be seen today in both ancient art, such as rock carvings and painting, and in place names. Salmon is also mentioned in the first Norwegian legislation, the Gulatingsloven from around the year 1200. It refers to the fact that, even back then, people were concerned that the salmon should be allowed to migrate freely up the rivers so that those living higher up also had access to the salmon resource, which was considered a 'gift from God' (Aas et al. 2010). The national assessment conducted in 1999 shows how the value of salmon is emphasised in everything from fairy tales, legends, religion and poetry to place names and language (NOU, 1999:9). The report also mentions examples of craft traditions related to wild salmon, such as the construction of fishing gear, fishing flies and lures, boats and buildings, and that every year several books are published about salmon and salmon fishing in Norway. There are also several places that have salmon in their municipal or town coat of arms (e.g. Grane, Nordreisa, Kvalsund and Mandal). All these examples show that salmon is a strong symbol in Norwegian culture. For some groups, for example, the Sea Sami and the Sami living along the Tana Valley, wild salmon is particularly important for culture and settlement.

Wild Atlantic salmon is marketed both in Norway and internationally to anglers and tourists. The Norwegian government has also identified the promotion of salmon fishing tourism as part of its 'Green Tourism' strategy. Norwegian salmon is also a brand, where the symbolic value of salmon and unspoilt Norwegian waterways and coastal nature is used in the marketing of farmed salmon.

SEEA EA accounts for Atlantic salmon in Norway

Extent and condition accounts

The area of salmon-bearing stretches has been estimated for 449 salmon rivers, which cover the entire range of the Atlantic salmon populations in Norway.

The assessment of the status of Atlantic salmon populations in Norway is regulated by law (Ministry of Climate and Environment 2014). The quality standard for wild salmon consists of two sub-standards, i.e.: a. Spawning stock target and harvesting potential, and b. Genetic integrity.

The spawning stock target is the amount (kg) of female salmon, measured by weight, that must spawn for an optimal number of smolts to leave the river each year. Harvesting potential is assessed in relation to what is a 'normal harvesting level' for a stock. 'Normal harvest level' means the harvest level that the stock should be able to withstand each year based on knowledge of natural sea survival, while the stock reaches the spawning target. The harvest in % of normal harvesting level is calculated based on kg of fish.

Achievement of targets is classified (five classes from "very good" to "very poor") according to the average percentage achievement of targets over five years. The sub-standard is designed with differentiated requirements for the achievement of spawning stock targets adapted to different stock sizes, from naturally small to naturally large stocks.

Interventions in the river, that affect the area of the river that is available for spawning, and that result in reduced production capacity are highlighted in the quality standard, even if a new stable stock condition is established and the intervention has already been authorised.

The genetic integrity sub-standard consists of the three elements: (i) species hybridisation, (ii) degree of genetic introgression from escaped farmed salmon (monitored with molecular markers) and (iii) selection pressure caused by selective catch and by environmental factors. So far, genetic integrity is estimated by genetic introgression from escaped farmed to wild salmon (Karlsson et al. 2016) and is classified in a four-level system by Diserud et al. (2023).

The latest assessment of the conservation status of the species has been done following IUCN's Red List criteria in 2023, has classed the Atlantic salmon as Near Threatened (NT) due to an estimated decline in population size (IUCN 2023).

Biophysical supply and use accounts

Provisioning services to the local economies and tourism sector

The most obvious provisioning service provided by Atlantic salmon is fish meat, which is an attractive food source both nationally and internationally. Salmon has been the starting point for subsistence farming and the species has been an important part of the food supply for people living along rivers and the coast (Table 1).

Every year, 80,000 to 100,000 people participate in salmon fishing in around 350 rivers. There are 10,000 agricultural properties with fishing rights in salmon rivers and 1,000 different tourism companies offer organised salmon fishing (Meld. St. 9, 2011-2012[6]). This is an important part of tourism and strengthens businesses in many Norwegian villages. It is estimated that fishing for Atlantic salmon in the 50 most important rivers together generates a turnover of 1 billion Norwegian kroner every summer (see level of catch in Table 1). A calculation by the Norwegian Environment Agency ten years ago showed that a quarter of this goes to landowners who sell fishing rights, while the rest ends up in tourism companies and in the local environment, such as grocery stores, petrol stations and sports shops (van der Meeren 2013[7]).

