12.3 Faroes ecoregion – Aquaculture Overview

Table of contents

Executive summary

The current Faroese legislative framework on aquaculture was adopted in 2003, with objective to promote profitability and competitiveness in aquaculture within a sustainable framework with regards to animal and environmental health. Any aquaculture production requires a licence and an environmental permit.

Marine aquaculture facilities in the ecoregion are located along the coast of the Faroe Islands. Conditions at aquaculture sites range from sheltered fjords to areas of higher wave and current exposure typical to more offshore conditions.

Marine aquaculture production within the ecoregion is strongly dominated by Atlantic salmon, with some minor production of seaweeds.

The aquaculture industry, together with various suppliers to the industry, has major social and economic effects on Faroese society. Employment in the aquaculture industry has gradually increased from 2005, concurrent with the increase in production. About 5% of the total active labour force in the Faroe Islands work in the aquaculture industry.

The aquaculture industry is an important contributor (8%) to gross domestic product. During the past decade, the export value from the industry has represented 40–45% of the total exports of goods of the Faroe Islands. Despite a general increase in production costs, profitability of Atlantic salmon farming has been generally high, due to the absence of major diseases and a growing international market demand.

The single largest concern for salmon production in the ecoregion is sea lice; mitigating its effect has been the main driver of investments, innovations in farming practices and production technologies, and aquaculture regulations.

Sustainable aquaculture growth requires innovative production technologies to reduce its environmental effects. These include the diversification of existing culture systems in response to changing environmental or biological drivers, through the consideration of shellfish aquaculture, the expansion of seaweed aquaculture, and the development of offshore aquaculture.

Future developments will need to consider and apply an integrated approach to assess synergies and trade-offs among sectors, including commercial fisheries, shipping, and tourism. Offshore renewable energy developments will potentially also need inclusion while investigating consequences across environmental, ecological, and socio-economic dimensions. Future aquaculture development should also consider the effects of climate change.

Introduction

Faroese aquaculture is dominated by salmon farming, and farming practices are similar between the aquaculture sites. The farming occurs along the coast of the Faroe Islands.

The ecoregion is located in the area where warm saline waters from the Atlantic flow northwards in the upper water layer, while cold waters from the Arctic region flow south through deep channels. The well-mixed and homogenous Faroe shelf water is separated relatively well from the offshore oceanic water by a persistent tidal front at 100–150 m. The retention of the central shelf water mass supports a neritic ecosystem with distinct planktonic communities, benthic fauna, and fish stocks. The marine aquaculture operates inside the tidal front in nearshore areas. Conditions at the sites range from sheltered fjords to areas of higher wave and current exposure typical to more offshore conditions.

ICES considers the ecoregion scale as the relevant spatial scale to inform ecosystem-based management.

This overview provides:

- a summary of regional and temporal information on aquaculture activities, practices, and production of the cultured taxa;
- a description of the relevant policy and legal foundation;
- considerations of the environmental and socioeconomic interactions of aquaculture activities and practices;
- insights on the interaction of environmental, economic, and social drivers; and
- considerations of future projections and emerging threats and opportunities.

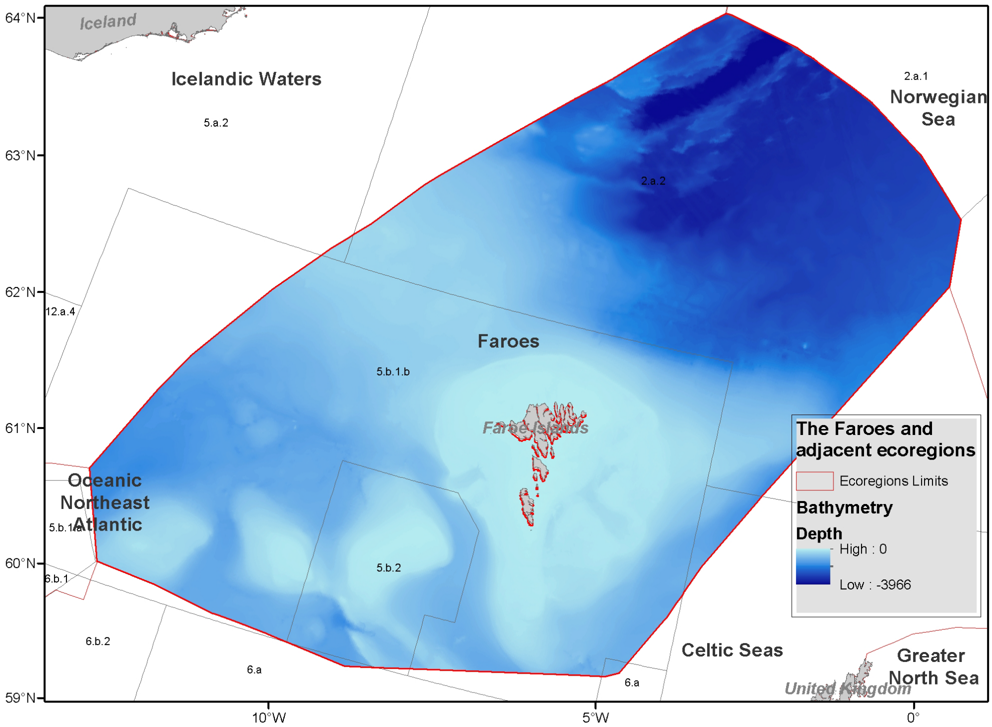

Figure 1 The Faroes and adjacent ecoregions.

Description and location of aquaculture activities and practices

In 1986 there were 65 farming areas, managed by approximately 50 companies. The number of sites and operators has decreased substantially, while the production at individual sites has increased. Farming areas have been gradually moved further out in the fjords, where currents are stronger and internal infection with sea lice is lower.

Thirty-five sites are currently allocated to Atlantic salmon farming, and three sites to seaweed farming (Figure 2). The permitted production is regulated by biological performance and environmental impact at the individual sites. There is, therefore, no obvious relation between the production volume and the size of the management site. The salmon farming sites are operated by three companies, while two additional companies farm seaweed. Not all of the authorised sites for salmon farming are active; eight sites have not been in operation since 2019, most of which are in sheltered locations. From 2019 to 2021 an average of 21–25 sites were simultaneously in operation in the ecoregion.

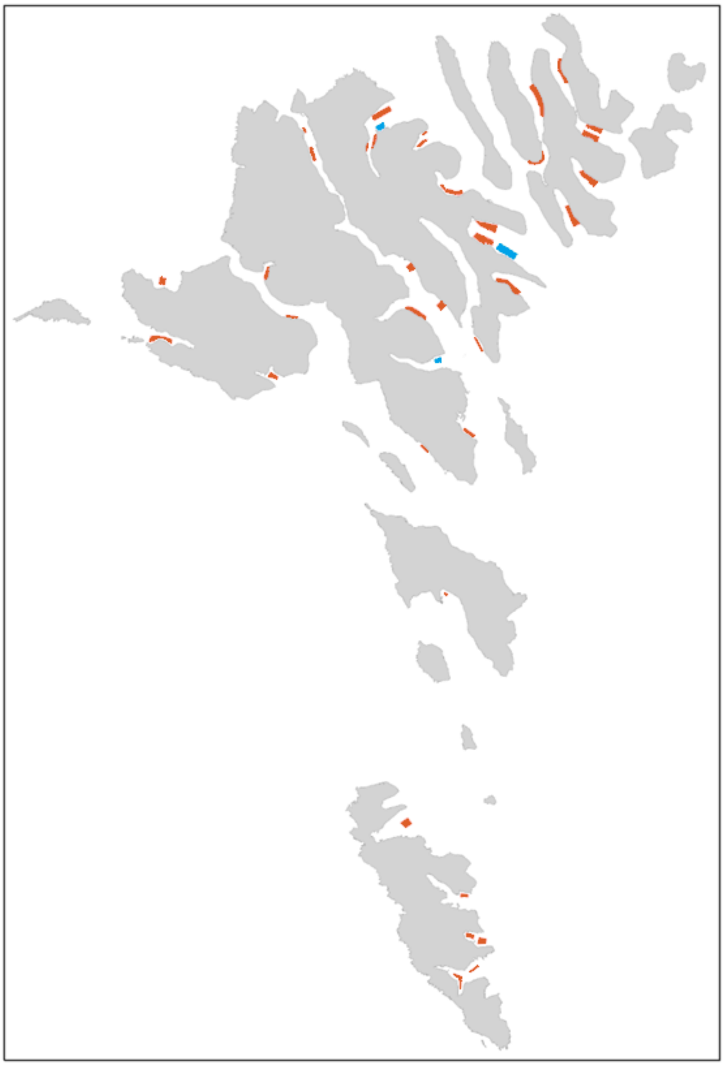

Figure 2 Location of production sites for Atlantic salmon (orange) and seaweed (blue) in the Faroes ecoregion. (Source: Aling).

The principle cage systems used in modern marine salmon farms, using moored floating circular pens with suspended nets and predator nets, have not changed much over time. The fish are still farmed in net pens, with free water exchange ensuring the supply of oxygenated water and waste removal from the pens. Technological developments in farming equipment have, however, allowed fish farming to move to more exposed areas.

The salmon farms at sea are supplied with smolts from eight smolt farms on land. Ova are imported from broodstocks in Norway and Iceland, and are also produced in the Faroe Islands. In previous years there has been a development towards smolts of a larger size being transferred to the sea cages; this reduces production time at sea as well as exposure to sea lice and other diseases (Figure 3). In 2021 the average weight of smolt at sea transfer was 425 g. This is considerably higher than in other salmon farming regions, where the average weight is typically below 200 g at transfer to sea.

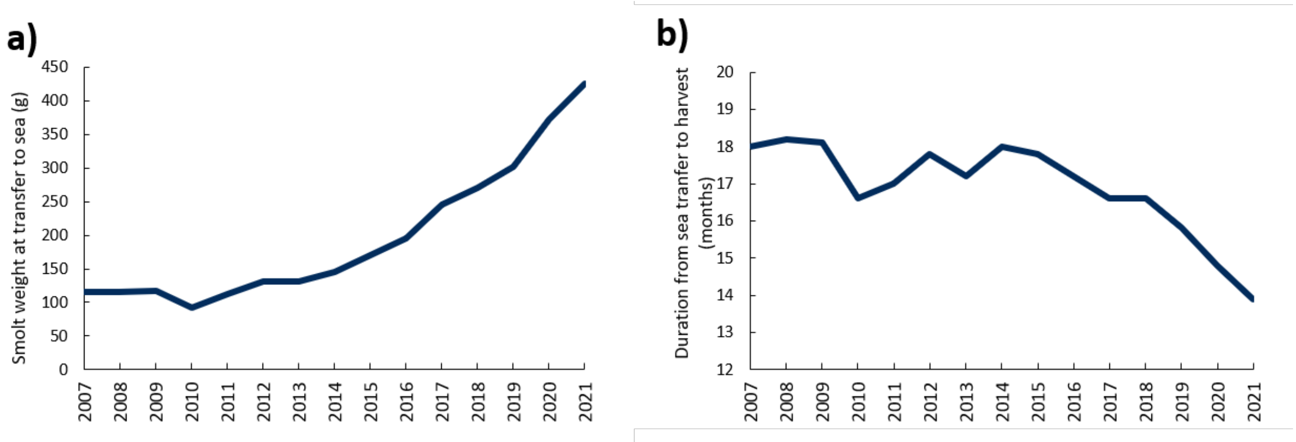

Figure 3 Dynamics of the average smolt weight at transfer to sea (a) and duration of the production cycle at sea (b) of Atlantic salmon during 2007–2021. (Source: Avrik sp/f).

