Salmon Farming in the Falkland Islands: A review of environmental and social challenges and opportunities

An independent report for Falklands Conservation

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Executive Summary

The global harvest of 2.2 million metric tonnes (mt) of farmed salmon in 2017 now greatly exceeds the catch of wild salmon (0.8 million mt), and with a wholesale value of approximately £12.5 billion GBP per year, it is an important economic commodity in all producing countries. In the Falkland Islands, a pilot project at Fox Bay in 1985 demonstrated the suitable environmental conditions for farming Atlantic salmon, and the Marine Farming Ordinance of 2006 established the potential to allow the licensing of fish farms in the Islands. Understanding or predicting the potential environmental and social repercussions of introducing salmon farming into any new location is challenging, yet essential for sustainable development within the unique environment and culture of the Falkland Islands.

The commercially viable minimum production in the Falkland Islands is estimated to be 35,000 mt and current discussions indicate a proposed initial 50,000 mt. Even ten years ago, the Faroe Island's 40,000 mt industry was noted as having a salmon farm in almost every suitable bay and fjord. Other basic comparisons with today's salmon farming industries in small island groups such as the Faroe Islands, the Shetland Isles and the Orkney Isles show that at the simplest level, a 50,000 mt scale of production would have a substantial "presence" in the Falkland Islands. The closed-containment option, often promoted for its potential to reduce direct environmental impacts by growing salmon in land-based tanks, is not currently considered to be commercially viable in the Falkland Islands.

The environmental impacts of salmon farming are regionally distinct, complex, and (despite often being the subject of considerable study) are in many cases highly contested. In general (i.e. across all production regions), the key environmental impacts relate to nutrient inputs into the water column, settlement of particulate wastes on the seabed, escapes, wildlife interactions, antibiotic and pesticide use, pathogens and parasites and their transfer to wild species, the production of feed ingredients, and the potential introduction of non-native species during live salmon movements. Typically only a few of these impacts are considered to be a high concern in any one region, but the combinations of impacts are surprisingly varied across regions.

The floating net pen production system for growing salmon to harvest size is ubiquitous, and while effective from a commercial perspective, its "open" nature of exchange with the surrounding environment combined with its vulnerability to storm damage and human error mean that the above suite of potential environmental impacts are ever present depending on the local circumstances. The regulatory structures in place in the developed countries in which salmon farming currently takes place are typically considered to be comprehensive, yet the effectiveness of their content and/or enforcement continue to be questioned in the light of any ongoing impacts. As a result, salmon farming industries continue to face local environmental opposition, in varying degrees of vociferousness, in every region that they operate.

Predicting which environmental impacts will be problematic (if any) within the unique circumstances of the Falkland Islands is challenging. These predictions are hampered by the limited baseline knowledge of the local marine biodiversity, of the potential behaviour of escaping Atlantic salmon, of the ecology of protected native fish species such as the Zebra Trout and Falkland Minnow, of the potential interactions with marine mammals and birds, of the potential parasites and pathogens that will infect farms, of the scale of chemical use needed to control those pathogens and parasites, of the potential for those pathogens and parasites to infect native fish, and of the potential for the introduction of non-native organisms during movements of live eggs or fish into the Islands. While examples of public reporting in Scotland and Norway highlight excellent data availability for salmon farm production monitoring, all salmon farming regions continue to suffer from baseline limitations in understanding impacts. This level of uncertainty multiplies the appropriate level of caution given the importance of the Island's ecosystems.

As an example, parasitic sea lice infect Atlantic salmon farms in all producing countries. Not only does this typically require the use and discharge of pesticide treatments, but the transmission of lice from farms to wild fish (e.g. to migratory salmon and sea trout juveniles) is an important and highly controversial impact. A comprehensive Norwegian review concluded parasitic sea lice are an expanding population threat that affects wild salmon populations to the extent that they may be critically endangered or lost, with a large likelihood of causing further reductions and losses in the future. As the Falkland's native Zebra Trout and the Falklands Minnow are both considered to spend time in coastal waters when they are young, they may be particularly vulnerable to sea lice from salmon farms during a critical life stage. Conversely, it is possible that the Falklands will have a similar situation to that in Region XII in southern Chile where sea lice are not currently a significant concern for salmon farms or wild fish. Reducing this uncertainty would be important to allow informed planning and policy making in the Falklands.

The social impacts of salmon farming, particularly in remote or rural areas, are similarly complex and contested. Defining the consequences as positive or negative is in the hands of each person according to their relationship and experiences with the new industry. It is clear that salmon farming brings employment and income to coastal communities. A 30,000 mt salmon farming company in southern Chile employs 337 full time production staff and 465 in processing, and the largest producer in the Faroe Islands (Bakkafrost) employs 1,104 full time equivalents (FTE) to produce, process and market 54,600 mt of salmon. In Scotland, 4,802 FTEs are employed on farm sites, hatcheries and processing of 171,000 mt, and salaries to all associated local workers are estimated at £270 million per year. These figures represent staffing for modern state-of the-art salmon farming systems. Bakkafrost is the largest private employer in the Faroe Islands, but the Island's population of 49,000 highlights the uncertainty with which the social and cultural impacts of a 50,000 mt salmon farming industry will be perceived in the much smaller Falklands community.

Direct incomes to local governments in the form of site licenses are highly variable across regions; for example, the UK's Crown Estate charges £27.50 per mt for salmon site leases in Scotland whereas Norway recently auctioned 14 new site licenses with a total capacity of 14,945 mt of salmon for £275 million (i.e. approximately £20,500 per ton of production, or £19.6 million per site). Bakkafrost has contributed approximately £15 million GBP into the islands' economy per year in corporate taxes, and while an independent financial report shows salmon farming companies in British Columbia contribute £74 million in federal, provincial and municipal taxes, the industry in B.C. also claims to contribute over £644 million annually to the provincial economy through all associated businesses and services.

With regard to the implications to the Falklands Government of establishing and regulating a salmon farming industry, the U.K.'s Scottish example shows a complex system involving many statutory bodies. In addition to an array of high-level planning frameworks, policies and regulations, the siting system in Scotland comprises a highly complex set of legislation, guidance and advice that cascades from the Scottish Government down to the statutory planning authorities. The consent process alone for a new fish farm site takes over two years, and even if some of the Scottish inefficiencies could be avoided, it is clear that the role (and therefore the human and financial resources) of the Island's government in the sustainable development of salmon farming will not be insignificant. Conversely, with mature salmon farming industries now operating in many developed countries, a range of examples of regulatory systems are available from which the Falklands could distill a bespoke and progressive structure that effectively rewarded sustainable practices.

The primary challenges to a sustainable salmon industry in the Falkland Islands relate to deficiencies in the baseline data needed to understand, predict, and subsequently manage the potential environmental and social impacts within the Falkland Islands' distinct characteristics. Once understood, it is possible that a variety of practical mitigation measures can minimize impacts, particularly at the site level, and using examples from the

Scottish salmon farming industry it can be shown that effective management of some cumulative waterbody or industry impacts is possible; however, these examples also highlight the comprehensive nature of the regulatory structures and agency capacities needed from local governments to do so. Despite apparently comprehensive and burdensome regulatory procedures, the robustness of both the content and enforcement of aquaculture regulation is typically contested in all regions.

With a global production of over two million metric tonnes and a mature industry of thirty years, salmon farmers typically argue that they are sustainable; however, it is clear (as discussed here) that there continue to be highly controversial impacts of salmon farming in all the main production regions. Yet wherever there are examples of high environmental concern, there are also examples of exceptions at the site, company, or waterbody level, due ether to specific environmental conditions, or due to better management. For example, sites in lower salinity locations can have less parasitic sea lice, less secondary infections, lower pesticide use, and less concern for impacts to wild fish. Such examples of better practices, better management, or better environmental conditions can be recognized by farm-level certification (e.g. the Aquaculture Stewardship Council), or NGO approvals (e.g. the Monterey Bay Aquarium's Seafood Watch program).

Overall, salmon farming globally is dominated by a small number of large publicly listed companies, and although clearly contributing to local governments and economies, the proposed production in the Falkland Islands will exploit the local ecosystem services for commercial profits and will rely on some kind of social licence to operate. While in theory at least, this can be done sustainably, many of salmon farming's environmental and social impacts continue to be poorly understood and controversial, and this is only exacerbated by the limited understanding of the Falkland Islands' distinct environments and communities. While examples of comprehensive regulatory structures, codes of good practice and technical standards are available, and other potentially mitigating factors can be envisaged, success stories in salmon farming are typically closely associated with distinct local circumstances or conditions. These conditions may or may not occur in the Falkland Islands, and a comprehensive Strategic Environmental Assessment is recommended to enable informed decision-making and policy for the long-term sustainability of development in the Islands.

Contents

Salmon Farming in the Falkland Islands: A review of environmental and social challenges and opportunities.

1 - Introduction to salmon farming

Please note all references and sources of information are listed by section in Appendix 1.

1.1 - Global Production

Small-scale salmon farming began in the 1960s and 70s, with harvested volumes increasing rapidly in several countries in the 1980s. Global production is currently approximately two million metric tons (mt), and while representing only a small part of the total global aquaculture production (currently ~100 million mt), it is an important global seafood commodity. The largest producers are Norway, Chile, Scotland and British Columbia, and annual growth is projected to be 3% from 2016 to 2020. The industry is dominated by a small number of large publicly listed companies; the top three producers in Norway represent >40% of production, and five companies represent >95% of production in Scotland.

