Monterey Bay Aquarium Seafood Watch®

Atlantic salmon

Salmo salar

Faroe Islands

Marine Net Pens

December 5, 2022

Seafood Watch Consulting Researcher

Disclaimer

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About Seafood Watch

Monterey Bay Aquarium's Seafood Watch program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Watch Assessment. Each assessment synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices," "Good Alternatives" or "Avoid." This ethic is operationalized in the Seafood Watch standards, available on our website here. In producing the assessments, Seafood Watch seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying assessments will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Watch assessments in any way they find useful.

Guiding Principles

Seafood Watch defines sustainable seafood as originating from sources, whether fished[1] or farmed that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

The following guiding principles illustrate the qualities that aquaculture farms must possess to be considered sustainable by the Seafood Watch program. Sustainable aquaculture farms and collective industries, by design, management and/or regulation, address the impacts of individual farms and the cumulative impacts of multiple farms at the local or regional scale by:

1. **Having robust and up-to-date information on production practices and their impacts available for analysis;**
   Poor data quality or availability limits the ability to understand and assess the environmental impacts of aquaculture production and subsequently for seafood purchasers to make informed choices. Robust and up-to-date information on production practices and their impacts should be available for analysis.
2. **Not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level;**
   Aquaculture farms minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges.
3. **Being located at sites, scales and intensities that maintain the functionality of ecologically valuable habitats;**
   The siting of aquaculture farms does not result in the loss of critical ecosystem services at the local, regional, or ecosystem level.
4. **Limiting the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms;**
   Aquaculture farms avoid the discharge of chemicals toxic to aquatic life or limit the type, frequency or total volume of use to ensure a low risk of impact to non-target organisms.
5. **Sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains;**
   Producing feeds and their constituent ingredients has complex global ecological impacts, and the efficiency of conversion can result in net food gains or dramatic net losses of nutrients. Aquaculture operations source only sustainable feed ingredients or those of low value for human consumption (e.g. by-products of other food production), and convert them efficiently and responsibly.
6. **Preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes;**
   Aquaculture farms, by limiting escapes or the nature of escapees, prevent competition, reductions in genetic fitness, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems that may result from the escape of native, non-native and/or genetically distinct farmed species.

1 "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates.

7. **Preventing population-level impacts to wild species through the amplification and retransmission, or increased virulence of pathogens or parasites;**
   Aquaculture farms pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites, or the increased virulence of naturally occurring pathogens.
8. **Using eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture;**
   Aquaculture farms use eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture, or where farm-raised broodstocks are not yet available, ensure that the harvest of wild broodstock does not have population-level impacts on affected species. Wild-caught juveniles may be used from passive inflow, or natural settlement.
9. **Preventing population-level impacts to predators or other species of wildlife attracted to farm sites;**
   Aquaculture operations use non-lethal exclusion devices or deterrents, prevent accidental mortality of wildlife, and use lethal control only as a last resort, thereby ensuring any mortalities do not have population-level impacts on affected species.
10. **Avoiding the potential for the accidental introduction of secondary species or pathogens resulting from the shipment of animals;**
   Aquaculture farms avoid the international or trans-waterbody movements of live animals, or ensure that either the source or destination of movements is biosecure in order to avoid the introduction of unintended pathogens, parasites and invasive species to the natural environment.

Once a score and rating has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ratings and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

Best Choices/Green: Buy first, they're well managed and caught or farmed in ways that cause little harm to habitats or other wildlife.

Good Alternatives/Yellow: Buy, but be aware there are concerns with how they’re caught or farmed.

Avoid/Red: Don't buy, they're overfished or caught or farmed in ways that harm other marine life or the environment.

Final Seafood Recommendation

Atlantic salmon farmed in marine net pens in the Faroe Islands

Criterion	Score	Rank	Critical?
C1 Data	6.82	Green	n/a
C2 Effluent	4.00	Yellow	No
C3 Habitat	6.93	Green	No
C4 Chemicals	4.00	Yellow	No
C5 Feed	4.05	Yellow	No
C6 Escapes	5.00	Yellow	No
C7 Disease	4.00	Yellow	No
C8X Source	–0.00	Green	No
C9X Wildlife	–2.00	Green	No
C10X Introduction of secondary species	–3.20	Yellow	n/a
Total	29.60		
Final score (0–10)	4.23		

OVERALL RANKING

Final Score	4.23
Initial rank	Yellow
Red criteria	0
Interim rank	Yellow
Critical Criteria?	0

Final Rank
Yellow

Scoring note – scores range from 0 to 10, where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Criteria 8X, 9X, and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects a very significant impact. Two or more Red criteria, or one Critical criterion (highlighted with black background and white text) result in a Red final result.

Summary

The final numerical score for Atlantic salmon produced in marine net pens in the Faroe Islands is 4.23 out of 10. This indicates that some concerns are evident in several of the criteria assessed, but with no Red criteria, the final recommendation is Yellow, “Good Alternative.”

Executive Summary

With a production in 2021 of 94,822 metric tons (mt) (gutted weight, equivalent to approximately 115,000 mt whole weight), the Faroe Islands is a relatively small producer of farmed salmon, representing approximately 3.6% of the 2.9 million mt global annual production. The Faroe Islands lie in an isolated location in the North Atlantic Ocean and operate approximately 30 farm sites with floating net pens that are typical of the industry globally. The sites are mostly in sheltered and semi-exposed locations throughout the islands but include some highly exposed sites. An academic study in 2008 noted that there is a fish farm "in almost every suitable bay and fjord." Three companies stock approximately 20 million smolts in total each year (20.3 million in 2021), with the largest company (Bakkafrost) stocking and harvesting approximately 70% of Faroese production. The remaining two companies (Hiddenfjord and Mowi) produce approximately 18% and 11%, respectively. The Faroe Islands have consistently exported the majority of the total production, with an average annual export to the United States over the last 5 years (2017 to 2021) of 13,250 mt (ranging from 10,490 mt to 16,257 mt).

The assessment involves criteria covering impacts associated with effluent, habitats, wildlife mortalities, chemical use, feed production, escapes, introduction of secondary species (other than the farmed species), disease, the source stock, and general data availability.[2]

A large amount of information and data was previously provided by the Faroese Fish Farmers Association (Havbúnaðarfelagið) in 2018, and updated in 2022 for this assessment. Further industry information is available from company reports and websites. This is most notably available from the largest company, Bakkafrost, but less so from Mowi (at least for specifics relating to the Faroe Islands) and minimally from Hiddenfjord. Publicly available information from official organizations has improved, but translation from Faroese to English remains a challenge for interested U.S. seafood buyers and consumers. Some data and documents were provided directly from the Environment Agency for this assessment, and personal communications with researchers in the Faroe Islands (particularly at the Aquaculture Research Station–Fiskaaling) and at other organizations have been useful for some topics. There is a moderate amount of academic research of relevance to the Faroe Islands, and Fiskaaling (and to a lesser extent the Faroe Marine Research Institute, Hastovan) publish relevant studies. Nevertheless, it is clear from the amount of Faroese language publications and presentations that there is additional information available that was not readily accessible for this assessment due to translation challenges. Overall, the data availability and quality were moderate or good, and the final score for Criterion 1—Data is 6.82 out of 10.

Salmon farms are a dominant contributor of anthropogenic nutrients into coastal waters in the Faroe Islands; however, there is no evidence that nutrients in the water column have any significant impact beyond the site's immediate or licensed area. But, benthic monitoring results

[2] The full Seafood Watch Aquaculture Standard is available at: http://www.seafoodwatch.org/seafood-recommendations/our-standards

at each site show that nearly half (47%) of sites were categorized as polluted or highly polluted (Condition 3 or 4) at peak biomass between 2018 and 2021. These impacts are overseen by a comprehensive regulatory system that was updated in 2018 (and a new benthic classification system was proposed in 2021). These impacts may be reduced and/or reversed by fallowing, but the results show that seabed communities in the immediate farm areas are frequently overwhelmed by salmon farm pollution. It is also possible that salmon farms contribute to observed seasonal low oxygen levels in deep-water layers in some Faroese fjords. From a cumulative perspective, fish farming is licensed in the majority of fjords and sounds in the Faroe Islands, but the data available from each site show little direct evidence that the effluent discharges cause or contribute significantly to cumulative impacts at a water-body or regional scale, particularly in the water column. Overall, the somewhat high level of sites in Condition 3 or 4 is a concern, and these data are considered to show that salmon farms in the Faroe Islands result in frequent impacts within the immediate vicinity of the farm. Because these impacts are considered to be reversible, the final score for Criterion 2—Effluent is 4 out of 10.

Except for the operational impacts on the seabed assessed in Criterion 2—Effluent, the general construction and installation of floating net pen salmon farms has a limited direct impact on the habitats in which they are sited. But, the net pens and their supporting infrastructures contribute much physical structure to nearshore habitats and are known to modify the physical environment at the farm location by modifying light penetration, currents, and wave action, as well as providing surfaces for the development of rich biotic assemblages that may further increase the complexity of the habitat. An average salmon farm contains approximately 50,000 m^2 of submerged artificial substrates that can be colonized by a large suite of hard-bottom associated species that may not otherwise find suitable habitat in a given area (e.g., muddy bottoms or in the water column). These additional species may have a variety of direct and cascading effects on the surrounding ecosystem, including inadvertently supporting the persistence and distribution of nonnative species. Salmon farms also attract a variety of wild animals as fish aggregation devices or artificial reefs, or repel other wild animals through disturbance such as noise, lights, or increased boat traffic. Changes in the behavior of wild fish around fish farms and even of their flesh quality due to the consumption of waste feed have been reported. Key aspects of these potential impacts are their circumstantial variability, their limited study, and the challenge of their quantification, particularly in the context of the confounding impacts of soluble and particulate effluent wastes (assessed in Criterion 2—Effluent). There is a regulatory system for siting and impact assessment in the Faroe Islands, and an area-based system for each water body, but it is unclear how the range of potential impacts associated with the infrastructure of the net pen systems are managed, including from a cumulative perspective. Overall, the habitats in which salmon farms are located are considered to be maintaining functionality with minor or moderate impacts, and the final score for Criterion 3—Habitat is of 6.93 out of 10.

Annual antimicrobial use of approximately 4,000 kg in 1999 declined rapidly to zero in 2004, and several data sources confirm that antimicrobials have not been used since. Pesticide use to control sea lice has been highly variable, but has also declined rapidly in recent years due to the increased use of nonchemical alternatives. An analysis of the detailed chemical use data provided by FFVA shows that there has been an average of 1.31 treatments per completed production cycle in recent years (2019 to 2021), or approximately 1 treatment per site per year, but when considering fallow periods, each site receives an average of approximately 0.8 treatments per year. The dominant treatment by frequency is emamectin benzoate (85% of treatments) and by weight is diflubenzuron (75% of total pesticide use). Azamethiphos is also used infrequently. Although the environmental impacts of pesticide use in net pen salmon farms remains challenging to determine, a comprehensive risk assessment in Norway currently consider there to be a "moderate" risk of environmental effects on nontarget species in the local area through the typical use of the in-feed treatments emamectin benzoate and diflubenzuron, and a moderate or low risk for the bath treatment azamethiphos. Full resistance to different pesticide groups has been shown in sea lice in the Faroe Islands, with some lice also partly resistant to second treatment types. Although the reduced use of pesticides will limit the development of resistance, 85% of treatments currently use the same pesticide, thereby also encouraging resistance. Overall, the treatment frequency is currently low, with pesticides that can be considered to have a mostly moderate risk of environmental impacts from their typical use. The sea louse population in the Faroe Islands has developed resistance to one or more treatments, so the final score for Criterion 4—Chemical Use is 4 out of 10.

The majority (75%) of salmon feed used in the Faroe Islands is produced on the Islands by Havsbrún (owned by Bakkafrost), with the remainder imported from Skretting in Norway. Although specific feed composition data were not provided, the feed assessment could be conducted using data gleaned from company reports, ASC audit reports, GSI, and the Ocean Disclosure Project (of which Bakkafrost is a member). Nevertheless, without specific data, some estimated and calculated values may be higher than reality, based on a precautionary approach. Marine ingredient use is relatively high, with a Forage Fish Dependency Ratio of 1.59, which means that, from first principles, 1.59 mt of wild fish would need to be caught to supply the fish oil needed to grow 1 mt of farmed salmon. The source fisheries are considered to be moderately sustainable, and the Wild Fish Use score is 3.6 out of 10. There is also a net loss of protein in the farming process, with 65.6% of the protein supplied in feed not accounted for in the harvested salmon (score of 3 out of 10). The feed footprint (calculated as the embedded climate change impact [kg CO_2-eq] of the feed ingredients) was 14.79 kg CO_2-eq kg^{-1} farmed seafood protein (score of 6 out of 10). The three scores combine to give a final score for Criterion 5—Feed of 4.05 out of 10. (See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.)

Reported escape events affect few sites each year in the Faroe Islands, but the net pen production system remains vulnerable to escape. The available data from company reports and the seafood media show tens of thousands of salmon (and sometimes hundreds of thousands) have escaped in most recent years, with the largest being nearly 370,000 in 2020. Despite the presence of Atlantic salmon from many countries in Northern Europe in the feeding grounds north of the Faroe Islands, there is no record of natural salmon populations in Faroese rivers. Thus, Atlantic salmon is considered nonnative to the Islands. Deliberate stocking of Atlantic salmon (from Iceland and later Norway) began in the 1940s and successfully established small populations in five rivers before the commencement of salmon farming. A hatchery operated by the Faroese Anglers Association (Sílaveiðafelagið) continues to stock smolts and fry (of salmon and sea trout) into local rivers each year. Although there are expected to be some ecological impacts from the escape numbers reported, they are likely to be small compared to the large annual managed releases, and the overall risk of impact is considered to be low. Overall, the high escape risk (Factors 6.1) and low risk of impact (Factor 6.2) combine to give a moderate final score of 5 out of 10 for Criterion 6—Escapes.

The Disease Criterion focuses on potential impacts to wild fish, for which there is limited information in the Faroe Islands. Native populations of sea trout are present, but of uncertain number. Bacterial and viral diseases cause low mortality in Faroese salmon farms and are considered a low concern for potential transfer and impact to wild fish. Parasitic sea lice on farmed fish are present in variable numbers, and while increasingly strict management measures minimize the numbers of lice per farmed fish during the periods of peak numbers of wild sea trout in coastal waters, the cumulative load of lice from farms and therefore the infection pressure in those waters is likely substantial. An ongoing research project by Fiskaaling that conducts annual sampling of wild sea trout is greatly increasing the knowledge base of sea lice interactions, but does not yet provide sufficiently robust data to reach any conclusions regarding the potential impact of lice from salmon farms as opposed to other natural infection sources in the area. Thus, the risk-based assessment has been used and the score is based on the open nature of the production system to the introduction and discharge of pathogens and parasites. The final numerical score for Criterion 7—Disease is 4 out of 10.

The primary farmed species, Atlantic salmon, is demonstrably independent of wild broodstock and wild fisheries due to the use of multigenerational domesticated broodstocks. In contrast, >3.75 million lumpfish (*Cyclopterus lumpus*) are used as cleaner fish in the control of parasitic sea lice on farmed salmon in the Faroe Islands and are considered to be reliant on wild caught broodstock to supply eggs. Approximately 80% of lumpfish used in Faroese salmon farms originate from wild-caught broodstock in Iceland, while a single fisher in the Faroes supplies approximately 200 adult lumpfish per year for local production. The Icelandic lumpfish fishery is certified by the Marine Stewardship Council, and the single fisher and small catch strongly suggest that the Faroe Islands fishery is not a sustainability concern. Therefore, neither Atlantic salmon nor lumpfish is considered in the scoring of Criterion 8X—Source of Stock, and the final score is a deduction of 0 out of –10.

Before 2015, the Faroese salmon farming industry deliberately killed hundreds of grey seals per year. Population estimates vary from a minimum of 550 seals (from the first formal count in 2018 and 2019) to expert estimates of 1,000 to 2,000, and it is clear that salmon farm mortalities negatively affected the size of the grey seal population and its ability to recover after commercial hunting. Recent management improvements have resulted in a dramatic decline in mortalities, and the Faroese Government initiated a ban on seal culls at salmon farms in May 2020. The data from 2021 indicate that the ban is initially effective, and the low current mortalities (e.g., due to accidental entanglement) are expected to continue. Moderate numbers of birds continue to die as a result of accidental entanglement in nets, but the species are considered to be of low concern. With considerable uncertainty in the population estimates of grey seals, understanding their recovery from previous high mortality at salmon farms remains challenging. Therefore, the risk assessment must be used, and because lethal control is no longer permitted, and accidental mortalities are considered to be limited to exceptional circumstances, the final score for Criterion 9X—Wildlife Mortalities is –2 out of –10.

The Faroese salmon farming industry has a developing local Atlantic salmon broodstock program, but is currently fully reliant on the import of ova from two companies in Norway and Iceland. In addition to importation regulations in the Faroe Islands that require health certificates and approval by veterinary authorities, the two ova-producing companies and their facilities are considered to have high biosecurity, and there is a low risk of introducing nonnative “hitchhiker” species, such as parasites or pathogens, into the Faroe Islands with movements of salmon ova. The salmon farming industry in the Faroe Islands also uses cleaner fish (lumpfish) imported from Iceland, originating from wild stocks. Although the ability to quarantine wild-caught broodstock and the same importation regulations in the Faroe Islands provide some biosecurity, disease remains a primary challenge to the use of lumpfish. There remains a risk of unintentionally introducing a nonnative species during shipments of live lumpfish into the Faroe Islands, and the final score for Criterion 10X—Introduction of Secondary Species is a deduction of –3.2 out of –10.

Overall, the final numerical score for Atlantic salmon produced in net pens in the Faroe Islands is somewhat low at 4.23 out of 10. This indicates that some concerns are evident in several of the criteria assessed, but with no red criteria, the final recommendation is Yellow, or “Good Alternative.”

Introduction

Scope of the analysis and ensuing recommendation

Species
Atlantic salmon (*Salmo salar*)

Geographic Coverage
Faroe Islands

Production Method(s)
Marine Net Pens

Species Overview

Brief Overview of the Species
Atlantic salmon is native to the North Atlantic Ocean with high numbers of discrete genetic subpopulations through Western Europe in the NE Atlantic and the North America landmass in the NW Atlantic. It is an anadromous species; birth and early life stages occur in freshwater rivers and streams, followed by a migration downstream and over long oceanic distances, where the bulk of feeding and growth takes place. After one or more years in the ocean, the species returns upriver to its original spawning ground to complete the cycle.

Although Atlantic salmon from various European nations occupy Faroese waters during their at-sea life stage, there have never been any native spawning populations in the rivers of the Faroe Islands (NASCO 2010a). Deliberate and ongoing stocking efforts since 1947 have resulted in four Faroese rivers currently hosting returning salmon, and in 2010, it was reported that 400 to 600 fish are harvested annually (NASCO 2010a). It is not currently clear if all these returning fish are the result of stocking, or if some “natural” reproduction takes place in the rivers.

Production System
All farmed salmon in the Faroe Islands are produced in floating net pens in coastal inshore or nearshore environments, typical of the salmon farming industry worldwide. The hatchery phase is conducted primarily in tanks in indoor recirculation systems on land. In the Faroe Islands, the average weight of smolts released to the sea for grow-out in 2021 was 425 grams, and this has been increasing rapidly to reduce the time at sea (for example, the average smolt weight was 92 grams in 2010) (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022). The at-sea grow-out phase is approximately 14 to 16 months, with a target harvest weight of 5.8 to 6.0 kg (Bakkafrost, 2022a).

In the 1980s, there were more than 60 producers (Rosten et al. 2013), but after extensive consolidation, there are now only 3 producers: Bakkafrost, Hiddenfjord/Luna, and MOWI.

The following assessment reflects only the marine net pen grow-out phase of salmon aquaculture in the Faroe Islands, because the hatchery/nursery phase is considered to be a lesser source of ecological impacts.

Production Statistics

The first efforts to farm salmonids in the Faroe Islands began in land-based systems in the 1960s, and farming in marine net pens started in the 1980s, with annual production reaching approximately 15,000 metric tons (mt) by the mid-1990s (Jacobsen, 2011). Total annual harvest data are available from the Statistics Faroe Islands (Hagstova Føroya)[3] from 1996 (Figure 1) and show that production increased to 94,822 mt (gutted weight) in 2021. This is equivalent to approximately 115,000 mt whole weight (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022). Of note in the long-term data is a large drop in production in the mid-2000s due to disease (see Criterion 7—Disease).

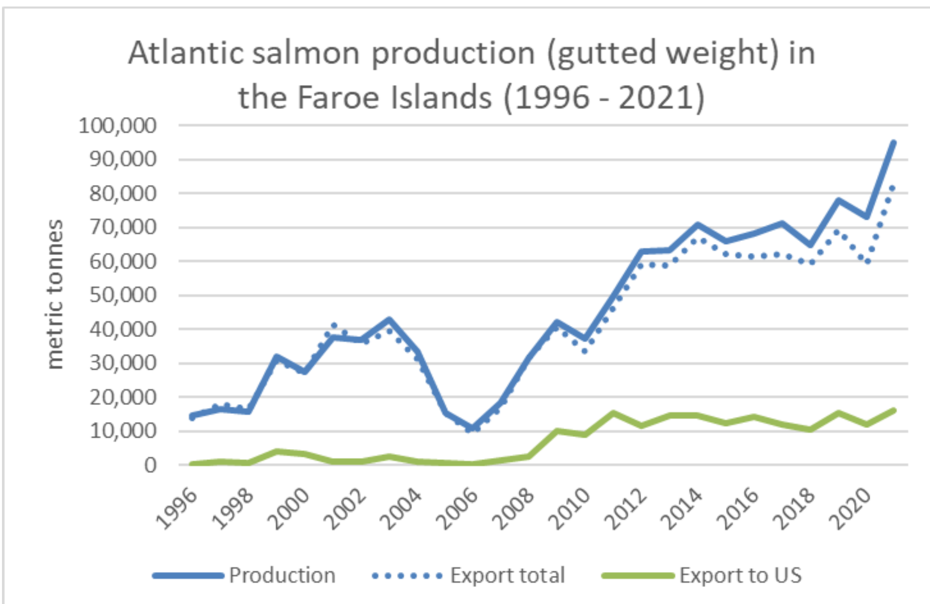

Figure 1: Atlantic salmon aquaculture production in the Faroe Islands, 1996 to 2021. Recent export quantities in total and to the United States (discussed below) are also shown. Production data from Statistics Faroe Islands Statbank, and export data from Bakkafrost (2022a).

[3] https://hagstova.fo/en/business/primary-sector/aquaculture

Bakkafrost, the largest operator in the Faroe Islands, produced 67,217 mt (gutted weight) of salmon in 2021 (Bakkafrost, 2022), representing 70.9% of total Faroese production. Mowi reported harvesting 9,932 mt in 2021 (gutted weight; Mowi 2022). The remaining 17,673 mt (of the 2021 total production of 94,822 mt) is assumed be produced by Hiddenfjord (for which no public harvest data are available).

The annual smolt input is approximately 20 million (20,340,000 in 2021[4]), and monthly fish count data from the Faroe Islands Food and Veterinary Authority (FFVA[5]) (Heilsufrøðiliga Starvsstovan) for every site show that 30 sites were active at some time in the last 3 years (2019–21). An interactive map of farm areas and salmon fjords is available at www.Kortal.fo. Figure 2 shows an example (see also Figure 3). In 2008, it was reported that there was a farm site "in almost every suitable bay and fjord in the Faroe Islands" (Thorstad et al. 2008), and this appears to continue.

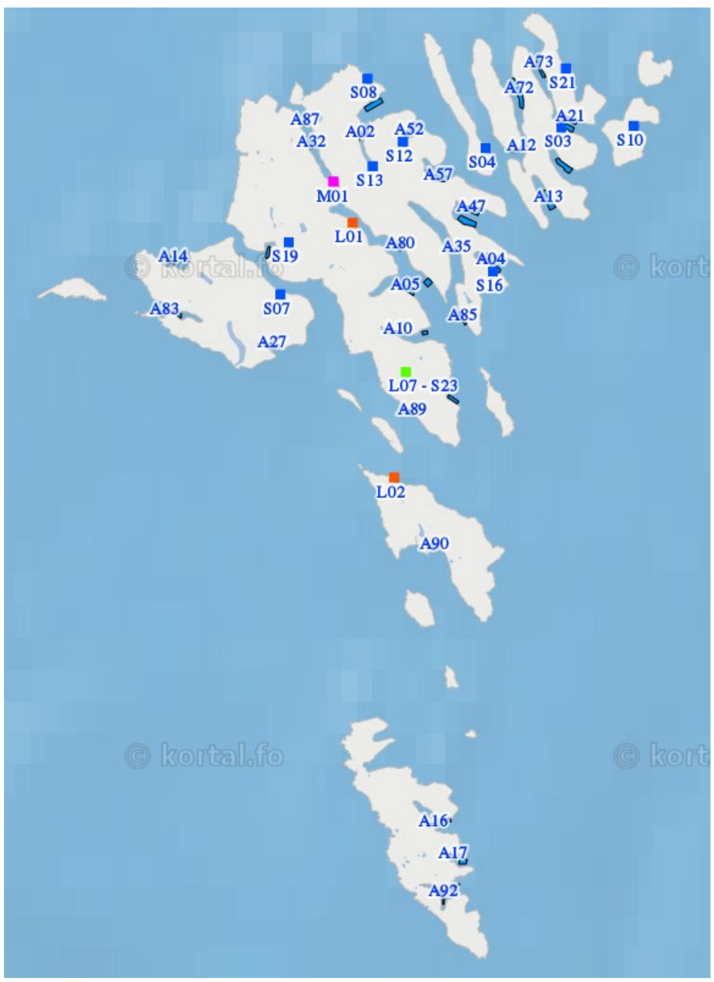

Figure 2: Map of Faroe Islands salmon farming operations. Labels prefixed "A" are grow-out sites, "S" are smolt sites, and the remainder are other aquaculture service locations. Image reproduced from www.kortal.fo.

[4] Data from Statistics Faroe Islands
[5] https://www.hfs.fo/webcenter/portal/HFS/aling

Global farmed Atlantic salmon production was approximately 2.9 million mt in 2021 (2,896,700 mt of whole fish according to Bakkafrost (2022)), Faroese production of 105,000 mt WFE accounts for approximately 3.6% of global production.[6] There are currently (as of September 2022) 17 sites certified to the Aquaculture Stewardship Council's Salmon Standard, but none certified to the Best Aquaculture Practices Farm Standard.

Import and Export Sources and Statistics

Export statistics are available from Statistics Faroe Islands (Statbank), and shown in Figure 1 from 1996 to 2021. The Faroe Islands have consistently exported the majority of the total production, with an average of 66,618 mt or 87.3% over the last 5 years (2017–21), with 83,018 mt exported in 2021 (or 87.6% of total production). The United States imported roughly one-fifth of this total (16,257 mt or 19.5% of total exports in 2021); the average annual export to the United States over the last 5 years (2017–21) of 13,250 mt (range 10,490 mt to 16,257 mt).

The Faroe Islands are therefore a small source of Atlantic salmon on the United States market, representing approximately 3.3% of the total U.S. supply of Atlantic Salmon (according to WFE data in Bakkafrost (2022)).

Common and Market Names

Scientific Name	*Salmo salar*
Common Name	Atlantic salmon
United States	Atlantic salmon
Spanish	Salmón del Atlántico
French	Saumon de l'Atlantique
Japanese	Taiseiyō sake

Product Forms

Harvested salmon is sold mostly whole-bodied and either fresh or frozen, with a smaller amount sold as portions (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018).

[6] The same value of 3.6% is obtained by using the Statistics Faros and MOWI figures for gutted weights.

Criterion 1: Data Quality and Availability

Impact, unit of sustainability and principle

- Impact: poor data quality and availability limits the ability to assess and understand the impacts of aquaculture production. It also does not enable informed choices for seafood purchasers, nor enable businesses to be held accountable for their impacts.
- Sustainability unit: the ability to make a robust sustainability assessment
- Principle: having robust and up-to-date information on production practices and their impacts available for analysis.

Criterion 1 Summary

C1 Data Category	Data Quality
Production	10.0
Management	7.5
Effluent	7.5
Habitat	5.0
Chemical Use	5.0
Feed	5.0
Escapes	7.5
Disease	5.0
Source of stock	10.0
Wildlife mortalities	5.0
Introduction of secondary species	7.5
C1 Data Final Score (0–10)	**6.82**

Brief Summary

A large amount of information and data was previously provided by the Faroese Fish Farmers Association (Havbúnaðarfelagið) in 2018, and updated in 2022 for this assessment. Further industry information is available from company reports and websites. This is most notably available from the largest company, Bakkafrost, but less so from Mowi (at least for specifics relating to the Faroe Islands) and minimally from Hiddenfjord. Publicly available information from official organizations has improved, but translation from Faroese to English remains a challenge for interested U.S. seafood buyers and consumers. Some data and documents were provided directly from the Environment Agency for this assessment, and personal communications with researchers in the Faroe Islands (particularly at the Aquaculture Research Station–Fiskaaling) and at other organizations have been useful for some topics. There is a moderate amount of academic research of relevance to the Faroe Islands, and Fiskaaling (and to a lesser extent the Faroe Marine Research Institute, Hastovan) publish relevant studies. Nevertheless, it is clear from the amount of Faroese language publications and presentations that there is additional information available that was not readily accessible for this assessment due to translation challenges. Overall, the data availability and quality were moderate or good, and the final score for Criterion 1—Data is 6.82 out of 10.

Justification of Rating

A large amount of information and data were previously provided in 2018 by the Faroese Fish Farmers Association (Havbúnaðarfelagið) through a community of business associations in the Faroe Islands managed by the Faroese Employers Association (Vinnuhúsið; translated as the "House of Industry"). These data were updated for this assessment (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022). The Faroes Fish Farmer's Association also operates an informational site at "Salmon from the Faroe Islands"[7] but this does not appear to be updated (the most recent news update as of July 2022 is from 2013).