Cleaner fish are commonly used as biological control of sea lice in the salmon farming industry. In the Faroes ecoregion only native species are allowed to be used as cleaner fish, which means the industry is limited to lumpfish. Lumpfish were introduced to the salmon aquaculture industry in 2014, and in 2018 they were in use at approximately half of the farming sites. Lumpfish for use in the salmon farming industry are predominantly imported from on-land facilities in Iceland and Wales, with only limited production in the Faroe Islands themselves. Most of the cleaner fish originate from wild caught fish, that are stripped at on-land facilities where the roes are hatched and the fish grown to the desired size.

Production over time

The first attempts at hatching and farming of rainbow trout were made in the 1950s, and pioneering attempts at hatching Atlantic salmon were conducted in the early 1970s.

Production of salmonids (Atlantic salmon and rainbow trout) started to expand in the 1980s (Figure 4). Because of higher profitability potential it is only Atlantic salmon that has been farmed since 2011. Farming of other fish species, such as Atlantic cod and Atlantic halibut, has been piloted but they are not produced commercially. Lumpfish are also imported and ongrown for use as cleaner fish in Atlantic salmon production.

Atlantic salmon production in the Faroes ecoregion, measured as gutted weight, has generally increased over time. A sharp decrease in production was registered in the mid-2000s, associated with outbreaks of Infectious Salmon Anaemia (ISA). Since that time aquaculture production has gradually increased, to over 88 000 tonnes in 2022.

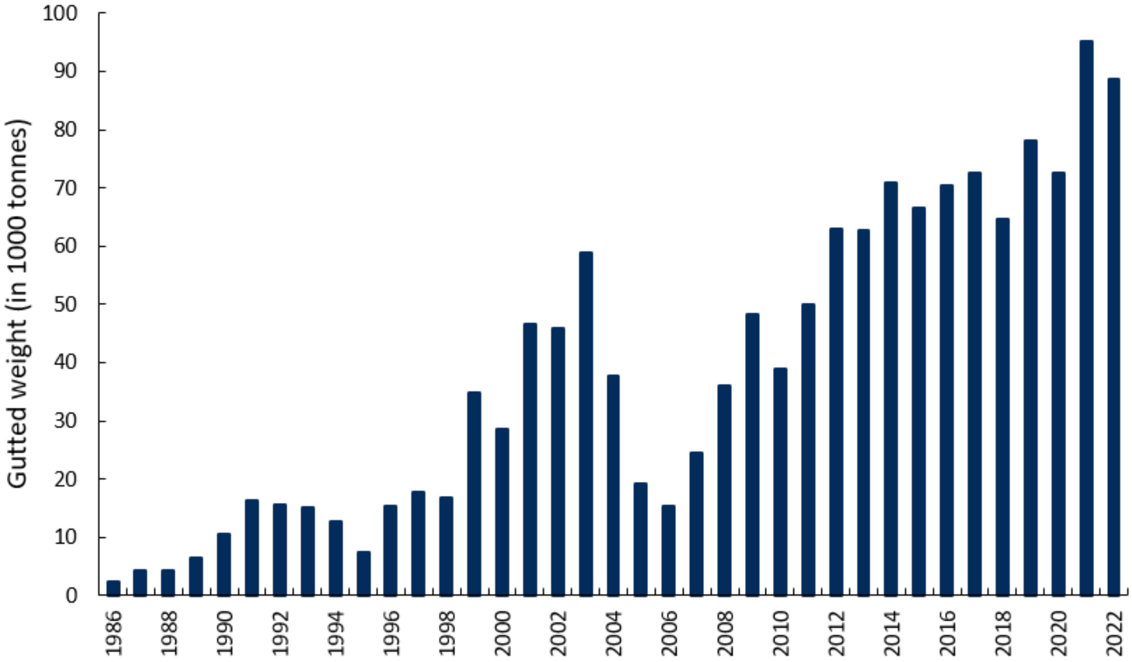

Figure 4 Harvest of Atlantic salmon and rainbow trout in the Faroes ecoregion, 1986–2022. (Source: Avrik sp/f).

The production of salmon varies considerably between farming sites, and not every active site produces salmon every year.

The standing stock of Atlantic salmon in on-land facilities has generally increased since 2006, and has exceeded 30 million in the past 4 years (Figure 5).

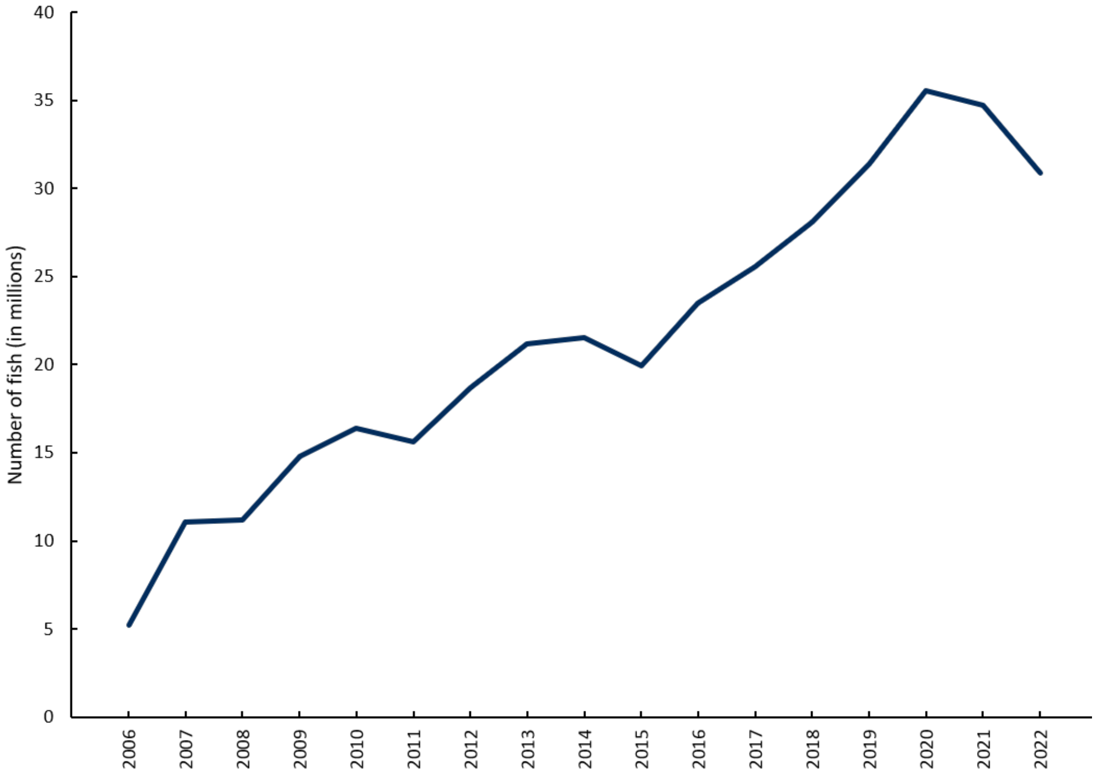

Figure 5 Standing stock of Atlantic salmon (from egg to smolt) in on-land facilities 2006–2022, expressed as the number of individuals on 1 January each year. (Source: Avrik sp/f).

Currently there is no commercial-scale shellfish farming in the ecoregion. Trials with blue mussel farming have, however, shown potential for farming with wild spat collection.

Aquaculture in the Faroes ecoregion has started to diversify in recent years, as seaweed farming steadily increases. The first trials began in 2010, with seaweed farms located at sites already allocated to salmon farms. In 2020 the first site licences dedicated to seaweed farming were distributed to companies not producing salmon, and in 2021 the total harvest of farmed seaweed was 185 tonnes in wet weight (Figure 6). It is predominantly *Saccharina latissima* and *Alaria esculenta* that are produced in the Faroe Islands, and the majority of macroalgae biomass is exported to European markets as food, food ingredients, and feed additives for livestock.

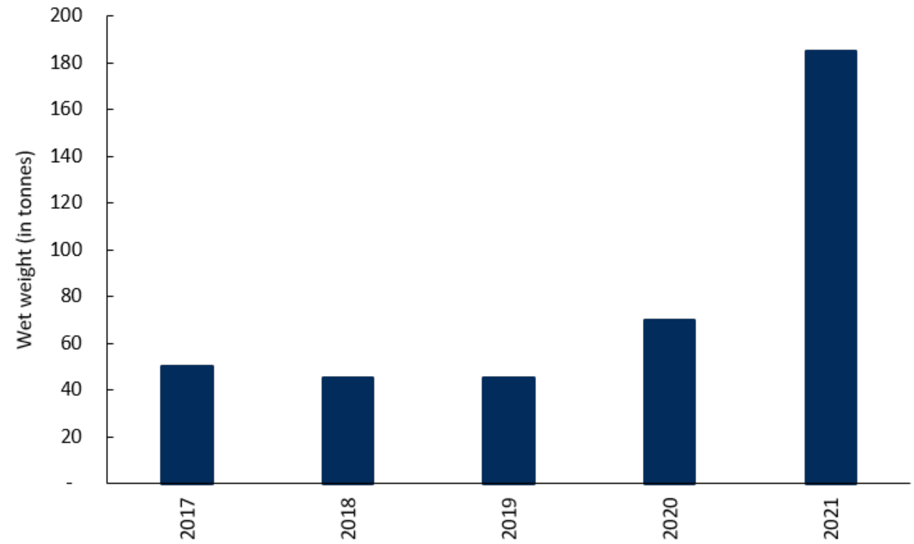

Figure 6 Harvest of farmed seaweed in the Faroes ecoregion. (Source: Faroese Fish Farmers Association annual statements).

Performance measures of salmon farming over time

The conversion of feed into biomass can be regarded as a measure of effectivity in salmon aquaculture. Multiple factors affect the Feed Conversion Ratio (FCR), including feed quality and feeding efficiency, but also environmental factors that affect fish health and survival. Economic Feed Conversion Ratio (eFCR) is the total amount of feed used to produce 1 kg of fish (including feed losses and mortalities). Biological Feed Conversion Ratio (bFCR) is the net amount of feed used to produce 1 kg of fish (not including mortalities). Lower FCR values indicate a better feed utilisation by fish.

Up to the ISA outbreaks in the early 2000s, the FCR gradually increased. The reform of the aquaculture industry in 2003 had a substantial positive impact on the feed conversion ratio (Figure 7). From 2006 to 2016, the FCR was relatively stable. After the introduction of mechanical and thermal sea lice treatments in 2016, the eFCR increased while the bFCR decreased (Figure 7).