1.2 - Regional Distribution

The geographical distribution of salmon farming is primarily limited by suitable water temperatures; Figure 1 shows a global sea surface temperature map overlaid with the location of salmon farming regions and their approximate annual production figures.

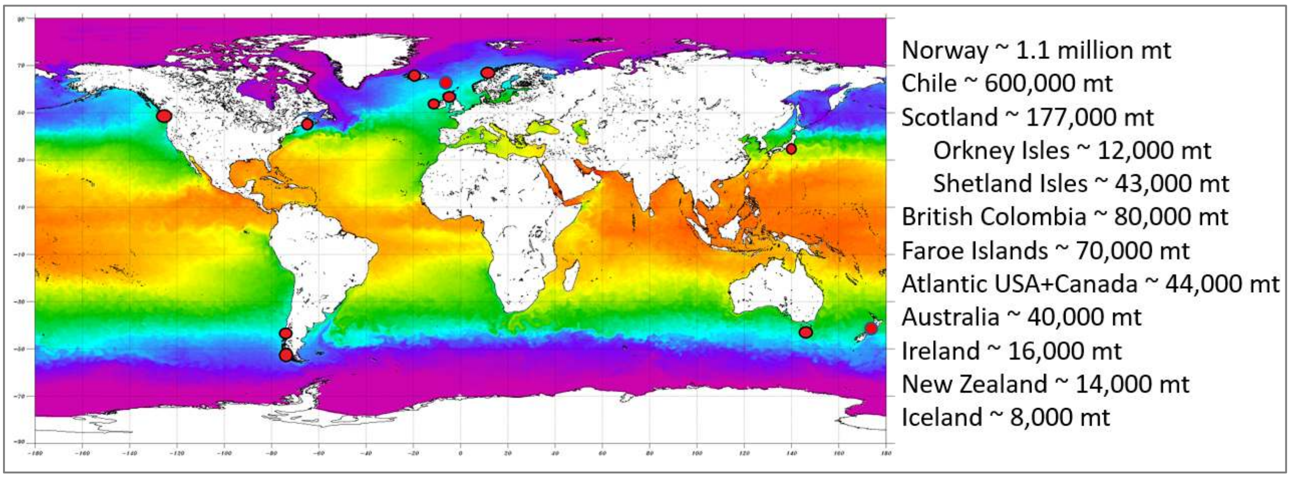

Figure 1: Global sea surface temperature map with salmon farming regions highlighted (red spots) and country-specific farmed salmon production figures. The pale blue map colour represents an average annual water temperature of 11°C. Base map is copied from NOAA.

1.3 - Economics

Farmed salmon is an important export in every region it is produced, and globally worth approximately £12.5 billion GBP per year wholesale. The value of Chile's farmed salmon exports was £4.6 billion in 2017; it is the largest agricultural export from British Columbia representing 40% of total exports and represents 20% of GDP in the Faroes. It is also Scotland's top food export accounting for 40% by value and £400-500 million.

1.4 - Farmed Species

More than 90% of global production is currently of Atlantic Salmon (*Salmo salar*). Other species include Chinook (*Oncorhynchus tshawytscha*) farmed in New Zealand and small amounts in British Columbia, and Coho (*Oncorhynchus kisutch*) farmed in small amounts in Chile and Japan.

1.5 - Production cycle basics

The salmon farming production cycle lasts about 3 years in total. Salmon eggs from domesticated breeding stocks are hatched and grown to approximately 150 to 250 grams in freshwater; this is typically conducted in tank-based indoor facilities using recirculated water (see Figure 2) and takes 10-16 months. The fish, now ready for life in seawater, are transported (typically by boat) to coastal net pens where they are grown to around 4-6 kg over a period of 14-24 months (see Figure 3). Appendix 2 has more details on the stages of production. After the fish are harvested, the site is typically fallowed for between 2 and 6 months before the next generation of fish is stocked at the same location.

Figure 2: Example of a salmon hatchery and 10 million smolt facility. Image – Nova Austral.

Figure 3: Example of net pen growout site (Shetland Isles) with feed barges and work boat. Surface components of the mooring system can be seen. The pens are covered with bird netting. Image – Andrew Schneider.

1.6 - Regulations and Management

Salmon farming is a mature industry and predominantly occurs in temperate developed countries that typically have relatively comprehensive regulations and data availability. For example, the regulatory framework in Scotland is internationally regarded as a benchmark standard; nevertheless, despite apparently comprehensive and burdensome regulatory procedures, the robustness of both the content and enforcement of aquaculture regulation is typically contested in all regions. Further details in Section 5.

1.7 - Industry Requirements

Fundamental siting requirements relate to water temperatures (the natural temperature range for Atlantic salmon is 0 - 20°C with the optimum for farming being between 8 and 14°C), depth minimum of 20m (some sites in Norway are more than 850m deep, whereas the entire Orkney Isles industry is in less than 35m), shelter from extreme weather conditions, and with moderate currents (ideally average current speeds >10-15 cm per second). While typical water depths in the Falklands are at the shallow end of the spectrum (20-40m), other conditions are ideal. A pilot salmon farm project in the Falkland Islands established at Fox Bay in 1985 demonstrated that Atlantic salmon responded positively to the conditions with optimism for the potential to expand production.

2 - Salmon Farming in the Falkland Islands – Practical Implications

2.1 - Siting – scale of production

A commercially viable scale of production in the Falkland Islands is considered to be approximately 35,000 mt. Ongoing discussions with the Pisco Group indicate initial planned production of 50,000 mt. Successful initial production in the Falklands is likely to attract interest in further expansion. Existing small island groups with similarities to the Falkland Islands can be used as examples of the likely siting density in the Falklands, particularly the Faroe Islands, Orkney Isles and the Shetland Isles. Figure 4 and Table 1 show the relevant scales of three representative island groups that currently have mature salmon farming industries.

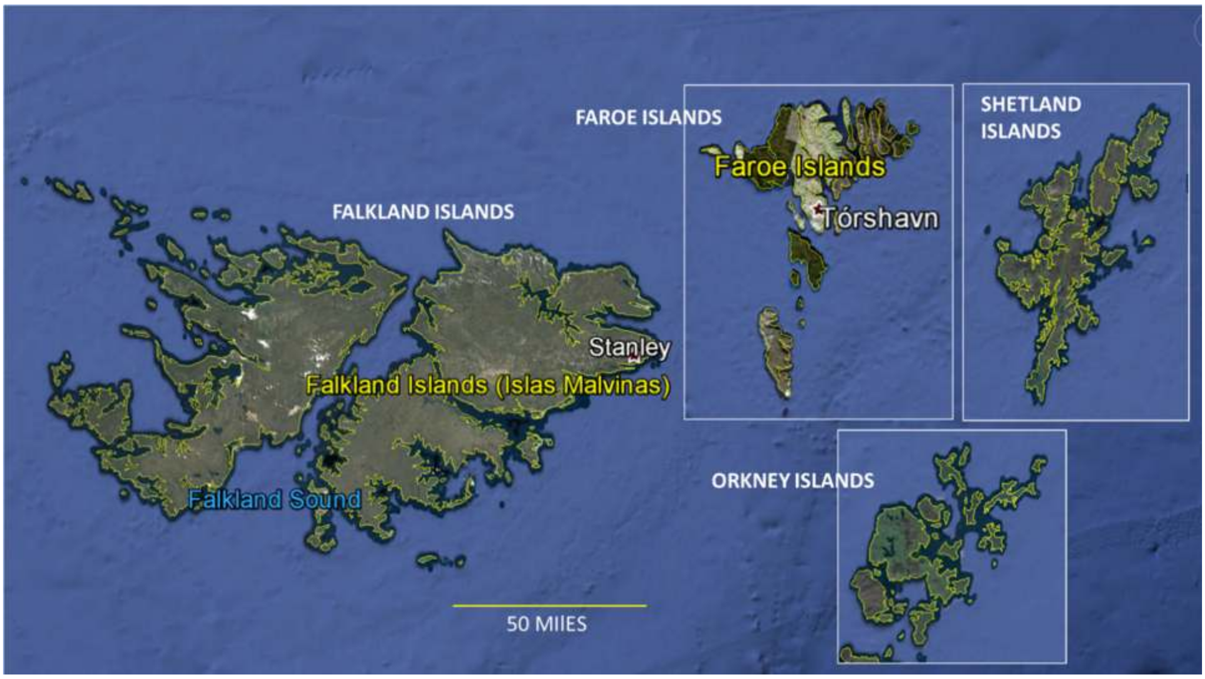

Figure 4: Maps of representative salmon farming regions compared to the Falkland Islands showing the relative size of the Faroe Islands, and the Shetland and Orkney Isles in Scotland. The scale is the same for each. Associated regional production figures are shown in Table 1. Images copied from Google Earth.

Table 1: Farmed salmon production figures for representative farming regions in comparison to the Falkland Islands. Note the total number of registered sites is typically higher than these figures for "active site"[1].

