FISHY BUSINESS

The Scottish salmon industry's hidden appetite for wild fish and land

July 2019

FEEDBACK

CONTENTS

1. FOREWORD

As a chef and one of the signatories of the Chef's Manifesto, I feel strongly that food should not only nourish us and taste delicious, but also contain ingredients which are grown with respect for the environment and where no good food goes to waste. I believe that, as chefs, we have the power to make tangible changes in the food system and as such, it is our responsibility to do so.

So I am delighted to be working with Feedback, and supporting their campaign Fishy Business, which is taking a closer look at the Scottish farmed salmon industry, and in particular whether this product can claim to be sustainable when it is fed on large quantities of wild-caught fish. While salmon has grown massively in popularity, there are so many other interesting foods we can explore which offer equal or greater taste and scope for culinary creativity. I see much potential in the shift away from excessive meat consumption, and I hope that the creativity and questioning attitude towards our food that inspired the Chef's Manifesto can extend to the farmed fish industry.

Could herring or blue whiting, both currently a constituent of the fish oil in farmed salmon feed, be a future food for people? Could farmed mussels or seaweed provide some of the Omega-3 we currently get from fish? Or could we learn to make more from less, eating different parts of the fish and keeping farmed salmon as a rare luxury rather than a regular meal?

To keep within our environmental limits, radical changes, including to how we produce our protein, are going to take place. And we need to think deeply about where the food we eat comes from, and how it is produced. Let's make sure whatever we eat, it creates a better future for our planet.

Merlin Labron-Johson, Chef

2. EXECUTIVE SUMMARY

A salmon farm seacage. Credit Peigi MacLean - Flickr (exec summary)

What we feed to the animals we eat is a question at the heart of the current and future sustainability of the global food system. The climate, ecosystem and biodiversity impacts of the mass production of animal feeds such as soya and maize has been widely explored by researchers and civil society. But within the growing industry of aquaculture, or farmed fish, lies a parallel challenge, one intimately related to the future of our ocean ecosystems and food security.

Farming fish requires feed: for the globally booming industry of farmed Atlantic salmon, this means feed containing wild-caught oceanic fish sourced from European, South American and West African waters, alongside other ingredients such as soya and vegetable oils. Previously an expensive treat, salmon is now ubiquitous in UK supermarkets and food service, a phenomenon driven by the exponential expansion of supply in farmed salmon, and parallel promotion of the product to consumers as a healthy and responsibly-produced source of protein.

A crucial corner of the global salmon aquaculture industry is found in the North West Scottish Highlands, where salmon farming has grown from a relatively small industry in the 1970s to be the UK's largest food export. The Scottish farmed salmon industry presents itself as an environmental, nutritional and national success story, despite being largely foreign-owned. But while trading heavily on its Scottish provenance, the industry faces controversy from a variety of angles: its impact on the Scottish waters surrounding fish farms, on farmed salmon welfare - with mortality rates running at around 20% - on Scottish wild salmon stocks which have seen a steep decline in the past decade, and on the wild fish which provides the cornerstone feed input for the industry. Despite ongoing challenges, having grown by over 90% between 1997 and 2017, the industry plans to expand by a further 100-165% by 2030 from a 2018 baseline. Indeed, this expansion is already underway, with 'supersized' salmon farms located in deep water locations given the go ahead by the Scottish regulator SEPA in June 2019.

In this report Feedback addresses the global sustainability equation, starting from a calculation of the implications of the industry's growth ambitions for its use of wild fish and land-based ingredients. We find that to fuel its expansion and without significant change in the reliance on marine ingredients, the Scottish industry will need to increase its use of wild fish from around 460,000 tonnes a year, to 770,000 tonnes a year. For context, the current quantity of wild fish fed to farmed Scottish salmon is roughly equivalent to the amount purchased by the entire UK population, and to fulfil growth ambitions this amount would need to increase by approximately two thirds. In addition, the industry relies on other land-based feed ingredients, such as soya and palm oil, which present widely-documented sustainability challenges in themselves.

Where and how this wild fish will be sustainably sourced is an unanswered question. While some progress on certification and use of by-products has been made, transparency is lacking to independently verify the industry's claims and to ensure that pressure on wild fish stocks will not negatively impact delicate ocean ecosystems, or human food security in the places where the wild fish is caught.