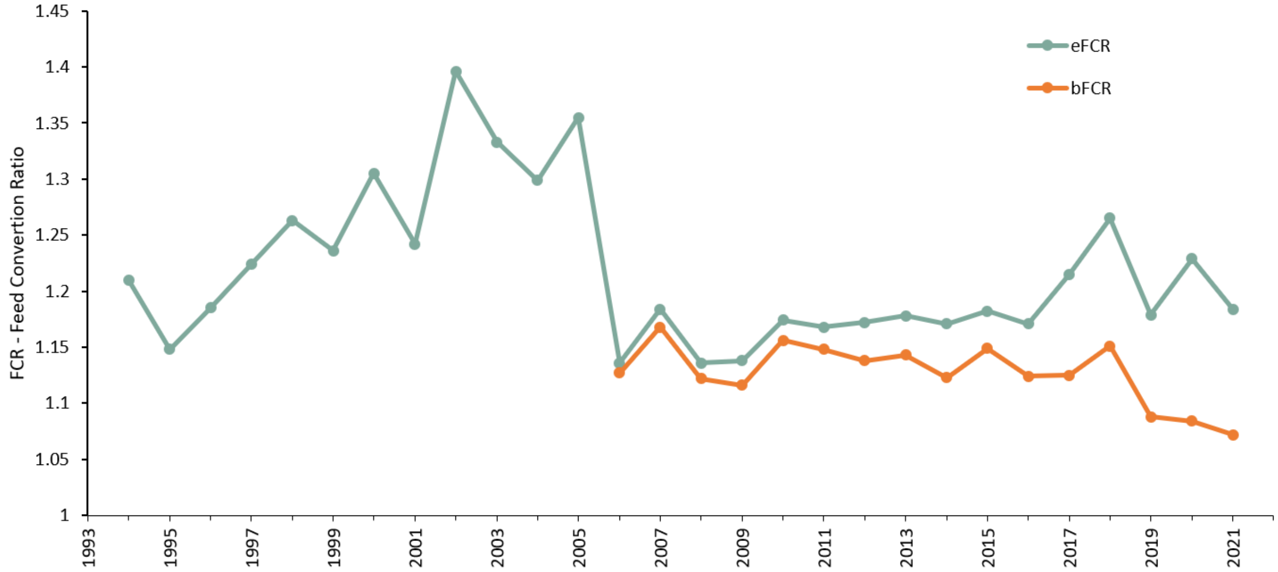

Figure 7 Dynamics of the economic (in light blue) and biological (in orange) Feed Conversion Ratio (FCR) for farmed Atlanic salmon at sea cages in the Faroes ecoregion, 1994–2021. (Source: Avrik sp/f).

The aquaculture reform in 2003 had a substantial positive effect on the mortality rate of farmed Atlantic salmon (Figure 8); it decreased from 28% in 2002 to <3% in 2005, and in turn had a positive effect on eFCR. During the first decade since then, the mortality rate of farmed Atlantic salmon has been lower in the Faroes ecoregion than in several other salmon-producing countries. Fish mortality rate has, however, gradually increased since 2005 with the introduction of mechanical and thermal lice treatments as well as moves offshore.

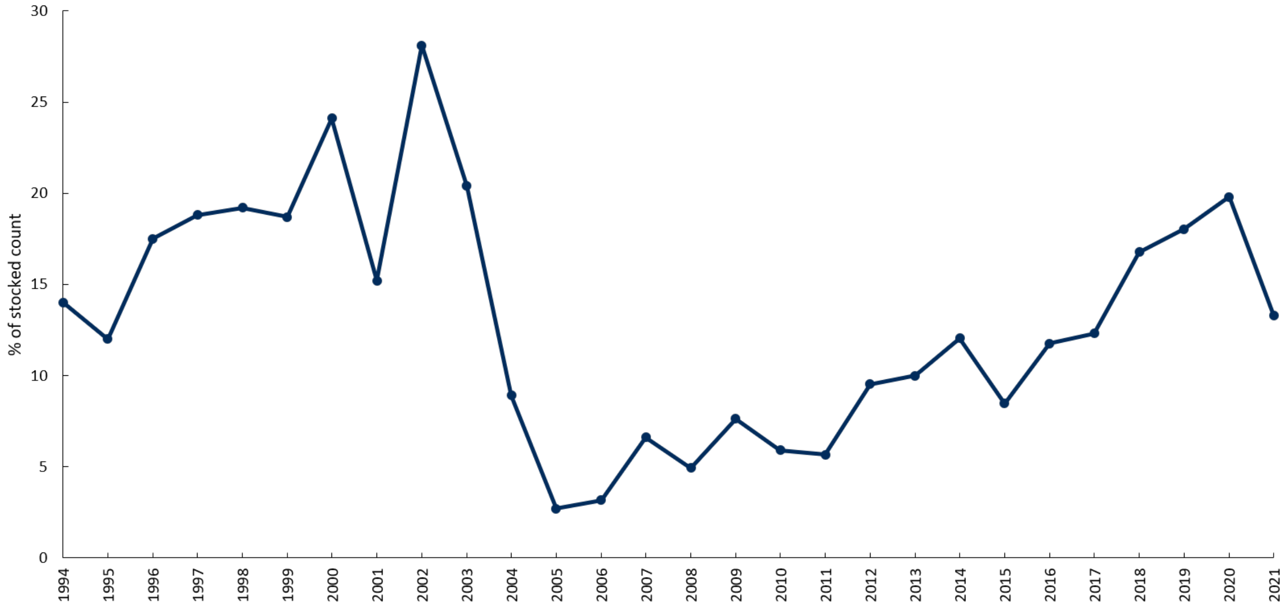

Figure 8 Mortality rate (%) of farmed Atlantic salmon and rainbow trout at sea cages in the Faroes ecoregion, 1994–2021. (Source: Avrik sp/f).

Policy and legal foundation

The current legislative framework on aquaculture was adopted in 2003. The objective is to promote profitability and competitiveness in aquaculture within a sustainable framework with regards to animal- and environmental health. The primary national legislative acts and regulations are:

- The Aquaculture Act (2009), which is the general and coordinating law;
- The Animal Welfare Act (2018);
- The Animal Diseases Act (2001), with the regulation on the establishment and biosecurity of aquatic farms (Biosecurity Regulation, 2019), and the Sea Lice Regulation (2016);
- The Environmental Protection Act (1988); and
- The Food Act (2010).

The coastal area is divided into management areas, typically on the scale of fjords. Only one fish farmer is allowed to operate in each management area; farming licences for low trophic species may also be issued in the management areas provided these pose no risk to the fish farming activity in the area. Two key pieces of development consent are required for the establishment of an aquaculture site, namely an aquaculture licence and an environmental permit.

<u>Licencing</u>

A licence issued by the Faroese Food and Veterinary Authority (FFVA) is required in order to build, prepare, restructure, expand, buy, or operate a site intended for the rearing of fish. Licences for aquaculture sites are only issued after the application has been reviewed by several relevant institutions; this is to ensure that they meet the requirements of the Environmental Protection Act, the Animal Diseases Act, and the Food Act, and that the decision does not conflict with other interests in the area such as urban planning or nature conservation. Licences for aquaculture ensure responsible working conditions as well as the required high standards for animal welfare and hygiene. The FFVA holds the final decision on site licences. In case of spatial conflicts between fish farms and other aquaculture activities, the fish farming activity take precedence. Licences are transferable and are issued for 12 years with the possibility of renewal.

For commercial aquaculture there is an upper limit for ownership, as each company cannot own more than 50% of the total commercial licences for salmon farming at sea. The licences do not have an upper limit for production, which is controlled operationally by the approval of production plans.

From 2012, non-Faroese companies or persons can not own more than 20% of the commercial licences. Companies or persons who had licences prior to 2012 were allowed to keep them. This limitation only applies to salmon farming at sea.

The FFVA manages the issuing of new licences by running licensing rounds for specific fjords and cultivated species. Applications for specific sites require consultation with relevant public authorities, municipalities, and other parties involved. Subject to approval by the Faroese Environment Agency (FEA) and the FFVA, the licences are issued stipulating the cultured species, biological stage (broodstock, smolt, fish), fresh water/sea, location (cadastral number or ocean coordinates), and validity period.

<u>Environmental permit</u>

Aquaculture production on land and sea is on the list of particularly polluting activities according to the Environmental Protection Act, and so environmental permits issued by the FEA are required. The permits impose conditions for operations at each aquaculture site that are aimed at minimizing the pollution from fish farms and their effects on the surrounding environment (see Management framework section).

There are currently three fish farming companies that hold environmental permits for aquaculture production at sea in the ecoregion. Each permit (fjord) has one or more sites where aquaculture production is allowed. In 2022 there were 22 environmental permits for aquaculture production at sea, with a total of 35 aquaculture production sites. There were 12 environmental permits for aquaculture production on land in 2022, and these were divided among five different companies.

Management frameworks

Biosecurity and fish welfare and health

National regulations have been implemented for establishing biosecurity and sea lice control at aquatic farms. The biosecurity regulation aims to prevent disease transmission between farms. The regulation affects:

- the approval of sites, by emphasizing distance to other aquaculture activities and considers production type, methods and quantity of biomass; and
- the day-to-day operation of the farm and the requirement of the farm to operate according to a biosecurity measures plan.

The number of salmon lice on the fish are regulated, while the common sea lice are monitored but not regulated. The sea lice regulation aims at preventing the spread of sea lice and the development of resistance to pharmalogical treatments. Biweekly assessments of sea lice counts are performed by the independent Aquaculture Research Station of the Faroe Islands and are reported to the FFVA. Data on lice infestation and use of pharmaceuticals at each location are published on the FFVA´s website. The biweekly assessments feed into a penalty system and each exceedance of the limit (weighted average of 1 adult female sea lice per fish from 1 August to 30 April, and 0.5 adult female sea lice from 1 May to 31 July) results in one penalty point for the farm, while each pharmaceutical treatment results in two penalty points. The number of fish allowed at the farm in the next production cycle, in combination with general management of welfare, depends on the amount of penalty points incurred:

- < 8 penalty points: increased number of fish allowed;
- 8–15 penalty points: same number of fish allowed; and
- > 15 penalty points: decreased number of fish allowed in next production cycle.

When three consecutive counts exceed the limit in the same production cycle, the operator is required to harvest all the fish at the site within 11 weeks. Furthermore, all operators are obliged to report weekly on fish health and welfare to the FFVA.

There is a substantial effort to diminish sea lice issues within the industry. Much of the technological development during recent years, such as the production of large smolt to shorten the production cycle at sea, and the gradual movement of farming sites to more exposed areas, is motivated by the need to better control sea lice. One fish farming company has recently initiated farming in semi-enclosed units at sea, in order to avoid sea lice infections.

Lumpfish, which is used as a cleaner fish in the aquaculture industry, is regularly monitored and assessed for its health.

Environmental monitoring

The national evaluation of the environmental status focuses on the seabed at- and around farming sites. Seabed surveys are carried out, using guidelines provided by FEA, by a third party (preapproved by the FEA) when fish biomass, and therefore pollution, peaks. The results of the seabed survey are used in a scoring system which determines environmental condition. The survey frequency is determined by the environmental condition during the previous production cycle at peak biomass. This means that if an effect was detected in a previous cycle, more frequent surveys will be required.

The FEA has put in place guideline warning- and limit values for pollution, both within and outside farm sites (Guidance, 19/2018). Guideline thresholds have been fixed for copper, zinc, and organic material, as well as for the overall level of pollution.