Country	Farmed Salmon Production (mt)	Active Salmon Sites	Coastline Length (miles)*	Land area (square miles)	Population
Faroe Islands	70,000	22	687	540	49,000
Orkney Isles	12,000	12	760	382	20,000
Shetland Isles	43,000	35	1,474	566	22,000
Falkland Islands	50,000	-	2,500	4,700	3,200

*Estimates; available figures are highly variable.

Figure 5 shows a map of the salmon farming sites in the Faroe Islands, and even 10 years ago when production was approximately 40,000 mt, it was noted that "there is a farm site in almost every suitable bay and fjord in the Faroe Islands".

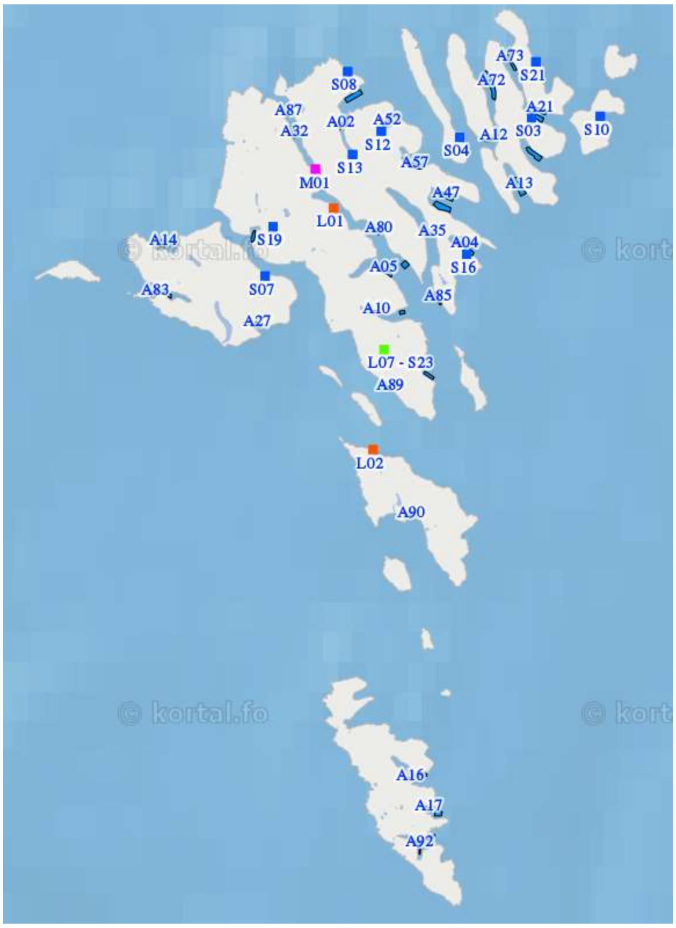

Figure 5: Map of Faroe Islands salmon farming operations. Labels prefixed "A" are grow-out sites, "S" are smolt sites. The remainder include hatcheries and broodstock sites. Image from www.kortal.fo.

[1] Scotland had 253 registered marine salmon sites in 2016, of which 136 were actually in production at any one time.

While the Falkland Islands are substantially bigger in area and coastline than the Faroes, it is clear that the introduction of a 50,000 mt salmon farming industry will have a substantial physical "presence" in the Falklands. Based on averages of production per site from different regions, there would be expected to be approximately 15-30 active grow-out sites initially in the Falklands to produce 50,000mt of salmon. The closed-containment option, often promoted for its potential to reduce direct environmental impacts by growing salmon in land-based tanks, is not currently considered to be commercially viable in the Falkland Islands.

3 - Issues: potential environmental impacts of salmon farming

The ubiquitous floating net pen system for growing salmon to harvest size (Figure 3) is "open" to the surrounding environment through the direct exchange of water, effluent wastes, chemicals, pathogens, and parasites. And even with current best practices, the system is inherently vulnerable to storm damage and human error. There is a substantial body of literature on the primary environmental impacts of salmon farming (and only a tiny amount is referenced here), yet in many cases, the impacts are complex, nuanced, and highly variable in each region. There is still considerable uncertainty and debate with regard to the actual impacts in any one production region; therefore, there is inevitably some uncertainty in describing the potential impacts of salmon farming in the Falkland Islands. This will be exacerbated by any limitations in the baseline knowledge of environmental conditions in the Falkland Islands. Very brief summaries on key impacts are provided below.

3.1 - Environment - Pollution

Salmon excrete both soluble and particulate wastes primarily as a result of incomplete digestion and absorption of their feeds. Emissions of dissolved nutrients from aquaculture can lead to increased plankton growth, and a greatly increased supply of organic material to the seabed communities.

3.1.1 - Soluble Nutrients in the Water Column

Given the current scale of human activities in the Falkland Islands, the production of 50,000 mt of salmon would represent the dominant anthropogenic nutrient input into the coastal environment[2]. Despite this, coastal nutrient dynamics and primary productivity in salmon farming regions are typically dominated by natural factors. Salmon farm wastes in the water column are usually not detectable beyond 100 m from a salmon farm, and while some questions remain about potential cumulative impacts from multiple proximal farms, it is considered unlikely that there will be significant impacts in the Falkland Islands unless large and/or multiple sites are concentrated in poorly-flushed water bodies.

3.1.2 - Particulate wastes on the seabed.

Salmon feces and uneaten food settle on the seabed in an area controlled largely by the water depth and the current speed; as a result, they generate a localized gradient of organic enrichment in the underlying and adjacent sediments. In depositional sites[3] this has profound impacts on organisms directly under the net pens, but the effects rapidly dissipate and decrease exponentially with increasing distance from the edge of net pens such that impacts are typically not observable at 100m from the farm. Farms located in erosional sites[4] with fast currents and can effectively disperse wastes and increase production in seabed communities.

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[2] This is the case in the Faroe Islands. The population is approximately 49,000, but fish farming is the main anthropogenic nutrient input into surface waters.

[3] Sites with low mean current speeds of approximately < 9 cm s^{-1} with mud and sediment seabeds.

[4] Sites with high mean current speeds of approximately >15 cm s^{-1} with a seabed dominated by rock, cobble and gravel and shell hash.

While the impact area can be largely predicted using depositional models[5], it is important to note that salmon farms will impact sensitive species such as the CITES-listed cold water wire-, hard- and lace-corals identified in the Falkland Islands unless care is taken in siting. This type of impact is currently identified as being poorly-understood in Norway and Chile, and the Falkland's Shallow Marine Surveys Group (SMSG) also recognises the limited understanding of the Island's underwater biodiversity and therefore of the species potentially impacted.

3.2 - Escapes of Farmed Atlantic Salmon in the Falkland Islands.

The escape of salmon from farms is considered to be inevitable. Large scale catastrophic escape events involving hundreds of thousands of fish may occur due to storm damage or human error, and large cumulative numbers of fish can also "trickle" escape during routine farm operations. Recent high-profile escapes such as the loss of 930,000 salmon weighing 3.4 kg from a salmon farm in Chile in July 2018 illustrate the ongoing vulnerability of the net pen production system (about 250,000 have been recaptured). Unlike several other species of salmonid which have been successfully introduced all over the world, Atlantic Salmon have been shown to be poor colonizers beyond their native range; the only self-sustaining populations established outside the specie's native range are in the Faroe Islands in the North Atlantic. Prior attempts to establish Atlantic Salmon in the Falkland Islands have not been successful but given the potential for farmed salmon to escape in varying numbers and sizes, and at different locations and different times of year, the potential for their establishment cannot be entirely dismissed.

Even without formal establishment of Atlantic salmon, direct ecological impacts from predation or competition with native fish are possible, but studies of Atlantic salmon beyond their native area have generally shown a poor ability to feed and survive after escape. It is also important to note that even if a species is considered highly unlikely to establish, the repeated introduction of farmed fish into the wild from escape events or trickle losses can still effectively maintain the presence of the species in the wild. Although the Falkland Islands have an impoverished freshwater fish fauna, the current concern regarding the impact of introduced Brown Trout (*Salmo trutta)* on the indigenous Zebra trout and Falklands Minnow would be indicative of concerns were Atlantic Salmon to escape or become established.

3.2.1 - Triploid Fish

If sterile triploid Atlantic salmon are used on farms, it should be noted that while the triplody process can be >98% effective, it is not 100% effective. Therefore, there are likely to be some reproductively viable fish within a farm population. In addition, escaped triploid fish may still migrate into freshwater and have ecological impacts on local fish populations. Triploids are not currently widely used in commercial salmon farming due to reduced growth performance, but a commitment to use them in the Falklands would be considered to further reduce the risks as discussed above.

3.3 - Wildlife interactions

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. Pinniped seals and sea lions are typically the greatest problem, but the once common practice of shooting nuisance seals at salmon farms has been greatly reduced due to better use of predator nets (underwater for seals and above water for birds) and increased awareness. Salmon farms in British Columbia salmon farms shot over 600 seals and sea lions per year in the late 1990s but killed less than five in 2016. Small numbers of seals also become accidentally entangled in the nets, as do small numbers of seabirds. Occasionally, larger marine

[5] E.g. DEPOMOD and AUTODEPOMOD

mammals have become entangled in salmon farm mooring systems, such as three humpback whales on separate occasions in British Columbia in 2016 (two of which died).