We call for greater transparency from the industry on feed sourcing, including which types of fish are used, where they are sourced and to provide conclusive and independently verifiable answers to a central question hanging over the industry: what role should farmed salmon play within globally sustainable diets? And if there is a place for large-scale salmon aquaculture, is the industry willing to commit to the transparency and accountability which would justify its role?

3. INTRODUCTION

In 2017 Scotland produced nearly 190,000 tonnes of farmed salmon. In addition to being sold as a high quality, premium product in retailers and restaurants around the UK, salmon exports are now valued at a record £600 million, with 85% of exports going to markets in high-income, industrialised countries, especially France and the USA (SSPO 2018). The industry has grown by 91% since 1997 (Marine Scotland Science 2018) , and is dominated by six large companies controlling 99% of the market (Marine Scotland Science 2018). In addition, the industry has widely publicised plans to grow further, with a target of increasing growth by another 100-165% from a 2018 baseline[1]. The Scottish salmon industry sells itself as quintessentially 'Scottish', building a global market position based on quality associations pinned firmly to the fish's provenance (SSPO 2019).

Scottish salmon farming must be understood within a global context of aquaculture expansion. While 40 years ago aquaculture provided 5% of the world's seafood, as the fastest-growing sector of the food system, it now accounts for approximately half of world's seafood consumption, with further projections for large-scale future growth (FAO 2018). Around 60% of the world's salmon production is farmed (Marine Harvest 2018), and in Scotland this figure reaches 100%, with the last wild salmon facility closing in late 2018 (Watson 2018).

A vital question when considering the long-term sustainability of any expanding industry is the nature of the inputs on which it relies, and how pressure on these inputs will reverberate through supply chains and ecosystems. The key feed inputs for salmon aquaculture are sourced primarily from global wild fisheries and land-based agriculture. They include fish oil and fishmeal made from wild-caught 'forage fish' – small oceanic fish that play a critically important role in moving nutrients through the food chain by eating plankton and making this available to marine animals higher up in the ecosystem, such as larger fish and seabirds. Based on publicly available data, Feedback estimates that a massive additional 310,000 tonnes of forage fish would need to be captured every year[2] to produce the fish oil needed in Scottish salmon diets if the industry expands as projected, and forage fish dependency ratios for oil in feed do not improve. For context, the current quantity of wild fish fed to farmed Scottish salmon is roughly equivalent to the amount purchased by the entire UK population (Seafish 2018), and to fulfil growth ambitions this amount would need to increase by approximately two thirds.

Plant-based salmon feed ingredients consist of wheat, soya and other plant proteins and cereals, as well as vegetable oils such as rapeseed. In addition to the pressure on wild fish stocks and ocean ecosystems, salmon feed also creates demand for land use, contributing to global pressure on agricultural land, biodiversity loss, and the climate impacts of land use change (Willett et al. 2019). This is particularly pertinent in the context of competition between the natural resources used to feed people directly and those used as feed inputs to animal agriculture and aquaculture.

1 The Scottish aquaculture industry plans to increase finfish production to 300,000-400,000 tonnes by 2030 (Scotland Food and Drink 2016; The Scottish Parliament 2018). Currently 96% of finfish production in Scotland is salmon (Marine Scotland Science 2018). Salmon production for 2017 was 189,707 tonnes and estimated production for 2018 is 150,774 (Marine Scotland Science 2018), meaning that to get to 300,000 tonnes would represent a 100%-165% increase in production, from a 2018 baseline.

2 This figure accounts for the fact that 33% of marine ingredients come from fish by-products (IFFO, 2016) and is in addition to the estimated 460 thousand tonnes of wild-caught fish currently used for fish oil production every year by the industry. Please see the appendix for further information on the calculations, data sources and assumptions behind this figure.