After each production cycle the farming operators send an evaluation of the completed cycle, the results of all seabed surveys, any other relevant information from the completed production cycle and a production plan for the upcoming cycle to the FEA for approval. The production plan has to be approved by FEA before fish can be stocked for the upcoming cycle.

Benthic fauna is not currently included in the evaluation of the environmental status. The fish farming areas that are under third-party certification monitor the benthic fauna as a part of that certification.

The data from national and third-party benthic monitoring are used to develop a national benthic macrofauna classification system in accordance with the European Union’s Water Framework Directive.

Marine mammals
From 2020, it has been illegal to shoot or otherwise deliberately kill marine mammals at seafarms. Registrations of accidental deaths due to entanglement are mandatory.

Ecosystem/environment interactions

This section describes the interactions between aquaculture activities and the environment in the Faroes ecoregion.

Increased feed use and environmental impacts from feed waste
The total annual feed used in Atlantic salmon farming in the ecoregion has doubled since 2008 (Figure 9). Although feed conversion has improved recently, the increased feed used poses additional pressure to the environment. The total amount of effluents from salmon farms to the ecoregion is yet to be estimated.

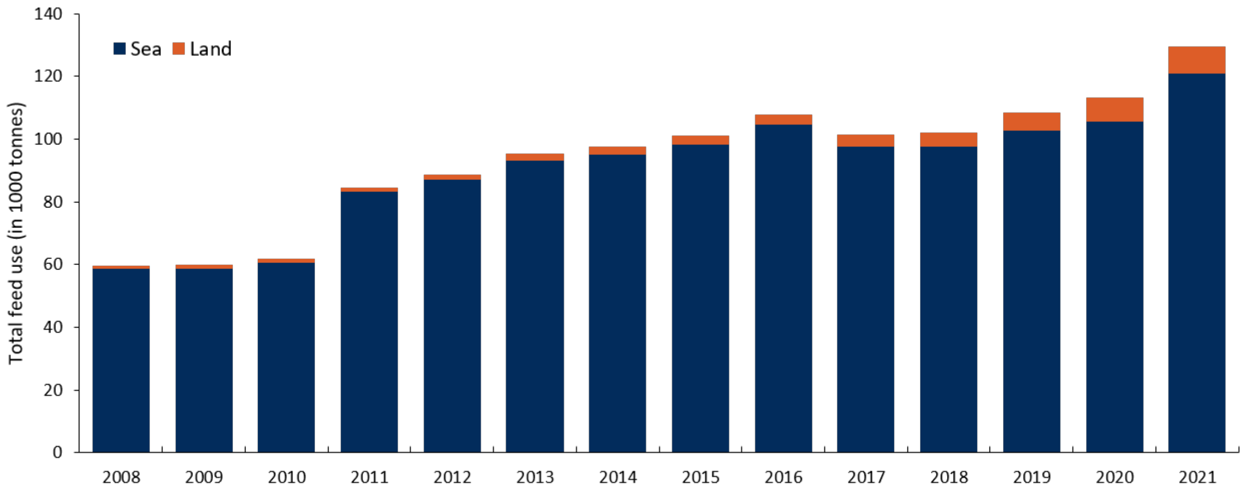

Figure 9 Total annual feed use in the Atlantic salmon farming industry on land (orange) and at sea (blue). (Source: Avrik sp/f).

There has been substantial development in the management of feeding strategies and feed composition, in order to reduce the feed conversion ratio and the waste effluent pressure on the environment. Technological developments in farming equipment have also allowed fish farming to occur in more exposed areas that can sustain higher biomasses than the more sheltered areas.

Emissions of dissolved nutrients and particulate organic matter (faeces and feed loss) are released directly into the environment from open net pens. Emissions of dissolved nutrients in this ecoregion are not considered to be an environmental challenge with today's production level, primarily because of the local hydrodynamic conditions. Impacts from particulate wastes on the seabed are highest closest to the farm, especially in low current locations, and are managed on a site-by-site basis via monitoring programmes.

Therapeutants
From an environmental perspective, the therapeutants of concern today are the drugs used in the treatment of sea lice. Sea lice are crustaceans, and drugs that target sea lice can potentially affect other crustaceans, ranging from planktonic organisms to crabs and lobsters. Both in-feed drugs and bath treatments are used.

Antibiotics have not been used for farmed salmon since 2004. Several chemicals are still used for sea lice treatments (e.g. azametiphos, diflubenzurone and emamectin), and these have been in use since the beginning of aquaculture in the Faroe Islands (Figure 10).

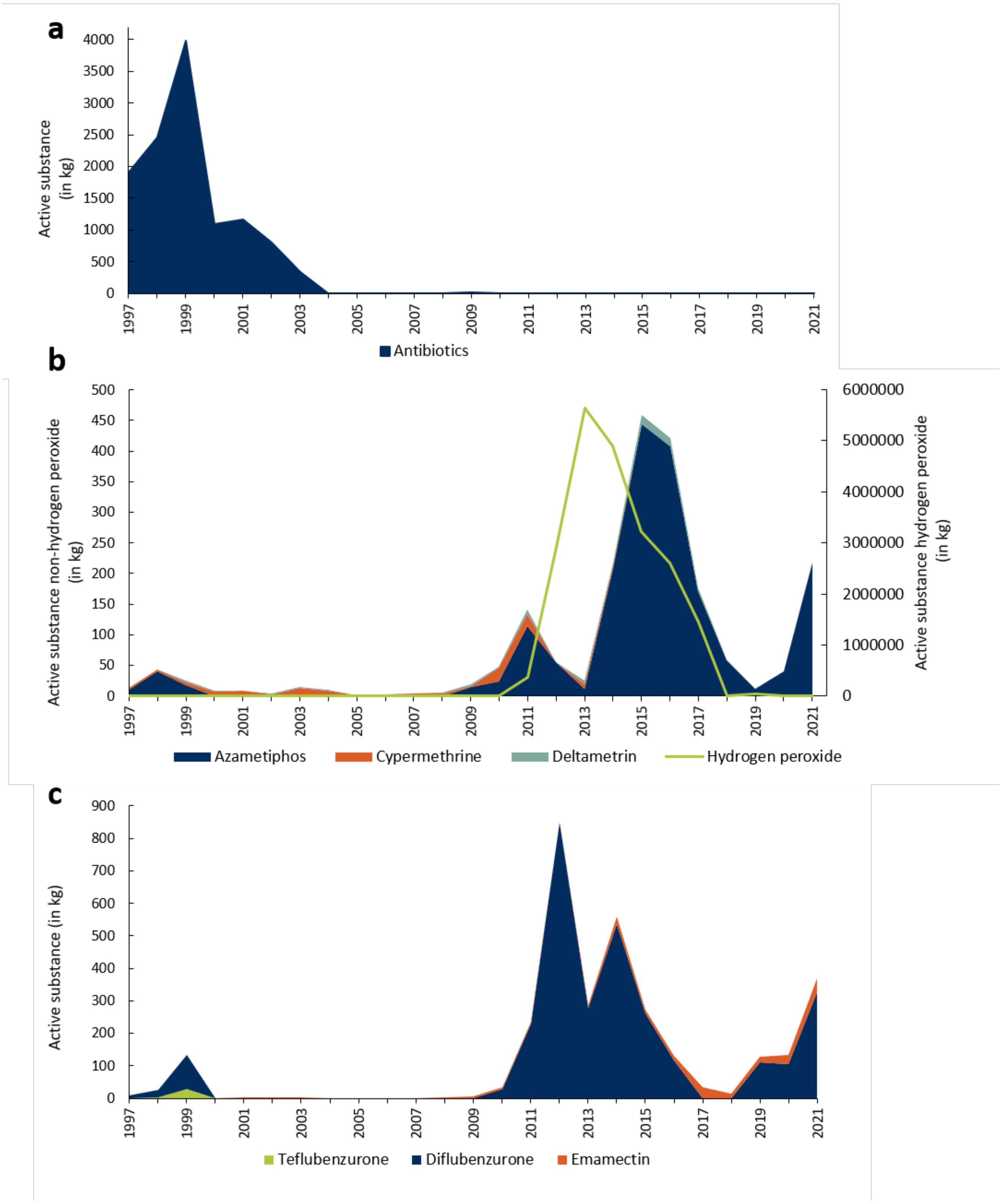

Figure 10 Use of antibiotics (Panel a) and chemical use for sea lice bath treatments (Panel b) and oral treatments (Panel c). Bath treatments with hydrogen peroxide are shown on the secondary axis in Panel b; other therapeutics are shown on a stacked axis. (Source: Landsapotekarin [Faroese Chief Pharmaceutical Officer], personal communication).

The limited evidence for the occurrence of cypermethrin and diflubenzuron around fish farms, where these had been used, indicates that cypermethrin was not detected in the environment, but diflubenzuron was detected in all samples in the proximity of the cages when the agent was in use.

Sea lice

The two sea lice species that affect farmed salmon in the ecoregion are the salmon louse (host-specific to salmonids) and the common sea louse (targetting salmonids but less host-specific). Salmon lice are present year round with typically highest abundance on the farmed fish in winter months. In contrast, common sea lice show strong seasonal patterns as they are present during winter and virtually absent during summer.

The salmon louse is the most abundant parasite that affects farmed Atlantic salmon and is considered the major threat to wild salmonids from aquaculture. There are no naturally wild salmon stocks in the Faroes fjords and rivers today, but sea trout are regulary occurring. Since 2019, the prevalence of sea lice on the native sea trout has regularly exceeded 50%, with an average infestation of between 5 to 10 lice per fish from May to August.

The residual currents flowing around the central shelf may transport sea lice from distant areas. In fjords, the level of infection is lower when the distance from the farm to the mouth of the fjord is shorter, as the planktonic sea lice stages are diluted out of the fjord to a higher degree.

Cleaner fish

The use of cleaner fish for delousing is common in the salmon industry and is considered a low impact method of lice control. Cleaner fish also pose little direct welfare risk to the salmon compared to chemical delousing, and particularly compared to mechanical and thermal delousing. The present use of cleaner fish in general is under debate, mainly due to animal welfare concerns. Relocating cleaner fish over long distances may present risks to local wild fish populations in terms of the transmission of pathogens and genetic introgression in the event of cleaner fish escapes. Today only lumpfish are used as cleaner fish in the ecoregion.

Fish welfare

In farms located in exposed areas waves and currents may reduce the available space in a salmon cage, while rough sea conditions (wave heights up to 3 m and current velocities up to 50 cm/s) may affect fish welfare and behaviour.

The effects from sea lice on fish welfare and the productivity of the aquaculture industry are multi-faceted. Due to treatment measures and management restrictions, sea lice rarely have direct serious impact on the health of the farmed salmon. The indirect effects are substantial, however. The treatments stress the salmon and result in reduced growth, increased susceptibility to disease, and increased mortality. This also varies according to life stages, as smolt in the grow-out stage are more vulnerable to sea lice.

The introduction of mechanical, thermal, and freshwater treatments also implies more handling of the farmed Atlantic salmon, resulting in increased mortalities during the recent years. Mortality of large fish in particular has increased due to handling connected to delousing activity (Figure 11).