In addition, the simple presence and daily operations of salmon farming (e.g. greatly increased coastal boat traffic, underwater sound, and the use of acoustic deterrents for seals) can disturb, alter the behaviour of, or exclude sensitive species. The preference for coastal, shallow waters and river-influenced habitats by Chilean dolphins puts them in direct conflict with a growing aquaculture industry, and aquaculture operations might negatively affect their movement, distribution, and behavioral patterns to the extent that it represents a potential threat to their populations. There is little indication that penguins interact directly with salmon farms (for example in Chile), but general disturbance is likely to be a concern in some areas. In general, animals with limited plasticity (i.e. a limited ability to avoid or adapt to disturbance) are likely to be the most vulnerable.

Given the Falkland Island's important fauna, any potential interactions with an inshore salmon farming industry are likely to be a significant concern. The most likely species to interact directly with farms appear to be southern sea lions, Commerson's and Peale's Dolphins, and any bird species that would be attracted to the net pens.

3.4 - Chemical Use

The expansion of commercial aquaculture has necessitated the routine use of veterinary medicines to prevent and treat disease outbreaks, assure healthy stocks, and maximize production. There is considerable regional variation in salmon farming's chemical use; for example, due to a predominance of viral diseases and effective vaccines in Norway, antibiotic use is very low, whereas with a predominance of bacterial pathogens in Chile and a lack of effective vaccines, Regions X and XI have extremely high antibiotic use[6]. These Chilean regions also have extremely high pesticide use to treat parasitic sea lice. In contrast, with little presence of the bacterial disease Salmonid Rikesttsial Septicaemia (SRS) or sea lice in Chile's Region XII, antibiotic and pesticide use are currently minimal. Regional variability in chemical use is driven by the local presence of different types of pathogen and parasites, and also by the scale and intensity of farm production.

Pesticides are applied either in-feed, or as bath treatments. Applications in-feed lead to an accumulation on the seabed in uneaten feed and in feces. The release of bath treatments results in a pesticide plume in the water column. Excessive pesticide use can affect non-target organisms in the vicinity of farms (particularly crustaceans). Antibiotics are typically applied in-feed, and the types used (typically listed as highly important to human medicine by the World Health Organization[7]) can affect microbial communities in the seabed and contribute to the development of antibiotic resistance in human and veterinary pathogens.

Given the Falkland Islands proximity and biogeographical connections to Region XII in Chile, it might be hoped that chemical use may also be minimal, however there is no assurance that the disease and parasite problems of Regions X an XI will not move further south, and indeed anecdotal evidence indicates this is already happening. In addition, the species of sea lice affecting farms in southern Chile are less responsive to the non-chemical methods currently gaining traction in north Atlantic salmon farming regions.

[6] Chile uses nearly 1,800 times as much antibiotic as Norway (the world's largest salmon producer), despite producing less than half as much fish.

[7] For example, the most common antibiotics used in salmon farming are Florfenicol and Oxytetracycline – both listed as "highly important to human medicine" by the World Health Organization.

3.5 - Disease

Bacterial diseases, viral diseases, and parasites are realities of intensive salmon farming; for example, the economic costs of disease and parasites in Chile are currently approximately £570 million and £290 million respectively per year. The industry in Chile was previously devastated by a disease outbreak caused by the Infectious Salmon Anemia virus (ISA) in the late 2000s. While it is possible that the environmental conditions and a carefully controlled industry in the Falkland Islands could avoid severe disease outbreaks, the experiences in Chile, and in other salmon farming regions, indicate this is unlikely in the longer term[8].

While there is a significant concern (but limited evidence) regarding the potential transfer of bacterial and viral diseases from salmon farms to wild fish, sea lice dispersed from farms have been shown to impact wild fish that either inhabit or migrate through salmon farming areas[9]. The presence of sea lice in the Falkland Islands is uncertain but highly likely, and as the Falkland Zebra trout and the Falkland Minnow are considered to spend time at sea when they are young (Ross, 2009), they may be particularly vulnerable to sea lice from salmon farms. Although not a native species, the brown trout could also be impacted, as it is in Norway and Scotland. The Chilean louse species *Caligus rogercresseyi* has also been reported from the Argentinean coast of south America, and is a host generalist (that is, it can infect many species of fish). Quantifying the potential impacts of sea lice on wild fish populations is complex and contested, but it is considered likely that sea trout (and char) were negatively impacted by sea lice along most of the coast of Norway in 2016.

In addition to ecological impacts, severe disease outbreaks cause large perturbations in the industry, economic losses, and are often accompanied by sudden changes in employment and social conditions (see section 4.1 below).

3.6 - Feed

Even if a feed mill were to be established in the Falklands, a salmon farming industry would have to accept the environmental and social impacts of the production of the ingredients used to formulate salmon feed. Life cycle assessments of salmon farming show that over 90% of the total environmental impact from egg to the harvested salmon is embodied in the production of feed ingredients, and the majority of those impacts do not occur in the country where the salmon are produced (i.e. the impacts occur where the feed ingredients are produced, and include habitat loss, pollution from fertilizer and pesticides, energy use, water abstraction etc). While there is clear potential for marine ingredients such as fishmeal and fish oil to be produced in the Falkland Islands, few other suitable feed ingredients (commonly soy, rapeseed, wheat) are currently produced locally, all these impacts would occur in other countries. In addition, it is important to note that once produced, the efficiency with which salmon retain key nutrients provided in feed is low; for example, only approximately 28% of the protein provided in the feed is retained in the salmon (see the pollution section above).

3.7 - Introduction of non-native species

The expanded and occasionally irresponsible global movements of live aquatic animals have been accompanied by the transboundary spread of a wide 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. Catastrophic disease outbreaks such as ISA in Chile

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[8] Sea lice moved south in Chile as the salmon farming industry expanded from Region X to Region XI, and although sea lice were previously considered to be absent in Chile's Region XII, they are now sufficiently prevalent that they require treatment with pesticides. The same lice species has also been reported from the Argentinean coast of south America.

[9] Sea lice levels on wild fish within 30 km (~19 miles) of one or more salmon farms in Norway were positively correlated with lice loads on those farms.

have been linked to the importation of infected salmon eggs. At least in the initial stages of salmon farming in the Falkland Islands (for example until local hatchery production is established), it is likely that there would be a substantial transfer of live fish (e.g. potentially smolts shipped from hatcheries in Chile) or eggs (most likely imported from biosecure facilities in Europe), perhaps in addition to equipment and personnel from Chile or elsewhere. Although modern salmon hatcheries have moderate to high biosecurity, a risk of introducing non-native pathogens or other organisms remains.

4 - Issues: potential social impacts of salmon farming

Given the unique culture of the Falkland Islands, its small population and the lack of significant unemployment, the social, cultural and community impacts of an inshore 50,000 mt salmon farming industry would likely be substantial. At the simplest level, a new industry would have a substantial "presence" in the Falklands. More explicitly, the underlying issue is that salmon farming represents a use of marine resources that is distinct from traditional activities, that puts pressure on urban services and infrastructure, brings in new people and culture, and many times competes for labour or with the development of other economic activities such as tourism. The acceptability of a salmon farming industry is thus constantly questioned.

It is important to note that defining the consequences of such changes as positive or negative is in the hands of each person, according to their relationship and experiences with the new industry. Unfortunately, few sociological studies have been conducted on aquaculture in developed nations, and the research focus remains on economic and societal conflict around resource use, environmental concerns, and potential recreational/leisure conflicts. Given that a great deal of contextual variability around aquaculture in communities remains, and many important questions are still unanswered, predicting the social impacts of the introduction of salmon farming to the Falkland Islands is challenging.

4.1 - Employment

An example of the current personnel required to produce 30,000 mt salmon in a remote region of southern Chile is shown in Table 2. These numbers should not be considered to extrapolate directly to the proposed 50,000 mt production, or to the specific circumstances in the Falkland Islands, but they give an indication of the full-time employees that might be required (note feed production is not included).

Table 2: Breakdown of employees at 30,000 mt salmon farm operation.

Operations	Full time personnel
Farms (includes harvest team, veterinarians, technical support)	236
Administration (includes logistics, HR, accounts, etc)	57
Fresh water hatchery and smolt production	27
Sales, cold storages and finished products logistic	10
Management team and miscellaneous	7
Processing*	465
Total (not including processing)	**337**
Total (including processing)	802

* It is likely, at least initially, that processing will be done outside the Falkland Islands.

For further examples, the largest salmon farming company in the Faroe Islands, Bakkafrost, employed 1,104 full time equivalents (FTEs) to produce, process and market 54,600 mt of salmon in 2017; and Scotland employed 267 FTEs in hatcheries, 1,310 FTEs in production, and 3,225 FTEs in the processing of 171,000 mt. .

On Canada's east coast, the New Brunswick's government states that the 25,000 mt salmon industry generates in excess of 2,000 direct and indirect jobs. While there are some regional differences, the basic salmon farming production system is very homogenous across them, and these figures include modern labor saving production techniques.

Regarding employee composition, Figure 6 shows a breakdown of Bakkafrost employees in the Faroes, categorized by sex, age and FT/PT employment. It is of relevance to the Falklands note that the Faroe Islands also have a very low unemployment rate of 2.2% (and Bakkafrost is the largest private employer on the islands), but the total Faroes population is approximately 49,000 compared to the Falkland's <3,000.