Additional or supporting company-specific data have been gleaned from annual reports (only for Bakkafrost[8] and Mowi[9]) and other online sources such as Bakkafrost's useful Sustainability-Data.[10] Bakkafrost is also a member of the Global Salmon Initiative, which publishes (and requires the company to publish) data of relevance to some of the criteria assessed here (Mowi also publishes[11] a small selection of data under the certification requirements of the Aquaculture Stewardship Council [ASC]). Additional data can be extracted site-by-site from ASC audit reports.[12] In contrast, only minimal data are available from Hiddenfjord's website, with a few useful values in the sustainability section of their website.[13]

The availability of public data from official organizations in the Faroe Islands has recently improved; for example, from "Statistics Faroe Islands" (Hagstova Føroya), [14] the Environment Agency (Umhvørvisstovan),[15] and the Faroes Food and Veterinary Authority (Heilsufrøðiliga starvsstovan, FFVA).[16] These data are discussed below where relevant, but it is particularly noted that the data from FFVA are challenging to access; see explanation in footnote.[17]

In addition to company-level and official data and information, there is a significant body of academic and public-private research conducted in the Faroe Islands; for example, the Faroe

[7] http://salmon-from-the-faroe-islands.com/
[8] https://www.bakkafrost.com/en
[9] https://www.bakkafrost.com/en/sustainability/
[10] https://mowi.com/investors/reports/
[11] https://mowi.com/sustainability/aquaculture-stewardship-council/asc-dashboard/
[12] https://www.asc-aqua.org/find-a-farm/
[13] https://hiddenfjord.com/
[14] https://hagstova.fo/fo
[15] https://www.us.fo/
[16] https://www.hfs.fo/webcenter/portal/HFS
[17] Go to the Heilsufrøðiliga starvsstova website (https://www.hfs.fo/webcenter/portal/HFS/pages_aling), go to "Aling," then "Hagtøl," then ignore the "web page blocked" warning and click on "Tal av laksi" for company, fish counts and stocking information, or "Lúsatøl" for sea lice counts, or "Heilivágur" for chemical treatments. Online translations do not function for these headings, but do generally allow sufficient understanding of the data themselves.

Marine Research Institute (Havstovan,[18] FMRI) provides a database of research publications, and Fiskaaling[19] is the "Aquaculture Research Station of the Faroes." The latter's website has many publications in English (and in academic journals), and direct contact was made with staff there.

As briefly noted above, regarding the accessibility of information in the Faroe Islands to U.S. seafood buyers or consumers, the common open-source translation services (e.g., Google Translate) were typically not effective at translating Faroese. Although some documents are published in English, many were not, and the inability to translate Faroese to English presented a data challenge in general. Regarding the Seafood Watch criteria in this assessment and the categories in the Data Criterion, the key data sources are as follows:

Industry and Production Statistics

Statistics Faroe Islands is the national statistical authority of the Faroe Islands and publishes country-level information on salmon production and export. An interactive map of the Faroe Islands, including all fish farm areas and specific site dimensions, is produced by the Environment Agency and available at www.kortal.fo (a sample screenshot of farm sites is shown in Figure 3, and a map of aquaculture areas is provided in Figure 6 in Criterion 2—Effluent). The map also provides basic information on the company operating each site.

[18] http://www.hav.fo/

[19] http://www.fiskaaling.fo

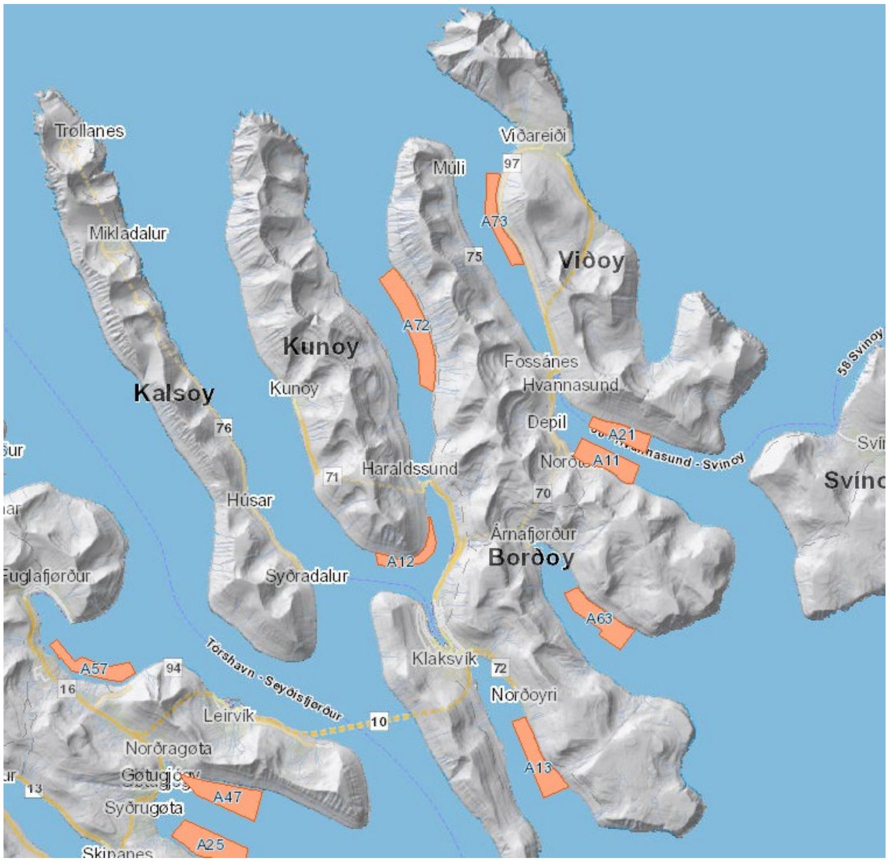

Figure 3: Sample screenshot of salmon farm ongoing locations in the NE Faroe Islands. Orange polygons show the boundaries of each aquaculture site. Image reproduced from www.kortal.fo.

The Faroes Food and Veterinary Authority (FFVA) provides several types of data, including fish count data for each site, from which the number of active sites and production cycles can be calculated. There may be some challenges with translation of information, but overall, the industry and production statistics are understood, and the data score is 10 out of 10.

Management

The FFVA (established under the Ministry of Foreign Affairs and Trade) is the key regulatory authority for aquaculture in the Faroe Islands. It provides a list of regulations on its website, and a database of regulations is available,[20] but only a small number of regulations are available in English. Havbúnaðarfelagið previously provided a list and translations of the relevant regulations, as did Fiskaaling (pers. comm., Knud Simonsen, Fiskaaling, 2018), although some have since changed. A recent update to environmental monitoring regulations occurred in 2018, and an unofficial English translation was provided by the Environment Agency for this assessment. Some criticisms of the industry's management, such as from FNU (pers. comm., Theresa Jákupsdóttir, FNU, 2018) give some uncertainty about the understanding of the regulatory effectiveness in practice in the Faroe Islands. Overall, though regulatory information

[20] www.logir.fo

is largely available, understanding of the regulations' practical implementation in the industry remains somewhat uncertain. The data score for Management is 7.5 out of 10.

Effluent

In general, there is a substantial body of literature on the physical, chemical, and biological implications of nutrient waste discharges from net pen fish farms, including salmon farms; recent reviews such as Price et al. (2015) or comprehensive assessments in other countries (e.g., Grefsrud et al., 2022a,b) provide a useful summary. The nutrient and phytoplankton dynamics of Faroese waters are routinely monitored by the Faroe Marine Research Institute (FMRI), and results are published in occasional summary or review documents (e.g., Eliasen et al., 2017a,b; Gaard et al., 2011). Although this monitoring does not focus on salmon farming areas, there is some relevance, and more specific research is also available on nutrient dynamics from aquaculture sites in the Faroe Islands; e.g., á Norði et al. 2011, 2018; Gaard et al. 2011.

Benthic impact monitoring data from 2010 to 2015 for all sites were previously provided by Havbúnaðarfelagið in 2018, and an aggregated summary of all sites from 2018 to 2021 was provided by the Environment Agency (detailed site-level reports were available on request, but would entail a substantial preparation time for delivery by the Environment Agency). As noted above, a translation of the updated (2018) benthic monitoring protocol was also provided by the Environment Agency. A proposed new benthic classification is available in Mortensen et al., (2021). The data score is 7.5 out of 10 for Effluent.

Habitat

The location and layout of each site is available in the Environment Agency's mapped database (example in Figure 3), and along with readily available satellite images (e.g., Google Earth), these allow a simple overview of salmon farm locations and habitats. These images of floating net pens also demonstrate a broad lack of functional conversion of habitats for farm construction and installation. The review of McKindsey (2011) provides a useful compilation of potential habitat impacts associated with the infrastructure of net pens, and other academic studies provide additional information on the attraction or repulsion of wildlife, hydrodynamics, and other operational activities such as the use of submerged lights. In general, there are few specific data available on the impacts of the infrastructure or their operation (other than the discharge of nutrient wastes addressed in Criterion 2—Effluent) and these potential impacts have been poorly studied and are difficult to quantify. Information on siting requirements is also part of the Environment Agency's guidance document (although the impact assessment reports themselves do not appear to be readily available to the public). With some uncertainties in poorly understood impacts of industrial activities in the coastal zone, the data score for Habitat is 5 out of 10.

Chemical Use

As a result of regulatory changes (Executive Order 80, June 2019), site-level chemical use data began to be published by FFVA and are available from that date until the present. The data are frequently updated (they must be published within 7 days of reporting to the FFVA), but are still challenging to access in Faroese through online translations of the FFVA website (as explained above). The FFVA provides information for each treatment with the site number, date, treatment type, and quantity used. Havbúnaðarfelagið provided data on all chemical treatments on salmon farms from 2007 to 2019, aggregated across all farm sites (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018, 2022). Similar data are available for the largest company (Bakkafrost) from the Global Salmon Initiative (GSI).[21] Earlier trends in chemical use were available from Gustavson et al. (2009). Some dated information was available on resistance to sea lice pesticides in Østergård (2010). Although some impact monitoring has been done in the Faroe Islands, the results are not available in English, so there was no direct information on impacts or environmental monitoring. Some indications can be gleaned from studies on the same chemicals in other regions, e.g., Lillicrap et al. (2016), Samuelsen et al. (2015), Macken et al. (2015), Langford et al. (2011 & 2014), SARF098 (2016), Gebaur et al. (2017). With limited understanding of impacts of chemical use, the data score for Chemical Use is 5 out of 10.

Feed

There are two feed companies supplying Faroese salmon farms: Havsbrún,[22] which is owned by Bakkafrost, and Skretting Norway,[23] which is owned by Mowi. Both previously provided useful data on feed composition through Havbúnaðarfelagið, with one (Skretting) providing a much greater level of detail. Updated information for this assessment was not provided, so it was limited to basic feed composition data available from company annual reports (e.g., Bakkfrost; 2022a; Mowi, 2022a), sustainability reports (e.g., Bakkafrost 2022b), and company websites (e.g., Bakkafrost data[24]). A time-series of economic feed conversion ratio (eFCR) values was provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022). A second series of values was estimated from Bakkafrost's feed use and production data (Bakkafrost, 2022a), in addition to values in ASC audit reports (not available for all sites) and academic literature. Values for Forage Fish Dependency Ratio (FFDR, which is similar to the Forage Fish Efficiency Ratio used in the Seafood Watch Aquaculture Standard) were also gleaned from ASC audit reports. Overall, the available information gives a moderately reliable representation of the feed performance of the industry, and the data score for Feed is 5 out of 10.

Escapes

There is a legal requirement to report escape incidents (numbers, causes, and response actions) to the FFVA, but there does not appear to be any formal public reporting of escape events or numbers lost. But, sufficient data can be obtained from a variety of sources, including the GSI, company annual reports, seafood media, and data previously provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018). Information on the lack of historical (i.e., natural) native salmon populations to Faroese rivers was available from the North Atlantic

[21] https://globalsalmoninitiative.org/
[22] https://www.havsbrun.fo/
[23] https://www.skretting.com/
[24] https://www.bakkafrost.com/en/sustainability/data/

Salmon Conservation Organization (NASCO) and on local stocking of salmon in the Faroe Islands from the Faroese Anglers Association, Sílaveiðafelagið.[25] Peer-reviewed literature, some of which focused on broad or non-Faroese geographies, were used to analyze the potential for competitive interactions between escapees and wild salmon in the oceanic environment. Despite some uncertainties, the information gives a good understanding of the potential impacts, and the data score for Escapes is 7.5 out of 10.

Disease

Disease-monitoring data from the FFVA are not currently available from their website,[26] and only high-level summary data on monitoring for OIE diseases are available from the OIE website.[27] Data on mortality rates (from the FFVA) were provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022) and additional company-specific data are available from other sources such as GSI (Bakkafrost only) and from company annual reports or other sustainability reports. The FFVA is now required (after June 2019) to publish biweekly sea lice counts for each site,[28] and these data are updated frequently (although as noted above, they are challenging to find). Sea lice have been well-studied globally (e.g., the review by Groner et al., 2016), and research on sea lice dynamics in the Faroes is conducted by Fiskaaling; examples include: á Norði et al. (2015, 2016); Gislason (2017); Kragesteen et al. (2018, 2021); and Patursson et al. (2017). Information on the presence and vulnerability of wild fish in the Faroe Islands is limited, but Fiskaaling's sea trout project and annual reports (Eliasen et al., 2021, 2022) provide some initial data on sea trout ecology and provide sea lice counts on wild fish in 2019 to 2021. Fiskaaling's research is welcome (as has been the personal communication with Kirsten Eliasen at Fiskaaling), but quantifying the potential impacts on wild sea trout populations remains challenging. Overall, the data provide some useful information, but the potential impacts to wild sea trout remain uncertain. The data score for Disease is 5 out of 10.

Source of Stock

Havbúnaðarfelagið provided information on the source of all salmon eggs used in the Faroe Islands, and it is clearly indicated that these are farm-raised domesticated sources. Regarding the use of cleaner fish (the lumpsucker, *Cyclopterus lumpus*), anecdotal industry information is available in Bakkafrost and Mowi company reports in addition to already dated studies, such as Johannesen et al. (2018) and Whittaker et al. (2018). Personal communication with experts at Fiskaaling (pers. comm., Ása Johannesen and Kirsten Eliasen, Fiskaaling, July 2022) and with a facility rearing lumpfish in the Faroe Islands (pers. comm., Regin Arge, Æsir Marine, July 2022) provided the necessary information with which to understand the different sources and their characteristics. Some fishery data are available from Iceland through the Marine Stewardship Council certification process, in addition to specific details from the Faroe Islands (pers. comm.,

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[25] http://www.laks.fo/

[26] https://www.hfs.fo/webcenter/portal/HFS/aling/page141?_adf.ctrl-state=3yi0ap735_1&_afrLoop=2080893034993872#!%40%40%3F_afrLoop%3D2080893034993872%26_adf.ctrl-state%3D3yi0ap735_5

[27] https://wahis.oie.int/#/home

[28] https://www.hfs.fo/webcenter/portal/HFS/Aling

Regin Arge, Æsir Marine, July 2022). With a robust understanding of both Atlantic salmon and lumpfish, the data score for Source of Stock is 10 out of 10.

Wildlife and Predator Mortalities

Two reports from the North Atlantic Marine Mammal Commission (NAMMCO, 2016; NAMMCO, 2021) provide useful data and information on the mortality of grey seal at salmon farms in the Faroe Islands and the farms' impacts on seal populations. Mortality data for birds and marine mammals were provided by Havbúnaðarfelagið for all three companies (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018, 2022). Data on marine mammal and bird mortalities for one company (Bakkafrost) also continue to be available from GSI and remain useful, given the dominance of Bakkafrost in total production in the Faroe Islands. None of the data indicate the species involved, but some ASC audit reports provide recent numbers and species lists. Because a ban on lethal control has reduced marine mammal mortalities to zero, or close to zero, confidence is much higher in the data from the industry's perspective. Nevertheless, there is high uncertainty in the estimates of the population numbers of grey seal with which to understand its recovery from previous mortalities at farms. The data score is 5 out of 10 for Wildlife and Predator Mortalities.

Introduction of Secondary Species

As noted above, the source of all salmon eggs is known, and information from the suppliers' websites (Salmobreed[29] and Stofnfiskur[30]) is sufficient to determine the biosecurity levels of the origins of these animal movements. For cleaner fish, a figure from Bakkafrost (2022b), supported by expert personal communication, identified the proportions of lumpfish originating in the Faroe Islands as opposed to being imported from Iceland. Some information is available on importation health screenings and certification in the Faroe Islands, but some uncertainty remains regarding the risks of introducing "hitchhiker" organisms during live shipments of lumpfish. The data score for Introduction of Secondary Species is 7.5 out of 10.

Conclusion and Final Score

A large amount of information and data was previously provided by the Faroese Fish Farmers Association (Havbúnaðarfelagið) in 2018, and updated in 2022 for this assessment. Further industry information is available from company reports and websites. This is most notably available from the largest company, Bakkafrost, but less so from Mowi (at least for specifics relating to the Faroe Islands) and minimally from Hiddenfjord. Publicly available information from official organizations has improved, but translation from Faroese to English remains a challenge for interested U.S. seafood buyers and consumers. Some data and documents were provided directly from the Environment Agency for this assessment, and personal communications with researchers in the Faroe Islands (particularly at the Aquaculture Research Station–Fiskaaling) and at other organizations have been useful for some topics.

[29] http://salmobreed.no/en/our-fish/

[30] http://stofnfiskur.is/

There is a moderate amount of academic research of relevance to the Faroe Islands, and Fiskaaling (and to a lesser extent the Faroe Marine Research Institute, Hastovan) publish relevant studies. Nevertheless, it is clear from the amount of Faroese language publications and presentations that there is additional information available that was not readily accessible for this assessment, due to translation challenges. Overall, the data availability and quality were moderate or good, and the final score for Criterion 1—Data is 6.82 out of 10.

Criterion 2: Effluent

Impact, unit of sustainability and principle

- Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.
- Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.
- Principle: not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level.

Criterion 2 Summary

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0–10)	**4**	**YELLOW**

Brief Summary

Salmon farms are a dominant contributor of anthropogenic nutrients into coastal waters in the Faroe Islands; however, there is no evidence that nutrients in the water column have any significant impact beyond the site's immediate or licensed area. But, benthic monitoring results at each site show that nearly half (47%) of the sites were categorized as polluted or highly polluted (Condition 3 or 4) at peak biomass between 2018 and 2021. These impacts are overseen by a comprehensive regulatory system that was updated in 2018 (and a new benthic classification system was proposed in 2021). These impacts may be reduced and/or reversed by fallowing, but these results show that seabed communities in the immediate farm areas are frequently overwhelmed by salmon farm pollution. It is also possible that salmon farms contribute to observed seasonal low oxygen levels in deep-water layers in some Faroese fjords. From a cumulative perspective, fish farming is licensed in the majority of fjords and sounds in the Faroe Islands, but the data available from each site show little direct evidence that the effluent discharges cause or contribute significantly to cumulative impacts at a water-body or regional scale, particularly in the water column. Overall, the somewhat high level of sites in Condition 3 or 4 is a concern, and these data are considered to show that salmon farms in the Faroe Islands result in frequent impacts within the immediate vicinity of the farm. Because these impacts are considered to be reversible, the final score for Criterion 2—Effluent is 4 out of 10.

Justification of Rating

The Faroe Islands Environment Agency (Umhvørvisstovan) describes fish farming as a highly polluting activity, and the salmon farming industry is therefore subject to environmental licensing according to the Faroese Parliamentary Act on Environmental Protection (Umhvørvisstovan, 2018). As discussed below, the regulatory system relates primarily to the seabed impacts of settling particulate wastes. This Effluent Criterion considers the impacts of nutrient-related farm wastes within and beyond the immediate farm area for both soluble effluents in the water column and particulate wastes on the seabed.

The nutrient dynamics of Faroese waters have been well-studied as described and referenced below, and some of the salmon industry's benthic monitoring data have also been made available from the industry and from the Environment Agency through personal communication (pers. comm., Katrin Jensen, Umhvørvisstovan, July 2022). With an additional body of scientific literature, the score for the Effluent category in Criterion 1—Data is 7.5 out of 10, and the Evidence-Based Assessment method in the Seafood Watch Aquaculture Standard has been used.

Salmon excretes both soluble and particulate wastes, primarily as a result of incomplete digestion and absorption of the feeds, and salmon net pen aquaculture represents a substantial release of nutrients and particulate matter into the environment in which farms are sited. These discharges are in addition to nutrients released into coastal waters by human populations (sewage), industry, and agriculture (Grefsrud et al., 2022a,b). Fish farming is licensed in the majority of fjords and sounds in the Faroe Islands and is considered the major source of anthropogenic organic carbon and nutrients in these coastal areas (Mortensen 1990)(Gaard et al., 2011)(á Norði et al., 2011).

The waters around the Faroe Islands can be categorized into three types: shelf areas, exposed sounds and bays, and sheltered fjord systems (Eliasen et al., 2017a,b)(Gaard et al., 2011). The salmon farming industry occupies sites mostly within the fjords, but some sites are located in exposed bays (see the site map in Figure 2). Moretensen et al. (2021) noted that any new aquaculture sites are now generally placed outside fjords at more exposed sites. It is interesting to note that, while the number of net pens has remained similar across the major salmon farming nations from 2005 to 2020, there have been large increases in their size; for example, the Faroe Islands have seen a 212% increase in farm sizes (measured as the total surface area enclosed by cages per site) (McIntosh et al., 2022). The larger farms produce more waste at an individual site in accordance with the increased biomass of fish.

There is a substantial body of literature on physical, chemical, and biological implications of nutrient waste discharges from net pen fish farms, including salmon farms, and recent reviews such as Price et al. (2015) provide a useful summary. Price et al. (2015) conclude that modern operating conditions have minimized the impacts of individual fish farms on marine water quality; effects on dissolved oxygen and turbidity have been largely eliminated through better management, and near-field nutrient enrichment to the water column is usually not detectable beyond 100 m of the farm (when formulated feeds are used, feed waste is minimized, and farms are properly sited in deep waters with flushing currents). But, when sited nearshore, extra caution should be taken to manage farm location, size, biomass, feeding protocols, orientation with respect to prevailing currents, and water depth to minimize near- and far-field impacts. And, Price et al. caution that, regardless of location, other environmental risks may still face this industry; for example, significant questions remain about the cumulative impacts of discharge from multiple, proximal farms, potentially leading to increased primary production and eutrophication.

This analysis of the salmon industry's nutrient-related impacts is separated into soluble effluents and their impacts in the water column, and into particulate wastes and their impacts on the seabed. But, it is important to note that these impacts are connected; that is, increased production of phytoplankton and zooplankton in the water column (resulting from increased nutrient availability) also leads to increased settlement of organic material to the seabed (with consequences for benthic and suprabenthic oxygen concentrations and animal communities). Also, the breakdown and resuspension of concentrated wastes on the seabed below net pens returns nutrients to the water column and/or results in resettlement in distant locations (Grefsrud et al., 2022a,b)(Keeley et al., 2013).

Soluble Effluent

Regarding the region in general, on the Faroes shelf and in the exposed sounds and bays (where some salmon farms are located), the tidal currents are quite strong, causing effective mixing and preventing stratification of the water column (Patursson et al., 2017)(Kragesteen et al., 2018). The Faroe Marine Research Institute (FMRI) has frequently conducted monitoring on nutrients, chlorophyll, and dissolved oxygen in Faroese waters since the mid-1990s (e.g., weekly to biweekly), and though the raw data are not readily available, the results are available in occasional published analyses (e.g., Eliasen et al., 2017a,b)(Gaard et al., 2011)(á Norði et al., 2011). Although not closely related to salmon farms, at the regional level there are large fluctuations in primary productivity (influenced by hydrographical conditions) and no trend is apparent between years (Eliasen et al., 2017a,b)(á Norði et al., 2018).

In the more sheltered fjord systems (where the majority of farms are located), the environmental conditions are different, with lower current velocities, greater stratification, and estuarine circulation; because of the relatively high exchange rates and a relatively high influx of nutrients with the inflowing seawater, these are natural conditions for high primary production (Gaard et al., 2011). In these locations, there are episodes (days to weeks) with oxygen depletion that threaten nonmobile flora and fauna (that cannot migrate to more favorable locations) and the lobster fishery, although it is emphasized that any contribution from aquaculture is uncertain (pers. comm., Maria Dam, Environment Agency, 2018).

A recent study of a typical Faroese fjord (the Kaldbaksfjørður) noted that, although the fjord's watershed is mostly uncultivated and unpopulated (and therefore the main anthropogenic nutrient input to the euphotic zone was from fish farming activity), the high natural inflow of nutrients implied that the anthropogenic (i.e., aquaculture) input has little effect on the primary production (á Norði et al., 2018[31]). Schlund (2022) analyzed the growth of the sugar kelp macroalgae (*Saccharina latissimi*) in the Faroe Islands next to a salmon farm site and at a reference location. Her analysis showed that, although phosphate and ammonium were

[31] Referencing Gaardi et al. (2011) and á Norði et al. (2011).

elevated at the fish farm site, growth rates of *Saccharina latissimi* were similar at both sites due to sufficient natural nutrient levels in the fjords for optimal growth.

There is a legal requirement for monitoring dissolved oxygen on the fish farms on a daily basis (although it is noted that this is done at cage depth for fish welfare purposes and will not reflect potential oxygen depletion in deep-water layers), and the FMRI conducts annual monitoring of chlorophyll-a, nutrients, and dissolved oxygen in some of the fjord systems in late summer. The results show that nutrient and primary productivity dynamics are dominated by natural factors with large fluctuations between years with no trend (pers. comm., Gaard, FMRI, 2018). This suggests that the greatly increased farmed salmon production over recent decades has not led to significant changes in the nutrient dynamics of the Faroe Island's fjords.

There are no specific nutrient monitoring regulations or limits in the water column relating to salmon farms in the Faroe Islands, but there is a minimum separation distance between sites of 1 km between a smolt site and any other salmon site, or 2.5 km between two grow-out sites in the same fjord (and a minimum 2-month fallow period between production cycles).[32] Results of ammonia, total nitrogen, and nitrate monitoring (although limited in the number of sites) in public audit reports from certification to the Aquaculture Stewardship Council's Salmon Standard show no significant difference between the results obtained at the reference stations and those taken within the net pen array and at 50 m from the net pen array (e.g., ASC, 2022).

Overall, there is little evidence that effluent wastes from salmon farms have a significant impact on nutrient or phytoplankton dynamics, or more broadly on water quality in Faroese fjords.

<u>Particulate effluent</u>

At the water-body level, á Norði et al. (2018) showed that deposited particulate organic carbon in the Faroe Islands is mainly of marine origin (i.e., not from agriculture or domestic runoff), and maximum sedimentation rates were associated with the spring plankton bloom (terrestrial material accounted for only 1% of total carbon). Salmon farms are likely to change those nutrient dynamics at the site level and potentially beyond.

Organic material from salmon farms in the form of fecal particles and uneaten feed settles on the seabed in an area controlled largely by the settling speed of the particles, the water depth, and the current speed; as a result, the particulates generate a localized gradient of organic enrichment in the underlying and adjacent sediments (Black et al., 2008)(Keeley et al., 2013, 2015). In the Faroe Islands, the Environment Agency notes that, in some places, feed and feces settle directly below cages; in others, they deposit in depressions away from the cages; and in some instances, they are carried away by the current and not seen again (Umhvørvisstovan, 2018). Grefsrud et al. (2022a,b) consider that a localized impact under net pen farms is inevitable, and changes can primarily be anticipated in total volatile solids, redox potential, and

[32] According to Executive Order No 80 of 14 June 2019 on the disease prevention operation of fish farming. Note that this relates to disease prevention rather than nutrient impacts.

sulfur chemistry in the sediments in the immediate vicinity of operational net pens, along with changes to the species composition, total taxa, abundance, and total biomass. Significant decreases in both the abundance and diversity of macrofauna are sometimes seen under farms located in depositional areas, which are characterized by slow currents and fine-grained sediments, while net pens located in erosional environments with fast currents and sediments dominated by rock, cobble, gravel, and shell hash can dramatically increase macrobenthic production (Keeley et al. 2013).

According to á Norði et al. (2011), the initiation of farming activity at two new farm sites in the Faroe Islands immediately changed the benthic conditions at both locations, with considerably increased organic carbon and nitrogen content in the sediment, and continuous accumulation was observed at both sites during the 7.4-month sampling period. But, the area of impact (i.e., the benthic footprint) was limited, and though the impact was apparent at 30 m away (black sediment with bacterial mats), at 60 m distance, the only visible farming impact was that the top 3 cm of the sediment were slightly darker than at the reference station. At 90 m distance from the farm, no signs of farming activity were observed. In this study (á Norði et al., 2011), the authors noted that the deposition of food and fecal waste from the farm had no effect on the overall conditions in the central basin of the fjord, but emphasized the need for accounting for spatial variations when extrapolating results from a single or few stations to the scale of the entire fjord.

In some localities in the Faroe Islands, the fjord's deep sills may prevent periodical free exchange of the seawater close to bottom in summer, and in some years, natural conditions cause reduced oxygen content in this deep-water layer for short periods in late summer (pers. comm., Gaard, FMRI, 2018). In addition, periods with oxygen depleted deep-water layers of the water column also occur in fjords that do not have deep sills during periods of limited water exchange; it is not known whether fish farming is a major contributor to this phenomenon in either type of location, but it would not be expected to alleviate the situation (pers. comm., Maria Dam, Environment Agency, 2018). It is of relevance to note two studies in the Kaldbaksfjørður in the Faroe Islands: one undertaken at a time of active salmon farming (Gard et al., 2011) and one at a time without such activity (Østerø et al., 2022). When comparing these two studies (and noting that natural interannual variation may be a factor), the nutrient availability, chlorophyl a concentrations, and the oxygen concentrations in the stagnant bottom water were highly similar, and do not indicate changes in nutrient or phytoplankton dynamics due to the presence of fish farming (pers. comm., á Norði, Fiskaaling, October 2022).

Seabed surveys are the basis for environmental monitoring of fish farming, according to regulations most recently updated in 2018, and benthic monitoring is required every production cycle at peak biomass (or within 1 month of it). According to an unofficial translation of the Environmental Monitoring Guidelines provided by the Environment Agency, the following samples are taken (the number and precise location of which are determined by the farm size and current characteristics):

- Cage samples: taken at the individual cages/units.
- Site samples: collected from the part of the farming site where no farming is taking place, in order to monitor the overall level of pollution in the farming site.
- Fjord samples: taken outside the farming site. Fjord samples should indicate how aquaculture is affecting the environment beyond the farming site.
- Reference samples (SS): taken from a fixed location outside the farming site. One reference sample is required for each farming site. Reference samples should be as representative of the natural unpolluted farming fjord seabed as possible.

Two types of assessment are conducted: simple and chemical. The simple assessment occurs immediately upon taking the sample, and has four parts:

1. Visual fauna assessment: are animals larger than 1 mm present in sample?
2. pH and redox test of the top 1 cm of the sample.
3. Sensory assessment: evaluation of bubbles, color, odor, texture, and sludge thickness.
4. Photos of all samples.

The chemical analysis is laboratory-based, with testing for copper and zinc contents in sediment as well as for organic material measured as loss on ignition. Each assessment (i.e., the results from all sampling locations) generates an overall result for the site in one of four categories of benthic condition (i.e., one condition result for the simple assessment and one condition result for the chemical assessment).

- Condition 1 = unpolluted
- Condition 2 = some pollution
- Condition 3 = polluted
- Condition 4 = highly polluted

The final condition of each site is determined by the worst condition value from either the simple or chemical assessment. A “Condition 3” result is defined as a “warning” that must be followed by a management plan to recover the site and subsequent demonstration of recovery. A “Condition 4” result means that the Environment Agency determines the subsequent sampling protocol and restocking permissions. Simonsen (2015) indicates that there are also more nuanced options available, noting that if benthic samples exceed threshold values, then actions such as restrictions in feeding, moving the farm, or early slaughter of fish may be issued by the authorities.