Today's fishing of Atlantic salmon in the sea is heavily regulated and primarily takes place along the coast of Finnmark in northern Norway. The local economic significance (gross turnover) of salmon sea fishing was estimated by the Norwegian Environment Agency in 2013 to be around 20 million Norwegian kroner. Although commercial fishing today is less extensive than in the past, it still has direct economic value for sea salmon fishermen (Pedersen et al. 2021) and is also a source of food. In addition, commercial fishing has a cultural significance and is important for preserving historical traditions. Sea

[6] Landbruks- og matdepartementet 2011. Landbruks- og matpolitikken — Velkommen til bords. https://www.regjeringen.no/no/dokumenter/meld-st-9-20112012/id664980/

[7] Data in this study are from the Norwegian Environmental Agency, the source is no longer available.

fishing can also be a contributory factor in maintaining settlement in areas with a high rate of out-migration (NOU 1999:9).

Table 1: Number of Atlantic salmon caught and released in Norwegian watercourses, and sea fishing during the period 2019-2022. (Source: Statistics Norway).

Atlantic salmon	**2019**	**2020**	**2021**	**2022**
Nr of fish caught	83 179	94 592	56 865	70 111
Nr of fish released	21 172	28 752	21 357	27 189
Weight fish caught in rivers (kg)	293 456	312 820	196 853	256 647
Weight fish caught in the sea (kg)	219 214	214 791	97 844	133 651

Provisioning of genetic resources and maintenance of genetic variation

Another important supply service from Atlantic salmon is the genetic resources that underpin current and future use and ensures the capacity of the species to persist in changing environmental conditions, including climate change. Atlantic salmon populations have declined sharply in many parts of their range and today about a third of all wild salmon in the Atlantic is from Norway. Norway has therefore a special and international responsibility to protect the species.

Wild salmon stocks are also a genetic resource for the aquaculture industry. Today's farmed salmon is bred from a selection of around 15 Norwegian Atlantic salmon stocks, after testing 40 different salmon strains . in the 1970s (Gjedrem et al. 2010), and it is likely that it will be necessary to obtain new genetic material from wild salmon for aquaculture in the future (St.prp. nr. 32, 2006-2007). In this way, wild salmon populations are an *in situ* gene bank for storing and safeguarding genetic variation, which can help to solve future disease or production problems in the aquaculture industry (NOU, 1999:9). In addition, different hereditary traits can also prove useful for conservation and restoration purposes. The fact that Atlantic salmon individuals return to their home river to reproduce means that populations from different rivers are genetically differentiated and locally adapted.

Each individual population is worthy of protection and has a genetic composition that cannot be recreated if it is lost. It is therefore important to preserve salmon populations from many different rivers to ensure sufficient genetic diversity. The most efficient and economically sustainable way to do this is to ensure that the populations exist as viable populations in the wild. In the Pacific Ocean, it has been shown that genetic variation between populations of Pacific salmon helps maintain the yield in the fishery (Schindler et al. 2010).

Norway has an *ex situ* gene bank for Atlantic salmon since the mid-1980s, when milk was collected and frozen from male salmon in 150 salmon rivers under the auspices of the Norwegian Environment Agency. In 2013, the Norwegian government established a live gene bank for Atlantic salmon and sea trout (*S. trutta*) populations in the Hardangerfjord where they are threatened by aquaculture, particularly sea lice and escaped farmed salmon. There is solid scientific evidence that salmon lice from aquaculture (Vollset et al. 2023) and escaped farmed salmon threaten wild salmon populations (Karlsson et al. 2016, Glover et al. 2020, Bolstad et al. 2021, Diserud et al. 2022) and thus also the ecosystem services provided by Atlantic salmon. Earlier, live gene banks had been established to protect salmon populations that were threatened by a non-native freshwater parasite, *Gyrodactylus salaris*.