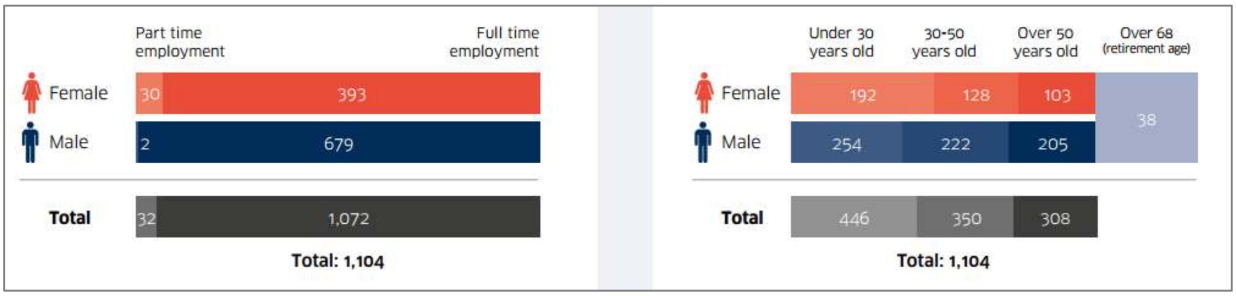

Figure 6: Example of a salmon farming company's employees categorized by sex and age in the Faroe Islands. Graph from Bakkafrost.

Employment in salmon farming can be volatile, and aquaculture in general can cause unwanted societal effects when it produces boom and bust cycles or otherwise collapses; for example, due to disease outbreaks, food safety recalls, or natural disasters. During the ISA disease outbreak in the Chilean salmon farming industry, the unemployment rate in the Puerto Montt region increased from 4% to 13% during 2008 and 2009, and then returned to 4% in 2011 following the recovery. In 2016, an algal bloom in Chile killed large numbers of farmed salmon and resulted in 5,000 job losses. Such algal blooms have been noted in the Falkland Islands, and may occur more frequently with climate change.

4.2 - Economic Impacts (figures in GBP)

Understanding the economic benefits to the specific communities engaged in salmon farming is complex. In many cases, after intense consolidation of smaller companies[10], a small number of very large companies dominate and are listed on international stock exchanges. Their operational focus is on production for profit, and they rely on local environmental ecosystem services and to some degree on a community acceptance or "social license", but they also return money to those communities through salaries, payments for services and corporate taxes etc.

Direct returns to local governments from site leasing/licensing are highly variable across regions; Scotland has a basic lease fee from the Crown Estate of £27.50 per mt of production, British Columbia also has a minor fee of £1.55 ($2.65 CAD) per ton, and the Faroe Islands government receives up to 4.5% of a company's calculated annual revenue[11] as a license fee. In contrast, in June 2018 the Norwegian government auctioned 14 new site licenses with a total capacity of 14,945 mt of production for £275 million (NOK 2.9 billion) (i.e. approximately

[10] There were sixty small scale salmon farming companies in the Faroe Islands in the 1980s; now there are three.

[11] The "revenue" is calculated as total production (gutted weight) multiplied by the average world market salmon price.

£20,500 per ton of production, or £19.6 million per site). Various additional but lesser costs are associated with environmental licenses and inspections etc[12].

The salmon farming industry is keen to promote its perceived positive community benefits; for example, the International Salmon Farmers Association promotes “the economic prosperity the sector creates in coastal communities around the world”. In British Columbia, the 92,800 mt per year industry claims it directly contributes £24 million in federal, provincial and municipal taxes, and indirectly contributes £50 million in taxes. Overall this industry claims it contributes over $1.1 billion dollars (£644 million) annually to the provincial economy and provides about 5,000[13] year-round full-time jobs in B.C.'s coastal communities - paying 30% higher than B.C.'s median income. The New Brunswick government states that the 25,000 mt salmon industry contributes over $30 million in wages and benefits to the economy on an annual basis. Bakkafrost, the largest producer in the Faroe Islands states it has contributed approximately £15 million GBP into the islands’ economy per year in corporate taxes. In Scotland, salaries to all associated local workers in the salmon farming industry are estimated at £270 million per year.

4.3 – Implications for government; an example from the U.K.

The Scottish Government is supportive of the sustainable growth of aquaculture as set out in Scotland’s National Marine Plan, but the current aquaculture consenting and permissions regime has been amended and added to as the industry has developed and now comprises a highly complex set of legislation, guidance and advice that cascades from the Scottish Government down to the statutory planning authorities. An overview of licences, consents and assessments required for Scottish finfish aquaculture is shown in Appendix 3.

At the Scottish Government level, the National Planning Framework sets out the statutory strategy for Scotland’s long-term spatial development and is supported by Scottish Planning Policy. In addition, Scotland’s National Marine Plan adopted in 2015 sets out objectives and marine planning policies for aquaculture, meeting obligations required under the Marine (Scotland) Act 2010. The Scottish Marine Regions Order 2015 sets out the boundaries for eleven marine regions, and the UK’s Operational Programme for the European Maritime and Fisheries Fund requires the Department for Environment, Food and Rural Affairs (DEFRA) to produce a multi-annual plan for the sustainable development of aquaculture. The Government also has a Strategic Framework for Scottish Aquaculture (2009) which also calls for improved systems for licensing aquaculture developments.

A Government Ministerial Group for Sustainable Aquaculture (MGSA) supports Scotland’s aquaculture industry to achieve its 2020 growth targets, and includes a Capacity Working Group, a Containment Working Group, a Wellboats Working Group, a (wild fish) Interactions Working Group, and a Farmed Fish Health & Welfare Working Group. Previously there was also an Aquaculture Planning Taskforce and an Improved System for Licensing Aquaculture Development (ISLAD) Working Group. ISLAD oversaw the implementation of Delivering Planning Reform for Aquaculture (DPRA), and set out a Working Agreement between Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage (SNH), Marine Scotland Science (MSS) and District Salmon Fishery Boards (DSFBs) in how they provide advice to Local Authorities to inform Planning Permission decisions for fish farms.

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[12] An example of the Scottish Environmental Protection Agency’s 2018 environmental regulation charging scheme can be found here: https://www.sepa.org.uk/regulations/authorisations-and-permits/charging-schemes/charging-schemes-and-summary-charging-booklets/

[13] This figure is considered to include all secondary jobs in added-value processing, marketing, distribution and so on throughout the seafood supply chain downstream of the harvested “farm-gate” product.

Just the consent process for a new finfish site in Scotland (i.e. before regulation of production begins) takes over two years (elaborated graphically in Appendix 4). Overall, although the Scottish system is considered by the government to be robust, it has evolved into a complex system. It is challenging to associate any financial cost of these activities, but even if some of the Scottish inefficiencies could be avoided in the Falklands, it is clear that the role (and therefore the human and financial resources) of the Island's government in the sustainable development of salmon farming will not be insignificant.

4.4 - Changing Cultures and Livelihoods

As an example from rural and remote areas, industry proponents in Scotland claim aquaculture provides a range of social and community impacts in areas where farms and related activities are located:

• increased local populations and improved age structures through new employees and their families moving in, and people not having to leave their home area for work.
• additional employment and income (some of which is spent locally).
• new and enhanced skills with employment that has proved sustainable over time.
• more families in rural and remote areas which improves the demographic structure and sustainability of communities.
• the important work carried out locally by partners of aquaculture employees (teaching, nursing, etc.).
• roles that staff and their families play in voluntary activity (including coastguard, fire services, etc.).
• the contribution made by employees' children to the survival of local schools with small rolls; use of company harbour facilities for other commercial and leisure purposes.
• the survival of small local businesses (hotels, fuel supplies, local maintenance services, etc.).
• financial support that companies have given to local groups and causes, enabling events and activities to take place and for people to travel to participate in activities elsewhere.

In contrast, there is typically community and environmental opposition to salmon faming wherever it is practiced; for example, in the Faroe Islands, the local environmental NGO claims the continuous and highly unsustainable growth of the industry destroys natural environments and sustainable uses of the fjords, and exerts a strong influence on the politics in the Islands despite local opposition to salmon farming projects.

The day-to-day operations of a 50,000 mt salmon farming industry are likely to substantially increase inshore boat traffic and cross-island land traffic for the servicing of growout sites, shore bases, a hatchery and other operations. Importation of equipment and services will likely be substantial, in addition to other routine activities such as net cleaning, net repair, boat and other equipment maintenance, veterinary and fish health support, harvest and associated handling/export. Energy use will be substantial, and there is likely to be an increase in plastic waste, redundant equipment, noise, odours, and light. Appendix 4 gives an indication of the secondary activities associated with salmon farming.

As a practical example the authorization of twenty-six salmon farming sites in Chiloé Island in Northern Patagonia (an island with a distinct culture and isolated rural identity) brought a scale of production totally foreign to the locals and began a transformation of the island and its towns. While attractive due to fixed and stable salaries (and therefore representing a move away from the economic uncertainty of traditional work), it's arrival led to the abandonment of fields and subsistence fishing to engage in paid work delivered the industry. Demonstrably sustainable activities that protected ancestral knowledge handed down from generation to generation were replaced by globalized industrial salmon farming. Gradually new and larger warehouses were built along with housing construction for industry workers, and the municipality began to generate new projects to cover the basic needs of the population. Greater connectivity was made with other population centres with new transportation to reach them. Without a doubt, the changes boosted development in terms of economic growth, and in some respects took the small towns of Chiloe out of economic lethargy, but others see economic transformation that Chiloé experienced as a social and cultural setback.