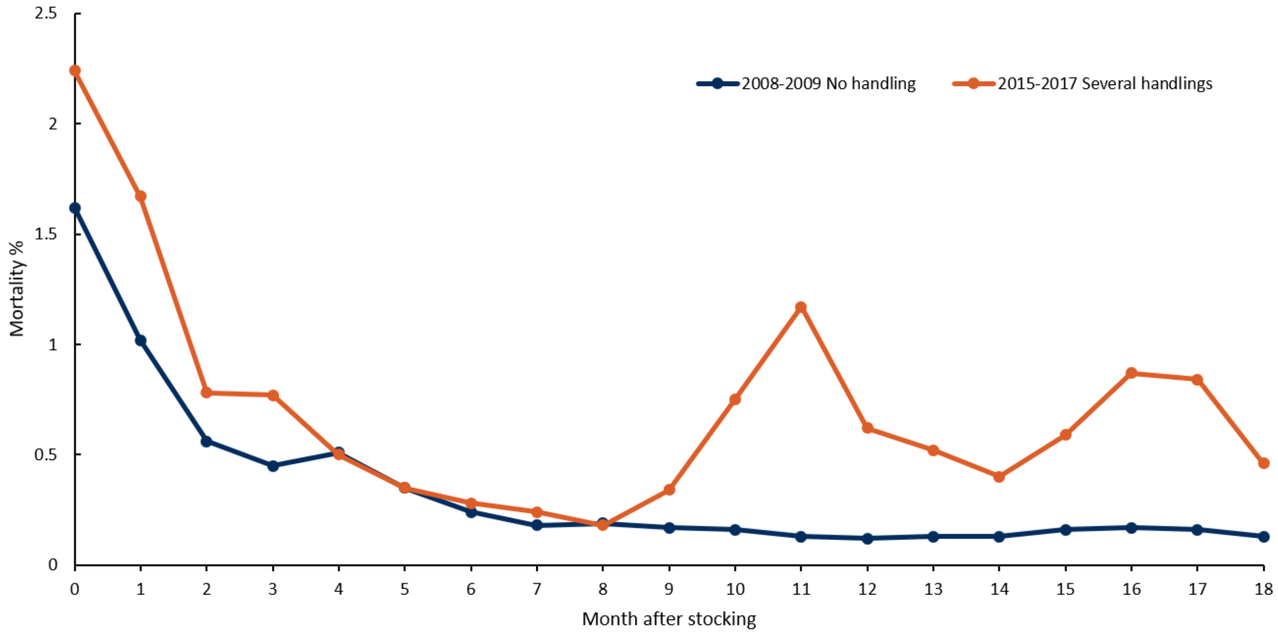

Figure 11 Monthly mortality at sea from stocking of Atlantic salmon smolts (% of stocked fish count) in years with limited handling of the fish (2008–2009) and in years with several handlings, just after the introduction of thermal and mechanical delousing (2015–2017). (Source: Avrik sp/f).

Genetic interactions

There is no major concern of genetic interaction due to escapees spawning with wild Atlantic salmon in the ecoregion. Although there is a salmon stocking program to sustain a sport fishery, and there could be genetic interactions with these stocked fish, there are no wild runs of Atlantic salmon neither in the coastal areas in the ecoregion nor in rivers of the Faroe Islands, where such interactions could occur.

Marine mammals and seabirds

Grey seals frequently interact with salmon farms as they feed near the farms and in some cases enter the cages, damaging the gear and farmed fish. Although there is a ban on lethal control, accidental mortalities such as entanglement may still occur. No marine mammal mortalities have occurred since January 2021.

The European storm petrel, of which the Faroe Islands holds the largest breeding colony in Europe, is observed at fish farms in the ecoregion. Due to the improvement of fish farm bid nets, seabird mortality as a result of entanglement in these nets has steadily declined and in 2021 the estimated bird mortality was around 50 individuals.

Seaweed farming

Seaweed farming can provide environmental benefits, such as food resources, habitat and shelter for wild fish and invertebrates, as well as nutrient and carbon removal. Seaweed farming's impact on the environment is likely to be low as the scale of operation is currently small in the ecoregion.

Social and economic context

The overall objective of the Faroese legislation on aquaculture is to promote profitability and competitiveness in aquaculture within a sustainable framework with regards to animal health and the environment. The nature and extent of aquaculture activities and production are, therefore, influenced by overarching social and economic considerations. The aquaculture industry, together with various suppliers to that industry, have huge social and economic effects on Faroese society.

Profitability

Profitability can fluctuate substantially over time as a result of biological factors (e.g. the ISA disease outbreak in the early 2000s) and economic factors, (e.g. feed prices; other production costs and global market prices related to supply and demand). Since 2006, profitability measured as the operating margin has generally been high (Figure 12), despite a general increase in production costs since 2009 (Figure 13). High profitability in the salmon farming industry is linked to the absence of major diseases and a concurrently growing international market demand. The higher profit in recent years has largely been driven by the increasing price of salmon, which has gradually increased from 16 Danish Kroner (DKK)/kg in 2003 to over 50 DKK/kg in recent years.

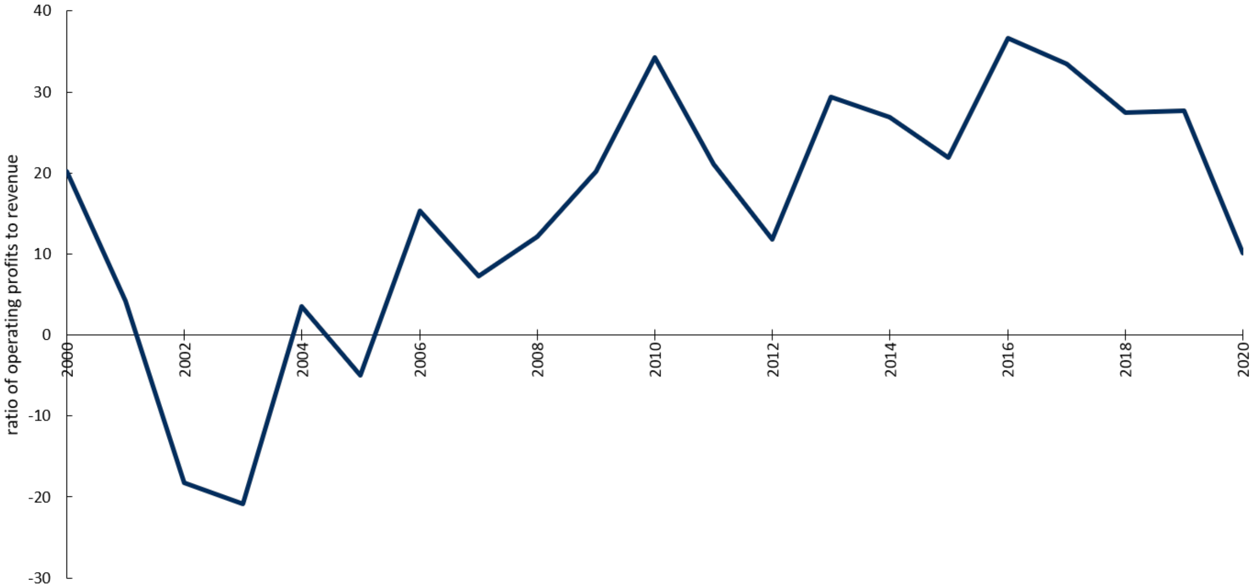

Figure 12 Operating margin (operating profit divided by operating revenues) for farming of Atlantic salmon in the Faroes ecoregion (2000–2020). (Source: Statistics Faroe Islands, Statbank, Business statistics).

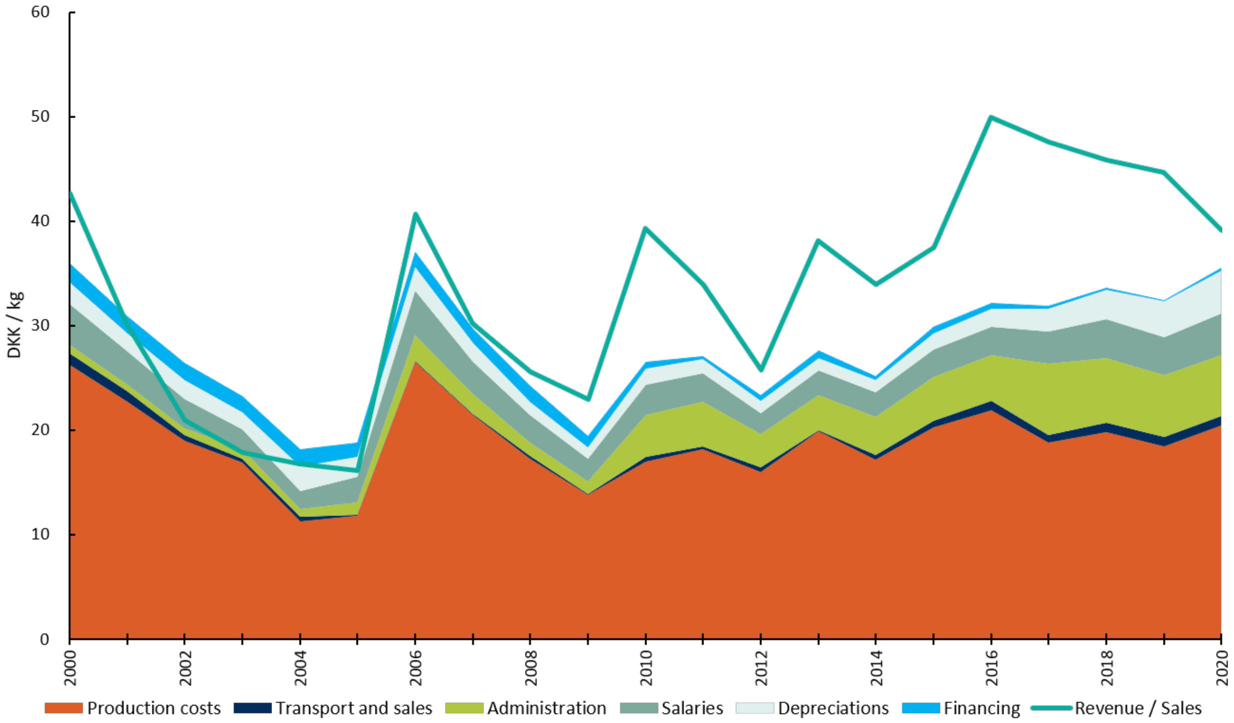

Figure 13 Production costs and revenues per kilogram in DKK in the Atlantic salmon farming industry. Production costs are calculated as costs divided by the slaughtered weight. The line depicts the revenue per produced kilo of salmon while the area chart depicts the cost structure of the industry. The space between the revenue line and the cost area represents the profits or deficits of the industry. (Source: Statistics Faroe Islands, Statbank, Business statistics).

Major investments in land-based rearing facilities (from around 100 million to around 500 million DKK annually) have been made in recent years, mainly to combat the major challenge of the farming industry - sea lice. Expanding land-based facilities extends the production time on land, reduces the production time in the fjords, and so reduces exposure to sea lice. As a result, the total value of the tangible assets in the salmon industry has increased from around 500 million DKK in 2010 to around 3500 million DKK in 2020 (Figure 14). The production cycle at sea has been reduced by more than eight months as a result of these investments, so salmon can be harvested before the infection pressure of sea lice escalates. This both reduces the need for delousing operations, and minimizes the risk of infection with other diseases at sea.