A new benthic classification system has been developed for benthic macrofauna in the Faroese fjords (Mortensen et al., 2021). This is intended to be used by the Environmental Agency (which commissioned its development) for assessing the potential impact of aquaculture in soft substrate locations (i.e., as opposed to hard or rocky substrates). A prior requirement for benthic macrofauna analyses (as part of the broader benthic monitoring process) was suspended in 2014 due to the lack of knowledge regarding the natural benthic macrofaunal composition and abundance in the different Faroese fjords (Mortensen et al., 2021). The proposed system is applicable to all Faroese fjords, but must account for differences in sediment type between fjords, because muddy sediments have significantly lower index values for benthic macrofauna compared to sandy sediments, which harbor a more diverse habitat environment as well as a more diverse and richer benthic community. The aim is to implement the classification system in the benthic monitoring program in the near future (pers. comm., á Norði, Fiskaaling, October 2022), and at the time of writing this report (November 2022), a working group under the Environmental Agency is reviewing the proposal (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022).

The benthic monitoring results from 2010 to 2015 were previously provided for this assessment by the industry (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018), and more recent results from 2018 to 2021 (i.e., after the update to the regulations) were provided by the Environment Agency (pers. comm., Katrin Jensen, Umhvørvisstovan, July 2022). This leaves a data gap for 2016 and 2017 where no data could be obtained. The most recent data (i.e., 2018 to 2021) for the simple and chemical assessments are plotted in Figure 4.

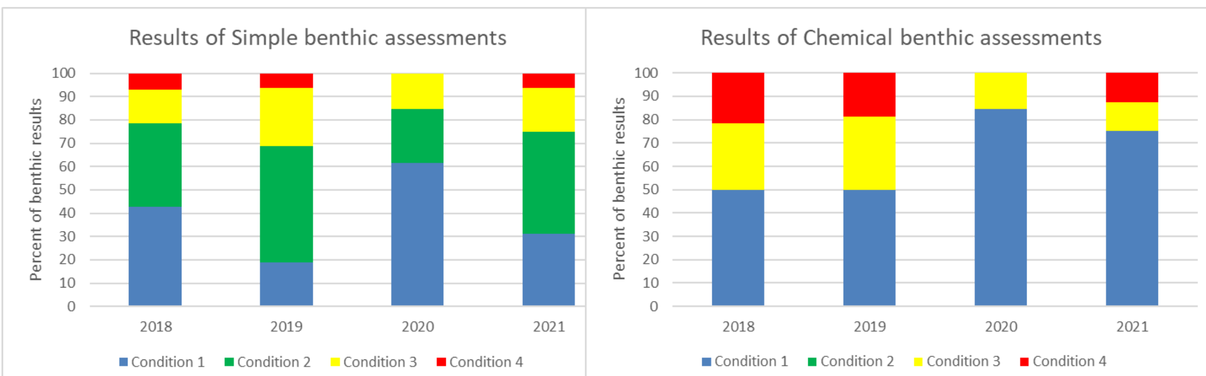

Figure 4: Benthic monitoring results by condition and year from 2018 to 2021 for the simple and chemical assessments as the percentage of all site results per year. Data provided by Umhvørvisstovan (pers. comm., Katrin Jensen, Umhvørvisstovan, July 2022).

These results show that, on average between 2018 and 2021, 76.7% of the simple assessment results were in Condition 1 or 2 (i.e., the sites were unpolluted or had some pollution) and 23.3% were in Condition 3 or 4 (i.e., polluted or highly polluted). The same average of the chemical results showed that 64.9% of sites were in Condition 1 or 2[33] and 35.1% were in Condition 3 or 4. But, when the worst results for each site were taken (i.e., the official final result), only 53% of results were in Condition 1 or 2 and 47.0% of results were in Condition 3 or 4 over the same period (2018 to 2021). The final results for 2018 to 2021, in addition to the previous data from 2010 to 2015, are shown in Figure 5.

[33] It is not clear why there are no Condition 2 results from these chemical assessments.

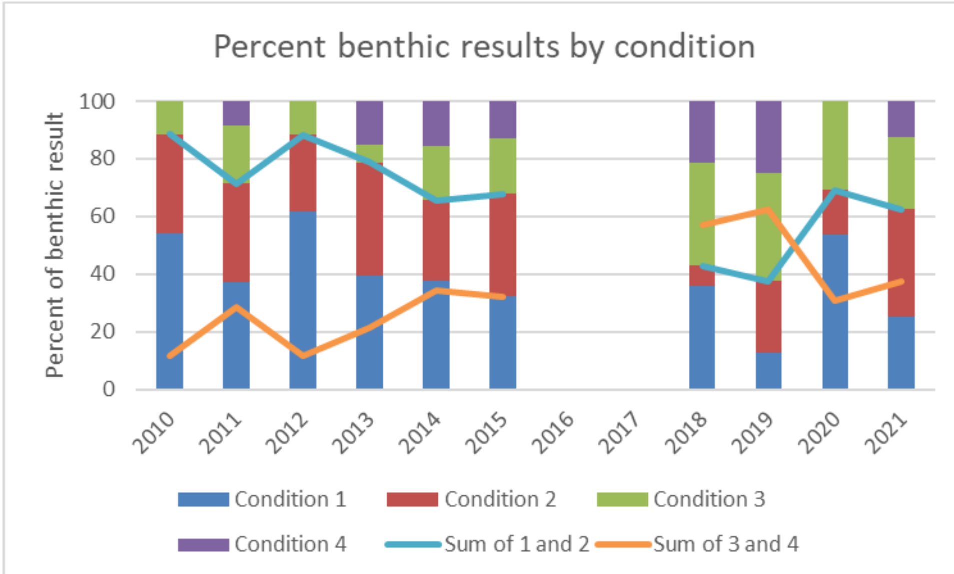

Figure 5: Final benthic monitoring results by condition and year from 2010 to 2015 and 2018 to 2021 as the percentage of all site results per year. Note that data could not be obtained for the years 2016 and 2017. Data shown were provided by Havbúnaðarfelagið (pers. comm., Maria Dam, Havbúnaðarfelagið, 2018) and Umhvørvisstovan (pers. comm., Katrin Jensen, Umhvørvisstovan, July 2022).

These results show a general decline in the number of sites in Condition 1 or 2 from 2010 to 2019 (and a corresponding increase in polluted and highly polluted sites in Condition 3 or 4). There is a large increase in Condition 1 from 2019 to 2020, and the reason for this is uncertain but may be associated with the new monitoring regulations initiated in 2018. Overall, in the last 4 years of monitoring data (i.e., 2018 to 2021), only slightly more than half the sites (53%) were in satisfactory condition (i.e., Condition 1 or 2), and nearly half (47%) were polluted or highly polluted (Condition 3 or 4) at peak biomass. During this period, an average of 14.7% of sites were highly polluted (Condition 4).

As mentioned previously, the final benthic result for each site determines the subsequent monitoring requirements. If the final result is Condition 1 (i.e., unpolluted), then the next monitoring is done as usual at the peak biomass of the following production cycle. If it is Condition 2 (some pollution) or 3 (polluted), the site must be sampled again before restocking with a new production cycle. The results of this pre-stocking monitoring do not prevent the stocking, but determine how often the site must be monitored during production. Table 1 from the Environment Agency's Benthic Monitoring Guidelines shows the requirements.

Table 1: Frequency of seabed surveys according to previous monitoring result. Table reproduced from (Umhvørvisstovan, 2018)

Environmental condition from most recent survey at peak biomass	Next survey is due:
1 – Unpolluted	At peak biomass
2 – Some pollution	Before fish is released at the site and at peak biomass.

3 – Polluted	a. Before fish is released and b. If the survey before release indicated: —Condition 1: at peak biomass —Condition 2 or 3: when biomass is 50% of peak biomass and at peak biomass —Condition 4: The Environment Agency will determine sampling requirements.
4 – Highly polluted	The Environment Agency will determine sampling requirements.

Although there is no evidence of a loss of functionality in fjordic ecosystems due to salmon farm wastes, anecdotal reports reflect a concern of local people to degraded environmental quality in some fjords (pers. comm., Theresa Jákupsdóttir, FNU, 2018), and the substantial percentage of sites in "polluted" or "very polluted" condition (e.g., 47% of sites from 2018 to 2021) indicate that benthic habitats are overwhelmed in these locations. There is a mandatory 2-month fallow period in the Faroe Islands, but data from Bakkafrost[34] show that this company had an average fallow period of 15.4 weeks between 2016 and 2021, which is substantially more than the regulatory minimum; however, it is unclear if this is due to company policy, or delays in restocking permissions due to unfavorable benthic results. Individual site monitoring results previously supplied by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018) from 2010 to 2015 show that, for all sites with results in Category 4, the condition had improved by the following annual monitoring. This potential for recovery indicates the reversibility of the benthic impacts from salmon farms, and comprehensive studies (e.g., Keeley et al., 2015) also conclude that these direct habitat impacts below the net pens are relatively rapidly reversible and can be recovered by fallowing and/or moving the farm. In practice, the occurrence of fallowing between production cycles only temporarily improves the benthic conditions before production begins again, and impacts are thus cyclical in nature (Keeley et al., 2015).

Regarding potential cumulative impacts, the fjords of the Faroe Islands are delineated into specific farming areas or management zones, within which production must be coordinated (and each area is typically allocated to a single company). An example map showing individual site locations and lease areas was provided in Figure 3, and Figure 6 shows all the aquaculture management zones in the Faroe Islands.

[34] https://www.bakkafrost.com/en/about-us/sustainability/data/

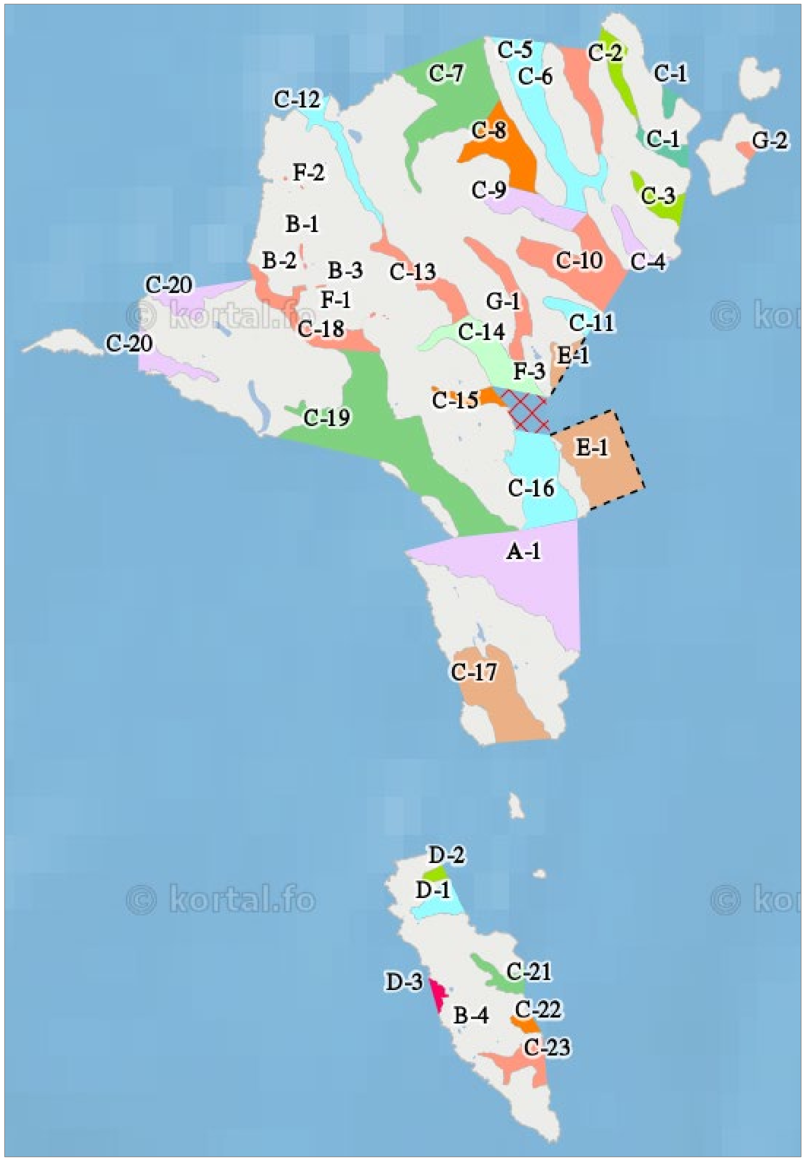

Figure 6: Map of aquaculture areas in the Faroe Islands. Map reproduced from www.kortal.fo

It can be seen that almost every waterbody within the islands is part of a management area. There is a general biomass density limit of 25 kg/m^3 during grow-out, and annual license plans must specify the maximum expected total biomass at each site. But, though licenses can require sites to coordinate production within and even between management areas, production overall does not appear to be managed according to total biomass on a cumulative or area basis, and impacts appear to be managed on a site-by-site basis, as dictated by the benthic monitoring results.

Conclusions and Final Score

Salmon farms are a dominant contributor of anthropogenic nutrients into coastal waters in the Faroe Islands; however, there is no evidence that nutrients in the water column have any significant impact beyond the site's immediate or licensed area. But, benthic monitoring results at each site show that nearly half (47%) of the sites were categorized as polluted or highly polluted (Condition 3 or 4) at peak biomass between 2018 and 2021. These impacts are overseen by a comprehensive regulatory system, which was updated in 2018 (and a new benthic classification system was proposed in 2021). These impacts may be reduced and or reversed by fallowing, but these results show that seabed communities in the immediate farm areas are frequently overwhelmed by salmon farm pollution. It is also possible that salmon farms contribute to observed seasonal low oxygen levels in deep-water layers in some Faroese fjords. From a cumulative perspective, fish farming is licensed in the majority of fjords and sounds in the Faroe Islands, but the data available from each site show little direct evidence that the effluent discharges cause or contribute significantly to cumulative impacts at a water-body or regional scale, particularly in the water column. Overall, the somewhat high level of sites in Condition 3 or 4 is a concern, and these data are considered to show that salmon farms in the Faroe Islands result in frequent impacts within the immediate vicinity of the farm. Because these impacts are considered to be reversible, the final score for Criterion 2—Effluent is of 4 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

- Impact: Aquaculture farms can be located in a wide variety of aquatic and terrestrial habitat types and have greatly varying levels of impact to both pristine and previously modified habitats and to the critical "ecosystem services" they provide.
- Sustainability unit: The ability to maintain the critical ecosystem services relevant to the habitat type.
- Principle: being located at sites, scales and intensities that maintain the functionality of ecologically valuable habitats.

Criterion 3 Summary

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		8
F3.2a Content of habitat regulations	3	
F3.2b Enforcement of habitat regulations	4	
F3.2 Regulatory or management effectiveness score		4.8
C3 Habitat Final Score (0–10)		**6.9**
Critical?	No	**GREEN**

Brief Summary

Except for the operational impacts on the seabed assessed in Criterion 2—Effluent, the general construction and installation of floating net pen salmon farms has a limited direct impact on the habitats in which they are sited. But, the net pens and their supporting infrastructures contribute much physical structure to nearshore habitats and are known to modify the physical environment at the farm location by modifying light penetration, currents, and wave action, as well as providing surfaces for the development of rich biotic assemblages that may further increase the complexity of the habitat. An average salmon farm contains approximately 50,000 m^2 of submerged artificial substrates that can be colonized by a large suite of hard-bottom associated species that may not otherwise find suitable habitat in a given area (e.g., muddy bottoms or in the water column). These additional species may have a variety of direct and cascading effects on the surrounding ecosystem, including inadvertently supporting the persistence and distribution of nonnative species. Salmon farms also attract a variety of wild animals as fish aggregation devices or artificial reefs, or repel other wild animals through disturbance such as noise, lights, or increased boat traffic. Changes in behavior of wild fish around fish farms and even of their flesh quality due to the consumption of waste feed have been reported. Key aspects of these potential impacts are their circumstantial variability, their limited study, and the challenge of their quantification, particularly in the context of the confounding impacts of soluble and particulate effluent wastes (assessed in Criterion 2—Effluent).

There is a regulatory system for siting and impact assessment in the Faroe Islands, and an area-based system for each water body, but it is unclear how the range of potential impacts associated with the infrastructure of the net pen systems are managed, including from a cumulative perspective. Overall, the habitats in which salmon farms are located are considered to be maintaining functionality with minor or moderate impacts, and the final score for Criterion 3—Habitat is of 6.93 out of 10.

Justification of Rating

Note that the operational impacts to benthic habitats beneath salmon farms resulting from settling particulate wastes are addressed in Criterion 2—Effluent.

Factor 3.1. Habitat Conversion and Function

Data on site locations and boundaries for every aquaculture site in the Faroe Islands are available from the Environment Agency's Føroyakort mapped database (see example in Figure 3). Figure 7 shows an example of a single site (ongrowing site A-12, chosen at random) from the Føroyakort map, alongside a readily available satellite image from Google Earth. The satellite images are sufficient to show that the net pens are located within the permitted area, and the detail can show whether the site (or a part of it) is in active production or fallow; for example, in Figure 7, the nine most westerly net pens are stocked, as evidenced by the presence of bird nets, feeding lines, and jumping fish (clearly visible in Google Earth).

Figure 7: An example of a site location and lease area from the Environment Agency's mapping tool (Føroyakort) (top image) and a satellite image of the same area from Google Earth (bottom image) showing the locations of net pens and providing an overview of the relevant surface habitats. In this example, close scrutiny of the satellite images shows the nine most westerly pens are currently in production.

From images such as those in Figure 7 and from other sites, it is apparent that the floating net pen containment system does not result in any gross functional conversion of surface habitats compared to (for example) the construction of ponds; however, that is not to say that there are no habitat impacts.

Taken together, the net pens and their supporting infrastructures (i.e., the floats and weights, and the mooring ropes, buoys, and anchors) contribute much physical structure to nearshore habitats (McKindsey, 2011). These added structures are known to impose on the physical environment at the farm location by modifying light penetration, currents, and wave action, as well as providing surfaces for the development of rich biotic assemblages that may further increase the complexity of the habitat (McKindsey, 2011). An average salmon farm contains approximately 50,000 m^2 of submerged artificial substrates that represent potential settlement space for biofouling organisms (Bloecher et al., 2015).

McKindsey (2011) provided a detailed review of "Aquaculture-related physical alterations of habitat structure as ecosystem stressors,[35]" and for net pen finfish aquaculture, the report is summarized as follows:

> On-bottom structures include anchoring devices for floating net pen fish farm, and vertical structure added to the water column include ropes and cage/net structures as well as buoys, etc. This infrastructure can be colonized by a large suite of hard-bottom associated species that may not otherwise find suitable habitat in a given area (e.g., muddy bottoms or in the water column). These have a variety of direct and cascading effects on the surrounding ecosystem. These structures also modify wave action and current regimes which may influence various ecosystem processes. Cage and netting structures may trap a variety of large organisms but data on this effect are rare.

McKindsey (2011) noted that an overriding issue in all discussions of these potential stressors is that most proposed effects from the addition of structure related to fish cage aquaculture are confounded by the addition of large quantities of feed to the environment (and thereby the soluble and particulate fecal wastes discussed in Criterion 2—Effluent), and any observable impacts may be due, at least in part, to this factor. McKindsey also noted that the effects related to the addition or modification of physical structure are not well studied, most effects have not been quantified, and the discussion of effects in the scientific literature is largely based on extrapolations from other systems. Though published 10 years ago, McKindsey also noted that major recent reviews on aquaculture-environment interactions (at that time) did not discuss the implications of these structures or did so only in a limited way.

A brief search for relevant literature since 2011 adds additional potential impacts; for example, the Canadian Department of Fisheries and Ocean (DFO, in a 2017 information webpage on the Alteration of Habitats[36]) also notes that the use of underwater lights may influence the behavior of wild fish by attracting them to—or causing them to avoid—farm sites, but also notes that the lights do not penetrate more than a few meters beyond marine nets, suggesting that their use has a minimal effect on the surrounding environment. Floerl et al. (2016) note that a large number of fish (and mussel) farms in North America, Europe, and New Zealand support extensive populations of biofouling invasive species, and the on-site cleaning of fouled net pens may inadvertently support the persistence and distribution of such species within aquaculture regions by the localized dispersal of nonindigenous propagules and fragments, or by the use of farm structures as stepping-stones for range expansion (Bloecher and Floerl,

[35] This was a Canadian study, but the findings are considered here to be directly relevant to farmed salmon net pen systems elsewhere.
[36] https://www.dfo-mpo.gc.ca/aquaculture/protect-protege/alteration-habitat-eng.html

2020). In New Zealand, MPI (2013) also note the potential for impacts to benthic habitats due to shading, but in keeping with McKindsey (2011), they note that no studies exist that separate the effects of shading from that of benthic enrichment; presumably because they occur concurrently, and the latter is thought to be the dominant stressor.

In addition to biofouling organisms attached to the novel substrates, Callier et al. (2018) reported the attraction and repulsion of wild animals to/from marine finfish farms (and bivalve aquaculture) and considered the effects related to the farm infrastructure acting as fish aggregating devices or artificial reefs, the provision of food (e.g., farmed animals, waste feed and feces, and fouling organisms associated with farm structures) and some farm activities (e.g., increased boat activity and cleaning). These authors noted that the distribution of mobile organisms associated with farm structures varies over various spatial (vertical and horizontal) and temporal scales (season, feeding time, day/night period). Also, the attraction/repulsion mechanisms have a variety of direct and indirect effects on wild organisms at the level of individuals and populations and may have implications for the management of fisheries species and the ecosystem in the context of marine spatial planning. Nevertheless, also in keeping with McKindsey et al. (2011), Callier et al. (2018) also noted considerable uncertainties regarding the long-term and ecosystem-wide consequences of these interactions.

Uglem et al. (2020) also note that salmon farms attract large amounts of wild fish that consume uneaten feed pellets, and as specific examples, Otterå et al. (2014) and Skilbrei et al. (2016) note that saithe (*Pollachius virens*) is by far the most numerous fish visitor to fish farms (on the Norwegian coast) and shows evidence of establishing core residence areas close to fish farms, such that the aquaculture industry is influencing the local saithe distribution. Again, Otterå et al. (2014) conclude that large-scale population effects are difficult to prove, but note it is possible that the dynamic relationship between the coastal and oceanic phases of saithe has been altered. Uglem et al. (2020) also note that the modified diet of the wild fish aggregating at salmon farms (i.e., the consumption of salmon feed pellets) may reduce the flesh quality of the fish, thus influencing the local fisheries (although they noted the changes in flesh quality were small). It is considered here that similar interactions with local or migratory fish populations are likely to occur in the Faroe Islands.

Regarding impacts of net pen structures to the hydrodynamic characteristics of affected habitats, it can be seen from the Environment Agency's mapped database that many salmon farms in the Faroe Islands are located in narrow fjords or inter-island channels. Herrera et al. (2018) noted (at a single salmon farm site in Chile) that the presence of the net pens modified the natural hydrodynamics of the channel, attenuating the intensity of the local velocity magnitude and generating recirculation and retention zones near them. They also noted that the effects were not confined locally because the perturbations introduced by the presence of net pens were propagated far from them. Similarly, a study in Norway (Michelsen et al., 2019) indicated some impact from the salmon farm on the measured current flow at distances from 90 to 320 m around it. But, these studies on water movements related primarily to animal welfare and the distribution of pollutants, and it is not known if changes to the hydrodynamics have other significant habitat impacts.

In the Faroe Islands, there do not appear to be any focused research efforts or other similar data to indicate the degree of impact resulting from the placement or presence of net pen arrays. But overall, the floating net pen salmon farm containment system is unusual among food production systems in that the "construction" of the farm has a relatively low direct habitat impact, yet the addition of the physical infrastructure and the site operations still have a variety of potential impacts on the habitats of the farm site. In addition, it is important to note that the inshore subtidal habitats of the Faroe Islands in which salmon farms are located are important for the early marine stages of wild salmonid populations such as sea trout. The evidence reviewed above emphasizes both the complexity and uncertainty regarding the scale of the impacts and the appropriate level of concern, but the examples cited do not indicate the loss of any critical ecosystem services from the affected habitats. Thus, the habitats are considered to be maintaining functionality with minor-moderate impacts, and the score for Factor 3.1 Habitat conversion and function for the floating net pens is 8 out of 10.

Factor 3.2. Farm Siting Regulation and Management

Factor 3.2a: Content of habitat management measures

Salmon farms in the Faroe Islands must obtain a license from the Environment Agency and from the FFVA before commencing any farming activities. According to the Parliament Act No. 83 of 2009 (with latest amendments in the recent Parliament Act No. 31 of 2022), the licenses have the potential to be valid for 12 years, provided that the terms in three other parliament acts relating to environmental protection, food safety, and animal diseases are fulfilled. The former is discussed below. If the conditions are not violated or no significant new knowledge arises, the license cannot be changed by the authorities until 5 years after the issuing date.

The Parliament Act on Environment Protection (No. 134 of 1988, amended by No. 128 of 2008) is administrated by the Environment Agency (under the Ministry of Health and Interior) such that all commercial activities in the Faroe Islands require an "environment approval" before they can start. Initial license production limits are based on benthic mapping and current measurements, and the same seabed analysis described in Criterion 2—Effluent must be completed before production but with double the number of samples. Additional license requirements (according to Executive Order no. 80 from 2019 on the establishment of, and prevention of spread of diseases in, fish farming operations) include an annual submission and approval of production plans, and at any time plans for two following productions cycles have to be in place. Under this regulation, a requirement of coordination with neighboring farms (both within and also beyond a management zone) may be set, as well as a restriction on the number of fish and biomass as part of the approval process of the production plans. Part of the terms in this annual production license are maximum expected biomass, which is controlled through the allowed number of fish to be stocked into the area based on compliance with the benthic monitoring (of fish health) requirements during production as discussed below.

It must be clarified that the "environmental approval" is not a formal Environmental Impact Assessment (EIA), and the licensing and regulatory process has been criticized by environmental organizations for allowing expansion of the industry to new sites in remote areas without a formal assessment, including robust public consultations (pers. comm., Theresa Jákupsdóttir, FNU, 2018). For example, a petition signed by almost 1,500 people called for the area "Á Víkum" (salmon farming operation A14) to become a nature conservation site, but despite this, the farming license was granted (pers. comm., Theresa Jákupsdóttir, FNU, 2018).

As noted in Criterion 2—Effluent (Figure 6), the fjords of the Faroe Islands are delineated into specific farming areas or management zones, within which production must be coordinated. From a cumulative perspective, it can be seen that almost every water body within the islands is part of a management area, but the dominant aspects of the site-level regulatory system are potential impacts associated with nutrient wastes (provided there are no additional concerns raised during procedural reviews relating to other aspects of the Environmental Protection act, the Animal Diseases Act, or the Food Act). Given the uncertainty attributed to the impacts described in Factor 3.1, this is perhaps not surprising, and overall, the management system is considered to require farms to be sited according to ecological principles or environmental considerations at the site level. Considering the uncertainties in the scale of the impacts described in Factor 3.1 and the nature of the site licensing process in the Faroe Islands, the score for Factor 3.2a is 3 out of 5.

Factor 3.2b: Enforcement of habitat management measures

The organizations responsible for enforcing licensing and monitoring are the Environment Agency and the FFVA, respectively. Although there are some data gaps and some language and translation challenges, the available data, particularly the recent data provided by the Environment Agency, indicate that the benthic sampling procedures take place as outlined in the regulatory guidance document. There are no readily available indications of penalties for any compliance infringements (GSI data show no environmental noncompliances for Bakkafrost from 2013 to 2020), but this is likely to relate to the manner of enforcement, wherein exceedances of allowable limits result in production limitations such as further testing or delayed and reduced stocking. It appears that the resources are available to enforce the regulations. There are some gaps in transparency and data availability, and it must be noted that it is not clear if there are "watchdog" organizations that challenge the industry, or if the regulatory process provides the option for their input or other robust public consultation.

Overall, the enforcement organizations are identifiable and active, but regarding the potential impacts outlined in Factor 3.1, the activities are perhaps limited in their effectiveness and/or have some gaps in transparency, particularly for any potential cumulative impacts. Nevertheless, the enforcement of the site licensing process is considered robust, so the score for Factor 3.2b—Enforcement of habitat management measures is 4 out of 5.

Factor 3.2 Conclusion

The final score for Factor 3.2 combines the scores for the regulatory content (Factor 3.2a, 3 out of 5) with the effectiveness of the enforcement (Factor 3.2b, 4 out of 5) resulting in a Factor 3.2 score of 4.8 out of 10.

Conclusions and Final Score

Except for the operational impacts on the seabed assessed in Criterion 2—Effluent, the general construction and installation of floating net pen salmon farms has a limited direct impact on the habitats in which they are sited. But, the net pens and their supporting infrastructures contribute much physical structure to nearshore habitats and are known to modify the physical environment at the farm location by modifying light penetration, currents, and wave action, as well as providing surfaces for the development of rich biotic assemblages that may further increase the complexity of the habitat. An average salmon farm contains approximately 50,000 m^2 of submerged artificial substrates that can be colonized by a large suite of hard-bottom associated species that may not otherwise find suitable habitat in a given area (e.g., muddy bottoms or in the water column). These additional species may have a variety of direct and cascading effects on the surrounding ecosystem, including inadvertently supporting the persistence and distribution of nonnative species. Salmon farms also attract a variety of wild animals as fish aggregation devices or artificial reefs, or repel other wild animals through disturbance such as noise, lights, or increased boat traffic. Changes in behavior of wild fish around fish farms and even of their flesh quality due to the consumption of waste feed have been reported. Key aspects of these potential impacts are their circumstantial variability, their limited study, and the challenge of their quantification, particularly in the context of the confounding impacts of soluble and particulate effluent wastes (assessed in Criterion 2—Effluent).

There is a regulatory system for siting and impact assessment in the Faroe Islands, and an area-based system for each waterbody, but it is unclear how the range of potential impacts associated with the infrastructure of the net pen systems are managed, including from a cumulative perspective. Overall, the habitats in which salmon farms are located are considered to be maintaining functionality with minor or moderate impacts, and the final score for Criterion 3—Habitat is of 6.93 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.
- Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments
- Principle: limiting the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms.