As stated previously, the most important aspects with regard to understanding potential social impacts of a new salmon farming industry in the Falkland Islands are firstly that the changes will be somewhat unpredictable, and secondly, that defining the consequences of such changes as positive or negative is in the hands of each person according to their relationship and experiences with the new industry.

5 - Challenges for the industry and for the Falkland Islands

5.1 - Baseline data deficiencies.

Access to baseline knowledge prior to development (as discussed above) is important for informed and effective decision making and planning. Documenting the state of the environment is one component of Strategic Environmental Assessment (SEA) within a broader Sustainability Assessment (SA).

Despite a large area of the Falkland Islands territory being shallow marine waters, little is known about these habitats and there are few conservation measures in place to protect them. The Falkland's Shallow Marine Survey Group has a number of reports on marine organisms around the islands, but the group also notes the Falkland Island's biodiversity is one of the least known in the world.

Important aspects of the life cycles of key species such as the Falkland Zebra trout and the Falkland Minnow are uncertain (for example whether they spend significant time at sea when they are young), yet understanding these aspects is essential to determining the potential impacts of salmon farms. The populations of these species in addition to many seabird, whale, dolphin and seal species are already exposed to a range of existing threats. As such, the lack of baseline data on most species and habitats in the Falkland Islands presents the biggest challenge in predicting the potential impacts of a salmon farming industry with regard to effective planning and decision making.

A useful example of planning can be seen in Chile's southernmost XII Region of Magallanes and Chilean Antarctica (this area is relevant to the Falklands because the rich marine flora of Patagonia, Tierra del Fuego and the Falkland Islands appears to form a discreet biogeographical grouping). A systematic planning process involving 74 experts and other stakeholders was undertaken to identify High Conservation Value Areas in the channels and fjords, and this area is of great interest for further salmon farming development in Chile. Using 39 conservation features, a portfolio of 33 High Conservation Value Areas covering 12% of the ecoregion was suggested. They also proposed a series of "Appropriate Areas for Aquaculture" and noted that despite some overlap between the aquaculture areas and some conservation features, all the proposed conservation targets could be met. Even so, it is important to note that the proposed aquaculture areas were in remote places where fine-scale data are lacking, and therefore their perceived lack of apparent potential conflict with their conservation targets may simply reflect the lack of data.

5.2 - Understanding likely Impacts

Determination of the likely environmental impacts of a new activity is also a phase of a SEA. This is linked to the baseline data deficiencies described above, but specifically relates to the limited understanding of salmon farming's impacts in general. Although many impacts have been comprehensively studied and there is some agreement at least in terms of determining "direction of change" indicators (and outlined in Section 3 above), quantifying potential impacts within the discreet characteristics of the Falkland Islands is difficult. Even within a comprehensive SEA and SA, there is still ample potential for different stakeholders to interpret or apply the available salmon farming scientific literature from a polarized positive or negative point of view.

5.3 - Infrastructure

The salmon farming production system relies on several practical components, namely suitable sites, containment structures and moorings, juvenile fish (smolts), feed, and a means of harvest and distribution. Of these, producing smolts and feed are the most likely challenges that will result in significant infrastructure in a remote location such as the Falklands (assuming marine sites are available and associated production equipment can be shipped relatively easily). While long-distance transport of feed is common and long-distance transport of smolts is possible, the construction of local smolt facilities is considered a priority to minimize the quality risks of the latter. Feed is expensive (costing 32% of the total costs of production in Chile and 43% in Norway), but is relatively easily shipped to farms in remote location such as the Falklands. Establishment of a feed mill still requires the delivery of all the feed ingredients and raw materials.

5.4 - Mitigation of environmental impacts

Identifying and enacting effective mitigating measures to address the likely impacts of salmon farming in the Falklands is also a challenge. Previous SEA studies in Scotland and the integration of their findings into the management of Scottish salmon farms indicate careful siting and/or the relocation of fish farms away from wild salmon rivers and poorly flushed sites can mitigate against some negative impacts such as interactions with wild salmonids and localised nutrient enrichment, but identifying effective mitigation measures for other impacts is not so easy.

Mitigation against seabed impacts is typically achieved by site-specific environmental impact assessments in addition to the use of modelling systems to define an Allowable Zone of Effect (AZE) and a maximum permitted site biomass (see the Industry Planning section below). Routine seabed monitoring at peak biomass in the production cycle, in addition to fallowing between cycles, typically allows a site to maintain acceptable Environmental quality standards (EQS) at the edge of the AZE on the basis that potentially severe impacts within it are acceptable. More broadly, benthic impacts can also be mitigated by using deep sites with moderate currents that disperse wastes over an area large enough that the per unit deposition is insignificant; however, it appears the majority of potential sites around the bays, inlets and islands in the Falklands will be in depths of 20-40m, and these would not be considered “deep”.

Reducing chemical use hinges on the types of pathogens and parasites present and the availability of effective measures to manage fish health including biosecurity, production intensity, vaccination, and effective non-chemical treatments. It is not possible to accurately predict which species of pathogens and parasites will affect salmon farms in the Falklands, but the current ineffectiveness of mitigation measures to reduce chemical use in neighbouring Chile is concerning. A suite of non-chemical measures against sea lice are being developed by salmon farmers globally, and while these are showing significant benefits against the sea lice species present in the North Atlantic and British Columbia (*Lepeoptheirus salmonis*), they have not been as effective against the smaller species of louse (*Caligus rogercressyi*) found in Chile (and potentially the Falklands).

The reliance on industry best practices and the application of technical standards for the design, construction and operation of salmon net pens (e.g. Norwegian Standard 9415) has demonstrably helped mitigate against escapes, yet large escapes continue to occur. The use of triploid fish would further mitigate against impacts, but as noted in Section 3, this is also not 100% effective.

The effectiveness of mitigation measures against the impacts of pathogens and parasites from salmon farms to wild fish wild fish populations (e.g. by imposing biosecurity measures, siting requirements, veterinary oversight, production limits, management of disease outbreaks, and specific limits on the number of sea lice parasites) continues to be hotly contested, and again varies by region according to their specific pathogen and parasite dynamics.

Mitigating against the introduction of non-native species (not including Atlantic salmon) during the importation of eggs is now done primarily by the use of eggs from biosecure facilities in Europe. As discussed previously, it is possible that prior to the establishment of a hatchery in the Falklands, live smolts would be shipped from Chile (smolts are currently shipped long distances from Chile's Region XIV south to farm sites in Region XII). Despite the use of best practice biosecurity measures, it is difficult to envision fully effective biosecurity measures for such shipments.

5.5 - Industry Planning, regulating, monitoring and enforcing

Many of the mitigation measures discussed above are active at the site- or company-level, whereas many of the impacts are cumulative from multiple sites or areas. Planning and regulation are therefore essential at the waterbody level, and both are greatly enhanced by the SEA process. Although highly recommended, it is not known if a SEA process will be followed in the Falkland Islands, but examples of the regulatory structures in existing salmon farming regions where some form of SEA has taken place may provide useful examples.

The U.K.'s Scottish example is perhaps the most relevant, and (further to Section 4.3 above) the Scottish Environmental Protection Agency (SEPA) contains a large amount of information on the environmental monitoring and licensing process of fish farms. As a brief summary, at the farm level, all operators must be granted a license under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (CAR). The licensing system uses models to determine a maximum site biomass and a site-specific AZE which are based on the predicted response of the seabed's fauna to increases in carbon deposition (specified as the Infaunal Trophic Index at the edge of the AZE).

At the waterbody level, the Locational Guidelines for Marine Fish Farms in Scottish Waters, updated in 2018, predict the abilities of 114 waterbodies in Scotland to tolerate enhanced nutrient levels and carbon deposition and thereby categorizes their environmental sensitivity to aquaculture development. The categories are used in the licensing and biomass limits for the waterbody as a whole and for individual farm sites within it. In Scotland, an AZE is typically in the order of 25 m from the farm (although its shape can be modified according to the dominant hydrographic characteristics - primarily depth and current). The current licensing system is currently under review, and SEPA is consulting on a proposed new system based on a Depositional Zone Regulation (DZR).

In addition to these basic siting requirements, there are many other measures in place in Scotland addressing other aspects of production, and the finfish aquaculture industry has an established Code of Good Practice (discussed in Section 6.3) which is independently audited and adopted by the large majority of producers. Overall, it is clear that substantial planning, ideally through a SEA and SA process, is required; and while the Falklands created a Marine Farming Ordinance in 2006 to allow the licensing of aquaculture sites, it is also clear from the Scottish example and others, that the development of suitable regulatory structures to manage a salmon farming industry in the Falklands will be an important challenge.

5.6 - Monitoring and enforcing

Establishing the ability to monitor the actual effects of new development is another component of a SEA and policy planning. Salmon farming industries in many regions (particularly Scotland and Norway) can be credited with excellent data availability from which publicly available evidence of monitoring and enforcement can be found. Scotland is again a good example for the Falklands, where several Scottish and U.K. agencies are responsible for managing and enforcing regulations and publishing data. The publicly accessible database "Scotland's Aquaculture" includes a large amount of information (partially listed in Table 3). It seems likely that the lack of such authorities and aquaculture management experience will (at least initially) be a substantial challenge for the Falkland Islands and a nascent salmon farming industry.