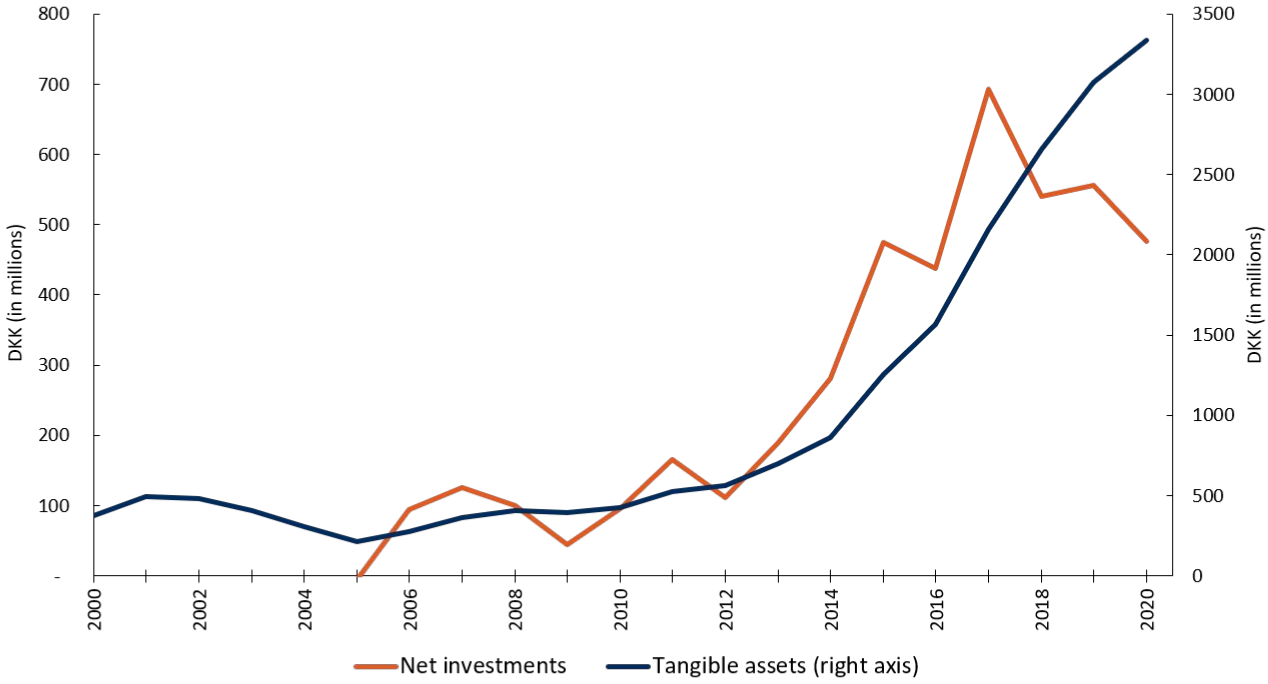

Figure 14 Net annual investments (left axis) and total value of tangible assets (right axis) in the Faroese aquaculture industry during 2000 – 2020. (Source: Statistics Faroe Islands, Statbank, Business statistics).

<u>National importance</u>

The aquaculture industry is a major contributor to the Faroes Islands' Gross Domestic Product (GDP). Prior to the ISA outbreak, the salmon industry's share of the total GDP was around 4%. In recent years this has increased to around 8% of the total GDP, though somewhat lower in 2020 due to the COVID-19 outbreak. By including the multiplier effect (e.g. purchases of goods and services and increase in employment by the industry), however, aquaculture contributes to around 16% of the total GDP. Two thirds of the multiplier effect stems from purchases of goods and services by the industry, while the remaining third originates from the employees' consumption. When additional revenue from taxes and derived spending by the public sector is also considered, it is estimated that aquaculture contributes to approximately 24% of the Faroese economy.

Since 2013 the export value from the aquaculture industry has been 40–45% of the total exports of goods (Figure 15, left panel). Aquaculture represents 24-28% of the total income on the balance of payments (e.g. imports and exports of goods, services, and capital), which further confirms the key role of the aquaculture industry in Faroese society (Figure 15, right panel).

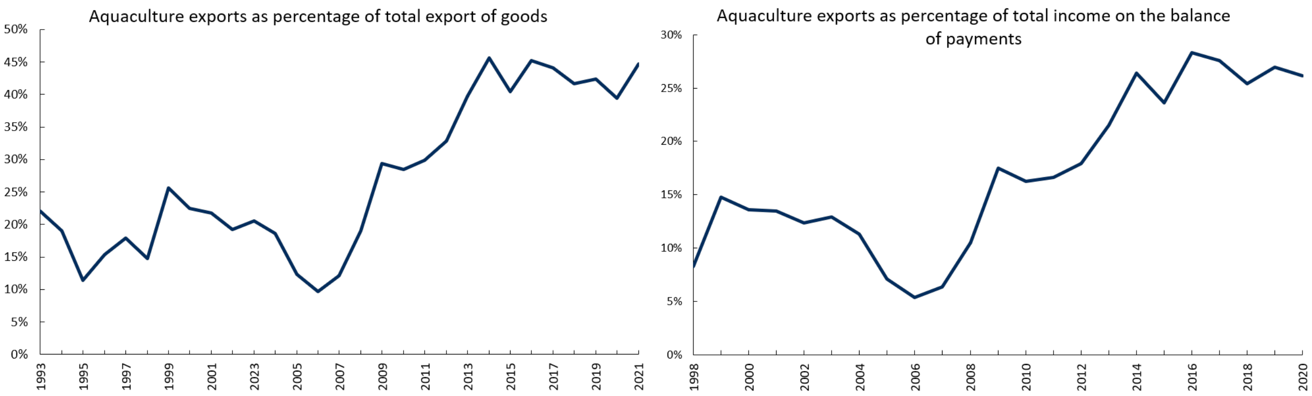

Figure 15 Exports from the Faroese aquaculture industry as a percentage of the total exports of goods, 1993–2021 (left panel), and as a percentage of the total income on the balance of payments in the Faroe Islands, 1998–2020 (right panel). (Source: Statistics Faroe Islands, Statbank).

<u>Regional dynamics in employment</u>

The employment in aquaculture has gradually increased over time, concurrent with the increase in production (Figure 16). Employment in fisheries and processing of wild catches has decreased at the same time, making aquaculture an increasingly important industry in the Faroe Islands in terms of job creation. The aquaculture value chain, including farming (breeding, juvenile production, and grow-out), harvesting, and processing, employed about 1350 people in 2021. This represented around 5% of the total active labour force in the Faroe Islands.

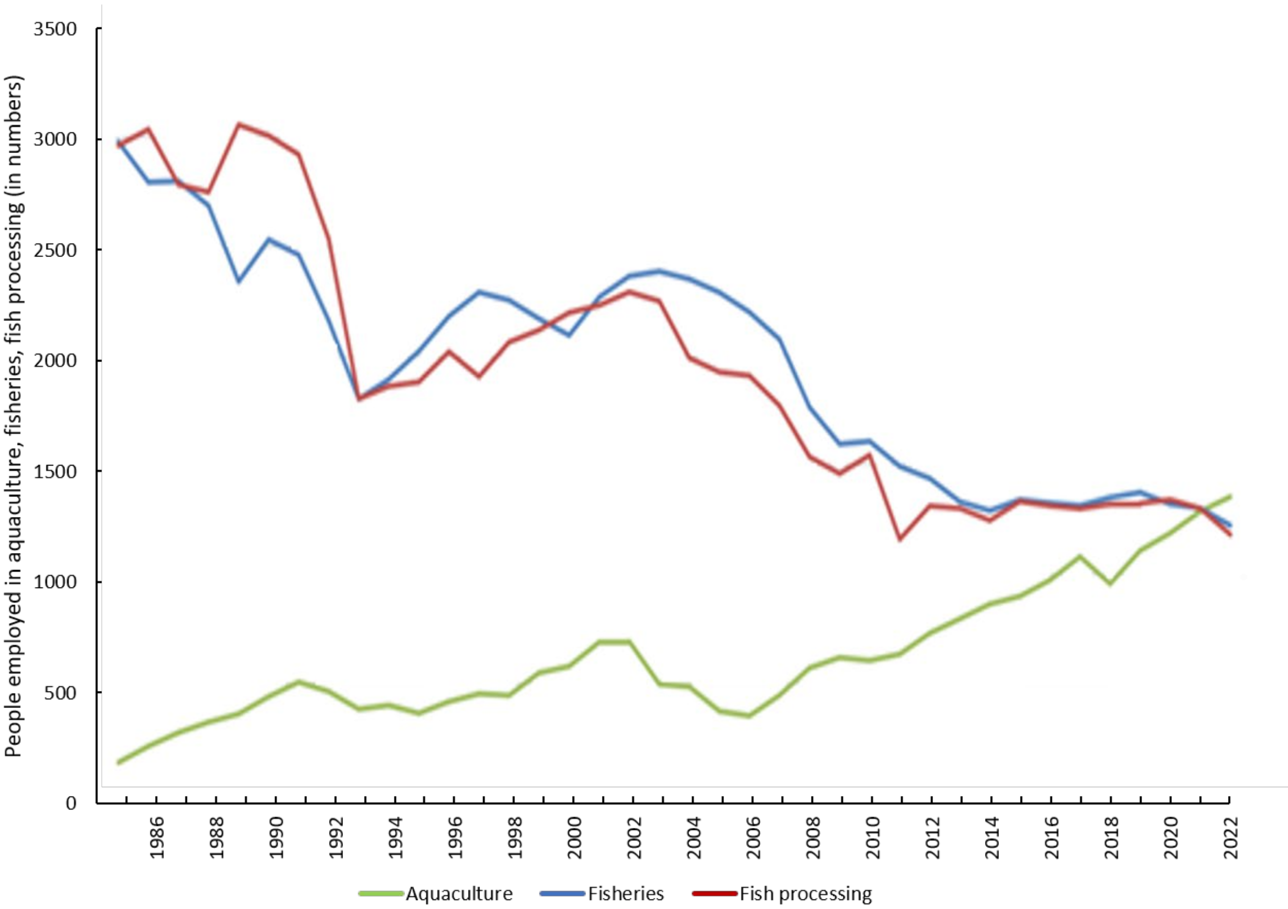

Figure 16 Employment in Atlantic salmon production and processing (aquaculture), and in fisheries and processing of wild catches (1985–2022). (Source: Statistics Faroe Islands, Statbank).

The people working in aquaculture are relatively young, and there are generally more men working in the industry than women. Of the total workforce in the Faroe Islands in 2021, 6% of the total male workforce worked in aquaculture compared to 4% of women.

In 2022, 37% of the total female workforce in the aquaculture industry was born outside the Faroe Islands. For the male workforce this was 18%. This is substantially higher than in other industries, where the corresponding figure is about 13%. About 80% of non-Faroese workers within aquaculture come from countries outside Europe.