Criterion 4 Summary

C4 Chemical Use parameters		Score
C4 Chemical Use Score (0–10)		**4.0**
Critical?	No	Yellow

Brief Summary

Annual antimicrobial use of approximately 4,000 kg in 1999 declined rapidly to zero in 2004, and several data sources confirm that antimicrobials have not been used since. Pesticide use to control sea lice has been highly variable, but has also declined rapidly in recent years due to the increased use of nonchemical alternatives. An analysis of the detailed chemical use data provided by FFVA shows that there has been an average of 1.31 treatments per completed production cycle in recent years (2019 to 2021), or approximately 1 treatment per site per year, but when considering fallow periods, each site receives an average of approximately 0.8 treatments per year. The dominant treatment by frequency is emamectin benzoate (85% of treatments) and by weight is diflubenzuron (75% of total pesticide use). Azamethiphos is also used infrequently. Although the environmental impacts of pesticide use in net pen salmon farms remains challenging to determine, a comprehensive risk assessment in Norway currently consider there to be a "moderate" risk of environmental effects on nontarget species in the local area through the typical use of the in-feed treatments emamectin benzoate and diflubenzuron, and a moderate or low risk for the bath treatment azamethiphos. Full resistance to different pesticide groups has been shown in sea lice in the Faroe Islands, with some lice also partly resistant to second treatment types. Although the reduced use of pesticides will limit the development of resistance, 85% of treatments currently use the same pesticide, thereby also encouraging resistance. Overall, the treatment frequency is currently low, with pesticides that can be considered to have a mostly moderate risk of environmental impacts from their typical use. The sea louse population in the Faroe Islands has developed resistance to one or more treatments, so the final score for Criterion 4—Chemical Use is 4 out of 10.

Justification of Rating

The expansion of commercial aquaculture has often necessitated the routine use of veterinary medicines to prevent and treat disease outbreaks, assure healthy stocks, and maximize production (FAO, 2012); however, the characteristics of chemical use are highly variable according to the species produced and the management characteristics. This Seafood Watch assessment focuses on antimicrobials and sea lice pesticides as the dominant veterinary chemicals applied in salmon farming and also considers the use of copper-based antifoulants. Although other types of chemicals may be used in salmon aquaculture (e.g., disinfectants or anesthetics), the risk of impact to the ecosystems that receive them is considered to be less than that for antimicrobials and pesticides. See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.

Detailed data on each chemical treatment of farmed salmon in the Faroe Islands are available online from the Faroes Food and Veterinary Authority (FFVA) (Heilsufrøðiliga starvsstovan) portal[37] from June 2019. These data are published in Faroese but can be understood sufficiently well and are updated regularly. They provide site numbers, dates, treatment types, method of application (in-feed or as a bath) and the quantity (by weight) used for every chemical treatment. Annual data aggregated at the industry level from 2007 to 2019 for each treatment type were provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018, 2022). Some similar data are published in company reports and (for Bakkafrost) from GSI. Because of apparent differences in reporting units or timeframes (e.g., by year or production cycle), data from different sources may vary and these differences are noted below where relevant.

Antimicrobial Use

The consumption of antimicrobials in the Faroe Islands aquaculture industry decreased drastically from about 4,000 kg in 1999 to 1,100 kg in 2000, and continued to decline steadily from 2001 to 0 kg in 2004 (Gustavson et al., 2009). This was considered to be the result of better disease management practices and vaccination (Brudeseth et al., 2013)(Midtyling et al., 2011). The combined data from FFVA and Havbúnaðarfelagið show zero antimicrobial use between 2007 and the present. Further supporting evidence is available for the largest producer (Bakkafrost) through GSI and ASC audit reports (and some Mowi sites). Various company reports and websites also report the same long-term avoidance of antimicrobial use.[38] [39] [40] Although it is considered possible that a disease outbreak could lead to the use of antibiotics at any time, these data support a conclusion that antibiotics are not currently used in the Faroese salmon farming industry and have not been used for nearly two decades.

Pesticides

The primary target for pesticides in salmon farming is the parasitic sea louse, *Lepeophtheirus salmonis*, and to a lesser extent *Caligus elongatus*, which together with similar louse species in

[37] https://www.hfs.fo/webcenter/portal/HFS/aling
[38] https://mowi.com/blog/mowi-annual-report-2021/
[39] https://www.bakkafrost.com/en/sustainability/data/
[40] Hiddenfjord: Our Products: https://hiddenfjord.com/our-products/

other regions are considered to be the most economically important ectoparasites affecting Atlantic salmon culture worldwide (Covello et al. 2012). Pesticides are also used to treat Amoebic Gill Disease (AGD) caused by the parasite *Paramoeba perurans* (Wynne et al., 2020).

Pesticide use – type and quantity

The data provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018, 2022) and from the FFVA show a complex pattern of pesticide use; six different treatment types were used in quantities that varied substantially from year to year. For example, the use of hydrogen peroxide increased from zero in 2010 to a peak of 5,645 mt in 2013 and then declined again to zero in 2020. The combined data (from Havbúnaðarfelagið and FFVA) for the total quantities of each treatment from 2007 to 2021 are shown in Figure 8.

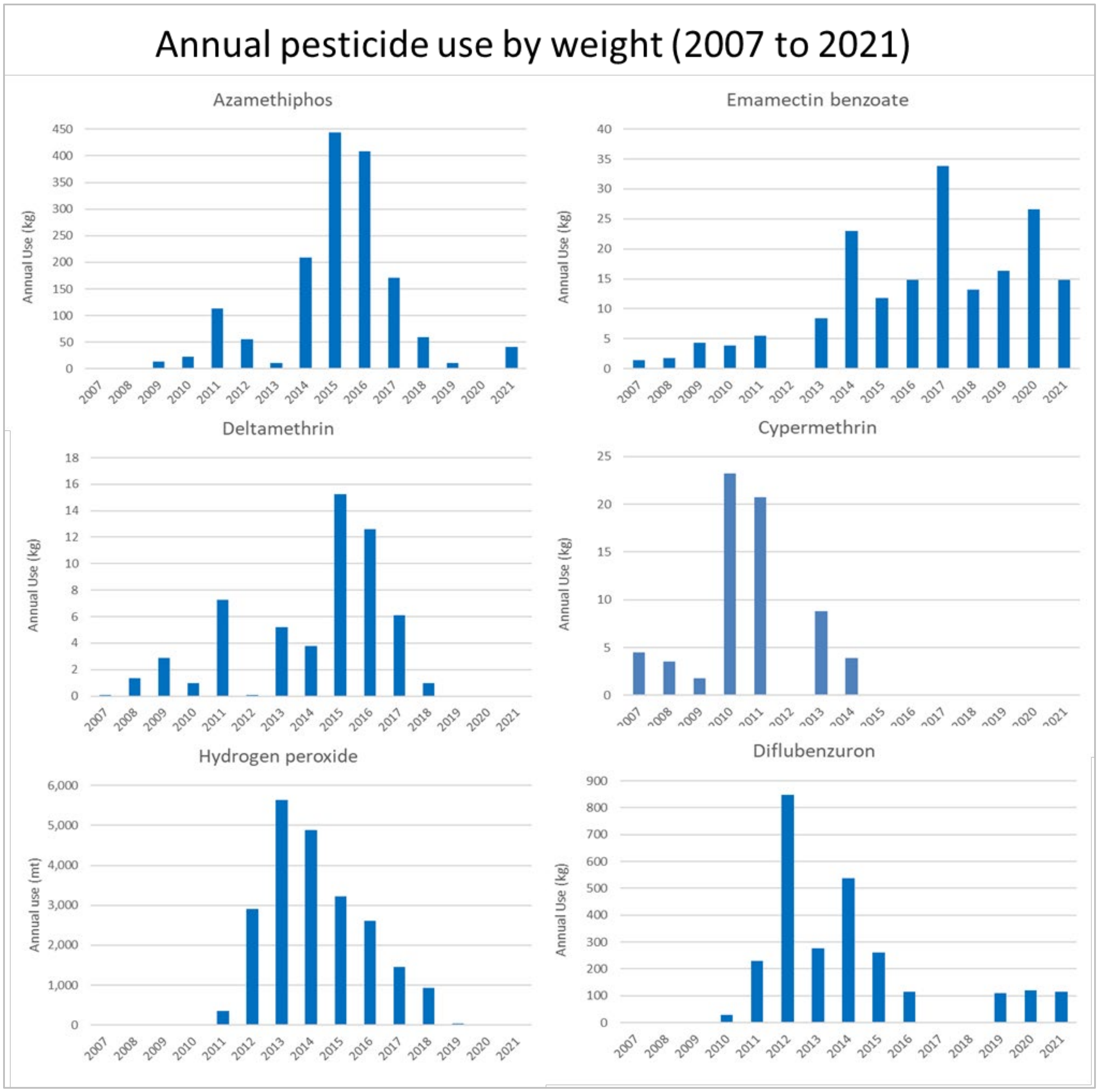

Figure 8: Annual pesticide use in Faroe Islands salmon farms from 2007 to 2021. Note the different scale and units of the y-axes for each of the six treatment types. Data from FFVA (2020 and 2021) and Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018, 2022) (2007 to 2019).

The recent decline in use (except for emamectin benzoate) is consistent with the increased use of nonchemical alternative treatments for sea lice; for example, Kragensteen et al., (2021) reported that the number of sea lice treatment events per year (of all treatment types, chemical and nonchemical) steadily increased to over 90 per year during 2016−2018 but shifted from chemical to mechanical treatments starting in 2016, such that there were almost exclusively mechanical treatments in 2018. A further example is provided by data from the GSI for the largest producer in the Faroe Islands (Bakkafrost), which shows peaks of in-feed pesticides and hydrogen peroxide (a bath treatment) in 2014 and a peak of other bath treatments in 2016, followed by a steep decline of all treatments, such that for this company (representing approximately 70% of Faroese production), there were no bath treatments of any kind from 2018 to 2020, and relatively small amounts of in-feed treatments (Figure 9). Nevertheless, the ongoing challenge to control sea lice is indicated by the increase in the use of both in-feed and bath treatments in 2021.

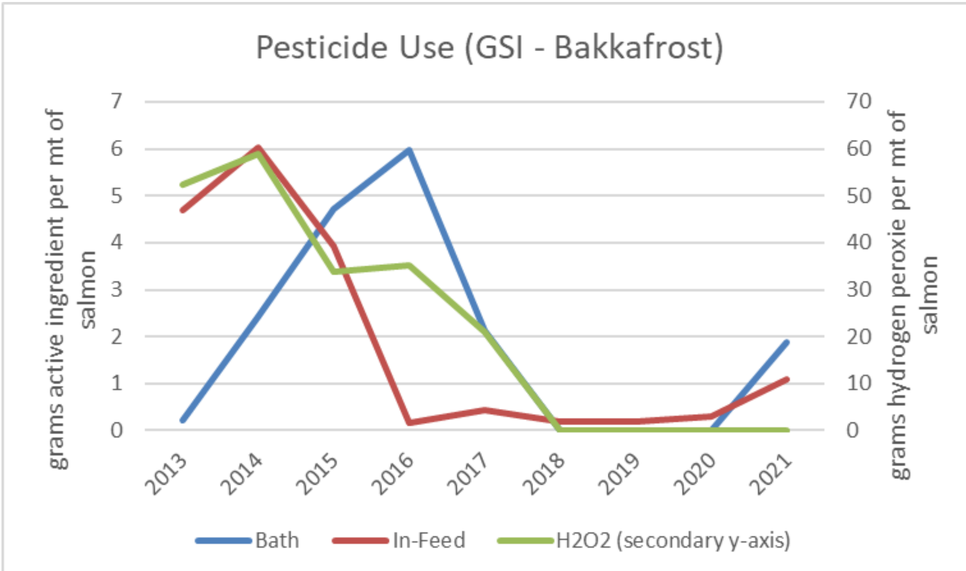

Figure 9: Annual pesticide use by Bakkafrost from 2013 to 2021 in grams active ingredient per mt of production. Note that hydrogen peroxide is plotted against the secondary (right) y-axis. Data from GSI (and also published by Bakkafrost).

During the 36-month period of the FFVA data used here (June 2019 to the end of 2021), there were 60 chemical pesticide treatments, of which 52 (85%) were of the active ingredient emamectin benzoate (trade name Slice), 5 (9%) were azamethiphos (trade name Salmosan), and 3 (6%) were diflubenzuron (trade name Releeze). In contrast, because of differences in the toxicity and application method between treatment types, the total pesticide use by weight during the same period (371.4 kg) was dominated by diflubenzuron (75%), with emamectin benzoate only 14% of the total (Figure 10).

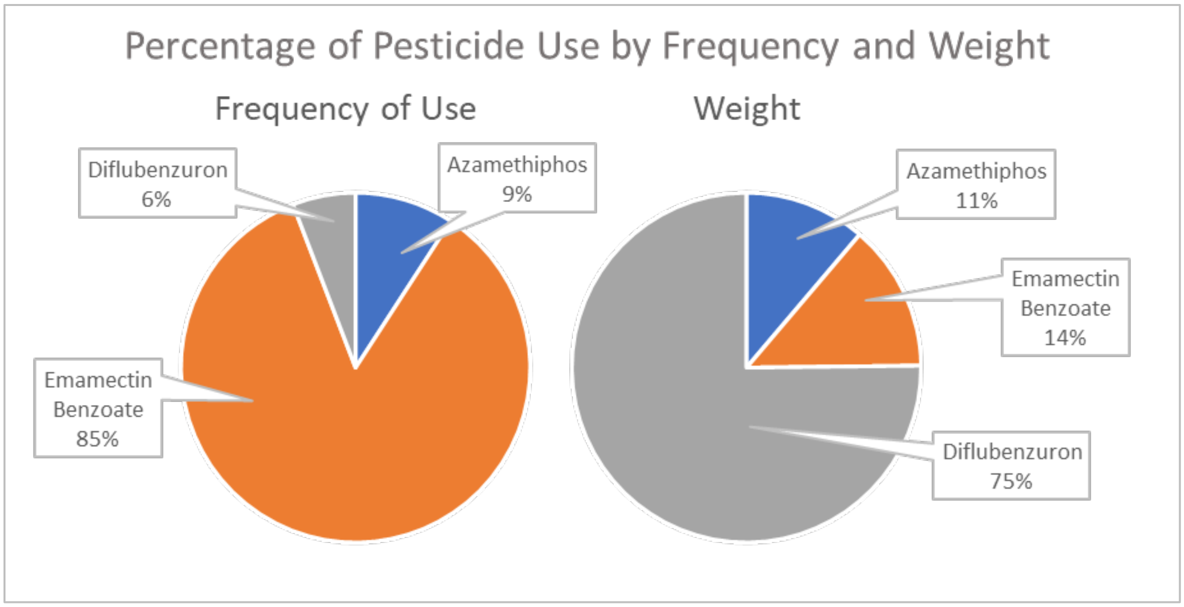

Figure 10: Percentage of pesticide use by treatment type and weight (active ingredient) for all applications to Faroese salmon farms from June 2019 to the end of December 2021. Data from FFVA.

Considering the common peak-decline patterns of pesticide use in Figure 8, the relative use of pesticides (i.e., in grams of active ingredient per mt of production) will be affected by the increasing salmon production over this 2007 to 2021 data period (see Figure 1). But, the dominant peak-decline patterns remain, and the relative pesticide use in 2021 was 1.56 g/mt for diflubenzuron, 0.57 g/mt for azamethiphos, and 0.20 g/mt for emamectin benzoate.

During the more recent data period from FFVA (June 2019 to the end of 2021), the monthly fish count (i.e., stocking) data[41] show that there were 29 sites in use (i.e., stocked) at any one time, giving a crude average of 0.83 treatments per site per year, based on 60 treatments at 29 sites over 2.5 years. Because the different sites have variable periods when there is no production (i.e., fallow), this average of 0.83 will be lower than a value based only on active (i.e., stocked) periods.

The detailed stocking data from FFVA show that the same period (June 2019 to end of 2021) covered parts of 69 production cycles and included 30 complete and 6 almost complete production cycles (considered to be ≥15 months, based on the average completed cycle length of 15.4 months). Of these 36 "complete" cycles, 19.4% had zero pesticide treatments, 44.4% had one, 22.2% had two, and 13.9% had three treatments (Figure 11).

[41] https://www.hfs.fo/webcenter/portal/HFS/pages_aling

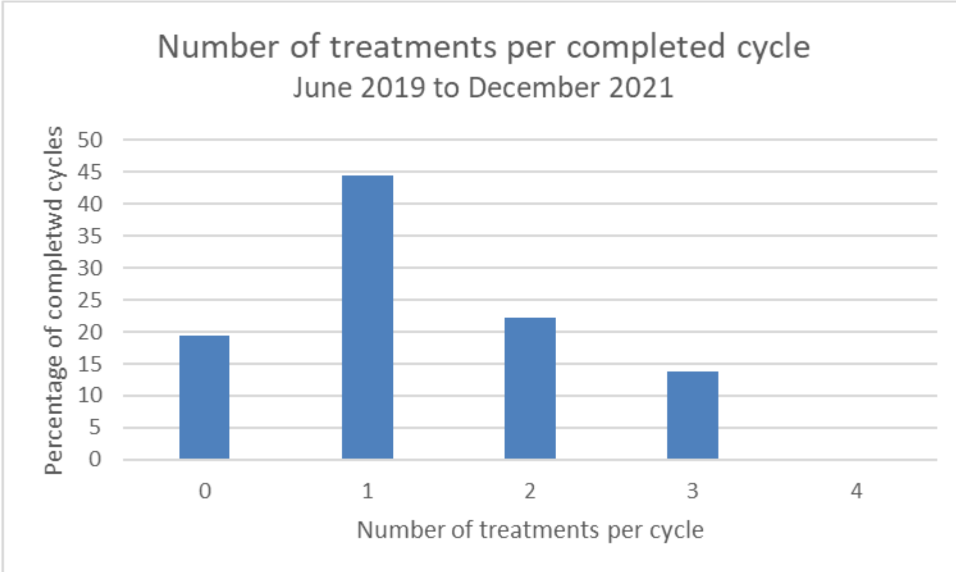

Figure 11: Number of pesticide treatments per completed and almost completed (≥15 months) production cycles between June 2019 and the end of 2021. Data obtained and analyzed from FFVA.

A simple average of the number of treatments per "complete" cycle shows 1.31 treatments per cycle over this period, or with the average cycle length of 15.4 months (1.28 years), this provides another crude average of 1.02 treatments per year per site.

Finally, an analysis of the number of stocked months and the number of treatments across all sites for the same period allows the number of treatments per stocked-site-month to be calculated and converted to an average number of treatments per stocked-site-year for each site.[42] These values averaged across all 29 active sites (Figure 12) show that 59.7% of sites had zero treatments per 12 months of production (i.e., a stocked-site-year), and 19.5% had one treatment. The remaining 20% had two, three, or four treatments per stocked-site-year (14.5%, 3.9% and 2.6%, respectively).

[42] For example, if a site were stocked for 10 months in 2021, and received 1 treatment during that period, there would be 0.83 stocked-site-years (10 divided by 12) and 1.2 treatments (1 divided by 0.83) per stocked-site-year for that site for the year 2021.

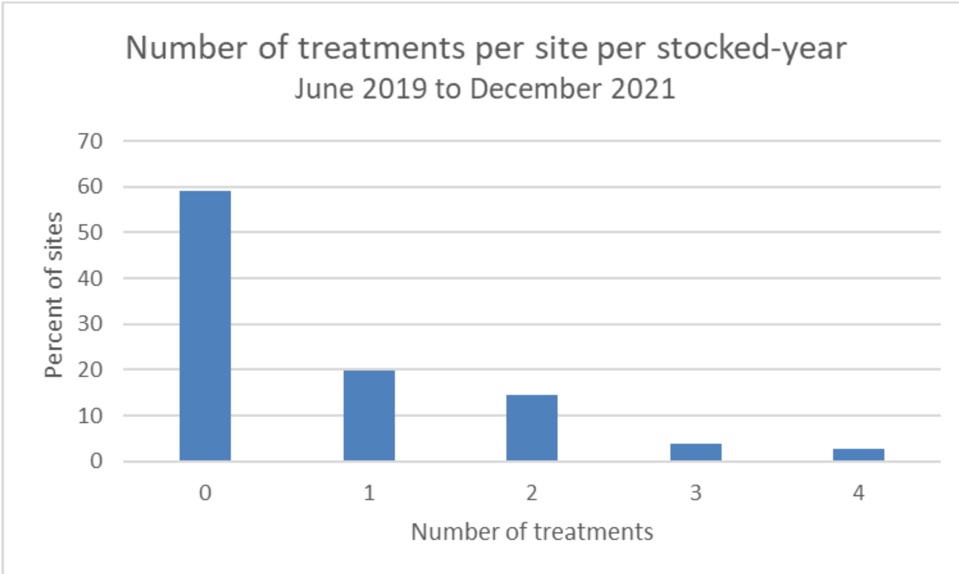

Figure 12: Number of pesticide treatments per stocked-site-year, where a stocked-site-year is 12 months of stocked production (between June 2019 and the end of 2021).

The average number of treatments per stocked-year per site across all sites for the period June 2019 to the end of 2021 shows 0.99 treatments per stocked-year. Considering the variability in pesticide use by year seen in the analysis above (Figure 8), this average number of treatments per stocked year can also be separated by year (Figure 13).

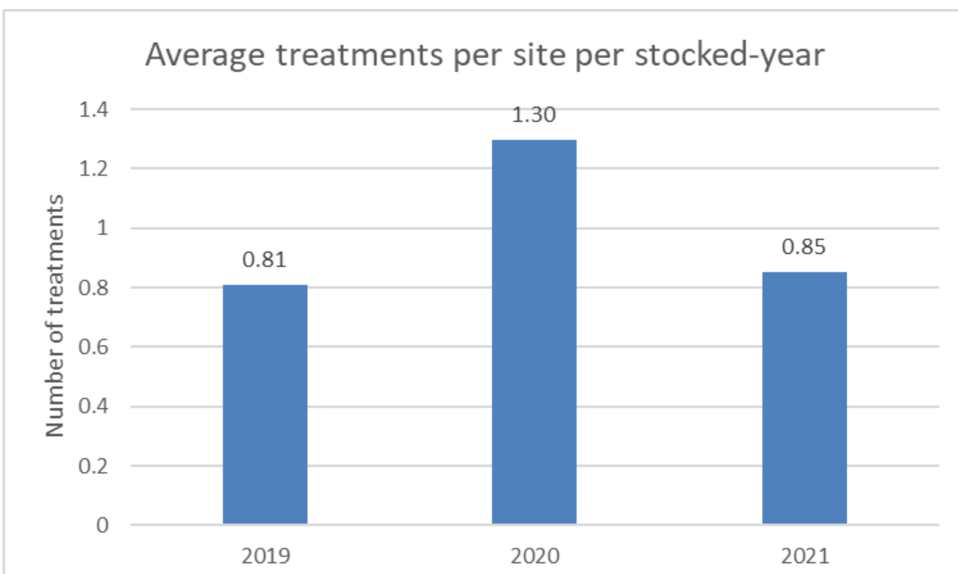

Figure 13: Average number of pesticide treatments per stocked-year for all sites in the most recent three data-years.

In conclusion, this analysis shows that pesticide use on salmon farms in the Faroe Islands has declined in the long term, with a concurrent reduction in the number of treatment types used, but there continues to be some use, given the likely variability in sea lice pressure from year to year. The dominant treatment (by frequency) is emamectin benzoate, but by weight is diflubenzuron. On average, there has been approximately 1 treatment per production cycle in recent years, varying annually between approximately 0.8 and 1.3 treatments per site per year.

Reduced sensitivity of sea lice to pesticides

From a global perspective, Aaen et al. (2014) documented the development of resistance to multiple sea lice treatments in all major salmon farming regions (except Western Canada) when sea lice are a sufficiently severe production problem that the repeated use of chemical treatments is required.

In the Faroe Islands, the complex cyclical patterns of pesticide use (shown from 2007 in Figure 8) are most likely due to the patterns of evolving resistance noted throughout the North Atlantic. In their paper titled "Losing the 'arms race': multiresistant salmon lice are dispersed throughout the North Atlantic Ocean," Fjørtoft et al. (2021) describe how, as pesticides used early in the industry's development became compromised by emerging resistance, new ones were introduced. Fiskaaling conducts sensitivity testing for the industry in the Faroe Islands, and though recent data were not available, reduced sensitivity had previously been shown in 2010 for cypermethrin, deltamethrin, and emamectin benzoate (Østergård, 2010).

The genetic study by Fjørtoft et al. (2021) shows that the salmon louse in the North Atlantic has developed multiple resistance to most of the available delousing compounds. In the Faroe Islands, Fjørtoft et al.'s study of organophosphate (e.g., azamethiphos) and pyrethroid (e.g., cypermethrin, deltamethrin) pesticides showed how resistance to these pesticides developed from 2009 to 2016. In 2009, 95% of sea lice were sensitive to both treatment types, while only 5% of sea lice showed partial resistance to organophosphates. By 2016, only 32% were sensitive to both, 39% were partly resistant to one treatment group, 27% showed full resistance to one or other treatment group, and 2% were resistant to one group and partly resistant to the other. There were still no sea lice that were fully resistant to both treatment groups (Figure 14).

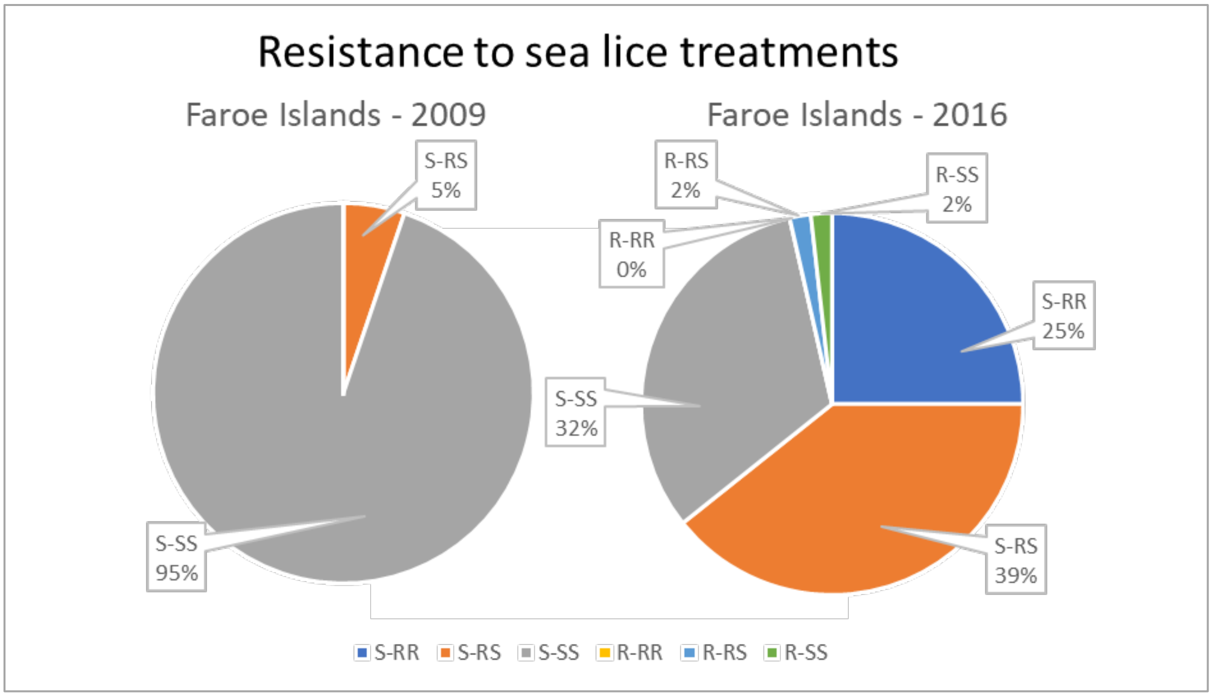

Figure 14: Detection of resistance to organophosphate and pyrethroid pesticides in sea lice samples in the Faroe Islands in 2009 and 2016. Key: the letter before the dash indicates resistance to pyrethroids (R = resistant, S = sensitive), and after the dash refers to organophosphates (SS = fully sensitive, RS = partly resistant, RR = fully resistant). Data from Fjørtoft et al. (2021—supplementary information).

The complex pattern of pesticide use in the Faroe Islands and the recent rapid evolution of nonchemical alternatives is most likely due to the development of resistance, which in turn is the result of pesticides' repetitive and/or excessive use. The general transition to nonchemical treatments greatly mitigates the development of resistance, but the continued use of these treatments, as shown by the recent FFVA data, particularly of emamectin benzoate, is considered to maintain the likelihood of ongoing resistance in sea lice in the Faroe Islands.

<u>Quantifying impacts</u>

The fate and environmental impact of sea lice treatments and their metabolites varies according to the chemical type and the treatment method, but the presence of a chemical in the environment does not necessarily mean that it is causing harm (SEPA, 2018). Studies on pesticide residues and impacts have been undertaken in the Faroe Islands (Dam & Mortesen, 2013; Hoydal & Dam, 2003; Mikkelsen et al., 2002), but the reports are only available in Faroese and online translation attempts were largely unsuccessful; therefore, more general information and studies from other regions are referred to below.

The three treatments most recently used in the Faroe Islands are emamectin benzoate, diflubenzuron, and azamethiphos. Azamethiphos is a bath treatment, while diflubenzuron and emamectin benzoate are administered orally in feed. These pesticides are nonspecific (i.e., their toxicity is not specific to the targeted sea lice) and they may affect nontarget organisms, particularly crustaceans, in the vicinity of treated net pens (Grefsrud et al., 2022a).

There is a large body of literature on these pesticides (e.g., Burridge et al., 2010; Samuelsen et al., 2015, 2020; Macken et al., 2015; Lillicrap et al., 2015; Parsons et al., 2020; Bjørkan & Rybråten, 2019; Torvik, 2021; Fang et al., 2018), but while the impacts of pesticide use in general continue to be studied and reviewed, Urbina et al. (2019) considered the real effects of these pharmaceuticals on the marine environment to remain largely uncertain. Even the exposure to hydrogen peroxide at relatively low concentrations, which has broadly been considered environmentally benign (Lillicrap et al., 2015), has recently been associated with irreversible negative effects on polychaete species (Fang et al., 2018). Therefore, while it continues to be challenging to quantify the level of concern regarding pesticides, it is clear that it is not insignificant.

A comprehensive Norwegian risk assessment (Grefsrud et al., 2022a,b) considered many aspects of pesticide use, including the quantities used, dilution and spreading, product degradation, seasonal variations, overlaps in consumption and occurrence of nontarget species, and the sensitivity of likely nontarget species. Thus, they conclude that, when a farm is treated with the pesticides discussed here, it will probably have a local effect on nontarget species, but they note that the effect will vary with the chosen treatment type, time of year, and local conditions at the time of treatment/discharge. Overall, considering all the available information (and noting the specificity to pesticide use in Norway), Grefsrud et al.'s assessment concluded that the risk of environmental effects on nontarget species through the typical use of emamectin benzoate and diflubenzuron was moderate, and for azamethiphos was low in the winter and moderate in the summer. It is important to note that the knowledge certainty for these assessments was moderate, and that even with increased knowledge, it will be a great challenge to identify effects at the ecosystem level, because there are many factors and the interactions between them are quite complex (Grefsrud et al., 2022,a).