The five existing live gene bank facilities can store up to 55 populations. In addition, frozen gene banks are used to store genetic variation for an almost unlimited period, and for supplementary contributions to production in the live gene bank. The current production strategy in the gene banks is to store a representative selection of broodstock in land-based facilities until the environmental threats in nature have been removed or sufficiently reduced, and with subsequent re-establishment.

Cultural ecosystem services – Recreational fishing

Recreational fishermen may pay very high sums for fishing rights. Studies of willingness to pay have a long tradition in Norway (see e.g. Navrud 1988).

In addition to the personal benefits, recreational fishing also has positive effects for society. Salmon fishing is an integral part of Norwegian culture, particularly in local communities or certain social groups. Through a shared interest in fishing, Atlantic salmon can be the starting point for an important part of the experience, knowledge and social life that gives people meaning, for example, through fishing associations or during joint celebrations such as the opening of the fishing season and the like (Parkkila et al. 2010).

Furthermore, salmon anglers also pay a government fee (in addition to fishing licenses) to the Norwegian State Fisheries Fund, and the funds are used for management and measures for sustaining salmon and sea trout populations. Around 70,000 fishermen have paid fishery tax in recent years (see Table 2 for the years 2015-2022 from the Norwegian Environment Agency). This means that recreational fishing for wild salmon can also be said to have an important socio-economic value linked to the value of managing/caring for nature (Parkkila et al. 2010).

Table 2: Number of fishermen that paid government fishing fees (in addition to fishing licence to landowners) 2015-2022. Source: Norwegian Environment Agency.

Fee type	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Individual	48 511	50 649	53 540	50 176	50 585	51 256	44 525	46 461
Family group	7 365	8 019	7660	7 209	7 061	8 167	6 949	6 310
Sea, before 1 July	534	545	614	697	718	790	409	347
Sea, after 1 July	362	385	404	351	420	460	230	199
Sum	56 772	59 598	62 218	58 433	58 784	60 673	52 113	53 317
No. of fishermen	68 247	71 979	74 382	69 881	70 661	74 606	64 621	63 829
No. of fishermen / Family group fee	2 558	2 544	2 588	2 588	2 682	2 706	2 800	2 666

Economic valuation of provisioning- and tourism related services

The Norwegian management of Atlantic salmon has been largely based on the principles set by Millennium Ecosystem Assessment (MA 2005) and the Economics of Ecosystems and Biodiversity (TEEB 2010) based their ecosystem services approach. A broad assessment of the value of salmon for human well-being was prepared for a Norwegian public enquiry as early as in 1999 (NOU 1999:9). The assessment provided a review of the economic values associated with recreational fishing, tourism and commercial fishing, as well as other ecosystem services attached to the species including learning about and experiencing nature as well as health benefits were associated with the Norwegian population’s motivation for protecting Atlantic salmon.

Costs related to the conservation of salmon

In addition to the use value, an illustration of how highly Atlantic salmon is valued by Norwegian society is the large amount of money spent annually to preserve salmon stocks. Section 1 of the Salmon and Inland Fisheries Act states: ‘The purpose of the Act is to ensure that natural populations of anadromous salmonids, inland fish and their habitats as well as other freshwater organisms are managed in accordance with the Nature Diversity Act and in such a way that the diversity and productivity of nature is preserved. Within this framework, the Act shall provide a basis for the development of the stocks with a view to increased yield, for the benefit of licence holders and recreational fishermen.’

An estimate from 2023 (Norwegian Environment Agency, pers. comm. November 2023) shows that the public costs of protecting anadromous salmonids against various threat factors was 318 million Norwegian kroner in the 2023 budget (Table 3). The largest budget was allocated to maintaining the gene-bank of Atlantic salmon populations.

Table 3: Summary of the yearly costs to protect Atlantic salmon from negative anthropogenic factors in Norway. Source: Norwegian Environment Agency (2023).