Sub-regional dynamics in employment

Prior to the ISA outbreak in the early 2000s, aquaculture was particularly important in four of the seven regions - Norðstreym, Suðuroy, Norðoyggjar and Vágar. The disease caused multiple bankruptcies and resulted in a consolidation of the industry into two regions - Eysturoy and Vágar (Figure 17). This has also affected the labour market, as inhabitants of Eysturoy and Vágar are increasingly working in the aquaculture industry, while other regions largely show a tendency towards stagnation in employment in the sector.

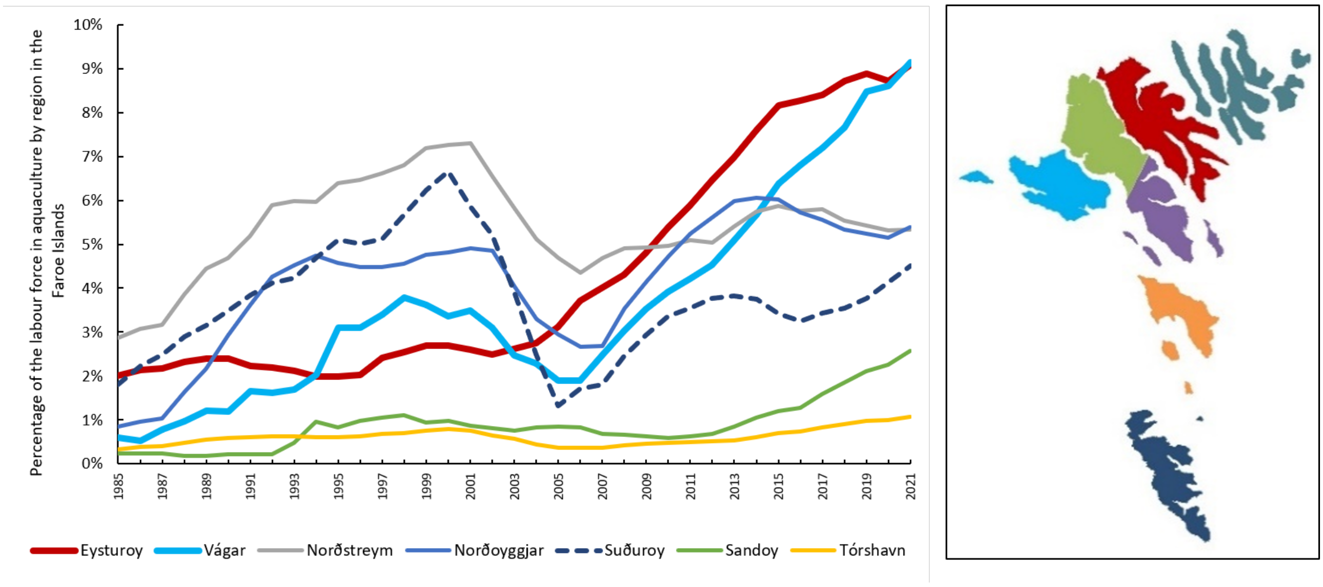

Figure 17 Sub-regional dynamics of the labour force working in the aquaculture industry in the Faroe Islands, shown as the percentage of the total active labour force, 1985–2021. The location of the regions of the Faroe Islands is shown in the right panel. (Source: Statistics Faroe Islands, Statbank).

Social acceptability

In adjacent ecoregions, there is some evidence that the public has varying perceptions of aquaculture. Based on the limited evidence, there are no indications that suggest any general public resistance to aquaculture operations. There are no environmental NGOs that generally oppose aquaculture development in the Faroe Islands.

In the Faroe Islands there are little data available to understand the public's perception of aquaculture, but it appears to have high social acceptance. Based on a survey about diverse environmental issues, with 500 respondents, 67% of respondents 'agreed' that the aquaculture industry should be subject to stricter environmental regulations (FNU, 2022).

Interaction of environmental, economic, and social drivers

General growth of the aquaculture industry in the ecoregion over time has largely been driven by the aquaculture industry itself, but this has been in collaboration with researchers, technological developers, and government authorities.

A combination of factors were responsible for two major declines in aquaculture production in the early 1990s and 2000s; these included disease outbreaks, sea lice infections, and financial instability. Decreases in fish price also led to a reduction in fish farm stock levels due to the associated financial risk. Major reforms to the national aquaculture legislation in 2003, which happened in collaboration with the industry, financial institutions, and the authorities, resulted in a substantial increase in aquaculture production in the ecoregion. This exemplifies how environmental, economic, and social drivers simultaneously influenced aquaculture production in the ecoregion over time (Figure 4).

In addition to aquaculture, different human activities operate in coastal regions of the Faroes ecoregion. These include the fishing, tourism, shipping, and energy sectors, which all provide the regional context for interactions among environmental, economic, and social drivers relevant to the management and further development of aquaculture. Interactions between sectors include those that come directly through competition for space, and those that come indirectly through effects on the environment, as well as social and economic interactions across different spatial scales.

Aquaculture activities may interact with fisheries by competing for space. Such cases have occurred with the lobster fishery in some fjords and sounds where these activities operate in the same areas. Competition for space may occur in coastal areas with the operation of a large number of fishing boats, using jigs, longlines, and small trawls. The gradual expansion of salmon farms to exposed areas may lead to further competition for space. There could also potentially be competition for space between recreational fisheries, shipping, the energy sector (winds and tidal currents), and the aquaculture industry.

The coastal region is a nursery area for several local fish stocks, such as cod, saithe, whiting, and plaice; there is some concern, mainly within the fishing sector, about whether the fish farming activity might affect recruitment to these fish stocks.

Future projections and emerging threats and opportunities

Diversifying the industry

Aquaculture production in the Faroes ecoregion is largely dominated by Atlantic salmon and is a well-consolidated and innovative farming sector. Salmon farming already occupies nearly all suitable locations for traditional farming in open net cages on the Faroese coastline. The single largest threat to salmon production in the ecoregion is sea lice, which has also been the main driver of innovations in farm practices and production technologies. Further expansion will require innovations in farming methods, including semi-enclosed systems and/or increased expansion to more offshore locations. There are currently no plans for the adoption of on-land recirculating aquaculture systems (RAS) for full life cycle production of salmon in the ecoregion. RAS systems are, however, currently being used for production of larger smolts before transferring to farm sites at sea.

There is ongoing discussion regarding the need to diversify the aquaculture industry, in order to better utilize the marine space and to minimize the risk associated with over-reliance on a single species. Changes to aquaculture legislation in 2019 now allow the farming of multiple species of different trophic levels within the 22 management areas throughout the ecoregion. Macroalgae could potentially diversify the single species farming industry, and production projections estimate as high as 6000 tonnes wet weight of macroalgae by 2025. Further expansion is dependent on environmental permits, and only three macroalgae aquaculture licences have been issued to date.

Investigations are currently ongoing to begin commercial shellfish farming.

Effects of climate change

Based on the evidence from the adjacent ecoregions, the effects from climate change are multifaceted and will affect the aquaculture industry through multiple stressors in a complex manner. These include: 1) sea level rise and extreme water levels, 2) increased intensity and frequency of storms and wave exposure, 3) changes in air and/or sea temperature, 4) extreme temperatures and heatwaves, 5) ocean acidification, 6) deoxygenation, and 7) changes in precipitation/run-off.

The ways multiple stressors and their interactions may affect the aquaculture industry is recognized as an area that needs attention, in order to maintain or increase aquaculture production under climate change. However, the effects of climate change on the environment and aquaculture in the ecoregion is poorly known. More frequent and more intense storms are among the largest general concerns for the ecoregion, as they may create challenging conditions for salmon welfare in response to waves and currents, inducing stress, wounds, and other injuries to the farmed fish.

Increases in seawater temperature may enhance individual growth rates of salmon. Heatwaves above optimal temperature can lead to reduced appetite, however, resulting in slower growth and thermal stress to the fish. While the temperature is expected to increase further during this century, it is unlikely that the sea temperature in the ecoregion will increase beyond the thermal tolerance of salmon.

Sea lice infection pressure is predicted to increase due to increasing seawater temperatures. Two important risk factors for the outbreak of Amoebic Gill Disease are increased seawater temperature and salinity.

Changes in precipitation and run-off from land may have pronounced effects on stratification and seawater exchange in the fjords, where the water circulation is estuarine driven. This may alter the carrying capacity of those fjords.

Integration of different sectors

It is likely that the future growth of the aquaculture industry in the ecoregion will require more space, increasing pressure on the marine ecosystem, and elevating interactions with other human activities. These include commercial fisheries, shipping, and tourism, as well as potentially offshore renewable energy developments. Future developments will need to consider and apply an integrated approach to assess synergies and trade-offs among different sectors, while investigating consequences across environmental, ecological, and socio-economic dimensions.

Future sustainable development of the coastal area may benefit from the development of a marine spatial plan for the entire area.

Table 1 Summary of main knowledge gaps and data needs regarding aquaculture within the Faroes ecoregion.

Topic	Knowledge gaps and data needs
Description and location of aquaculture activities and practices	• Description of salmon culture facilities
Production over time	• Statistics on seaweed production (by species) • Statistics on lumpfish imports and farming
Ecosystem/environment interactions	• Time-series of coastal water quality • Time-series of benthic fauna in reference areas • Effects of therapeutants • Use of vaccines to negate use of antibiotics • Sea lice infection on native trout • Ecosystem effects of seaweed farming • Impact of aquaculture activities on the recruitment of commercial fish stocks • Escapees of cultured taxa and cleaner fish • Genetic introgression in wild lumpfish • Disease transmission to wild fish populations by lumpfish
Social and economic context	• Public perception and social acceptance of aquaculture • Sectorial-level statistics on people available on the labour market • Statistics on different stages of the supply chain (smolt farms, sea farms, harvesting and processing) • Multiplier effects of aquaculture on other industries
Interaction of environmental, economic, and social drivers	• Identification of marine natural conservation areas
Future projections and emerging threats and opportunities	• Time-series on aquaculture-relevant climatic variables • Local projections of expected climate change • Long-term planning of multiple human activities in coastal areas

Data sources

Aling. https://www.landsverk.fo/fo-fo/borgari/kervi%C3%B0/aling. Last accessed: February 24, 2023.

Avrik sp/f. Data obtained through personal communication. The company owner, Rúni Dam, is a member of Workshop on the Faroes ecoregion Aquaculture Overview (WKFAROESAO).

Faroese Fish Farmers Association annual statements: https://www.industry.fo/vinnugreinafe-loeg/havbuna%C3%B0arfelagi%C3%B0. Last accessed 2 March 2023.

Landsapotekarin [Faroese Chief Pharmaceutical Officer – FPO]. Data obtained through personal communication.

Statistics Faroe Islands (Statbank): https://hagstova.fo/en#. Last accessed 04 March 2003.

Statistics Faroe Islands, Statbank, Business statistics: https://hagstova.fo/en/business/primary-sector/aquaculture. Last accessed 04 March 2023.