<u>Antifoulants</u>

Copper is used as a minor element in salmon feed (the majority of which will be deposited in feed and fecal wastes on the seabed), but the much greater use in salmon farming is typically for antifoulants on fish farm nets (Grefsrud et al., 2022a,b). Copper is an important factor for some enzyme reactions in organisms but is toxic if the concentration of copper compounds becomes too high, and it can affect different organisms at different stages of development. Therefore, it can lead to reduced species diversity if the concentration in a given habitat is higher than the species' tolerance limits (Grefsrud et al., 2022a,b).

Data previously provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018) from 2007 to 2016 showed variable annual use of a copper impregnation solution on salmon farm nets in the Faroe Islands (Figure 15). Without more recent data, the ongoing use remains uncertain, but the dominant producer, Bakkafrost, reports that it discontinued the use of copper net treatments in 2018 (Bakkafrost, 2022b). Mowi (2022) reports that the use of copper has been reduced, but does not indicate it has been eliminated, and data from Hiddenfjord are not readily available.

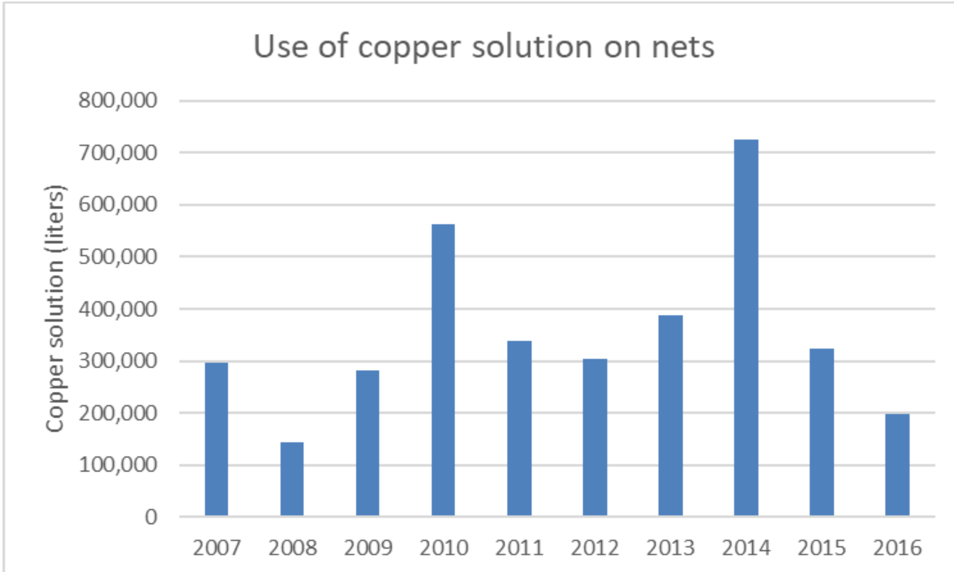

Figure 15: Annual use of copper net impregnation solution (in liters) in the Faroe Islands from 2007 to 2016. Data previously provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018).

The use in liters of copper solution gives an indication of the scale of use, but does not give any indication of the eventual concentrations of copper in the environment around fish farms, nor its availability in sediments, nor the sensitivity of local organisms in the Faroe Islands (and therefore gives no indication of the environmental impacts). Copper is one of the parameters that must be measured during benthic sampling in the Faroe Islands, and has warning and limit values that affect the management of the site (see Criterion 2—Effluent). No data are currently available on detected levels, but the lack of use of copper net treatments by the largest company representing 70% of production gives some confidence that the overall concern can be considered low.

Conclusions and Final Score

Annual antimicrobial use of approximately 4,000 kg in 1999 declined rapidly to zero in 2004, and several data sources confirm that antimicrobials have not been used since. Pesticide use to control sea lice has been highly variable, but has also declined rapidly in recent years due to the increased use of nonchemical alternatives. An analysis of the detailed chemical use data provided by FFVA shows that there has been an average of 1.31 treatments per completed production cycle in recent years (2019 to 2021), or approximately 1 treatment per site per year, but when considering fallow periods, each site receives an average of approximately 0.8 treatments per year. The dominant treatment by frequency is emamectin benzoate (85% of treatments) and by weight is diflubenzuron (75% of total pesticide use). Azamethiphos is also used infrequently. Although the environmental impacts of pesticide use in net pen salmon farms remains challenging to determine, a comprehensive risk assessment in Norway currently consider there to be a "moderate" risk of environmental effects on nontarget species in the local area through the typical use of the in-feed treatments emamectin benzoate and diflubenzuron, and a moderate or low risk for the bath treatment azamethiphos. Full resistance to different pesticide groups has been shown in sea lice in the Faroe Islands, with some lice also partly resistant to second treatment types. Although the reduced use of pesticides will limit the development of resistance, 85% of treatments currently use the same pesticide, thereby also encouraging resistance. Overall, the treatment frequency is currently low, with pesticides that can be considered to have a mostly moderate risk of environmental impacts from their typical use. The sea louse population in the Faroe Islands has developed resistance to one or more treatments, so the final score for Criterion 4—Chemical Use is 4 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

- Impact: feed consumption, feed type, ingredients used and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and their efficiency of conversion can result in net food gains, or dramatic net losses of nutrients. Feed use is considered to be one of the defining factors of aquaculture sustainability.
- Sustainability unit: the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation.
- Principle: sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains.

Criterion 5 Summary

C5 Feed parameters	Value	Score
F5.1a Forage Fish Efficiency Ratio	1.59	
F5.1b Source fishery sustainability score (0–10)		4.0
F5.1: Wild fish use score (0–10)		3.6
F5.2a Protein INPUT (kg/100 kg fish harvested)	49.13	
F5.2b Protein OUT (kg/100 kg fish harvested)	16.90	
F5.2: Net Protein Gain or Loss (%)	–65.60	3.0
F5.3: Species-specific kg CO_2-eq kg^{-1} farmed seafood protein	14.79	6.0
C5 Feed Final Score (0-10)		**4.05**
Critical?	No	Yellow

Brief Summary

The majority (75%) of salmon feed used in the Faroe Islands is produced on the Islands by Havsbrún (owned by Bakkafrost), with the remainder imported from Skretting in Norway. Although specific feed composition data were not provided, the feed assessment could be conducted using data gleaned from company reports, ASC audit reports, GSI, and the Ocean Disclosure Project (of which Bakkafrost is a member). Nevertheless, without specific data, some estimated and calculated values may be higher than reality, based on a precautionary approach. Marine ingredient use is relatively high, with a Forage Fish Dependency Ratio of 1.59, which means that, from first principles, 1.59 mt of wild fish would need to be caught to supply the fish oil needed to grow 1 mt of farmed salmon. The source fisheries are considered to be moderately sustainable, and the Wild Fish Use score is 3.6 out of 10. There is also a net loss of protein in the farming process, with 65.6% of the protein supplied in feed not accounted for in the harvested salmon (score of 3 out of 10). The feed footprint (calculated as the embedded climate change impact [kg CO_2-eq] of the feed ingredients) was 14.79 kg CO2-eq kg^{-1} farmed seafood protein (score of 6 out of 10). The three scores combine to give a final score for

Criterion 5—Feed of 4.05 out of 10. (See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.)

Justification of Rating

The Seafood Watch Aquaculture Standard assesses three feed-related factors: wild fish use (including the sustainability of the source), net protein gain or loss, and the feed "footprint" or global area required to supply the ingredients. For full details of the calculations, see the Seafood Watch Aquaculture Standard document.[43]

Feed Composition

Basic feed composition data are available from company annual reports (e.g., Bakkfrost; 2022a; Mowi, 2022a), sustainability reports (e.g., Bakkafrost 2022b), and company websites (e.g., Bakkafrost data[44]). Previous data supplied by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018) indicated that approximately 75% of Faroese salmon feed is produced by the local manufacturer Havsbrún[45] (owned by Bakkafrost), and this supplies Bakkafrost and some of Hiddenfjord's production. The remainder is imported from Skretting[46] in Norway to supply Mowi and the remaining Hiddenfjord/Luna production. Thus, the following approximate feed formulation (Table 2) has been used to estimate a 75:25 weighted average feed for use in this assessment.

Table 2: Feed composition data (all values in % of total feed) from Bakkafrost and Mowi and a weighted feed composition based on a 75:25 ratio of feed use between the two companies. Data from Bakkafrost (2022a,b) and Mowi (2022a).

Feed Ingredient	Bakkafrost (Havsbrún)	Mowi (Skretting)	Weighted Feed
Fishmeal from whole fish	25.6[b]	12.3[a]	22.3
Fishmeal from by-products	12[b]	5.8[a]	10.5
Fish oil from whole fish	5.2[c]	9.3[a]	6.2
Fish oil from by-products	8.7[c]	2.1[a]	7.1
Wheat	23.5	17.6	22.0
Soybean meal	7.8	13.5	9.2
Fava bean meal	0	6.2	1.6
Pea meal	0	6.2	1.6
Guar	0	2	0.5
Corn	0	0.5	0.1
Vegetable oil	13.9	20	15.4
Vitamins, minerals, etc.	3.3	4.5	3.6
Total	100	100	100

[a] According to Mowi (2022), total inclusion levels of fishmeal and fish oil are 18.1% and 11.4%, respectively, and of those ingredients, 32% and 18% of fishmeal and fish oil, respectively, come from trimmings/by-products. These values are used to calculate the separate values for fishmeal and fish oil from whole fish and by-products in the table.

[43] http://www.seafoodwatch.org/seafood-recommendations/our-standards
[44] https://www.bakkafrost.com/en/sustainability/data/
[45] https://www.havsbrun.fo/
[46] https://www.skretting.com/

[b] According to Bakkafrost (2022a), total inclusion levels of fishmeal and fish oil are 37.6% and 13.9%, respectively. The Bakkafrost report also states "the proportion of fish meal that comes from fish trimmings and off-cuts was almost a third." A value of 32% has been used here (i.e., the same as Mowi).
[c] The same Bakkafrost report also notes that their fish oil includes a high proportion derived from by-products. Without a specific value from Bakkafrost, the Forage Fish Dependency Ratio and eFCR values for all Bakkafrost sites in the most recent Aquaculture Stewardship Council audit reports (accessed June 29, 2022) were used to calculate the effective whole-fish fish oil inclusion level (noting that the ASC FFDR equation does not incorporate by-product sources). This whole-fish fish oil inclusion value of 5.2% was used to split Bakkafrost's 13.9% total fish oil into 5.2% from whole fish and 8.7% from by-products.

Feed Conversion Ratio

The Economic Feed Conversion Ratio (eFCR) is an important factor in this assessment. It is calculated by dividing the weight of total feed use by the total harvest weight. A higher number indicates less efficient feed use. eFCR data from 1994 to 2021 were provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022), and are shown in Figure 16. The long-term average over the entire period is 1.22, and the most recent 5-year average (i.e., 2017 to 2021 and including the variability around 2018) is 1.21.

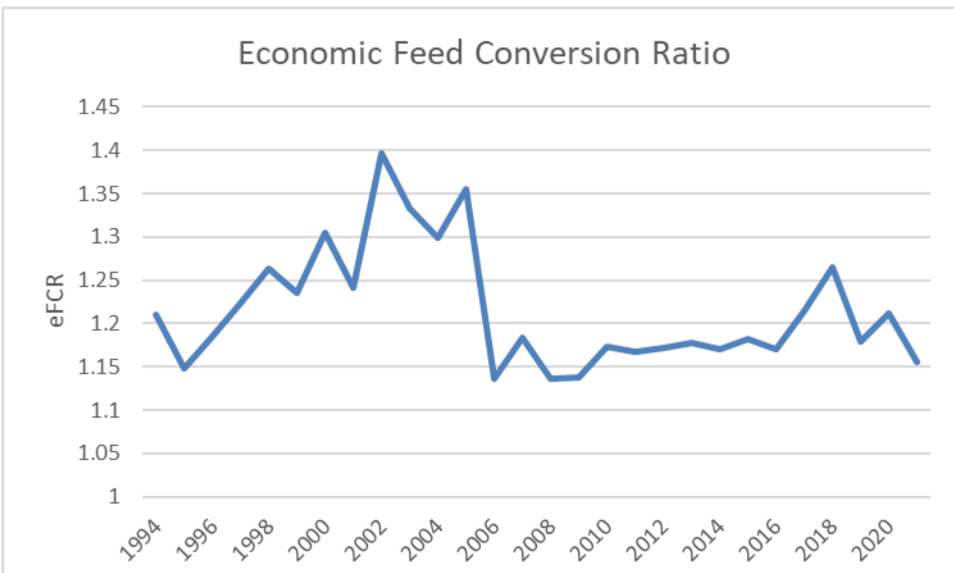

Figure 16: Economic feed conversion ratio values from 1994 to 2021, aggregated for all production. Data provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022).

A second set of data gleaned from Bakkafrost (2022a) for the total feed use and total harvest of farmed salmon from 2012 to 2021 (for all companies in the Faroes) can also be used to calculate the eFCRs for this period (Figure 17). The patterns and values of eFCR are different from the data provided by Havbúnaðarfelagið, and the long-term average from 2012 to 2021 of 1.31 is higher but is the same as the 5-year average from 2017 to 2021.

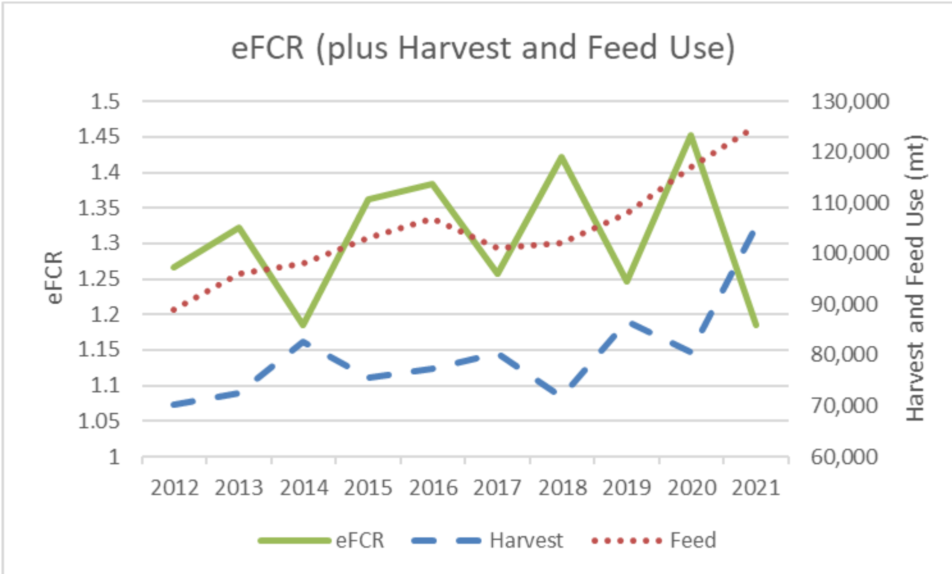

Figure 17: Calculated eFCR values based on total feed use and total harvest, from Bakkafrost (2022a).

Values for eFCR are also available in some ASC audit reports, with an average of 1.18 from 11 recent reports (range of 1.08 to 1.29). A general eFCR value for farmed Atlantic salmon in the academic literature (i.e., not specific to any region) is 1.3 (Tacon et al., 2021; Naylor et al., 2021; Tacon, 2020) and also in Mowi's Industry Handbook (2022). Noting that the data in Bakkafrost (2022a) are specified as being "estimated," the industry-specific data provided by Havbúnaðarfelagið (which matches the independently audited values from ASC reports) are used here, and specifically the most recent 5-year average that takes some account of recent variability; i.e., 1.21.

Factor 5.1. Wild Fish Use

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)

Using the inclusion levels of fishmeal and fish oil in the weighted feed in Table 2, the eFCR of 1.21, and the default yield values for fishmeal and fish oil from whole fish (22.5% and 5%, respectively),[47] the FFER values for fishmeal and fish oil are 1.23 and 1.59, respectively. This means that, from first principles, 1.59 mt of wild fish would need to be caught to supply the fish oil used to grow 1 mt of farmed salmon. Given its position in the North Atlantic and its business interests in marine fisheries and feed production (Havsbrún), Bakkafrost acknowledges that it uses high inclusion levels of fishmeal and oil compared to other companies (Bakkafrost, 2022a,b).

These FFER values are mostly higher than the average Forage Fish Dependency Ratio (FFDR) values obtained from the most recent ASC audit reports (accessed June 29, 2022) for 21 Faroe

[47] These are default values from the Seafood Watch Aquaculture Standard, based on global values of the yield of fishmeal and fish oil from typical forage fisheries (from Tacon and Metian, 2008).

Islands sites (including all Bakkafrost sites) (Figure 18). The ASC calculation is quite similar to the Seafood Watch Aquaculture Standard except for a small inclusion (5%) of by-products in the latter.

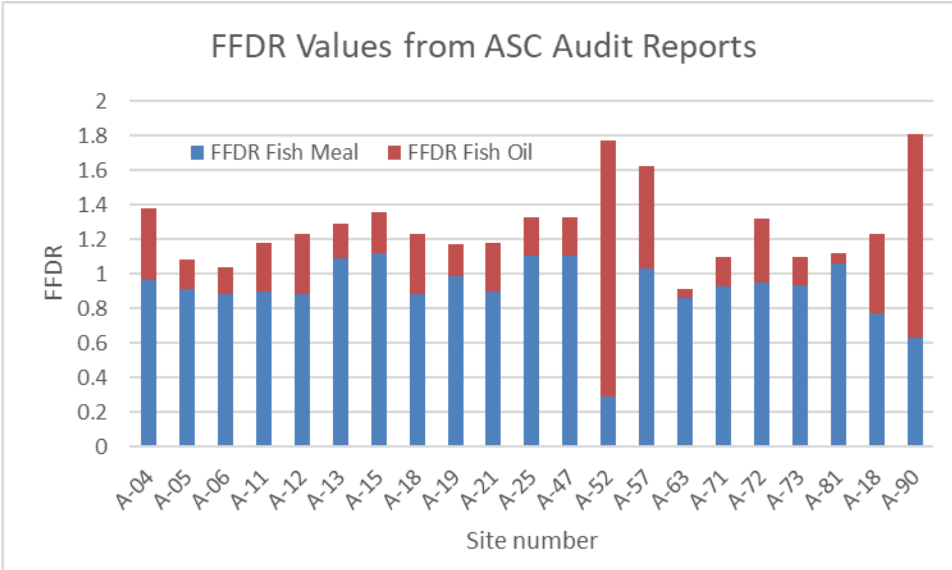

Figure 18: Forage Fish Dependency Ratio (FFDR) values from ASC audit reports for 21 sites in the Faroe Islands. Blue bars show the FFDR for fishmeal, and the red bars show the higher FFDR values for fish oil.

The values calculated here (1.23 and 1.59 for fishmeal and fish oil, respectively) are also higher than the annual average FFDR values for Bakkafrost from GSI, which have declined in the time series available to 0.94 and 0.65 for fishmeal and fish oil, respectively (Figure 19). The differences in these values are considered to be due to variations in the eFCR values used, and the yield values for fishmeal and fish oil from whole fish. With better data availability from the Faroe Islands producers, these apparent improvements could be better recognized.

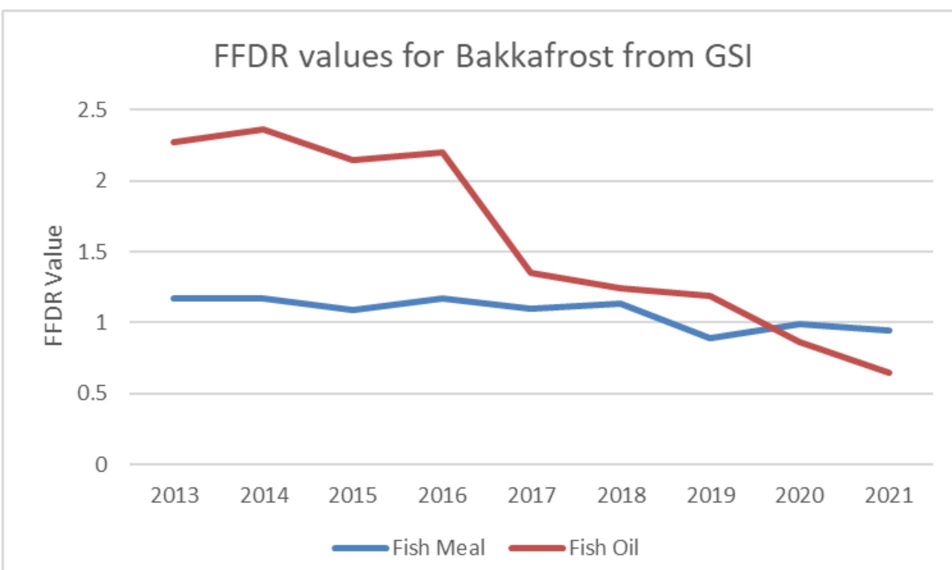

Figure 19: Average annual Forage Fish Dependency Ratio (FFDR) values from GSI for Bakkafrost from 2013 to 2021.

Factor 5.1b – Sustainability of the source of wild fish

Bakkafrost participates in the Ocean Disclosure Project[48] and the fisheries listed as the sources of fishmeal and fish oil are shown in Table 3, along with information on their Fishsource[49] scores and the corresponding Seafood Watch score for Factor 5.1b.

Table 3: Fishery data for Bakkafrost from the Ocean Disclosure Project, alongside Fishsource scores and certification information, and Seafood Watch scoring information.

Fishery	Fish Source scores and certification	Seafood Watch (0–10)
Antarctic krill	All scores >8. MSC certified	10
Atlantic herring; NE Atlantic spring spawners	One score <6, Marin Trust certified	4
Atlantic mackerel; NE Atlantic	One score <6, Marin Trust certified	4
Blue whiting; NE Atlantic	One score <6, Marin Trust certified	4
Greater Argentine; Northeast Arctic, North Sea, Skagerrak and Kattegat	Not assessed but Marin Trust certified	4

The feed company Skretting that supplies Mowi and much of Hiddenfjord does not participate in the Ocean Disclosure project, but Skretting's headquarters in Norway does. Although the (large number of) fisheries listed may not be specifically relevant to the Faroe Islands, the company sources 100% of marine raw materials that are either certified to the Marine Stewardship Council, Marin Trust (formerly IFFO-RS), or part of fisheries improvement projects aimed at achieving the Marine Trust certification (Mowi, 2022a). Considering the information for both Mowi (Skretting) and Bakkafrost, the most appropriate industry-wide score for Factor 5.1b is 4 out of 10, based on the Marin Trust certifications.

In combination with the FFER value of 1.59, the sustainability score results in a final score for Factor 5.1—Wild Fish Use of 3.6 out of 10.

Factor 5.2. Net Protein Gain or Loss

The feed company Havsbrún that supplies Bakkafrost has five feed pellet sizes, from 3 mm to 12 mm, with the protein content varying from 48% for the 3 mm to 40% for the 12 mm.[50] Using Havsbrún's recommended fish sizes for each pellet size,[51] and an average harvest weight

[48] https://oceandisclosureproject.org/
[49] https://www.fishsource.org/
[50] https://www.havsbrun.fo/
[51] For example, the 6 mm pellet (43% protein) is recommended for salmon from 300 g to 800 g (i.e., growth of 500 g), whereas the 9 mm pellet (40% protein) is recommended for 800 g to 2,500 g and a growth of 1,700 g.

between 2019 and 2021 of approximately 5.3 kg (Bakkafrost, 2022a), a weighted protein content for the production cycle is calculated to be 40.6%. An equivalent value for Skretting feeds was not readily available, so the value of 40.6% (representing approximately 75% of production in the Faroe Islands) was used here.

Therefore, 1 ton of feed contains 406 kg of protein, and 1.21 tons of feed are used to produce 1.0 ton of farmed salmon (eFCR). The net protein input per ton of farmed salmon production is 491.3 kg. Aas et al. (2019) specify a whole-body composition of farmed salmon of 16.9% crude protein; therefore, with only 169 kg of protein in 1 ton of harvested whole salmon, there is a net loss of 65.6% of protein provided in the feed. This results in a score of 3 out of 10 for Factor 5.2.

Factor 5.3. Feed Footprint

This factor is an approximation of the embedded climate change impact (kg CO_2-eq) of the feed ingredients required to grow 1 kilogram of farmed seafood protein. The calculation is performed by mapping the ingredient composition of a feed used against the Global Feed LCA Institute (GFLI) database[52] to estimate the climate change impact (CCI) of 1 metric ton of feed, followed by multiplying this value by the eFCR and the protein content of whole harvested salmon. If an ingredient of unknown or unlisted origin is found in the GFLI database, an average value between the listed global “GLO” value and worst listed value for that ingredient is applied; this approach is intended to incentivize data transparency and provision. The detailed calculation methodology can be found in Appendix 3 of the Seafood Watch Aquaculture Standard.

Table 4 shows the values calculated from the GFLI database for the feed ingredients listed in Table 2 above, regarding their inclusion level in salmon feed. The values are based on Bakkafrost feeds (from Havsbrún) representing 75% of production in the Faroe Islands. Because of the licensing agreement, the specific values for each ingredient from the GFLI database are not reproduced here, but the calculated value per mt of feed for each ingredient is shown.

Therefore, by weighting based on the growth, the 9 mm pellet in this example has a greater influence on the final total protein value.

[52] http://globalfeedlca.org/gfli-database/gfli-database-tool/

Table 4: Estimated embedded global warming potential of 1 mt of a salmon feed used in the Faroe Islands based on general feed composition data gleaned from company reports (for Bakkafrost, representing 75% of Faroese farmed salmon production) and fishery data from the Ocean Disclosure Project. GFLI refers to the Global Feed Lifecycle Institute.

Ingredient	Ingredient listing in the GFLI Database	Inclusion %	kg CO_2 eq/mt feed
Fishmeal	NE Atlantic herring and blue whiting and general sources	32.7	437.16
Fish oil	NE Atlantic herring and blue whiting and general sources	13.3	117.05
Wheat	Wheat flour, from dry milling, at plant/GLO Economic Wheat flour, from dry milling, at plant/ES Economic	22.0	172.07
Soy	Soybean expeller, from crushing (pressing), at plant/GLO Economic Soybean expeller, from crushing (pressing), at plant/AR Economic	9.2	361.14
Bean meal*	Broad bean, meal, at plant/RER Economic	1.6	17.77
Pea meal	Pea, meal, at plant/RER Economic Pea, protein-isolate, at plant/RER Economic	1.6	37.01
Guar	Not listed in GFLI	0.5	0
Corn	Maize flour, from dry milling, at plant/GLO Economic Maize flour, from dry milling, at plant/PL Economic	0.1	1.53
Vegetable oil	Crude vegetable oil blend, from crushing, at plant/GLO Economic Crude vegetable oil blend, from crushing, at plant/RER Economic	15.4	924.03
Vitamins, minerals*	Total minerals, additives, vitamins, at plant/RER Economic	3.6	42.35
Total		**100.0**	**2,067.8**

* These ingredients are a single line item in the GFLI database and therefore not averaged.

As can be seen in Table 4, the estimated embedded GWP of 1 mt of salmon feed is 2,067.8 kg CO_2-eq. Considering a whole harvested farmed salmon protein content of 16.9% (from Aas et al., 2019) and an eFCR of 1.21, it is estimated that the feed-related GWP of 1 kg of farmed salmon protein is 14.79 kg CO_2-eq. This results in a score of 6 out of 10 for Factor 5.3—Feed Footprint.

Conclusions and Final Score

The majority (75%) of salmon feed used in the Faroe Islands is produced on the Islands by Havsbrún (owned by Bakkafrost), with the remainder imported from Skretting in Norway. Although specific feed composition data were not provided, the feed assessment could be conducted using data gleaned from company reports, ASC audit reports, GSI, and the Ocean Disclosure Project (of which Bakkafrost is a member). Nevertheless, without specific data, some estimated and calculated values may be higher than reality, based on a precautionary approach. Marine ingredient use is relatively high, with a Forage Fish Dependency Ratio of 1.59, which means that, from first principles, 1.59 mt of wild fish would need to be caught to supply the fish oil needed to grow 1 mt of farmed salmon. The source fisheries are considered to be moderately sustainable, and the Wild Fish Use score is 3.6 out of 10. There is also a net loss of protein in the farming process, with 65.6% of the protein supplied in feed not accounted for in the harvested salmon (score of 3 out of 10). The feed footprint (calculated as the embedded climate change impact [kg CO_2-eq] of the feed ingredients) was 14.79 kg CO2-eq kg^{-1} farmed seafood protein (score of 6 out of 10). The three scores combine to give a final score for Criterion 5—Feed of 4.05 out of 10. (See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.)

Criterion 6: Escapes

Impact, unit of sustainability and principle

- Impact: competition, genetic loss, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations
- Sustainability unit: affected ecosystems and/or associated wild populations.
- Principle: preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes.

Criterion 6 Summary

C6 Escape parameters	Value	Score
F6.1 System escape risk (0–10)	2	
F6.1 Recapture adjustment (0–10)	0	
F6.1 Final escape risk score (0–10)		2
F6.2 Invasiveness score (0–10)		8
C6 Escape Final Score (0–10)		**5**
Critical?	No	Yellow

Brief Summary

Reported escape events affect few sites each year in the Faroe Islands, but the net pen production system remains vulnerable to escape. The available data from company reports and the seafood media show that tens of thousands of fish (and sometimes hundreds of thousands of fish) have escaped in most recent years, with the largest being nearly 370,000 in 2020. Despite the presence of Atlantic salmon from many countries in Northern Europe in the feeding grounds north of the Faroe Islands, there is no record of natural salmon populations in Faroese rivers. Thus, Atlantic salmon is considered nonnative to the Islands. Deliberate stocking of Atlantic salmon (from Iceland and later Norway) began in the 1940s and successfully established small populations in five rivers before the commencement of salmon farming. A hatchery operated by the Faroese Anglers Association (Sílaveiðafelagið) continues to stock smolts and fry (of salmon and sea trout) into local rivers each year. Although there are expected to be some ecological impacts from the escape numbers reported, they are likely to be small compared to the large annual managed releases, and the overall risk of impact is considered low. Overall, the high escape risk (Factors 6.1) and low risk of impact (Factor 6.2) combine to give a moderate final score of 5 out of 10 for Criterion 6—Escapes.

Justification of Rating

Factor 6.1. Escape Risk
There is a legal requirement to report escape incidents to the FFVA,[53] including information on root cause analysis, incident handling, and how the farming company intends to prevent further incidents (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018) but there does not appear to be any formal public reporting of escape events or the number lost. But, sufficient data can be obtained from a variety of sources including the GSI, company annual reports, seafood media, and data previously provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018). These data are shown collectively in Figure 20 along with the number of reported escape events each year (each escape event each year has a different color).