MEASURE	COST IN 1 000 NORWEGIAN KRONER (2023)
Genebank	74 742
Gyrodactylus treatment	48 600
Pink salmon	41 260
Monitoring/population status/research	30 385
Liming of acidified rivers	73 300
Fish passages	14 500
Operation of the Tana River fish management	4 000
Visitors' Centres for Atlantic salmon	11 106
Funding for Atlantic salmon conservation measures (open calls)	20 115
Total cost	*318 008*

In addition to the costs presented in Table 3, significant voluntary efforts are made each year, particularly in connection with the monitoring and outtakes of escaped farmed salmon and with outtakes of pink salmon in many watercourses. Significant amounts of money are also spent on research and on the operation of administrative bodies with responsibilities to manage Atlantic salmon, including the Norwegian Food Safety Authority, the Directorate of Fisheries, and the Norwegian Water Resources and Energy Directorate (NVE).

Another significant sum that is not included in the above includes the costs that hydropower producers incur to maintain salmon populations in regulated watercourses. These include indirect use values, mitigation measures such as the construction of fish passages, addition of spawning gravel, fish surveys, cultivation and gene bank activities. For example, the company Statkraft alone spends approximately 30 million Norwegian kroner per year on cultivation measures.

Many hydropower licences are required to release a minimum flow of water on the affected stretch of the river, and this minimum flow is usually higher in salmon rivers than in other rivers. No exact calculation has been made of how much this represents in terms of lost energy production, but one estimate is that it could be equivalent to a value of 1 billion Norwegian kroner (if the minimum water flow is equivalent to 2 TWh and the power price is 0.50 Norwegian kroner/kWh). The general licence conditions also require hydropower developers to pay licence fees. These are paid annually to the state and to the municipalities that are affected. In 2009, the total amount of licence fees paid to the Norwegian state was 36 million Norwegian kroner.

The aquaculture industry is also implementing several measures to prevent and counteract negative effects on Atlantic salmon. This applies to measures to combat salmon lice in fish farms, measures to prevent the escape of farmed salmon and recapture measures when escapes are detected. In 2015, the Directorate of Fisheries introduced a traffic light system to regulate the increase in biomass in aquaculture along the Norwegian coast. This system is based on a two-year calculation of sea lice-induced mortality on migrating wild salmon smolts in 13 production areas along the coast, where values below 10 per cent allow a biomass increase of farmed salmon of 6 per cent, values between 10-30 per cent freeze the biomass, and values above 30 per cent result in a reduction in biomass of 6 per cent. The calculations are made annually per aquaculture production area.

Economic estimates for a Resource Rent tax on the aquaculture industry

Norway has experienced an extraordinary expansion of the aquaculture industry in the past decade (Greaker and Lindholm 2022). The industry holds licences for using fjords and sea areas issued by the state that confer a protected right to operate indefinitely. Statistics Norway identified that the resource rent (RR) in aquaculture had risen strongly since 2012 and estimated that for the period 2016 to 2018 it was worth just over 20 billion Norwegian kroner[8]. In 2021, the resource rent was estimated at 11.8 billion Norwegian kroner, and "salmon and trout farming" alone have contributed between 80 and 90 per cent of the gross product in Norwegian aquaculture over the past 10 years.

Based on the very high values of the resource rent in aquaculture (Greaker and Lindholm 2022), the Norwegian Government argued that it was reasonable for society to receive a share of the extraordinary return generated through the exploitation of coastal and fjord resources. It was stressed that Norway had a long tradition of wealth distribution. The Prime Minister stated that "In Norway, we have a long tradition of ensuring that the value created with our shared natural resources benefits the community" and the Minister of Finance "The Norwegian model of the community having a share of the profits from the utilisation of our natural resources has served us well. The resource rent tax on petroleum has been crucial to the development of the Government Pension Fund. By introducing a resource rent tax for the aquaculture industry, we are continuing this tradition, where it is possible to create jobs and make money, while at the same time giving local communities and the community a share of the value created from the coast". Further, "When the profit from this industry is very high, part of this profit goes now to the local communities and society as a whole, which can use it for good schools, good healthcare, care for the elderly and good welfare throughout the country".