Sources and references

á Norði, G., Glud, R. N., Gaard, E., and Simonsen, K. 2011. Environmental impacts of coastal fish farming: Carbon and nitrogen budgets for trout farming in Kaldbaksfjørour (Faroe Islands). Marine Ecology Progress Series, 431: 223–241. https://doi.org/10.3354/meps09113

á Norði, G., Simonsen, K., Danielsen, E., Eliasen, K., Mols-Mortensen, A., Christiansen, D. H., Steingrund, P., Galbraith, M., and Patursson, Ø. 2015. Abundance and distribution of planktonic *Lepeophtheirus salmonis* and *Caligus elongatus* in a fish farming region in the Faroe Islands. Aquaculture Environmental Interactions, 7: 15-27 https://www.jstor.org/stable/24864883

Abrahamsen, H., and Patursson, Ø. 2017. Description of measurements at the aquaculture site Sandsvág. Fiskaaling rit 2017-15.

Animal Diseases Act. 2001. Løgtingslóg nr. 16 frá 23. februar 2001 um djórasjúkur, sum seinast broytt við løgtingslóg nr. 31 frá 17. mars 2022 (16-2001). https://logir.fo/Logtingslog/16-fra-23-02-2001-um-djorasjukur-sum-broytt-vid-logtingslog-nr-18-fra-8-mai. Last accessed: February 27, 2023.

Animal Welfare Act. 2018. Løgtingslóg nr. 49 frá 30. apríl 2018 um djóravælferð (Djóravælferðarlógin), sum seinast broytt við løgtingslóg nr. 31 frá 17. mars 2022 (49-2018). https://logir.fo/Logtingslog/49-fra-30-04-2018-um-djoravaelferd-Djoravaelferdarlogin. Last accessed: February 27, 2023.

Aquaculture Act Amendment. 2020. Løgtingslóg um broyting í løgtingslóg um aling av fiski v.m. (Bann fyri tilætlað at avlíva havsúgdjór í samband við alivirksemi) (65-2020). https://logir.fo/Logtingslog/65-fra-14-05-2020-um-broyting-i-logtingslog-um-aling-av-fiski-vm. Last accessed: February 27, 2023.

Aquaculture Act. 2009. Løgtingslóg um aling av fiski v.m., sum seinast broytt við løgtingslóg nr. 31 frá 17. mars 2022 (83-2009). https://www.logir.fo/Logtingslog/83-fra-25-05-2009-um-aling-av-fiski-vm. Last accessed: February 27, 2023.

Biosecurity Regulation. 2019. Kunngerð nr. 80 frá 14. juni 2019 um stovnan og sjúkufyrbyrgjandi rakstur av alibrúkum (80-2019). https://logir.fo/Kunngerd/80-fra-14-06-2019-um-stovnan-og-sjukufyribyrgjandi-rakstur-av-alibrukum. Last accessed: February 27, 2023.

Dam, M., and Mortensen, R. 2014. Kanningar av diflubenzuron í og við úrvald aliøki í Føroyum í 2013. Umhvørvisstovan [Faroese Environment Agency]. https://www.us.fo/Default.aspx?ID=13912. Last accessed: 24 February 2023.

Eliasen, K., Danielsen, E., Johannesen, Á., Joensen, L.L., and Patursson, E. J. 2018. The cleaning efficacy of lumpfish (*Cyclopterus lumpus* L.) in Faroese salmon (*Salmo salar* L.) farming pens in relation to lumpfish size and seasonality. Aquaculture 488: 61-65. https://doi.org/10.1016/j.aquaculture.2018.01.026

Eliasen, K., Johannesen. U., V., Petersen, S., Bergkvist, K. S. G. 2022. Annual report 2021. The sea trout project. Fiskaaling rit 2022-01. https://www.fiskaaling.fo/media/2793/2022-01_annual-report-2021-the-sea-trout-project.pdf. Last accessed: 28 February 2023.

Environmental Protection Act. 1988. Løgtingslóg nr. 134 frá 29. oktober 1988 um umhvørvisvernd, sum seinast broytt við løgtingslóg nr. 168 frá 16. desember 2021 (134-1988). https://logir.fo/Logtingslog/134-fra-29-10-1988-um-umhvorvisvernd-sum-seinast-broytt-vid-logtingslog-nr-128-fra-22. Last accessed: February 27, 2023.

Erenbjerg, S. V., Albretsen, J., Simonsen, K., Sandvik, A. D., and Kaas, E. 2020. A step towards high resolution modelling of the central Faroe shelf circulation by FarCoast800. Regional Studies in Marine Science, 40(1):2–3. https://doi.org/10.1016/j.rsma.2020.101475

Falconer, L., Telfer, T. C., Garrett, A., Hermansen, Ø., Mikkelsen, E., Hjøllo, S. S., McAdam, B., and Ytteborg, E. 2022. Insight into real-world complexities is required to enable effective response from the aquaculture sector to climate change. PlosClimate 1(3): e0000017. https://doi.org/10.1371/journal.pclm.0000017

Faroese Environment Agency. 2018. Environmental Monitoring of Fish Farming. Guidance document 19/2018 (Unofficial translation, June 2020). https://www.us.fo/Default.aspx?ID=14048. Last accessed: 24 February 2023.

Food Act. 2010. Løgtingslóg nr. 58 frá 26. mai 2010 um matvørur v.m., sum seinast broytt við løgtingslóg nr. 102 frá 13. juli 2017 (58-2010). https://logir.fo/Logtingslog/58-fra-26-05-2010-um-matvorur-vm. Last accessed: February 27, 2023.

Føroya Nátturu og Umhvørvisfelag (FNU) – Faroese Nature and Environment. 2022 https://www.fnu.fo/. Last accessed: 2 March 2023

Hasan, M. R., and New, M. B. Eds. 2013. On-farm feeding and feed management in aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. 67 pp. https://www.fao.org/3/i3481e/i3481e00.htm. Last accessed: 27 February, 2023.

ICES. 2023. Workshop on the Faroes ecoregion Aquaculture Overview (WKFaroesAO). ICES Scientific Reports. 5: 28. 87 pp. https://doi.org/10.17895/ices.pub.21551541

Jacobsen, H. 2011. Ringar á sjónum, Søgan um føroysku alivinnuna. Havbúnaðarfelagið: Tórshavn.

Jacobsen, H. 2020. Úr eyga til varandi aling, Fiskaaling 50 ár. Fiskaaling: Tórshavn.

Johannesen, Á., Patursson, Ø., Krstmundsson, J., Dam, S. P., Mulelid, M., and Klebert, P., 2022. Waves and currents decrease the available space in a salmon cage. PlosOne 17(2): e0263850. https://doi.org/10.1371/journal.pone.0263850

Klebert, P., Patursson, Ø., Endresen, P. C., Rundtop, P., Birkevold, J., Rasmussen, H. W. 2015. Three-dimensional deformation of a large circular flexible sea cage in high currents: Field experiment and modelling. Ocean Engineering 104: 511-520. https://doi.org/10.1016/j.oceaneng.2015.04.045

Kragesteen, T. J., Simonsen, K., Visser, A. W., and Andersen, K. H. 2018. Identifying salmon lice transmission characteristics between Faroese salmon farms. Aquaculture Environmental Interactions 10:49-60. https://doi.org/10.3354/aei00252

Kragesteen, T. J., Simonsen, K., Visser, A. W., Andersen, K. H. 2021. Estimation of external infection pressure and salmon-louse population growth rate in Faroese salmon farms. Aquaculture Environment Interactions, 13: 21-32. https://doi.org/10.3354/aei00386

Laksáfoss, M. 2015. Sources of economic growth in Faroe Islands 1985–2014. Report for the Faroese Vessel Owner's Union.

Monterey Bay Aquarium. 2018. Seafood Watch - Atlantic salmon; Faroe Islands - Marine Net Pens. 86 pp. https://seafood.ocean.org/wpcontent/uploads/2018/09/MBA_SeafoodWatch_AtlanticSalmon_Faroes_Report.pdf. Last accessed: 24 February 2023.

Monterey Bay Aquarium. 2022. Seafood Watch - Atlantic salmon; Faroe Islands - Marine Net Pens. 112 pp. https://prod.seafoodwatch.org/recommendation/salmon/atlantic-salmon-38769?species=302. Last accessed: 24 February 2023.

Nystøyl, R. 2022. Atlantisk Laks - Status og Utsikter. Presentation at Aliráðstevnan, 20 May 2022, Tórshavn. https://www.industry.fo/kunning/tiltoek/hildin-tiltoek/alira%C3%B0stevnur-2008-2022/alira%C3%B0stevnan-2022. Last accessed: 24 February 2023.

Patursson, E. J., Simonsen, K., Visser, A. W., and Patursson, Ø. 2017. Effects of exposure on salmon lice Lepeophtheirus salmonis population dynamics in Faroese salmon farms. Aquaculture Environment Interactions, 9: 33-43. https://doi.org/10.3354/aei00209

Porter, B. 2021 How do Storm-petrels interact with marine developments and light pollution in the Faroe Islands? Results from a pilot study in summer 2021.

Reid, G. K., Gurney-Smith, H. J., Marcogliese, D.J., Knowler, D., Benfey, T., Garber, A. F., Forster, I., *et al.* 2019. Climate change and aquaculture: considering biological response and resources. Aquaculture Environmental Interactions, 11:569-602. https://doi.org/10.3354/aei00332

Sandvik, A. D., Dalvin, S., Skern-Mauritzen, R., Skogen, M.D., and Byron, C. 2021. The effect of a warmer climate on the salmon lice infection pressure from Norwegian aquaculture. ICES Journal of Marine Science 78(5):1849–59. https://doi.org/10.1093/icesjms/fsab069

Sea Lice Regulation. 2016. Kunngerð nr. 75 frá 28. juni 2016 um yvirvøku og tálming av lúsum á alifiski, sum seinast broytt við kunngerð nr. 93 frá 3. juni 2021 (75-2016). https://www.logir.fo/Kunngerd/75-fra-28-06-2016-um-yvirvoku-og-talming-av-lusum-a-alifiski. Last accessed: 27 February, 2023.

Solstorm, F. 2017. The effect of water currents on post-smolt Atlantic salmon, Salmo salar (L.): A welfare approach to exposed aquaculture. PhD Thesis. Bergen: University of Bergen. http://hdl.handle.net/1956/16129

Østerø, S. L., Erenbjerg, S. V., Johannesen, T. T., Olsen, E. L. and á Norði, G. 2022. Fjarðarannsókn: Kaldbaksfjørður. Fiskaaling rit 2022-03.

Recommended citation: ICES. 2023. Faroes ecoregion – Aquaculture Overview. In Report of the ICES Advisory Committee, 2023. ICES Advice 2023, section 12.3. https://doi.org/10.17895/ices.advice.22219393

Annex

Table A1 Common and scientific names of species.

Common name	Scientific name
Atlantic cod	*Gadus morhua*
Atlantic halibut	*Hippoglossus hippoglossus*
Atlantic salmon	*Salmo salar*
Blue mussel	*Mytilus spp.*
Brown trout	*Salmo trutta*
Common sea louse	*Caligus elongatus*
European storm petrel	*Hydrobates pelagicus*
Grey seal	*Halichoerus grypus*
Lumpfish	*Cyclopterus lumpus*
Norway lobster	*Nephrops norvegicus*
Plaice	*Pleuronectes platessa*
Rainbow trout	*Oncorhynchus mykiss*
Saithe	*Pollachius virens*
Salmon louse	*Lepeophtheirus salmonis*
Sea trout	*Salmo trutta trutta*
Whiting	*Merlangius merlangus*