Table 3: Examples of monitoring and enforcement data available from "Scotland's Aquaculture" database.

Information	Relevant Authority
Site details – name, grid reference, licensing company, activity status	Marine Scotland
Lease area and lease dates	Crown Estate
Site facilities – number of net pens, species and size of fish	Marine Scotland
Fish escapes – species, size, reason, escape #, recapture #	Marine Scotland
Movement restrictions – date and reason (disease) for restriction	Marine Scotland
Licence conditions – maximum biomass, pesticide limits	SEPA
Monthly biomass and treatment reports	SEPA
Annual emissions of copper, zinc, nitrogen, phosphorous, carbon	SEPA
Pesticide treatment residues – levels compared to EQS	SEPA
Environmental Monitoring Surveys – type of survey, date, result	SEPA
Map – All aquaculture sites, marine and freshwater	Marine Scotland
Map – Disease management areas	Marine Scotland
Map - Special Protection Areas with marine components	Scottish Natural Heritage
Map - Locational Guideline Areas	Marine Scotland

6 - Opportunities: can salmon farming be environmentally sustainable in the Falkland Islands

With a global production of approximately two million metric tonnes and a mature industry present in many regions for thirty years, salmon farmers typically argue that their industry is sustainable; however, it is clear (as discussed in various sections above) that there continues to be highly controversial impacts of salmon farming in the main regions. For example, a comprehensive review of major threats to wild Atlantic salmon in Norway in 2017 concluded escaped farmed salmon and parasitic sea lice are expanding population threats that affect wild salmon populations to the extent that they may be critically endangered or lost, with a large likelihood of causing further reductions and losses in the future. The scale of these concerns continues to be highly contested, and this is the case for similar impacts of escapes and sea lice in Scotland, the impacts of sea lice and other pathogens in British Columbia, and the impacts of chemical use in Chile. Nevertheless, there are examples of better practices (and/or better circumstances) in each of these countries.

6.1 - Recognition of better practices

Despite the regional uncertainty in impacts it is possible to see how at least individual farms, companies, or discreet farming areas can be considered to be demonstrably sustainable. For example, the Monterey Bay Aquarium's Seafood Watch program has a green "Best Choice" recommendation for salmon farms in New Zealand (farming Chinook or King salmon), and for an individual company in Norway. It also has yellow "Good Alternative" recommendations for British Columbia as a whole, for the Orkney Isles region of Scotland, and for two companies in Chile and one in Norway.

Farm-level certification is widely adopted in salmon farming. The Global Aquaculture Alliance certifies approximately 40 farms and 4 hatcheries to its Best Aquaculture Practices standards, and the Aquaculture Stewardship Council certifies approximately 200 sites (with more in-assessment) to its Salmon Standard. The approach of these two organisations (at least simplistically on paper) is based on different interpretations of "responsible" aquaculture. The GAA sets standards at a level that recognizes good practices with an emphasis on excluding the worst producers, whereas the ASC standards were set at a level intended to represent the best producers. In practice, this distinction is not so clear, and assessing the true performance of the standards is complex. Certification to either of these standards will almost certainly reduce the risk or scale of impact in the Falkland Islands, but cannot be relied on to address all potential impacts or fully assure "sustainable" production.

The Monterey Bay Aquarium's Seafood Watch program recognizes the ASC salmon standards to be equivalent to a yellow "Good Alternative" recommendation but has not recognized GAA as such (due to less specificity in the standards). Other certification schemes are available including GlobalG.A.P. and Friend of the Sea, but the robustness and effectiveness of these standards is not easy to determine. Finally, organic certification is an option with the U.K.'s Soil Association (or other organic certifiers), typically for niche markets.

6.2 - Circumstances verses Practices

These examples of better practices are typically a combination of better management and locational circumstances. In New Zealand, Chinook salmon is not affected significantly by sea lice or disease, and there is no pesticide or antibiotic use. Although a non-native species, Chinook was deliberately introduced prior to salmon farming and continues to be stocked into the wild by the government, so farm escapes are a low concern. The "green" company in Norway operates alone in a large fjord with low salinity (and therefore low sea lice). It has excellent monitoring data to demonstrate that the company's fish are not present in the wild (i.e. escaped), and that it does not use pesticides or antibiotics (helped by the low salinity and the low production density in the fjord). The Orkney Isles have a high flushing rate and low sea lice problems and therefore low chemical use.

It is possible that the Falkland Islands may be another example of ideal circumstances for sustainable salmon farming. It is possible that Atlantic salmon (especially triploids) won't establish or have any escape impact; it is possible that there won't be any sea lice or pesticide use; it is possible that a low production density, the remote location, and cold water will avoid serious diseases and the use of antibiotics; it's possible that there won't be any impact on native fish, and it is possible that well-selected sites will have minimal benthic impacts and minimal interactions with the Falkland's important bird and marine mammal populations. None of these things, particularly considering the limited baseline data, can be assured.

6.3 - Codes of Good Practice

In addition to regulatory requirements, examples of good salmon farming practices or "best management practices" can be found in Scotland's comprehensive Code of Good Practice for Finfish Aquaculture (CoGP). The CoGP covers all aspects of production in freshwater and marine locations, and while the recommendations are somewhat general in nature, it includes many examples of practices that will almost certainly reduce the risk or scale of impact in the Falkland Islands.

Simplistically, these include:

- Effective limits on stocking density and on the total biomass of fish at each site
- Effective area or waterbody management with limits on total biomass of fish based on nutrient and pathogen carrying capacities

- Effective biosecurity of all operations and including fallowing
- Effective management of fish health to minimize disease and disease transfer
- Effective feed management to optimise nutrient uptake and minimise wastes
- Effective management of site operations (fuel, oils, wastes, noise etc).
- Effective monitoring and reporting of impact-specific parameters

6.4 - Specific opportunities in the Falkland Islands

6.4.1 – Environmental Impacts

With regard to the dominant environmental impacts of salmon farming identified in Section 3, the following is an outline of actions that may enable sustainable farmed salmon production in the Falkland Islands.

<u>Soluble Nutrients in the Water Column</u>

- Locate sites in well-flushed areas.
- Assess carrying capacity in the waterbodies identified as suitable salmon farming locations.
- Establish robust site and waterbody biomass limits (example - Scotland's locational guidelines).
- Conduct baseline and ongoing monitoring of nutrient and phytoplankton levels. Publish results.
- Enforce biomass limits, and reduce them or relocate sites if needed.

<u>Particulate wastes on the seabed.</u>

- Locate sites in well-flushed areas and conduct baseline site assessments (e.g. EIA) to avoid priority species and habitats.
- Define an allowable zone of effect, and acceptable impacts within it, at its edge, and beyond it.
- Conduct benthic monitoring at peak biomass in every production cycle. Publish results.
- Fallow sites minimum 8 weeks between cycles.
- Consider cumulative impacts of multiple sites in waterbodies or larger areas of the Islands.

<u>Escape of farmed salmon</u>

- Companies establish Fish Containment Management Plans and follow established technical guidelines for site construction (net pen construction and mooring), monitoring and maintenance, and operational procedures.
- Ensure site construction is location relevant – i.e. relates to the site-specific and Falklands-specific exposure.
- Use triploid fish.
- Establish recapture capabilities, and establish an ability to activate studies on fish dispersal (e.g. monitoring of local rivers)
- Establish a public platform for the industry to report losses and for the public to report observations of escaped salmon in the wild. Publish results.

<u>Wildlife Interactions</u>

- Assess potential sites (e.g. EIA) and avoid locations of importance (e.g. breeding, foraging, migration) to key species.
- Companies establish Wildlife Management Plans and follow industry best practices on predator net deployment above and below water.
- Prohibit acoustic deterrents
- Establish procedures and circumstances for "exceptional use only" of lethal control for key species.
- Establish a public reporting platform for all mortalities.

- Enforce and relocate/close sites as necessary.

Chemical Use
It is not known which pathogens and parasites (if any) might affect Atlantic salmon in the Falklands. Therefore, in general:

- Limit stocking densities and set site-specific and waterbody biomass limits to minimize the risk of disease outbreak and transfer.
- Ensure professional veterinary oversight for detection and treatment of disease.
- Follow established best practices for antibiotic and pesticide use.
- Prohibit antibiotics listed as “critically important for human medicine”[14], and limit the use of those listed as “highly important”.
- Record and publish antibiotic and pesticide use.
- Consider (if possible) establishing salmon produced in the Falklands as chemical-free (i.e. antibiotics and pesticides).

Disease

- Baseline – confirm the potential interaction of salmon farms with protected endemic fish species (e.g. their migration to marine environments).
- Companies establish Fish Health Management Plans and follow established best practices for all aspects of biosecurity.
- Avoid siting salmon near the rivers of these species.
- Continuously monitor the development of pathogens and parasites in salmon farms and assess (and monitor if possible) the risks to wild fish. Publish fish health records.

Feed
The environmental impacts of feed production occur at distant locations. To maximise efficiency of use:

- Ensure feed ingredients come from sustainable marine and terrestrial sources.
- Use best practices in feeding technology to minimize uneaten feed waste
- Use best practice in feed handling to minimize “fines” (crushed feed pellets).
- Maximise fish health to maintain appetite.
- Consider promoting the use of alternative ingredients, particularly by-products, to reduce the use of human-edible ingredients in feeds.