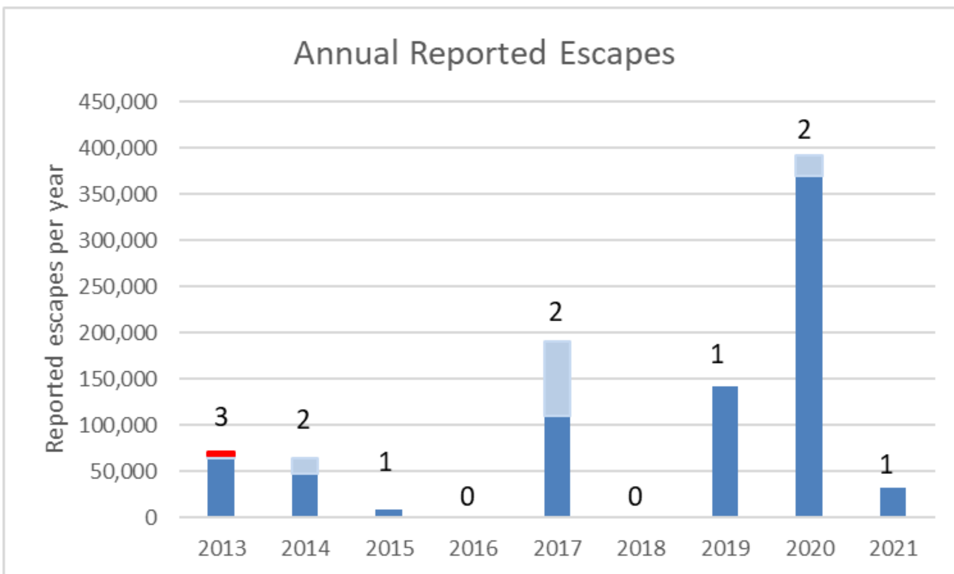

Figure 20: Reported farmed salmon escape events in the Faroe Islands from 2013 to 2021. The numbers show the number of events each year, with each event shown in a different color. Data from GSI, company annual reports (Mowi and Bakkafrost), seafood media, and from Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018).

These data show highly variable annual escape numbers, with a low number of reported events affecting a small number of sites. The size of each reported escape event is also highly variable, ranging from 3,000 (in 2013) to 368,998 (in 2020). All these losses have been attributed to storms and severe weather, but this effectively means human error in the design, construction, operation, or maintenance of the containment system and its infrastructure (moorings, etc.) appropriate to the conditions in the Faroe Islands. Although the escape events affect few sites each year, the large escapes of tens of thousands (and sometimes hundreds of thousands) of

[53] Article 41.2. Executive order on the establishment of and disease prevention in aquaculture facilities. No 80, 2019.

fish in the majority of recent years demonstrate the ongoing vulnerability of the net pen containment system.

Escape statistics are usually based on reports by the farmers themselves and are likely to underestimate (significantly, in some circumstances) the actual number of fish escaping from farms (Glover et al., 2017). Although isolated, large-scale catastrophic escape events are clearly limited to a small proportion of the sites in the Faroe Islands, the small-scale, so-called "trickle losses" or leakage of tens of fish can also be significant, and those from sites commonly holding a million fish are likely to be undetected and therefore unreported (Taranger et al., 2011). Sistiaga et al. (2020) noted that the escape of small smolts through farm cage netting is a major challenge faced by the Norwegian salmon farming industry when the smolts placed in the net pens are smaller than the size estimated by the farmers. Importantly, Skilbrei and Wennevik (2006) note that small-scale unreported escape events (in Norway) may make up a large portion of the total escaped farmed fish, and the analysis by Skilbrei et al. (2015) suggests that the total numbers of post-smolt and adult escapees have been two to four times higher than the numbers reported to the authorities.

In conclusion, it is clear from the reported data that the peaks in total escapes in recent years are dominated by infrequent mass-escape events, and overall, the reported escape events are limited to a minority of farms. Nevertheless, they continue to occur and can result in the loss of large numbers of fish. The annual Norwegian risk assessment (Grefsrud et al., 2022a) contends that, as long as farmed salmon are produced with current technology, which are mainly open cages in the sea (i.e., the same system as that used in the Faroe Islands), the risk of major escape incidents will be present. Trickle losses are also likely to be substantial yet may not be detected and/or reported. Ultimately, it is clear that net pen salmon farms continue to be vulnerable to both large-scale and small-scale escapes.

<u>Recaptures</u>

The farming companies in the Faroe Islands are required to "make concrete attempts to recapture escaped fish,"[54] including in rivers, and they have standard operating procedures regarding recapture (e.g., recapture nets), but no data for recapture success are available (NASCO, 2010b; pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022).Therefore, there is no recapture adjustment to the Factor 6.1 Escape Risk score.

<u>Presence of escaped farmed salmon in the wild</u>

Wild Atlantic salmon are distributed over large areas in the North Atlantic Ocean, with historic fisheries north of the Faroe Islands, where mainly salmon that originated in European rivers (as opposed to North America) are exploited (Thorstad et al., 2008). According to Thorstad et al. (2008) and references therein, long-term time-series data from the wild salmon fisheries north of the Faroe Islands showed a low proportion of farm-origin salmon until 1989 (<5%), then an increase to about 40% in 1989–91, followed by a decrease to 20–25% in the mid-1990s.

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[54] Article 41.2. Executive order on the establishment of and disease prevention in aquaculture facilities. No 80, 2019.

Thorstad et al. (2008) considered that these fish were probably escapees from Norwegian fish farms. Hansen and Jacobsen (2003) tagged salmon in this fishing area, and though most tags were subsequently recovered in Norway, Scotland, and Ireland (i.e., the recovery location indicates the likely origin of the salmon due to their homing behavior), none were recovered in the Faroe Islands. Although now dated, Thorstad et al. (2008) noted that there was no monitoring for escaped farmed fish in the Faroe Islands, and there is no indication that any has been implemented since.

Overall, for Factor 6.1—Escape Risk, large escape events continue to occur, albeit affecting only a small proportion of sites in the industry. There does not appear to be any monitoring of escaped fish in the wild to know if additional trickle losses occur, and there is no justification for a recapture score. The escape risk score is therefore driven by the inherent risk of escape in net pen production systems as evidenced by the recent large escapes in the industry, and the score for Factor 6.1—Escape Risk is 2 out of 10.

Factor 6.2. Competitive and Genetic Interactions

According to the North Atlantic Salmon Conservation Organization (NASCO, 2010a), there are no records of any natural wild salmon population in Faroese rivers or fjords due to the small size of the rivers. Therefore, despite the presence of migratory salmon from various countries in the feeding grounds of the North Atlantic around the Faroe Islands, the rivers of the islands have never hosted natural resident/returning spawning populations of Atlantic salmon. Farmed Atlantic salmon present in the Faroe Islands is therefore considered nonnative.

Regarding the potential establishment of Atlantic salmon in Faroese rivers as a result of farm escapes, several studies in Atlantic North America and Norway have shown that escaped fish can disperse rapidly—within hours to days (e.g., Bungay et al., 2021; Dempster et al., 2018; Hamoutene et al. 2018; Skilbrei & Jørgensen, 2010; Skilbrei et al., 2010; Chittenden et al., 2011; Solem et al., 2013; Skilbrei, 2013; Skilbrei et al., 2014; Whoriskey et al., 2006). In contrast, in a simulated escape study in Newfoundland, Hamoutene et al. (2018) reported that migration to the open ocean (from the fjord-like Fortune Bay) was rarely observed in the size/age classes tagged in their study, and it was assumed that most individuals experienced natural mortality due to predation and starvation within Fortune Bay within a few weeks of release. Similar outcomes were seen by Whoriskey et al. (2006) from a simulated escape in Maine.

It is well established that mortality of escaping farmed fish is high; for example, in addition to the Hamoutene et al. (2018) findings in Newfoundland, Grefsrud et al. (2022) consider that most farmed salmon that escape disappear into the sea and are likely to die of starvation, disease, or be eaten by predators, and the review by Glover et al. (2017) suggested that most escaped salmon from marine farms do not return to fresh water. Observation of the empty stomachs in farmed escapees captured in coastal areas, in combination with the lack of change in fatty acid profile in escapees over time, indicated that escapees from marine cages often struggle to adapt to feeding on natural food items once they are in the sea (Glover et al., 2017). In some regions, seal predation is also suspected to cause high mortality of escapees (Whoriskey et al., 2006), and this appears likely in the Faroe Islands (see Criterion 9X—Wildlife

Mortalities). In general, the dispersal, migration, survival, and ecological interactions of escaping salmon have been shown to be complex and to vary considerably with the age of escaping fish, the location, and particularly the time of year (Skilbrei, 2010)(Hansen and Youngsson, 2010)(Olsen and Skilbrei, 2010).

Atlantic salmon is generally considered to be a poor colonizer beyond its native range, and the only evidence of self-sustaining populations of anadromous Atlantic salmon becoming established anywhere in the world is in the Faroe Islands (Thorstad et al., 2008). From 1947, Atlantic salmon fry from Iceland were released into several rivers in the Faroe Islands, and in the early 1960s, mature salmon were caught by anglers as well as by electro-fishing in two rivers (NASCO, 2010b). This led to the construction of a hatchery for salmon and sea trout (*Salmo trutta*), and almost every year since then, some form of enhancement has been undertaken (currently by the Faroese Anglers Association, Sílaveiðafelagið[55]), resulting in the establishment of grilse[56] stocks in a further three rivers. According to the Anglers Association, salmon roe from Norway were later introduced to the Faroese stock in the 1980s in an attempt to get a higher proportion of multiple sea-winter returns. The Anglers Association hatchery currently stocks 40,000 smolts and 25,000 fry each year of Atlantic salmon and sea trout (*Salmo trutta*), but the numbers of each species are not specified.

It is not known if farmed escapes are routinely among the deliberately stocked fish that enter the rivers; for example, while 400 to 600 salmon are caught each year by anglers (Solas et al., 2020), no data are available except for an Anglers Association note[57] that in recent years, "some escapees from aquaculture cages have joined the 'wild' salmon population." It is not known if these farmed fish come from the reported escape events or from other trickle losses. Overall, with the deliberate and ongoing efforts to establish and maintain Atlantic salmon in Faroese rivers (using Icelandic and then Norwegian stocks), there is not considered to be any additional potential for the establishment of Atlantic salmon in the Faroe Islands due to aquaculture escapes, or any significant potential for genetic interactions with any wild populations.

Regarding the potential competition of escaped farmed salmon with wild salmon, the Faroese waters of the North Atlantic are important feeding grounds for wild salmon, and NASCO (2010a) emphasized the importance of minimizing escapes that may migrate to this area. For example, Jacobsen et al. (2012) showed that salmon tagged and released in the Faroe Islands as part of the deliberate stocking efforts were caught in the Faroese fishery to the north of the islands. Few studies have investigated feeding competition between wild and cultured salmon in the ocean, but there is reason to believe that competitive interaction can occur in Atlantic salmon in ocean areas with high densities of cultured fish (Jonsson and Jonsson, 2006). In a study of feeding habits of wild and escaped farmed salmon in the Northeast Atlantic, Jacobsen and Hansen (2001) reported successful feeding by escaped farmed salmon (i.e., those that had

[55] http://www.laks.fo/

[56] Grilse are salmon that return to fresh water after only 1 year at sea.

[57] http://laks.fo/Fishing%20on%20the%20Faroe%20Islands/

successfully migrated there from their escape sites in Norway, Scotland, and potentially the Faroe Islands), and concluded that there was no difference in condition factor, number, and weight proportions of prey, or in diet between wild and escaped farmed salmon.

Given the numbers of escaped fish listed above, plus the potential for unreported or undetected trickle losses, the ecological interactions between escaping farmed and wild fish (and their associated impacts) are likely to occur to some extent in open oceans and coastal or riverine waters in the Faroe Islands, and could potentially affect species other than Atlantic salmon (such as sea trout). But, the large-scale annual managed releases of hatchery-raised salmon and trout in Faroese rivers are considered to exceed the potential impacts of somewhat random farm escapes in these environments.

Regarding the Seafood Watch scoring, despite the presence of migratory salmon from various countries in the waters of the North Atlantic around the Faroe Islands, the rivers of the islands have never hosted natural resident/returning spawning populations of Atlantic salmon, so Atlantic salmon is considered nonnative to the Faroe Islands. Although the successful stocking and ongoing enhancement of a small number of small populations by the Sílaveiðafelagið shows that establishment is possible, there is no evidence that farmed salmon escapees would significantly contribute to the establishment of any new populations (i.e., in addition to the ongoing stocking and enhancement efforts). Similarly, ecological impacts between farm escapes and wild salmon or sea trout in the region are likely to be dominated by the annual managed releases.

Although it is conceivable that salmon escaping farms in the Faroe Islands could migrate to rivers elsewhere in northern Europe and contribute to concerns regarding genetic introgression (e.g., Glover et al. 2017), this appears to be a low risk without a direct homing instinct. Therefore, considering the deliberate establishment of Atlantic salmon in all possible rivers[58] in the Faroe Islands in the mid-1900s (in addition to more recent and ongoing stocking), there is considered to be a low risk of competition, predation, disturbance, or other impacts to wild species or their habitats and ecosystems. The score for Factor 6.2 is 8 out of 10.

Conclusions and Final Score

Reported escape events affect few sites each year in the Faroe Islands, but the net pen production system remains vulnerable to escape. The available data from company reports and the seafood media show tens of thousands of salmon (and sometimes hundreds of thousands) have escaped in most recent years, with the largest being nearly 370,000 in 2020. Despite the presence of Atlantic salmon from many countries in Northern Europe in the feeding grounds north of the Faroe Islands, there is no record of natural salmon populations in Faroese rivers. Thus, Atlantic salmon is considered nonnative to the Islands. Deliberate stocking of Atlantic salmon (from Iceland and later Norway) began in the 1940s and successfully established small populations in five rivers before the commencement of salmon farming. A hatchery operated by the Faroese Anglers Association (Sílaveiðafelagið) continues to stock smolts and fry (of

[58] The Faroes is mountainous, and relatively few rivers are navigable for salmon (Hansen & Gislason, 2010).

salmon and sea trout) into local rivers each year. Although there are expected to be some ecological impacts from the escape numbers reported, they are likely to be small compared to the large annual managed releases, and the overall risk of impact is considered low. Overall, the high escape risk (Factors 6.1) and low risk of impact (Factor 6.2) combine to give a moderate final score of 5 out of 10 for Criterion 6—Escapes.

Criterion 7: Disease; Pathogen and Parasite Interactions

Impact, unit of sustainability and principle

- Impact: amplification of local pathogens and parasites on fish farms and their retransmission to local wild species that share the same water body
- Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites.
- Principle: preventing population-level impacts to wild species through the amplification and retransmission, or increased virulence of pathogens or parasites.

Criterion 7 Summary

C7 Disease parameters		Score
Evidence or risk-based assessment	Risk	
C7 Disease Final Score (0–10)		**4**
Critical	No	Yellow

Brief Summary

The Disease Criterion focuses on potential impacts to wild fish, for which there is limited information in the Faroe Islands. Native populations of sea trout are present, but of uncertain number. Bacterial and viral diseases cause low mortality in Faroese salmon farms and are considered a low concern for potential transfer and impact to wild fish. Parasitic sea lice on farmed fish are present in variable numbers, and though increasingly strict management measures minimize the numbers of lice per farmed fish during the periods of peak numbers of wild sea trout in coastal waters, the cumulative load of lice from farms and therefore the infection pressure in those waters is likely substantial. An ongoing research project by Fiskaaling that conducts annual sampling of wild sea trout is greatly increasing the knowledge base of sea lice interactions, but does not yet provide sufficiently robust data to reach any conclusions regarding the potential impact of lice from salmon farms as opposed to other natural infection sources in the area. Thus, the risk-based assessment has been used and the score is based on the open nature of the production system to the introduction and discharge of pathogens and parasites. The final numerical score for Criterion 7—Disease is 4 out of 10.

Justification of Rating

This Disease Criterion assesses the impacts, or the potential for impacts, to wild fish from pathogens and parasites on salmon farms. Although a variety of wild fish species could potentially be affected, the salmonid-specific nature of some of the pathogens and parasites discussed below means that the salmonid species group is the primary focus of concern. There are two native salmonids in the Faroe Islands: the brown trout (*Salmo trutta*), which is widespread in lakes and rivers, and Arctic charr (*Salvelinus alpinus*), which has a native population in only one lake (Malmquist et al., 2002). With no evidence of native anadramous[59] populations of charr, the focus of potential impacts is on anadramous brown trout; i.e., sea trout.

Regarding data availability, the Fish and Animal Disease Department of the FFVA monitors health status through all stages of production on salmon farms, based both on monthly health status and biomass reports, as well as on-site inspections. Disease monitoring data are available from the FFVA on its website,[60] but without an English version or other translation capabilities, they are largely inaccessible. High-level summary data on monitoring for OIE diseases are available from the World Animal Health Information System (WAHIS) website,[61] but there are only two years, 2016 and 2017, for which Faroese data are available. Previously, more detailed monitoring data and results were provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018). Further information on mortality rates of farmed fish is available from other sources such as GSI and company reports. As discussed further below, the Aquaculture Research Center in the Faroe Islands (Fiskaaling) has initiated a project to study sea lice numbers on wild sea trout, but there is no apparent direct monitoring of bacterial or viral pathogens or their impacts (if any) on sea trout in the Faroe Islands. The disease data quality and availability is therefore considered only moderate (i.e., Criterion 1 score of 5 out of 10 for the Disease category), and the Seafood Watch Risk-Based Assessment was utilized.

Farmed salmon mortality rates

Mortality data from 1994 to 2021 were provided by the FFVA through Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022), and are shown in Figure 21. A separate set of data from GSI for the largest producer (Bakkafrost) from 2013 to 2021 are also shown. In the early 2000s, high mortalities due to an outbreak of infectious salmon anemia (ISA) in the Faroe Islands were a major contributor to a large decline in farmed salmon production from 43,000 mt in 2003 to approximately 10,000 mt in 2006 (Simonsen, 2015). This is clearly visible in Figure 21 (and in the production data in Figure 1).

The GSI mortality data for Bakkafrost in Figure 21 are generally substantially lower than those for all producers from the FFVA, but it must be noted that there are different calculation methods. The data from the FFVA are calculated as the difference between the number of fish released and the number harvested, divided by the total number of fish released, whereas the GSI calculation is somewhat unclear.[62] Using the straightforward calculation from the FFVA, it can be seen that mortality, though variable, has been trending upward since 2006, and is likely to be affected by the increasing use of nonchemical (i.e., physical) sea lice removal techniques (discussed below, and in Criterion 4—Chemical Use).

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[59] Those fish migrating to marine waters and returning to fresh water to spawn. It is this anadromous component of the population that is at risk from sea lice from salmon farms.

[60] Heilsufrøðiliga starvsstovan - https://www.hfs.fo/webcenter/portal/HFS

[61] WAHIS (woah.org)

[62] The equation is available on the GSI website (https://globalsalmoninitiative.org/en/sustainability-report/sustainability-indicators/) but the formatting makes the equation and its underlying intent unclear.

The FFVA data (blue line in Figure 21) show that the 3-year average (2019 to 2021) of 17.0% is slightly higher than what Hiddenfjord considers to be the global average of 15%.[63] Hiddenfjord itself states a mortality rate of 4.94% in 2021, but the calculation method is not stated. In 2021, the Bakkafrost mortality was 10.3%, and the company states[64] that the top causes for reduced survival in 2021 were treatment handling, transfer mortality, and diseases (specifically noting Cardiomyopathy Syndrome, CMS). The relative contributions of these three causes to the total mortality are not clear.

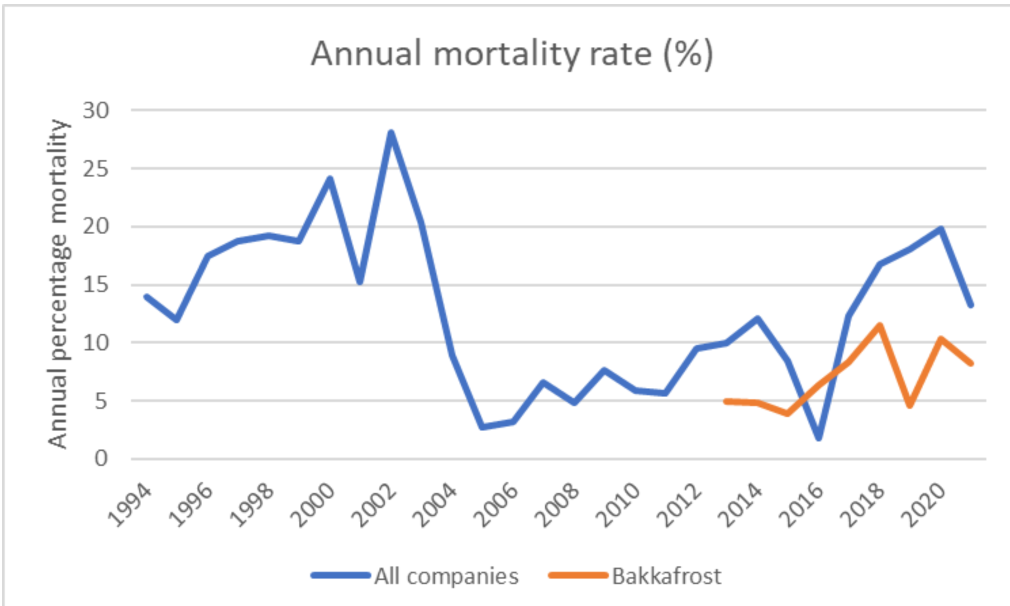

Figure 21: Annual mortality of farmed salmon from the FFVA (blue line; data provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022)), and for Bakkafrost only (data from GSI). Note that these two datasets are unlikely to be comparable due to different calculation methods.

In general, the diseases prevalent in the Faroe Islands in recent years were amoebic gill disease (AGD, caused by a parasite), bacterial kidney disease (BKD), infectious salmon anemia virus (ISA), cardiomyopathy syndrome (CMS), and heart and skeletal muscle inflammation (HSMI) (Bakkafrost 2022a). Amoebic gill disease (which can cause mortality directly) also commonly contributes to mortalities in other circumstances where poor gill health is a factor, such as during sea lice treatments. Because sea lice treatments are an important component of the total annual mortality, sea lice are an important indirect cause of mortality (discussed further below).

<u>Bacterial and viral disease on salmon farms</u>

The consumption of antimicrobials is considered to be a good indicator of the occurrence of bacterial diseases (Sommerset et al., 2021), and though diseases such as BKD have been detected recently (Bakkafrost 2020b), they appear to be manageable without antimicrobial use

[63] https://hiddenfjord.com/truly-sustainable-farming/

[64] https://www.bakkafrost.com/en/about-us/sustainability/data/

(see Criterion 4—Chemical Use). Therefore, bacterial pathogens are currently considered a lesser concern (regarding potential impacts to wild salmonids) compared to viral pathogens, and lesser again to parasites.

Regarding viruses, disease inspections by the FFVA at all Faroese marine and freshwater farming sites concentrate on four OIE-listed viral pathogens: infectious salmon anaemia (ISA), viral haemorrhagic septicaemia (VHS), infectious haematopoietic necrosis (IHN), and pancreas disease (PD). OIE WAHIS results[65] show a single case of ISA detected in 2016 that led to the early harvest of the site in 2017.

Other viral diseases beyond the OIE lists can also occur; for example, Garseth et al. (2017) reported that cardiomyopathy syndrome (CMS) caused by piscine myocarditis virus was rarely observed in the Faroe Islands, but this disease is noted by Bakkafrost as one of the three primary components of the total mortality. In general, there are scant publicly available data on the detection and subsequent impact of viral diseases in the Faroe Islands.

Salmon farms as reservoirs of bacterial or viral pathogens

Grefsrud et al. (2022b) provides a theoretical scenario in Figure 22 that shows how migrating salmonids may be affected after passing through an area of infection such as a farm. They also caution that a) the presence of a pathogen does not mean infection; b) infection does not mean the development of disease or the spread of infection; and c) illness does not mean death.

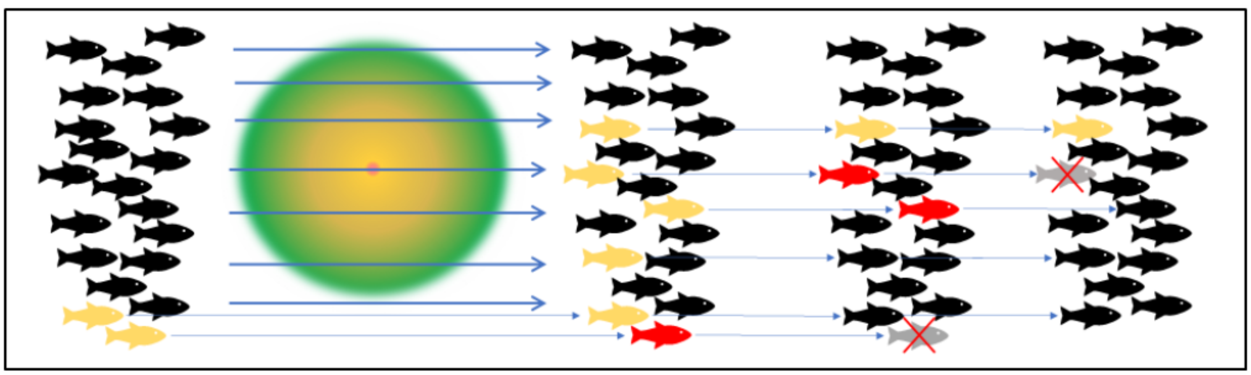

Figure 22: A theoretical scenario of migrating salmon smolts or sea trout in a fjord passing through areas with infection from farming. In such an area, the exposure varies greatly. Upon exposure, some individuals may become infected (yellow fish). Some infected individuals may become ill (red fish). Some sick fish may die (grey fish), some may recover, and some may become chronically infected (carriers). Some of the wild fish may be naturally infected regardless of farming, and some of them may also become ill and die. Image and caption reproduced (and translated) from Grefsrud et al. (2022b)

Considering the transfer of viral pathogens to wild salmonids in the Faroe Islands, particularly sea trout, Nylund et al., (2019) note that the only reservoir species for the ISA virus (in the North Atlantic) are Atlantic salmon and brown trout. There does not appear to be any routine monitoring of these pathogens in wild fish in the Faroe Islands. With caution, relevant studies from other regions can be used; for example, in Norway, the Institute of Marine Research

[65] https://wahis.oie.int/#/analytics

began extensive mapping activities of viral pathogens in wild salmonids in 2012, and this has become part of the institute's long-term monitoring activities (Grefsrud et al., 2022a,b). As a result, an "Annual report on health monitoring of wild anadromous salmonids in Norway" is published (e.g., Madhun et al., 2021) but focuses on a limited number of viruses (just two viruses in the 2021 report: ISA virus[66] and salmonid alphavirus[67]). They report the absence or low prevalence of viral infections in the tested migrating smolts in 2019, and note that this is consistent with previous findings in wild salmonids that showed no apparent relationship to the fish farming intensity or the frequency of disease outbreaks. Madhun et al. (2021) conclude with a suggestion that wild salmon is exposed to a low infection pressure from fish farming (in Norway).

Madhun et al. (2020) also note the possibility that infection may lead to rapid disappearance, altered behavior, or biased sampling of the infected fish, and while Grefsrud et al. (2022b) provide examples of mass deaths of fish in the wild (usually caused by novel introduced pathogens or special environmental conditions), studying disease in wild populations is complex; that is, mortality events are rarely observed, sampling efforts solely capture live fish, and weak and dying fish are probably predated before the disease progresses to mortality (Miller et al. 2014).

Although a direct extrapolation from the Norwegian situation to the Faroe Islands cannot robustly be made, the relatively limited concern regarding the risk of impacts of bacterial and viral pathogens in key studies, such as Madhun et al. (2021) and Grefsrud et al. (2022a,b), justifies a focus of this Seafood Watch assessment on parasites.

<u>Parasites</u>
Globally, the concern regarding parasite transfer from farmed salmon to wild fish has focused on parasitic sea lice; for a review, see Groner et al. (2016) and Grefsrud et al. (2022b)[68]. In Faroese fish farming areas, the temperature (6−12° C) and salinity (>30 ppt) are highly suitable for Atlantic salmon farming, but also for the production of sea lice (Kragensteen et al., 2021). As the salmon farming industry has grown, so has the number of salmon-louse hosts providing favorable conditions for the parasite. Like elsewhere in the Atlantic Ocean, the two most abundant sea lice species on salmon farmed in the Faroe Islands are the salmonid-specialist *Lepeophtheirus salmonis* and the generalist *Caligus elongatus* (á Norði et al., 2015). At sufficiently high host densities, salmon lice can develop into an epidemic, thus negatively affecting both salmon farms and wild salmonid stocks (Kragensteen et al., 2021).

The dynamics of sea lice have been well studied in the Faroe Islands (e.g., á Norði et al., 2015, 2016; Gislason, 2017; Kragesteen et al., 2018, 2021, Patursson et al., 2017). These studies show that Faroese aquaculture farms can produce large quantities of sea lice, and because of the farms' exposure to sea lice from tidal dispersion and freshwater forcing, some farms regularly

[66] Infectious Salmon Anemia Virus, causing ISA in Table 11
[67] Salmonid Alpha Virus, causing Pancreas Disease (PD) in Table 11
[68] This report is in Norwegian, but can be translated directly online from the Institute of Marine Research

experience severe sea lice epidemics, while others are barely affected (Patursson et al., 2017). The farms form a complex network of "emitters," "receivers," and "isolated" sites, and as much as 10% of lice released at one farm site might enter a neighboring fjord (Kragesteen et al. 2018).

There have been several recent changes to the sea lice monitoring protocols and the sea lice limits. Currently, Regulation No. 93 of 2021 is in place (which modified Regulation 75 of 2016), and lice counts are conducted by an independent third party (Fiskaaling[69]) at each site every 2 weeks year-round. In 2016, the limit for adult female *L. salmonis* salmon lice per fish was reduced from 2.0 to 1.5, and this was further reduced in 2021 to 0.5 from May 1 to July 31, and 1.0 for the rest of the year. These limits act as an absolute threshold (i.e., not a treatment threshold) and the farm has to take precautions before these limits are reached. If the threshold is exceeded too often[70] and/or there are too many medical treatments[71] at a farming site, the consequence is a potential forced slaughter, or a reduction in number of fish allowed to be stocked in the subsequent production cycle.

Thus, sites with high amounts of lice and pharmaceutical treatments have to reduce the number of fish. On the other hand, it is possible to increase the number of smolts if sea lice are well-controlled at the farm.

Monthly average sea lice counts of *L. salmonis* for all sites from 2012 to 2021 are shown in Figure 23. These show considerable variability, both seasonally within years and between years. Throughout most of the year, the average levels are below the previous threshold of 1.5 lice per fish, and also the newly introduced (2021) threshold of 1.0 lice per fish from August through April. Similarly, these average values for the years 2019 to 2021 meet the new threshold of 0.5 lice per fish from May through July.