After long and contested political debates, the RR estimates for aquaculture led to the design of a RR tax. However, and despite the intention of valuing ecosystem services, there has been no discussions of using tax revenues to support the protection of the wild Atlantic salmon populations and the habitats they require, as well as promoting practices that would reduce or avoid the most damaging impacts affecting the species survival, including its genetic integrity.

Discussion

The starting point that Greaker and Lindholm (2022) used for calculating RR is that the production of a natural resource can be expressed as a function where one or more ecosystem services are included as input factors and aimed at estimating the RR as a remuneration of these ecosystem services. This notion follows the fundamental idea of ecosystem services assessments as an approach to mainstream the value of nature into economic and other societal decision-making, i.e. to support decisions that ensure its conservation and sustainable use (MA 2005). The fact that the SEEA EA links ecosystems as service providing units and their condition as factors underpinning the capacity to supply ecosystem services makes the framework suited to inform decisions about sustainable use, and to monitor the outcomes of policies that aim to support it.

However, instead of supporting policies to foster the protection and sustainable use of nature, RR estimates were used as the basis to establish levels of a RR taxation scheme which was thought to be analogous to the tax on the oil and gas industry and which is based on wealth distribution objectives. Given that oil and gas is a finite resource, it does not make sense to invest in its sustainable use, since it is not renewable. However, it appears that the same extractive economic model from the fossil

[8] The Norwegian Government https://www.regjeringen.no/en/aktuelt/resource-rent-tax-on-aquaculture/id2929113/

resource industry has been transferred to a life-supported economic activity that requires stewardship and investment to maintain the long-term persistence of the resource.

In their overview over models and datasets to support the development of the SEEA EA in Norway, Rusch et al. (2024) did not include any ecosystem services generated by aquaculture. They considered that the 'contribution of the ecosystem' to aquaculture food production was minor compared to anthropogenic factors, a similar situation to that of food production in greenhouses (Hein et al. 2020). It also deemed challenging to identify, quantify and value the actual contribution of nature to the aquaculture industry. In contrast, they considered a series of intermediate services contributed by marine ecosystems to aquaculture including fish biomass used as feed, and the catch and cultivation of wrasses (amounting to ca 40 million fish per year) which are used to predate on salmon parasites, one of the measures to reduce parasite loads and minimize other more aggressive forms of treatment. The capacity to absorb and recirculate pollutants and eutrophication was also highlighted as important functions that could be modelled and accounted as ecosystem services, but lack of data makes these assessments not feasible at present. In addition, the long-term maintenance of the aquaculture industry is fully reliable on the viability and persistence of the wild salmon populations, even if exact contribution may be difficult to quantify and account for on a yearly basis. In this sense, RR calculations could be an approach to overcome the limitations of defining specific ecosystem service supply.

The persistence of Atlantic salmon populations may be seen as a benefit equivalent to option/bequest value, but it is essential to salmon farming (either in Norway or in other countries, would the species be introduced for farming) given that the Norwegian population is approximately 30% of the global population. However, while the RR approach appears to be suited to highlight and quantify the potential for wealth distribution and environmental protection actions, there seems to be important limitations of RR to reveal the dependency of the aquaculture industry on salmon and the fresh water and marine ecosystems on which it relies, and hence to "mainstream the importance of biodiversity for the economy and society".

The recent assessment commissioned by the Norwegian Ministry of Trade, Industry and Fisheries (NOU 2023:23) addressing integrated management of aquaculture has identified a series of potentially synergistic policies (Norske lakseelver et al. 2023) which have been considered of high potential to foster a transition by the aquaculture industry from current production systems to low or no impact production, through the adoption of existing new technology and setting higher standards of fish densities, and parasite loads. Could a thorough overview of the social and economic importance of salmon reflected in SEEA EA ecosystem condition and ecosystem services accounts proposed in this study improve the legitimacy and uptake of these recently proposed environmental policies?

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