Introduction of non-native species

- Ensure initial introductions of eggs or smolts come from biosecure sources and are shipped using biosecure methods (e.g. well-boats with closed or treated water exchange).
- Establish local production of eggs and smolts.
- Maintain established best practices for movements of equipment and personnel into the Islands.

6.4.2 – Regulation and management

With regard to the broader regulation and management of a salmon farming industry, Section 4.3 highlighted the complexities that can develop over time in regulatory and management systems for aquaculture consenting and operations. With mature salmon farming industries now operating in many developed countries, a range of examples of regulatory systems and tools are available from which an optimal progressive regulatory system for the Falkland Islands can be developed that rewards best practice.

[14] Listed by the World Health Organization

Appendix 1 - References

1.1 Global Production

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1.2 Regional Distribution

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1.3 Economics

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6 - Opportunities: can salmon farming be environmentally sustainable in the Falkland Islands

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Global Aquaculture Alliance - https://www.aquaculturealliance.org/

Best Aquaculture Practice - https://www.bapcertification.org/

6.3 - Codes of Good Practice

Code of Good Practice - http://thecodeofgoodpractice.co.uk/

Appendix 2 – Farmed salmon production cycle

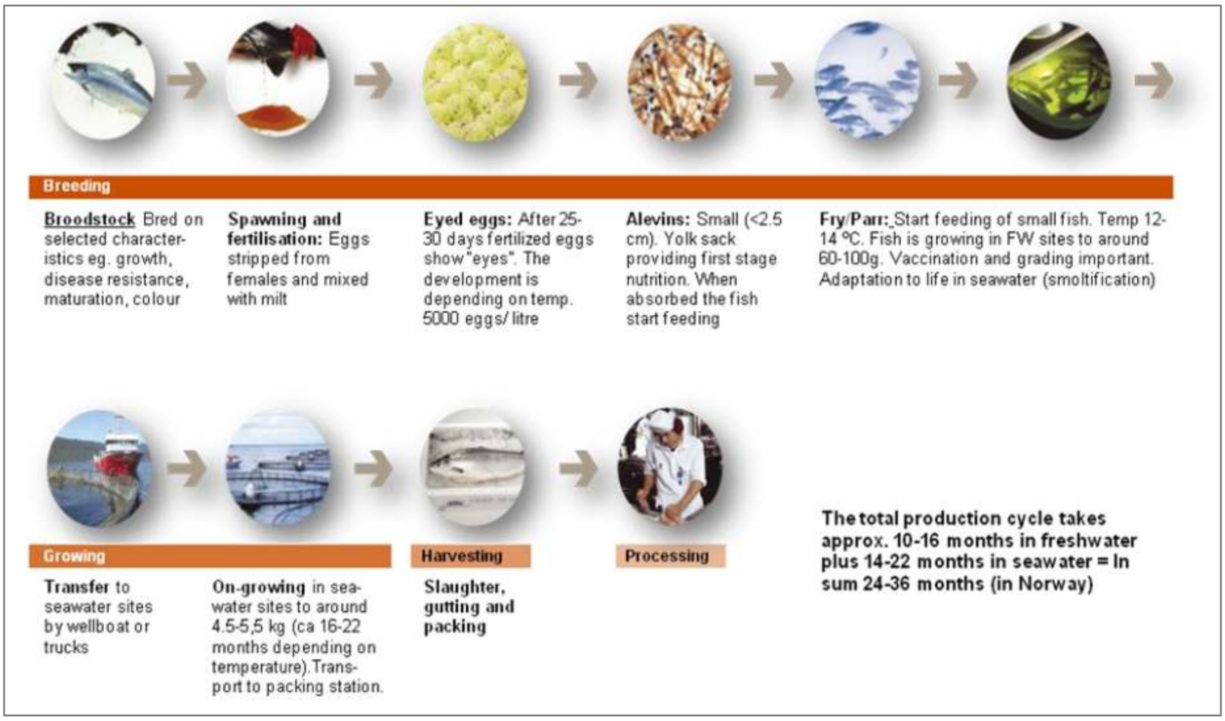

Image copied from Marine Harvest Salmon Industry Handbook, 2018.

Appendix 3 – Summary of licences, consents and assessments required for Scottish aquaculture.

Application	Authorising regulator	Legislation
Planning Permission	Local Authority (LA)	Town and Country Planning (Scotland) Act 1997
Environmental Impact Assessment (if necessary, mainly relevant to FF, but can be required for SF)	Local Authority (LA)	The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011
Marine Licence	Marine Scotland Licensing Operations Team (MS-LOT)	Marine Scotland Act 2010
Seabed Lease	The Crown Estate	The Crown Estate Act 1961
Authorisation to operate an Aquaculture Production Business (APB)	Marine Scotland Science Fish Health Inspectorate (MSS-FHI)	The Aquatic Animal Health (Scotland) Regulations 2009
Controlled Activity Regulations (CAR) licence	Scottish Environment Protection Agency (SEPA)	The Water Environment (Controlled Activities) (Scotland) Regulations 2011
Habitats Regulations Appraisal (if necessary)	All of the above	The Conservation (Natural Habitats, &c.) Regulations 1994 and its amendments
Works Licence	Shetland Islands Council	Zetland County Council Act 1974

Image copied from: Nimmo, F, McLaren, K, Miller, J and Cappell, R. 2016. Independent Review of the Consenting Regime for Scottish Aquaculture. The Scottish Government.

Appendix 4 – Overview of Scottish finfish consent process

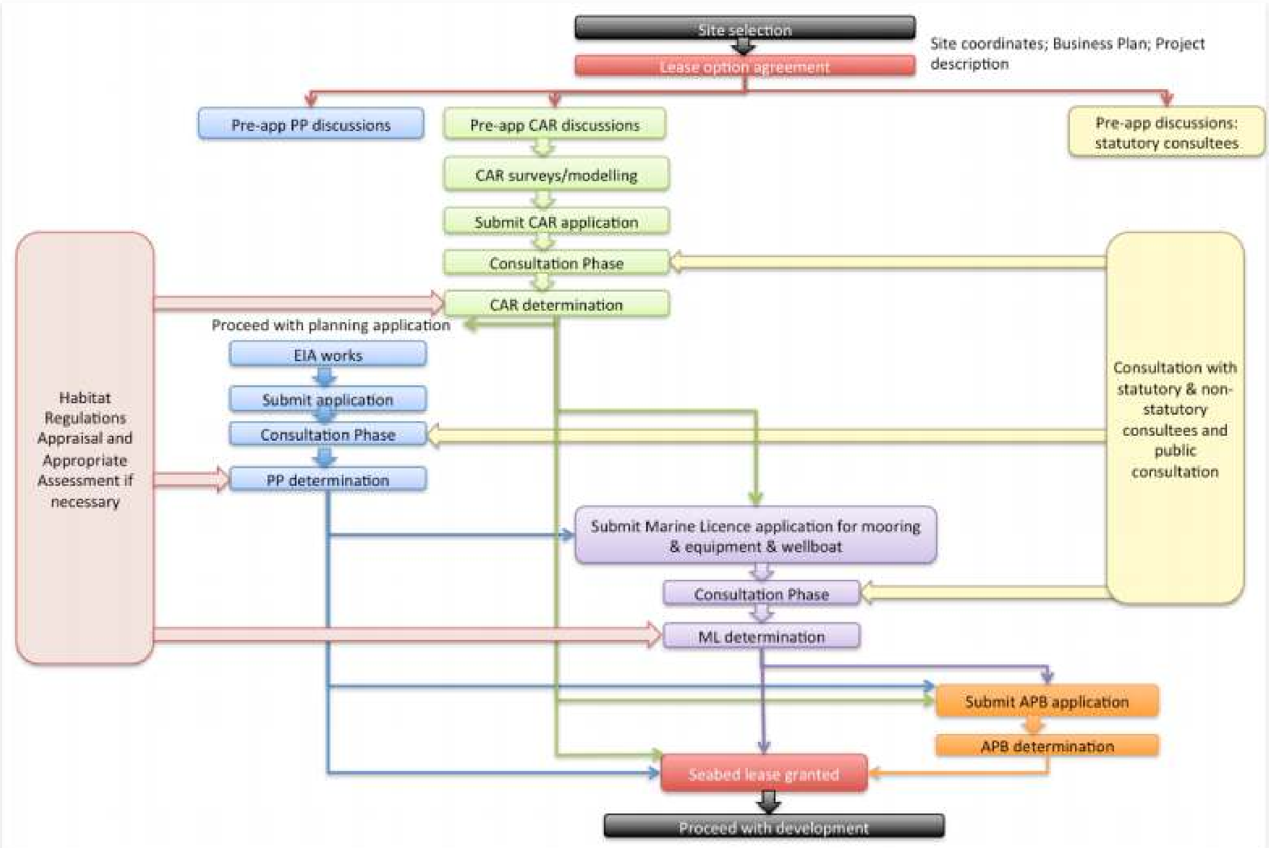

Image copied from: Nimmo, F, McLaren, K, Miller, J and Cappell, R. 2016. Independent Review of the Consenting Regime for Scottish Aquaculture. The Scottish Government.

Appendix 5 – Activities associated with salmon farming.

Image copied from Salmon Farming Sustaining Communities and Feeding the World; International Salmon Farming Association (2015).