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[69] P/F Fiskaaling is the Aquaculture Research Station in the Faroe Islands. It is a limited company, owned by the Faroese government. https://fiskaaling.fo/

[70] According to Fiskaaling (pers. comm., Kirstin. Eliasen, Fiskaaling, October 2022) and Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022), "too often" in this regard means that if a farming site has three consecutive counts that exceed the limit, or four counts in total, all the fish at the site must be harvested within 11 weeks. In addition, a penalty system is in place where each exceedance of the limit results in one penalty point (or a count of 2.0 adult female when the limit is 1.0 gives two penalty points, and so on). Each pharmaceutical treatment results in two penalty points. The number of fish allowed at the farm in the next production cycle is (among other factors) dependent on the amount of penalty points:

- <8 penalty point: increased number of fish
- 8–15 penalty points: same number of fish allowed
- >15 penalty points: decreased number of fish

[71] Note that the characteristics of "too often" or "too many" in these cases could not be found for this assessment.

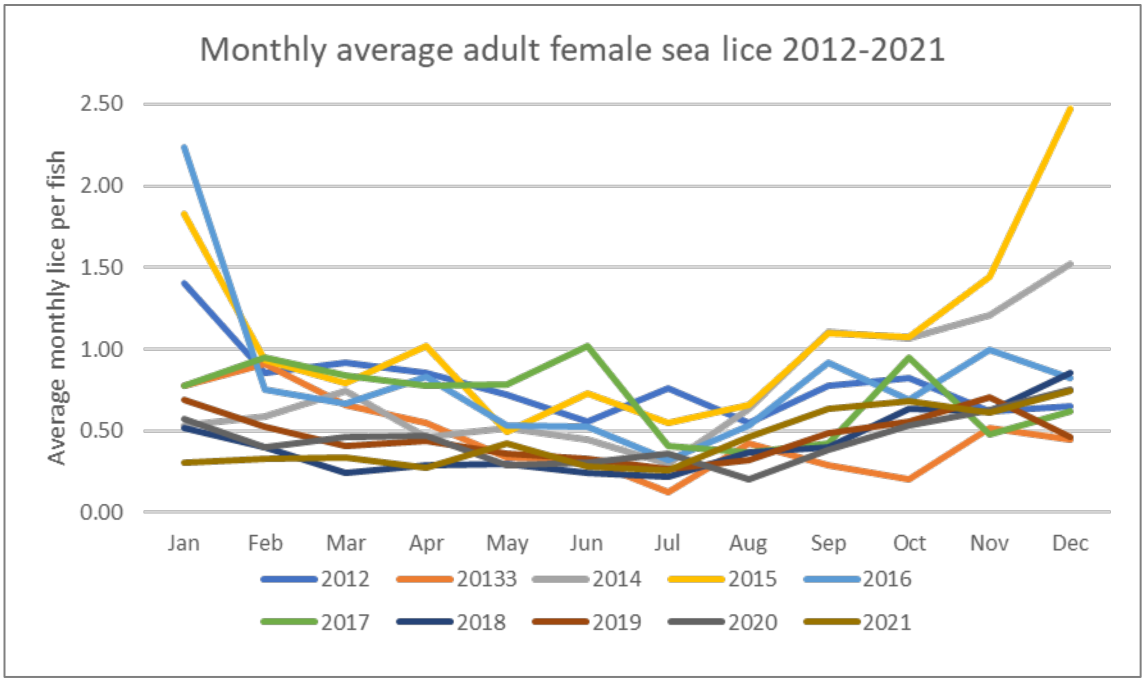

Figure 23: Average monthly adult female *L. salmonis* lice numbers per fish in the Faroe Islands from 2012 to 2021. Data from 2012 to 2017 from Fiskaaling, provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018)**.** Data from 2018 to 2021 from FFVA.

The monthly average lice counts across all sites in Figure 23 hide considerable variability in the counts at individual sites. Because of the highly variable geography and hydrography of the Faroe Islands, there are some sites that are barely affected by lice (Patursson et al., 2017), so these industry-level averaged counts mask peaks in louse numbers on some sites that may more frequently exceed the thresholds. Figure 24 shows the same monthly average *L. salmonis* lice counts for all sites for the last 3 years only (2019 to 2021), with the variability in the 2021 site level counts shown by one standard deviation bars. These monthly average counts imply that the industry has met the newly introduced lice limits of 1.0 and 0.5 (shown in red) over the last 3 years; however, the data show that individual counts can substantially exceed these limits.

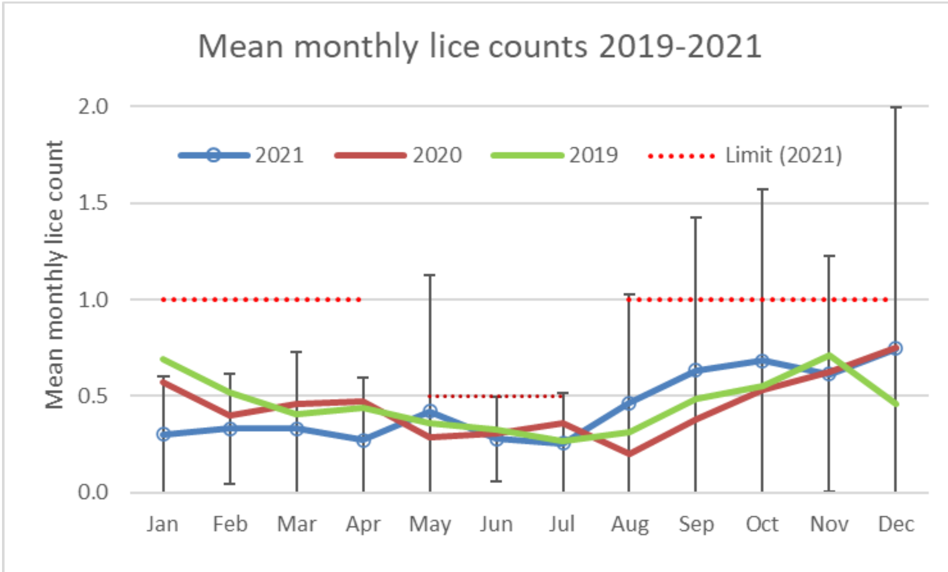

Figure 24: Average monthly *L. salmonis* louse counts from 2019 to 2021, with the standard deviation for 2021 shown by error bars. The most recent lice limits (introduced in July 2021) are shown by the red dotted line. Data from FFVA.

For further illustration, individual counts for each site from 2020 and 2021 are shown in Figure 25 (each site is counted every 2 weeks). This illustrates the variability in site-level counts and the number of samples exceeding the different limits.

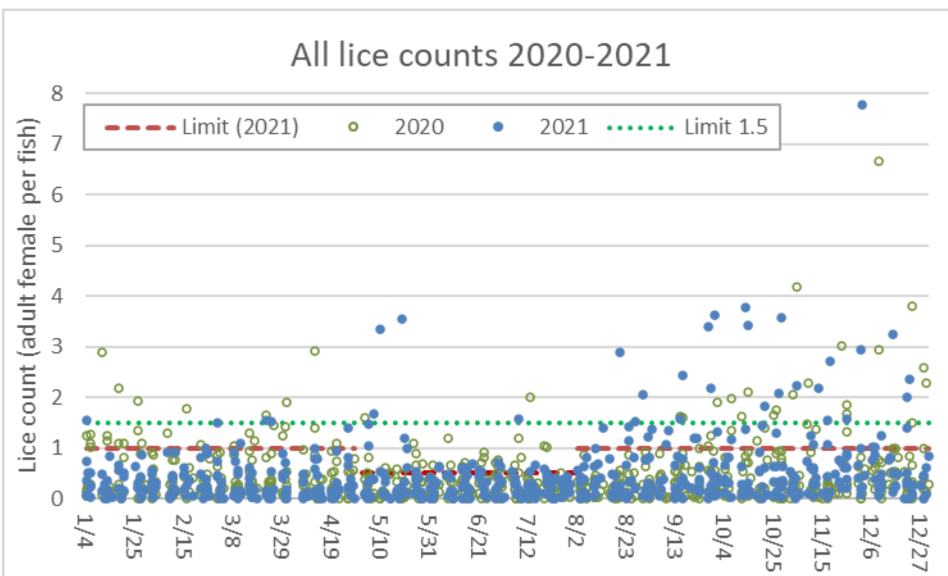

Figure 25: All site-level *L. salmonis* louse counts from 2020 and 2021. The limit of 1.5 lice per fish during these years is shown (green dotted line), plus the newly introduced limit in 2021 (red dashed line). Data from FFVA.

The purpose of the regulations regarding sea lice is to reduce the occurrence and spread of sea lice in farmed fish and to impair resistance to preventative treatment, but the regulations do not appear to be driven by, or to take account of, any potential impacts to wild fish such as sea trout. According to á Norði et al. (2015) and references therein, the main infective life cycle stage of sea lice (copepodids) is planktonic and tends to aggregate in shallow estuarine areas, and these may overlap with areas important to migrating sea trout. But, this information refers to studies outside the Faroe Islands, and the study by á Norði et al. illustrates a complex pattern of copepodid aggregation in the one studied location in the Faroe Islands. Anecdotal information from anglers in the Faroe Islands show that captured fish have higher slime levels or are "sloppy" when associated with infections of sea lice (pers. comm., Theresa Jákupsdóttir, FNU, 2018).

Sea lice impacts to wild fish populations

As noted above, without native salmon populations in the Faroe Islands, the focus of concern regarding potential impacts to wild fish is on wild sea trout. Sea trout is particularly vulnerable to sea lice impacts because it normally remains for extended periods in near-coastal waters (Thorstad et al., 2015)(Shephard et al., 2016). Relatively little is known about sea trout in the Faroe Islands; anecdotal information on angling websites indicates that it is "plentiful" in coastal waters,[72] but Brodersen et al. (2012), Jeppesen et al. (2002) and Malmquist et al. (2002) indicate that there are a limited number of waterways large enough to host natural populations of sea trout. A sea trout project currently ongoing at Fiskaaling[73] also acknowledges that the current knowledge about sea trout in Faroese lakes and ocean is limited. This assessment acknowledges the personal communication with Kirsten Eliasen at Fiskaaling and her assistance in interpreting the project reports to date.

Fiskaaling's sea trout project (Eliasen et al., 2021, 2022) has captured a total of 1,535 out-migrating sea trout from 2019–21 in the river Sandá, and also collected data on lice counts, condition, and scale samples from 563 sea trout caught (by anglers and by controlled gill netting) at sea in the same years. The vertical bars in Figure 26 show that the presence of sea trout in the ocean varies considerably by size and number at different times of the year, with a peak in July and August. The smallest size class (considered to be newly migrated to the ocean) appeared in April and May and disappeared in August/September. Figure 26 also shows the average number of sea lice per fish (all types and stages of lice—orange line) and the prevalence of lice (i.e., the percentage of fish that were infected with one or more lice—dark blue line).

[72] For example: http://eat-sleep-fish.co.uk/content/2017/03/faroe-islands

[73] https://fiskaaling.fo/en/departments/fish-health/sea-trout/

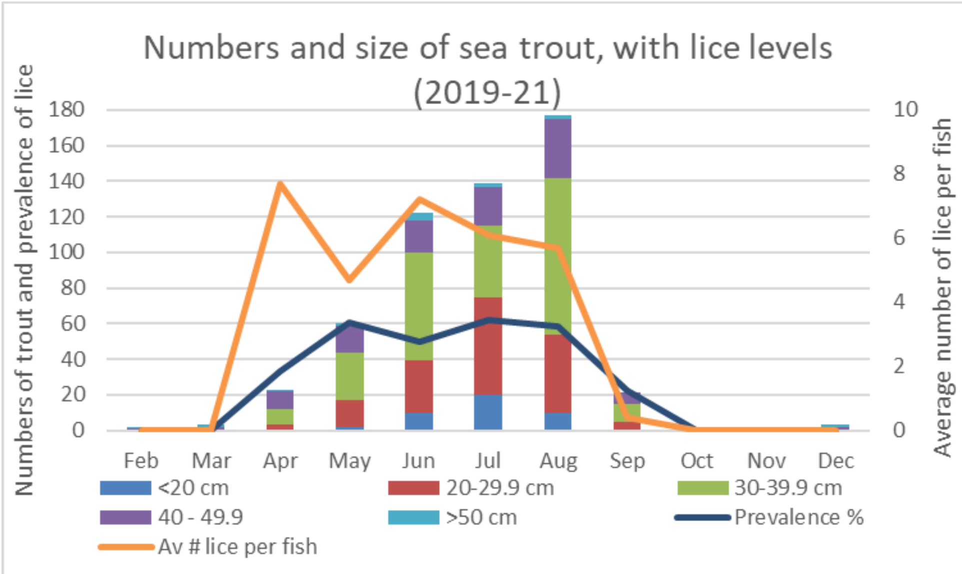

Figure 26: Numbers of sea trout caught at sea (by anglers and by gillnet) in different size categories from 2019 to 2021 (colored bars), along with the average numbers of lice (all lice species) per angler-caught fish (orange line and secondary y-axis) and the lice prevalence (dark blue line; prevalence is the percentage of fish that were infected with at least one louse). Data from Eliasen et al. (2022).

By comparing Figure 26 with the farm-level sea lice counts (Figure 25), it can be seen that the increasingly strict sea lice limits result in the large majority of farm counts being close to or below the limits during the April–September period that is important to sea trout. Nevertheless, the cumulative lice load (from all the fish in one farm, or from multiple farms) and the resulting infection pressure may still be substantial; for example, the total quantity of egg-bearing female lice across all farms varied from a minimum of 5 million to a maximum of 35 million between 2011 and 2018 (Kragensteen et al., 2021).

Of particular interest in the 2021 gill net sampling of wild sea trout was the targeting of two locations: one in the vicinity of salmon farming (Øravík) and the other represented sea trout far from salmon farming (Fámjin) (Figure 27).

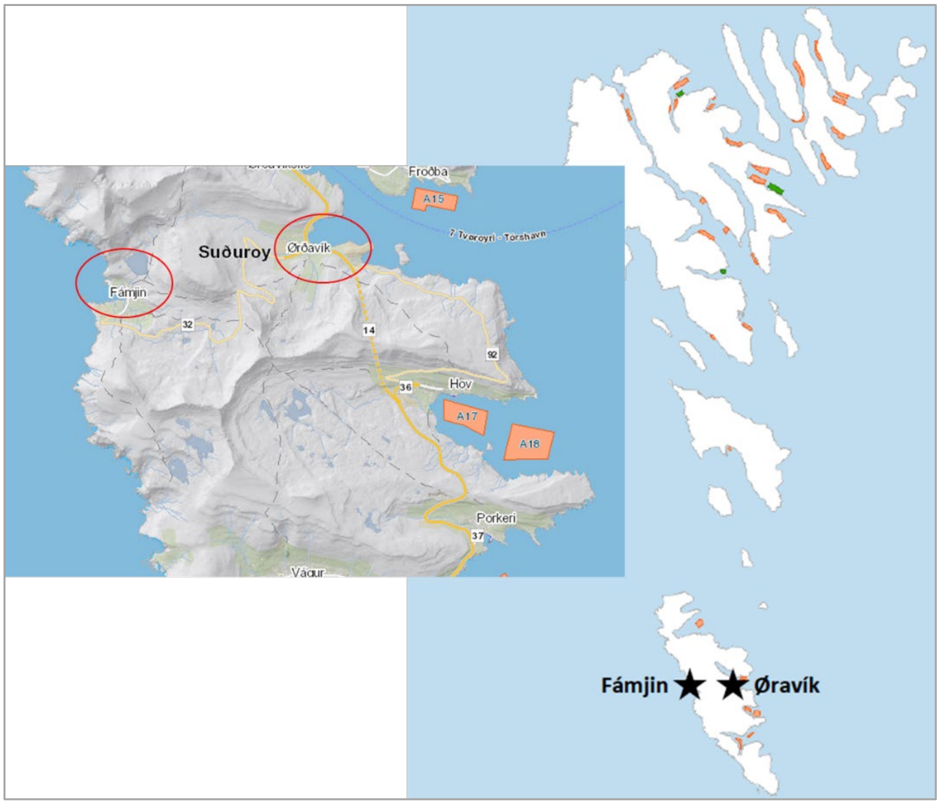

Figure 27: Sea trout gillnet sampling locations in the vicinity of salmon farms (Øravík) and distant from them (Fámjin). Images reproduced from www.kortal.fo and Eliasen et al. (2022). Orange polygons indicate salmon farming sites A-15, A-17, and A-18.

For reference, the sea lice count data from the FFVA for the salmon farm sites in the vicinity of the Øravík gillnet location (sites A-15 and A-18, which were stocked at the time of sampling) were plotted in Figure 28. They show low levels of lice per fish in A-15 (which had been recently stocked) and moderate levels of approximately 0.33 adult female *L. salmonis* lice per fish at A-18 (which was in its second year of production). Considering the total numbers of fish on each site, there was a total of approximately 425,000 adult female *L. salmonis* sea lice on farmed salmon on these two sites in the vicinity of the wild sea trout sampling location.

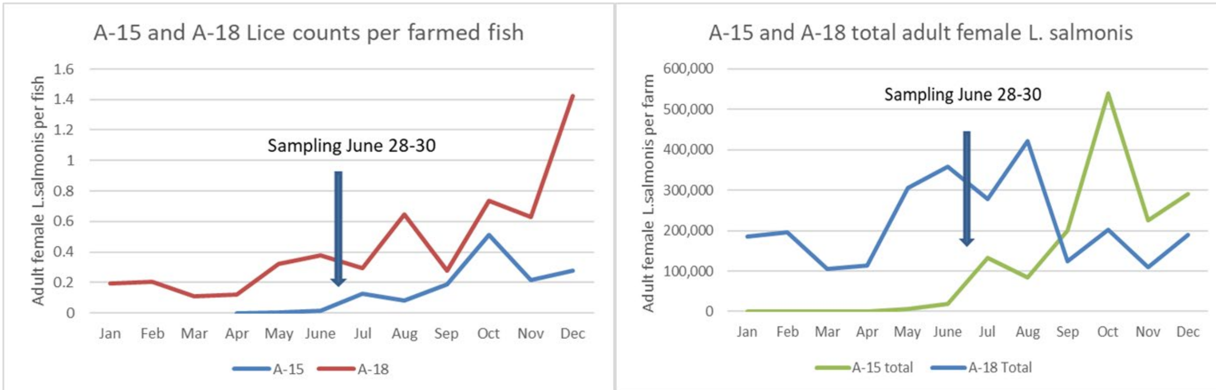

Figure 28: Left chart: adult female *L. salmonis* sea lice counts per farmed fish on farmed salmon in sites A-15 and A-18 in 2021. Right chart: the total number of *L. salmonis* adult female lice on each farm. The gillnet sampling dates in 2021 from Eliasen et al. (2022) are shown. Data from FFVA.

Regarding the impact of the sea lice counts on the wild sea trout, Eliasen et al. (2022) used the fish sizes and their lice numbers to separate them into five categories representing 0%, 20%, 50%, 75%, and 100% expected mortality, according to the salmon lice index presented by Taranger et al. (2012). Figure 29 shows these results from Eliasen et al. (2022) at both sites, with mortality predictions based on total lice counts (of both louse species), and secondly, only the salmon specialist *L. salmonis* (which is considered more likely to be associated with transmission from the farms).

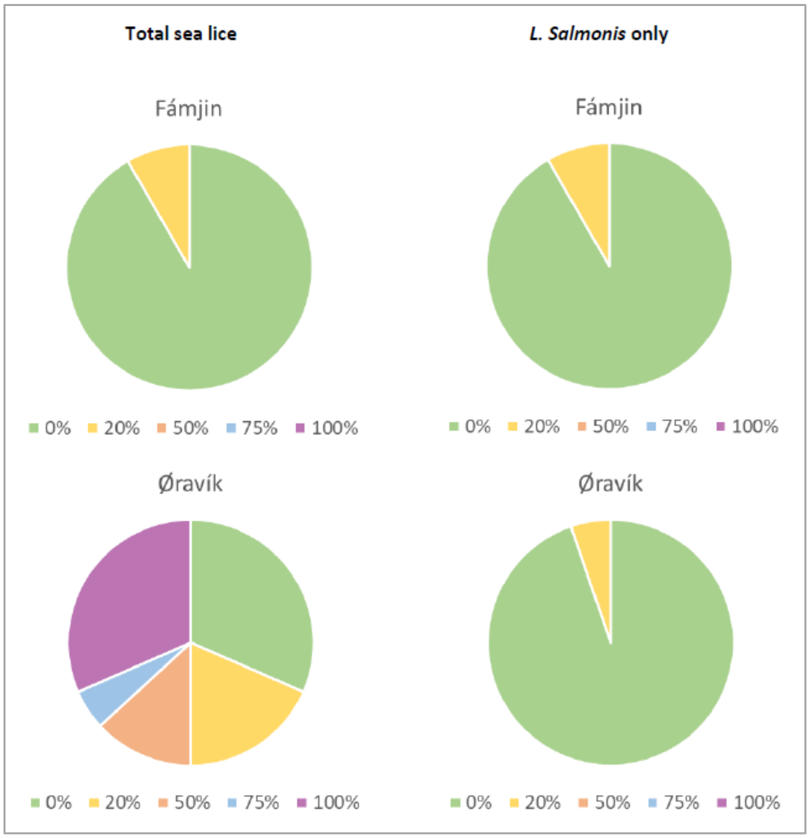

Figure 29: Percentages of wild sea trout in various predicted mortality categories according to their size and sea lice infection numbers. The fish were caught by gillnets at Øravík (close to salmon farms) and Fámjin (distant from salmon farms). The left two charts show mortality attributed to the total sea lice counts on wild sea trout, whereas the right two charts show the predicted mortality according to the numbers of *L. salmonis* sea lice only. Image reproduced from Eliasen et al. (2022).

Figure 29 shows that the predicted mortality attributed to total sea lice numbers (i.e., of both species of sea lice) is high at Øravík (close to salmon farms) and low at Fámjin (distant from salmon farms). But crucially, two main aspects rule out any possible conclusions regarding the contributions of lice from farmed salmon to these potential mortalities. First, the total sea lice numbers include the salmonid specialist species *L. salmonis* and the generalist *C. elongatus*; the latter has many potential natural hosts and therefore many infection sources in the Faroe Islands in addition to salmon farms (Eliasen et al., 2022). Second, the total sea lice numbers included large numbers of chalimus stages of sea lice, for which the species was not identified. Figure 30 shows that the total number of *L. salmonis* plus the chalimus of both species was much higher at Øravík (close to salmon farms) than at Fámjin, but for the salmonid specialist only, the number was lower at Øravík. If the chalimus were excluded from the mortality analysis, all the sea trout smolt were in the 0% mortality category. Therefore, the substantial contribution of chalimus lice stages to the mortality predictions, combined with the lack of species identification, mean that the contribution of the salmon-specialist *L. salmonis* (which is more likely to be associated with salmon farms) is not known. As a further reason to avoid any conclusions regarding the potential impact of lice from salmon farms, the total number of sea trout sampled in gillnets is low (maximum of 50 permitted each year) and the number sampled in 2021 at Fámjin (12) was much lower than at Øravík (38). Also, given the deliberate geographic separation of the two locations, there may be other reasons for differences in lice numbers between them.

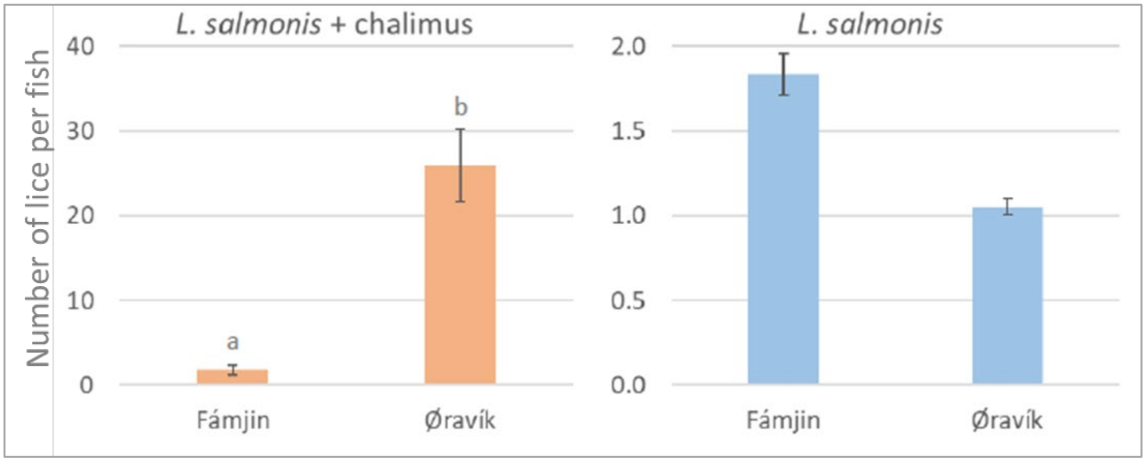

Figure 30: Left chart: the number of *L. salmonis* adults plus total chalimus stages of both louse species, showing higher total lice numbers at Øravík when chalimus of both louse species are included. Right chart: the numbers of *L. salmonis* adults only—note the different scale of the y-axis. Vertical bars indicate standard error; different letters indicate significant differences. Image reproduced from Eliasen et al. (2022).

It is also important to note that one of the main problems in measuring or predicting the scale of impact on salmon or sea trout is that the effect of lice on wild salmonids is context-sensitive; that is, the effect of lice is directly correlated with the overall survival in the ocean, so that in years of poor baseline survival, the effect of lice is large, while in years of good baseline survival, the effect of lice is almost not measurable (Vollset et al., 2015, 2019b)(Bøhn et al., 2020). Similarly, Bøhn et al. (2020) highlight that timing is crucial. In years with little overlap between lice blooms and Atlantic salmon smolt migration, only minor effects can be expected; conversely, in years with a strong overlap in timing, serious mortality effects can be expected.

<u>Other parasites</u>

Parasites such as *Paramoeba perurans*, which causes amoebic gill disease (AGD), can cause high mortalities on salmon farms both directly and indirectly from compromised gill function during stressful fish handling operations such as sea lice treatments (Oldham et al., 2016). Botnevik (2020) noted that, though AGD has been observed in a variety of farmed fish, it has only rarely been seen in wild fish and has not yet been observed in wild Atlantic salmon and wild sea migratory brown trout (as discussed previously regarding sea lice). Oldham et al. (2016) also noted that, despite numerous studies investigating potential reservoirs of *P. perurans*, no significant reservoir outside farmed salmon has been identified, and these authors (i.e., Oldham et al.) considered that there is little evidence of concern regarding transfer to wild salmonids or other species. Nevertheless, Botnevik (2020) noted that AGD is an increasing challenge in Atlantic salmon farming and suggested that there is a potential risk of it spreading from farmed fish to wild populations. In controlled challenge tests, Botnevik (2020) demonstrated that wild brown trout (and wild salmon) were susceptible to AGD. In the high dose challenge, a maximum of 60% of brown trout tested positive for *P. Perurans*, but the onset was delayed in brown trout (compared to a farmed Atlantic salmon strain). Of the brown trout in the high dose challenge, 20% showed AGD-like lesions for a short period, and the mortality of brown trout was limited to 2%. It therefore remains unclear if there are significant concerns regarding the potential transfer of *P. perurans* from farmed salmon to brown trout in the Faroe Islands.

Conclusions and Final Score

The Disease Criterion focuses on potential impacts to wild fish, for which there is limited information in the Faroe Islands. Native populations of sea trout are present, but of uncertain number. Bacterial and viral diseases cause low mortality in Faroese salmon farms and are considered a low concern for potential transfer and impact to wild fish. Parasitic sea lice on farmed fish are present in variable numbers, and though increasingly strict management measures minimize the numbers of lice per farmed fish during the periods of peak numbers of wild sea trout in coastal waters, the cumulative load of lice from farms, and therefore the infection pressure in those waters, is likely substantial. An ongoing research project by Fiskaaling that conducts annual sampling of wild sea trout is greatly increasing the knowledge base of sea lice interactions, but does not yet provide sufficiently robust data to reach any conclusions regarding the potential impact of lice from salmon farms as opposed to other natural infection sources in the area. Thus, the risk-based assessment has been used and the score is based on the open nature of the production system to the introduction and discharge of pathogens and parasites. The final numerical score for Criterion 7—Disease is 4 out of 10.

Criterion 8X: Source of Stock—Independence from Wild Fisheries

Impact, unit of sustainability and principle

- Impact: the removal of fish from wild populations for on-growing to harvest size in farms
- Sustainability unit: wild fish populations
- Principle: using eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

Criterion 8X Summary

C8X Source of Stock—Independence from wild fish stocks	Value	Score (deduction)
Percent of production dependent on unsustainable wild sources (%)	0%	–0
Use of ETP or SFW "Red" fishery sources	No	
C8X Source of stock Final Score (0–10)		**–0**
Critical?	No	Green

Brief Summary

The primary farmed species, Atlantic salmon, is demonstrably independent of wild broodstock and wild fisheries because of the use of multigenerational domesticated broodstocks. In contrast, >3.75 million lumpfish (*Cyclopterus lumpus*) are used as cleaner fish in the control of parasitic sea lice on farmed salmon in the Faroe Islands, and are considered to be reliant on wild caught broodstock to supply eggs. Approximately 80% of lumpfish used in Faroese salmon farms originate from wild-caught broodstock in Iceland, while a single fisher in the Faroes supplies approximately 200 adult lumpfish per year for local production. The Icelandic lumpfish fishery is certified by the Marine Stewardship Council, and the single fisher and small catch strongly suggest that the Faroe Islands fishery is not a sustainability concern. Therefore, neither Atlantic salmon nor lumpfish is considered in the scoring of Criterion 8X—Source of Stock, and the final score is a deduction of 0 out of –10.

Justification of Rating

Atlantic salmon

Atlantic salmon aquaculture has seen a multi-decadal establishment of breeding programs, aimed at selection for traits advantageous to farming (e.g., fast growth, disease resistance), which has been integral in the rapid growth of the industry (Asche et al. 2013)(Gutierrez et al. 2016). In the Faroe Islands, a local breeding population has been maintained since 1990, but egg production largely ceased in the mid-2000s after the ISA crisis (pers. comm., Knud

Simonsen, Fiskaaling, 2018). According to Bakkafrost (2022a), the company took ownership of the broodstock program in 2018 and has established one broodstock facility, with another due for completion in 2023. After the earlier decline in domestic egg production, eggs have primarily been obtained from Norway (Salmobreed[74]) and Iceland (Stofnfiskur[75]), from domesticated broodstocks (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018, 2022). Information on the scale of smolt production from the local Faroe Islands broodstock is not currently readily available; regardless, with the (global) industry-wide focus on domesticated broodstock, all salmon farmed in the Faroe Islands are considered to be independent of wild salmon populations.

<u>Cleaner fish</u>

Lumpfish (*Cyclopterus lumpus*) is now extensively used as cleaner fish in Norway, Ireland, Scotland, Iceland, and the Faroe Islands to remove parasitic sea lice from farmed salmon (Imsland and Reynolds, 2022). Lumpfish was first used as cleaner fish in the Faroe Islands in 2014, and though one-quarter of sites were using them in 2016, the number increased rapidly, and the majority of sites were considered to be using them in 2017 (Johannesen et al., 2018). Anecdotal information in company reports from Bakkafrost and Mowi (annual reports published in 2022) indicates that lumpfish continues to be an important component of integrated sea lice management, and currently all but one of the sites[76] are considered to be using lumpfish (pers. comm., Kirstin Eliasen, Fiskaaling, April 2022).

Lumpfish used during the 2014 to 2016 period were nearly all imported from Iceland (Whittaker et al., 2018)(Johannesen et al., 2018). Currently, Bakkafrost (2022b) notes that the first Faroese lumpfish were deployed from a new local hatchery in 2021 and accounted for 23% of the stock, and this matches the estimation of Arge (pers. comm., Regin Arge, ÆSIR Marine, August 2022) that 20% of lumpfish are produced in the Faroe Islands, with the rest imported from Iceland. A conservative estimate from Johannesen et al. (2018), with reference to the 2014–16 study period, noted a requirement of 2 million lumpfish to cover all salmon farms in the Faroe Islands at that time. But, with increased use of cleaner fish, and increased production, current use is estimated to be >3.75 million, with >3 million imported from Iceland (pers. comm., Regin Arge, ÆSIR Marine, August 2022). These are supplied partly as eggs, but largely as ready-to-deploy juveniles (pers. comm., Kirstin Eliasen, Fiskaaling, April 2022).

Whittaker et al. (2018) noted that nearly all lumpfish used in salmon farming are still derived from wild broodstock, and because they are generally used in a single salmon production cycle, satisfying aquaculture demands can put considerable pressure on wild stocks. Currently, captive breeding in the Faroe Islands and Iceland is quite low, and eggs largely come from wild sources (pers. comm., Regin Arge, ÆSIR Marine, August 2022). Johannesen et al. (2018) also noted that, although most eggs are obtained from wild females (of 2–3 kg), milt has increasingly been

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[74] http://salmobreed.no/en/our-fish/

[75] http://stofnfiskur.is/

[76] The single site exception has currents that are too high for lumpfish (Eliasen, pers. com., 2022)

obtained from captive-bred males (which start maturing in captivity at a much smaller size of 200–300 g).

Although it is anticipated that domesticated production of lumpfish will increase (in the Faroe Islands and Iceland), it is currently assumed on a precautionary basis that all female broodstock are wild-caught. In the Faroe Islands, there has been no historic commercial exploitation of lumpfish, other than as cleaner fish in the salmon farming industry (Johannesen et al., 2018). But, Whittaker et al. (2018) noted that lumpfish are caught elsewhere for their roe for human consumption (in addition to for the aquaculture industry), and reported that estimates of lumpfish population sizes were consistently low across the Northeast Atlantic (Iceland, Faroe Islands, and Norway). For reference, the International Union for the Conservation of Nature (IUCN)[77] lists *Cyclopterus lumpus* as "Near Threatened" in the North Atlantic with an unknown population trend, but the assessment is from 2013. Currently, there is a single fisher in the Faroe Islands supplying approximately 200 adult and mature lumpfish per year (pers. comm., Regin Arge, ÆSIR Marine, August 2022); although no information on the stock status is readily available, the single fisher and small catch strongly suggest that this is not a sustainability concern. The Icelandic lumpfish fishery is operated by Icelandic Sustainable Fisheries (ISF) and is currently certified by the Marine Stewardship Council (GTC, 2022). The fishery was first certified in November 2020[78] and is certified until 2025, with a harvest of 7,601 mt in 2021.

With robust information on the source, scale, and sustainability of wild-caught lumpfish, its use in salmon farms in the Faroe Islands can be demonstrated to be of minimal concern (for example, this would relate to a score of 6 out of 10 for fishery sustainability in Criterion 5—Feed, Factor 5.1b).

Conclusions and Final Score

The primary farmed species, Atlantic salmon, is demonstrably independent of wild broodstock and wild fisheries because of the use of multigenerational domesticated broodstocks. In contrast, >3.75 million lumpfish (*Cyclopterus lumpus*) are used as cleaner fish in the control of parasitic sea lice on farmed salmon in the Faroe Islands and are considered to be reliant on wild-caught broodstock to supply eggs. Approximately 80% of lumpfish used in Faroese salmon farms originate from wild-caught broodstock in Iceland, while a single fisher in the Faroes supplies approximately 200 adult lumpfish per year for local production. The Icelandic lumpfish fishery is certified by the Marine Stewardship Council, and the single fisher and small catch strongly suggest that the Faroe Islands fishery is not a sustainability concern. Therefore, neither Atlantic salmon nor lumpfish is considered in the scoring of Criterion 8X—Source of Stock, and the final score is a deduction of 0 out of –10.

[77] https://www.iucnredlist.org/species/18237406/45078284

[78] The fishery (or at least some component of it) was previously certified to the MSC, before recertifying under the ISF.

Criterion 9X: Wildlife Mortalities

Impact, unit of sustainability and principle

- Impact: mortality of predators or other wildlife caused or contributed to by farming operations
- Sustainability unit: wildlife or predator populations
- Principle: preventing population-level impacts to predators or other species of wildlife attracted to farm sites.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

Criterion 9X Summary

C9X Wildlife Mortality parameters		Score (deduction)
Single species wildlife mortality score		–2
C9X Wildlife Mortality Final Score		**–2**
Critical?	No	Green

Brief Summary

Before 2015, the Faroese salmon farming industry deliberately killed hundreds of grey seals per year. Population estimates vary from a minimum of 550 seals (from the first formal count in 2018 and 2019) to expert estimates of 1,000 to 2,000, and it is clear that salmon farm mortalities negatively affected the size of the grey seal population and its ability to recover after commercial hunting. Recent management improvements have resulted in a dramatic decline in mortalities, and the Faroese government initiated a ban on seal culls at salmon farms in May 2020. The data from 2021 indicate that the ban is initially effective and the low current mortalities (e.g., due to accidental entanglement) are expected to continue. Moderate numbers of birds continue to die as a result of accidental entanglement in nets, but the species are considered to be of low concern. With considerable uncertainty in the population estimates of grey seal, understanding its recovery from previous high mortality at salmon farms remains challenging. Therefore, the risk assessment must be used, and because lethal control is no longer permitted and accidental mortalities are considered to be limited to exceptional circumstances, the final score for Criterion 9X—Wildlife Mortalities is –2 out of –10.

Justification of Rating

The presence of farmed salmon in net pens at high density inevitably constitutes a powerful food attractant to opportunistic coastal marine mammals, seabirds, and fish that normally feed on native fish stocks (Sepulveda et al. 2015). Regarding marine mammals, the grey seal (*Halichoerus grypus*) is the only pinniped species that breeds in the Faroe Islands; it is present year-round and can be observed throughout the archipelago (Mikkelsen, 2007). The harbor seal (*Phoca vitulina*) was exterminated in the Faroe Islands in the mid-19th century by hunting

(Mikkelsen, 2010). Therefore, all marine mammal mortalities discussed here are considered to be grey seals.

Active control (i.e., lethal shooting of seals) began to change with increasing certification to international standards, such as the Aquaculture Stewardship Council and the Global Seafood Assurances Best Aquaculture Practices schemes, but the situation formally changed in 2020 when the Faroese government implemented a ban on the culling of marine mammals at salmon farms (effective January 1, 2021) (pers. comm., Bjarni Mikkelsen, Havstofan, August 2022). This ban was related to import restrictions (associated with the United States Marine Mammal Protection Act) on farmed salmon products. The legislation includes a penalty of up to two years in prison for breaches of the ban (pers. comm., Niels Winther, Havbúnaðarfelagið, 2022). The situation before and after this change is briefly discussed below.

<u>The situation before the 2020 ban on lethal seal control</u>

According to NAMMCO (2016), before 2020, the most significant human interaction of grey seal in the Faroe Islands was in connection with salmon farms, because there is no recreational hunt for grey seal in the Islands. Salmon farmers were licensed with rifle permits for shooting seals, and with no mandatory logbooks or record keeping, fish farmers were free to shoot all seals approaching the farm. A logbook system was established in 2009, but the statistics were unreliable, with the largest company's data not reported (NAMMCO, 2016).

NAMMCO (2021) provided a graph of estimated[79] grey seal mortalities at salmon farms between 2010 and 2019 (Figure 31). With improving awareness (e.g., relating to international certification, as noted above), particularly in anticipation of the 2020 government ban, the numbers can be seen to have dramatically declined from approximately 290 per year in 2010 to approximately 40 in 2019. According to the industry, the overall declines in marine mammal mortalities are considered to be the result of better prevention of predators entering the net pens and stronger internal decision-making at the company level before lethal control is used (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018).

It must be noted that there may be some errors in these estimated mortality numbers; for example, the combined data for Mowi and Bakkafrost previously available from GSI, and also provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018), showed that the total mortality of marine mammals in 2013 was 440. This is more than double the data in Figure 31 from NAMMCO (2021).

[79] Because of the missing data from the largest company, the total was estimated based on numbers from the other companies and a single year (2010) when the largest company did report its mortalities.

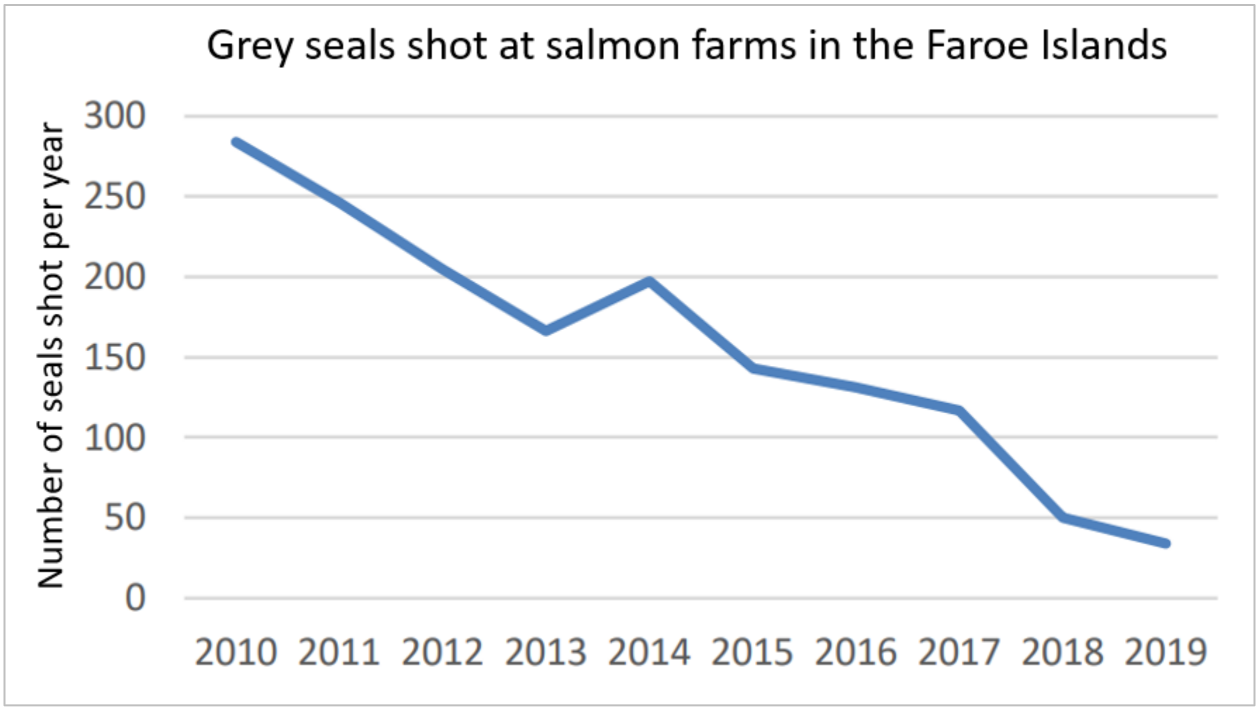

Figure 31: Grey seal mortality numbers (shooting) at salmon farms in the Faroe Islands from 2010 to 2019. Graph reproduced from NAMMCO (2021).

The situation after the ban on lethal seal control in 2020

As a result of the government ban, marine mammal mortality levels have steadily declined to nearly zero (NAMMCO, 2021). All aquaculture companies in the Faroe Islands must register incidents involving predator (including bird) mortalities (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018). Although there is a ban on lethal control (i.e., shooting), accidental mortalities such as entanglement may still occur; however, according to Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018), there have been no marine mammal mortalities (deliberate or accidental) since the ban became effective in January 2021.

GSI data on accidental mortalities of birds and both accidental and deliberate mortalities of marine mammals for Bakkafrost only are shown in Figure 32, with intentional mortalities of marine mammals declining from nearly seven per site per year in 2013 to zero in 2021. Data from Mowi's annual reports show that there were zero marine mammal mortalities in the most recent years of 2020 and 2021. The 3-year average marine mammal mortality for Bakkafrost from 2019 to 2021 is 0.51 per site per year. Therefore, despite the uncertainties in the numbers shot before 2020 (i.e., Figure 31), it seems clear that the numbers have declined to zero or close to zero.

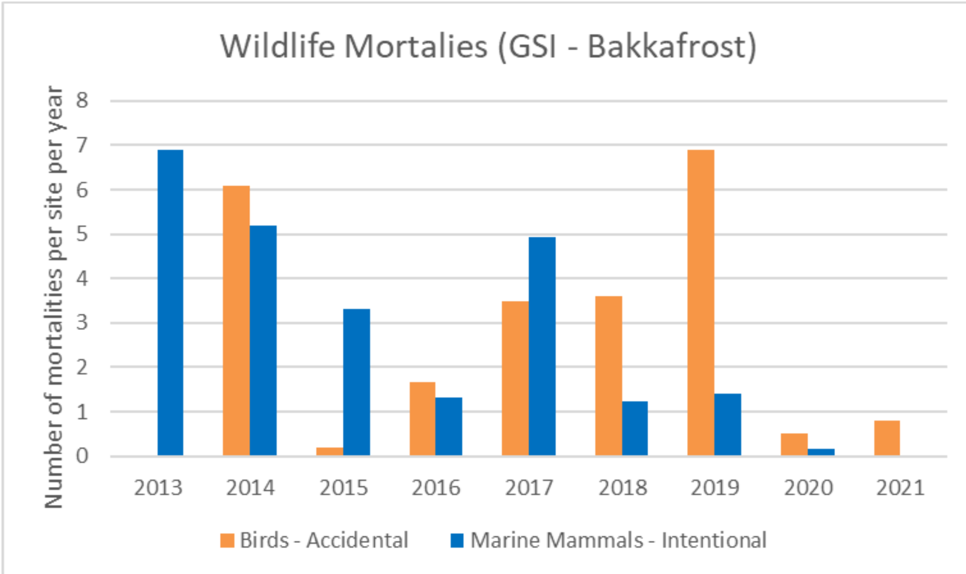

Figure 32: Bird and marine mammal mortalities per site per year from 2013 to 2021 for Bakkafrost sites only. Data from GSI.

<u>Bird mortalities</u>

Data on bird mortalities from all three companies provided by Havbúnaðarfelagið (pers. comm., Niels Winther, Havbúnaðarfelagið, 2022) show an average of 2.1 bird mortalities per site per year in 2021. Figure 32 also shows the GSI data for accidental bird mortalities (i.e., entanglements), and these are variable by year, with a recent peak of 6.9 birds per site per year in 2019. Information in recent ASC audit reports provides examples showing one or two mortalities of eider duck (*Somateria mollissima*) and great black-backed gull (*Larus marinus*). Previously, ASC audit reports have shown that a limited number of sites record mortalities of northern gannet, herring gull, lesser black-backed gull, and black-legged kittiwake. All are noted (in the audit reports) as species of least concern by the IUCN. The focus of this assessment is therefore on impacts to marine mammals—specifically, grey seal.

<u>Impacts to the grey seal population</u>

According to NAMMCO (2016) and Mikkelsen (2007), there was no reliable population estimate of grey seal in the Faroe Islands, and a best rough estimate was around 1,000 to 2,000 animals. After the first formal counting efforts in 2018 and 2019, NAMMCO (2021) reported a minimum population size of 550 seals, but emphasized the challenges of accurately determining the numbers (partly because of weather limitations, the use of sea caves as haul-out sites, and other sampling challenges). The population was considered to be recovering only slowly (despite commercial hunting having ceased), and mortalities at salmon farms were keeping the population at a low level (NAMMCO, 2021)(Mikkelsen, 2007). But, according to NAMMCO (2021), the ban on culling around fish farms (after over 10 years with a high number of seals shot on such sites) is assumed to allow the population to recover.

It appears clear that the annual lethal control of hundreds of seals at salmon farms negatively affected the size of the grey seal population and its ability to recover. Figures 31 and 32 now show that farm kills have declined considerably in recent years, and despite the very high concern regarding previous mortalities, this assessment must assume that the ban initiated by the Faroese government in 2020 will be upheld (the 2021 data support this assumption) and that any accidental mortalities will be limited to exceptional cases.

Conclusions and Final Score

Before 2015, the Faroese salmon farming industry deliberately killed hundreds of grey seals per year. Population estimates vary from a minimum of 550 seals (from the first formal count in 2018 and 2019) to expert estimates of 1000 to 2000, and it is clear that salmon farm mortalities negatively affected the size of the grey seal population and its ability to recover after commercial hunting. Recent management improvements have resulted in a dramatic decline in mortalities, and the Faroese government initiated a ban on seal culls at salmon farms in May 2020. The data from 2021 indicate that the ban is initially effective and the low current mortalities (e.g., due to accidental entanglement) are expected to continue. Moderate numbers of birds continue to die as a result of accidental entanglement in nets, but the species are considered to be of low concern. With considerable uncertainty in the population estimates of grey seal, understanding its recovery from previous high mortality at salmon farms remains challenging. Therefore, the risk assessment must be used, and because lethal control is no longer permitted, and accidental mortalities are considered to be limited to exceptional circumstances, the final score for Criterion 9X—Wildlife Mortalities is –2 out of –10.

Criterion 10X: Introduction of Secondary Species

Impact, unit of sustainability and principle

- Impact: movement of live animals resulting in introduction of unintended species
- Sustainability unit: wild native populations
- Principle: avoiding the potential for the accidental introduction of secondary species or pathogens resulting from the shipment of animals.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score.

Criterion 10X Summary

Scoring based on movements of the lumpfish

C10X Introduction of Secondary Species parameters	Value	Score (deduction)
F10Xa Percent of production reliant on trans-water-body movements (%)	77.0	0
Biosecurity score of the source of animal movements (0–10)		6
Biosecurity score of the farm destination of animal movements (0–10)		2
Species-specific score 10X Score		–3.2
C10X Introduction of Secondary Species Final Score		**–3.2**
Critical?	No	Green

Brief Summary

The Faroese salmon farming industry has a developing local Atlantic salmon broodstock program, but is currently fully reliant on the import of ova from two companies in Norway and Iceland. In addition to importation regulations in the Faroe Islands that require health certificates and approval by veterinary authorities, the two ova-producing companies and their facilities are considered to have high biosecurity, and there is a low risk of introducing nonnative "hitchhiker" species, such as parasites or pathogens, into the Faroe Islands with movements of salmon ova. The salmon farming industry in the Faroe Islands also uses cleaner fish (lumpfish) imported from Iceland, originating from wild stocks. Although the ability to quarantine wild-caught broodstock and the same importation regulations in the Faroe Islands provide some biosecurity, disease remains a primary challenge to the use of lumpfish. There remains a risk of unintentionally introducing a nonnative species during shipments of live lumpfish into the Faroe Islands, and the final score for Criterion 10X—Introduction of Secondary Species is a deduction of –3.2 out of –10.

Justification of Rating

This criterion provides a measure of the escape risk (introduction to the wild) of secondary species (i.e., other than the principal farmed species) unintentionally transported during animal shipments. See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.

According to the UN FAO (2012), the expanded and occasionally irresponsible global movements of live aquatic animals have been accompanied by the transboundary spread of a variety of pathogens. In some instances, these pathogens have caused serious damage to aquatic food productivity and resulted in serious pathogens becoming endemic in culture systems and the natural aquatic environment. The global salmon farming industry has suffered from the introduction of pathogens during the international movements of live animals, and transfers of live material are regarded as one of the most serious risk factors for spreading disease within the industry (Hjeltnes et al. 2016—referring to the Norwegian industry). Although the impacts to production are well-documented, the ecological impacts beyond the farm are less apparent.

Factor 10Xa. International or Trans-water-body Live Animal Shipments

Atlantic salmon

There is a single broodstock facility and there are at least six hatcheries/smolt production units for Atlantic salmon on the Faroe Islands (Bakkafrost, 2022a), but given the developing nature of the local broodstock program (see Criterion 8X—Source of Stock), the Faroese salmon farming industry is still wholly reliant on the import of salmon eggs (ova) from Norway and Iceland (pers. comm., Niels Winther, Havbúnaðarfelagið, November 2022). Bakkafrost (2022a) notes a strategy to buy high quality eggs from selected external suppliers, and imported ova were previously noted to come from two companies: in Norway (Salmobreed) and Iceland (Stofnfiskur) (pers. comm., Niels Winther, Havbúnaðarfelagið, 2018).

Movements of fish within the Faroe Islands are considered to be within the same water body and are not included in this assessment. Based on the ova imports, the industry is considered to be 100% reliant on the international movement of live fish (in the form of eggs), and the score for Factor 10Xa is 0 out of 10.

Cleaner fish

As noted in Criterion 8X—Source of Stock, salmon farms in the Faroe Islands use locally produced cleaner fish (lumpfish, *Cyclopterus lumpus*) in addition to importing them from Iceland as eggs and as juveniles ready to deploy in salmon farms. It is also possible that some are imported as fry for further development in the Faroe Islands (pers. comm., Ása Johannesen, Fiskaaling, August 2022). As discussed in Criterion 8X—Source of Stock, approximately 80% of the lumpfish used in the Faroe Islands are considered to be imported from Iceland. For the purposes of scoring, the specific figure of 23% local production of lumpfish in 2021 (Bakkafrost, 2022b) is used here, as opposed to the estimate of 20% from Arge (pers. comm., Regin Arge, ÆSIR Marine, August 2022). Therefore, 77% of Faroese salmon production is considered to be reliant on imported lumpfish. The score for Factor 10Xa for cleaner fish is 2 out of 10.

Factor 10Xb. Biosecurity of Source/Destination

The score for 10Xb is determined by the highest biosecurity characteristics of either the source or the destination of live animal movements. Given the openness of net pen production systems as the destination of live animal movements, the focus of this assessment is on the biosecurity of the source, i.e., the hatcheries, which typically have the potential for strong biosecurity.

Atlantic salmon

Each of the two ova-producing companies (Stofnfiskur and Salmobreed) operate land-based facilities with high biosecurity offering “disease-free” products; Stofnfiskur in Iceland is the first company to be certified to the World Animal Health organization’s (OIE) biosecurity Compartment Standard.[80] Salmobreed in Norway is a “sister company” to Stofnfiskur[81] that is considered to be operating under the same biosecurity protocols. Although these companies cannot be considered fully biosecure (i.e., having no connection to natural waterbodies), they are considered to have quite high levels of biosecurity that are above those of typical tank-based recirculation systems.

As noted in Criterion 7—Disease, there are numerous biosecurity regulations in the Faroe Islands, including some relating to the import of animal products and their movement within the islands. Regulation no. 113 of 2001 addresses the sale, import, and export of aquaculture animals and products, and Regulation no. 98 of 2003 addresses the transport of aquaculture animals. The salient content with respect to this assessment is that all imports of animals must be approved by the veterinary authorities and accompanied by a health certificate showing that the animals are free of OIE-notifiable diseases. With the land-based source facilities and the inspection procedures, the potential biosecurity is high. Nevertheless, there is inevitably some uncertainty regarding unknown and/or undetected pathogens, so the score for Factor 10Xb is 9 out of 10 for Atlantic salmon. When combined with Factor 10Xa, the final score for Criterion 10X is a deduction of –1 out of –10 for Atlantic salmon.

Cleaner fish

As discussed in Criterion 8—Source of Stock, the majority of lumpfish imported from Iceland are considered to originate from wild broodstock. Although these sources have no biosecurity, the ability to quarantine stocks, in addition to routine disease screening during production and before shipping, means that some biosecurity measures are in place. Yet the production of lumpfish is prone to disease; for example, Johannesen et al. (2018) consider that the greatest challenge in the hatchery production of lumpfish in the Faroe Islands has probably been related to outbreaks of bacterial diseases. The same authors note that diseases also have significant consequences for lumpfish after deployment in salmon net pens. The same approval and health certification by veterinary authorities noted above for salmon are considered to be applicable to lumpfish imports, but overall, there is considered to be some uncertainty or questioning of the robustness of biosecurity measures, given the prevalence of disease in lumpfish. The score for Factor 10Xb is 6 out of 10 for imported cleaner fish. When combined with Factor 10Xa, the final score for Criterion 10X is a deduction of –3.2 out of –10 for cleaner fish.

Conclusions and Final Score

[80] http://stofnfiskur.is/production/

[81] http://salmobreed.no/en/products/

The Faroese salmon farming industry has a developing local Atlantic salmon broodstock program, but is currently fully reliant on the import of ova from two companies in Norway and Iceland. In addition to importation regulations in the Faroe Islands that require health certificates and approval by veterinary authorities, the two ova-producing companies and their facilities are considered to have high biosecurity, and there is a low risk of introducing nonnative "hitchhiker" species, such as parasites or pathogens, into the Faroe Islands with movements of salmon ova. The salmon farming industry in the Faroe Islands also uses cleaner fish (lumpfish) imported from Iceland, originating from wild stocks. Although the ability to quarantine wild-caught broodstock and the same importation regulations in the Faroe Islands provide some biosecurity, disease remains a primary challenge to the use of lumpfish. There remains a risk of unintentionally introducing a nonnative species during shipments of live lumpfish into the Faroe Islands, and the final score for Criterion 10X—Introduction of Secondary Species is a deduction of –3.2 out of –10.

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Appendix 1: Data Points and all Scoring Calculations

Criterion 1: Data	
Data Category	**Data Quality**
Production	10.0
Management	7.5
Effluent	7.5
Habitat	5.0
Chemical Use	5.0
Feed	5.0
Escapes	7.5
Disease	5.0
Source of stock	10.0
Wildlife mortalities	5.0
Escape of secondary species	7.5
C1 Data Final Score (0–10)	**6.83**
	Green

Criterion 2: Effluent	
Effluent Evidence-Based Assessment	**Data and Scores**
C2 Effluent Final Score (0–10)	**4**
Critical?	NO

Criterion 3: Habitat	
F3.1. Habitat conversion and function	**Data and Scores**
F3.1 Score (0–10)	8
F3.2 – Management of farm-level and cumulative habitat impacts	
3.2a Content of habitat management measure	3
3.2b Enforcement of habitat management measures	4
3.2 Habitat management effectiveness	4.800
C3 Habitat Final Score (0–10)	**6.933**
Critical?	No

Criterion 4: Chemical Use	
All-species assessment	**Data and Scores**

Chemical use initial score (0–10)	4
Trend adjustment	0
C4 Chemical Use Final Score (0–10)	**4**
Critical?	No

Criterion 5: Feed	
5.1 Wild Fish Use	
5.1a Forage Fish Efficiency Ratio (FFER)	**Data and Scores**
Fishmeal from whole fish, weighted inclusion level %	22.300
Fishmeal from by-products, weighted inclusion %	10.500
By-product fishmeal inclusion (@ 5%)	0.525
Fishmeal yield value, weighted %	22.500
Fish oil from whole fish, weighted inclusion level %	6.200
Fish oil from by-products, weighted inclusion %	7.100
By-product fish oil inclusion (@ 5%)	0.355
Fish oil yield value, weighted %	5.000
eFCR	1.210
FFER Fishmeal value	**1.227**
FFER Fish oil value	**1.586**
Critical (FFER >4)?	No

5.1b Sustainability of Source fisheries	**Data and Scores**
Source fishery sustainability score	4.000
Critical Source fisheries?	No
SFW "Red" Source fisheries?	No
FFER for red-rated fisheries	n/a
Critical (SFW Red and FFER >=1)?	No
Final Factor 5.1 Score	**3.600**

5.2 Net Protein Gain or Loss (%)	**Data and Scores**
Weighted total feed protein content	40.600
Protein INPUT kg/100kg harvest	49.126
Whole body harvested fish protein content	16.900
Net protein gain or loss	–65.599
Species-specific Factor 5.2 score	**3**
Critical (Score = 0)?	No
Critical (FFER>3 and 5.2 score <2)?	No

5.3 Feed Footprint	**Data and Scores**
GWP (kg CO_2-eq kg^{-1} farmed seafood protein)	**14.790**

Contribution (%) from fishmeal from whole fish	14.407
Contribution (%) from fish oil from whole fish	2.644
Contribution (%) from fishmeal from by-products	6.783
Contribution (%) from fish oil from by-products	3.027
Contribution (%) from crop ingredients	73.139
Contribution (%) from land animal ingredients	0.000
Contribution (%) from other ingredients	0.000
Factor 5.3 score	**6**
C5 Final Feed Criterion Score	**4.050**
Critical?	**No**

Criterion 6: Escapes	Data and Scores
F6.1 System escape risk	2
Percent of escapees recaptured (%)	0.000
F6.1 Recapture adjustment	0.000
F6.1 Final escape risk score	2.000
F6.2 Invasiveness score	8
C6 Escape Final Score (0–10)	**5.0**
Critical?	No

Criterion 7: Disease	Data and Scores
Evidence-based or Risk-based assessment	Risk
Final C7 Disease Criterion score (0–10)	**4**
Critical?	No

Criterion 8X Source of Stock	Data and Scores
Percent of production dependent on wild sources (%)	0.0
Initial Source of Stock score (0–10)	0.0
Use of ETP or SFW “Red” fishery sources	No
Lowest score if multiple species farmed (0–10)	n/a
C8X Source of stock Final Score (0–10)	**0**
Critical?	No

Criterion 9X Wildlife Mortality parameters	Data and Scores
Single species wildlife mortality score	–2
System score if multiple species assessed together	n/a

C9X Wildlife Mortality Final Score	**–2**
Critical?	No

Criterion 10X: Introduction of Secondary Species	**Data and Scores**
Production reliant on trans-water-body movements (%)	77
Factor 10Xa score	2
Biosecurity of the source of movements (0–10)	6
Biosecurity of the farm destination of movements (0–10)	2
Species-specific score 10X score	–3.200
Multi-species assessment score if applicable	n/a
C10X Introduction of Secondary Species Final Score	**–3.200**
Critical?	n/a