In common with all global, corporate-controlled sectors, the Scottish salmon industry is beholden to create value generation for its shareholders, while having to ensure ongoing quality and production, itself dependent on the viability of the marine and terrestrial ecosystems in which operations are sited and feed inputs sourced. And while aquaculture is often touted as the 'blue revolution' – a sustainable source of protein to feed our ever-growing population – urgent questions remain to be answered before the Scottish industry can justify expansion, or make a claim to its role in meeting the future protein needs of the population:

1. Can the Scottish salmon industry meet its growth ambitions while decreasing its reliance on wild fish stocks?

2. Can the Scottish salmon industry meet its growth ambitions while reducing its land footprint?

3. Is Scottish salmon an environmentally sound way to help meet the world's protein needs?

After introducing the Scottish salmon industry, we turn to each of these three questions in this report, which we will further explore in subsequent research and which we hope will form the beginning of a dialogue with the industry.

BOX 1. KEY TERMS

Fed aquaculture: Aquaculture that is reliant on external feed inputs, as opposed to some aquaculture species which rely on available nutrients in their environment.

Forage fish: Also called prey fish, they are the food of higher trophic-level species such as large fish, marine mammals and seabirds (Cashion et al. 2017). The Lenfest Forage Fish Taskforce defines forage fish "in terms of their functional role in providing a critically important route for energy transfer from plankton to higher trophic levels in marine ecosystems" (Pikitch et al. 2012).

Finfish: A fish with fins, used in contrast with other kinds of fish, such as shellfish.

Reduction fishery: A fishery that uses or 'reduces' its catch to produce fish oil and fishmeal.

Feed conversion ratio: the weight of feed administered over the lifetime of an animal divided by the weight gained.

Forage Fish Dependency Ratio (FFDR): weight of the wild fish used in feed in relation to the weight of farmed fish produced.

Food-grade fish: Suitable for direct human consumption but may have varying levels of consumer acceptability depending upon geographic region.

Land Animal By-Products (LAPs): by-products of the livestock industry usually obtained through the processing of by-products not used for direct human consumption into stable materials such as meat and bone meal or tallow.

Prime food-grade fish: Suitable for direct human consumption and has wide consumer acceptance.

Food-feed competition over land and marine resources: Arises when arable land suitable for producing human-edible crops is used for feed crop production, and when food-grade fish is used for livestock and aquaculture feed production.

Krill: A small shrimp-like creature which plays a crucial role in the Antarctic ecosystem.

4. SCOTTISH FARMED SALMON – A PREMIUM PRODUCT IN HIGH DEMAND

An adult Atlantic salmon. Credit – Shutterstock

WHAT IS SCOTTISH FARMED SALMON?

Scottish farmed salmon is Atlantic salmon, Salmo salar, and it is by far the most commonly farmed fish in Scotland, accounting for 96% of finfish production (Marine Scotland Science 2018). Salmon are typically born in fresh water, migrate to the ocean and return to fresh water again to breed: this spectacular journey has been celebrated by the iconic image of salmon leaping upstream. However, wild salmon is now a protected species in Scottish freshwaters and the last wild salmon commercial facility closed in late 2018 (Watson 2018). In the wild, Atlantic salmon may live for several years if they reach maturity.

In farmed conditions, Atlantic salmon are generally hatched from eggs in fresh-water tanks, then transferred to floating sea cages after about a year, generally located in sheltered in-land saltwater areas. The salmon spend around 12-24 months at sea, being fed pelleted feed, before they are harvested (Global Salmon Initiative 2019b).

WHY IS SCOTTISH FARMED SALMON CONSIDERED TO BE A PREMIUM PRODUCT?

> "The export trade has been built solidly on the concept of Scottish provenance"
>
> Scottish Salmon Producers Organisation, 25 January 2018 (SSPO 2019).

According to the industry, farmed salmon "represents a huge Scottish success story, an outstanding example of a 'good food', both in terms of its exceptional nutritional value and its standards of production" (SSPO 2019). The industry positions its product in terms of two main concepts. The first is related to nutritional quality, largely linked to the Omega-3 content of the fish, a micro-nutrient essential for human health. The second relates to provenance and to the more nebulous concept of the industry's unique 'Scottish-ness'.

Considering the latter first, marketing of Scottish salmon is based on the carefully cultivated image of the Scottish sites of production, including imagery and brand names targeting these connotations, such as Marks and Spencer's 'Lochmuir' salmon range. Lochmuir is

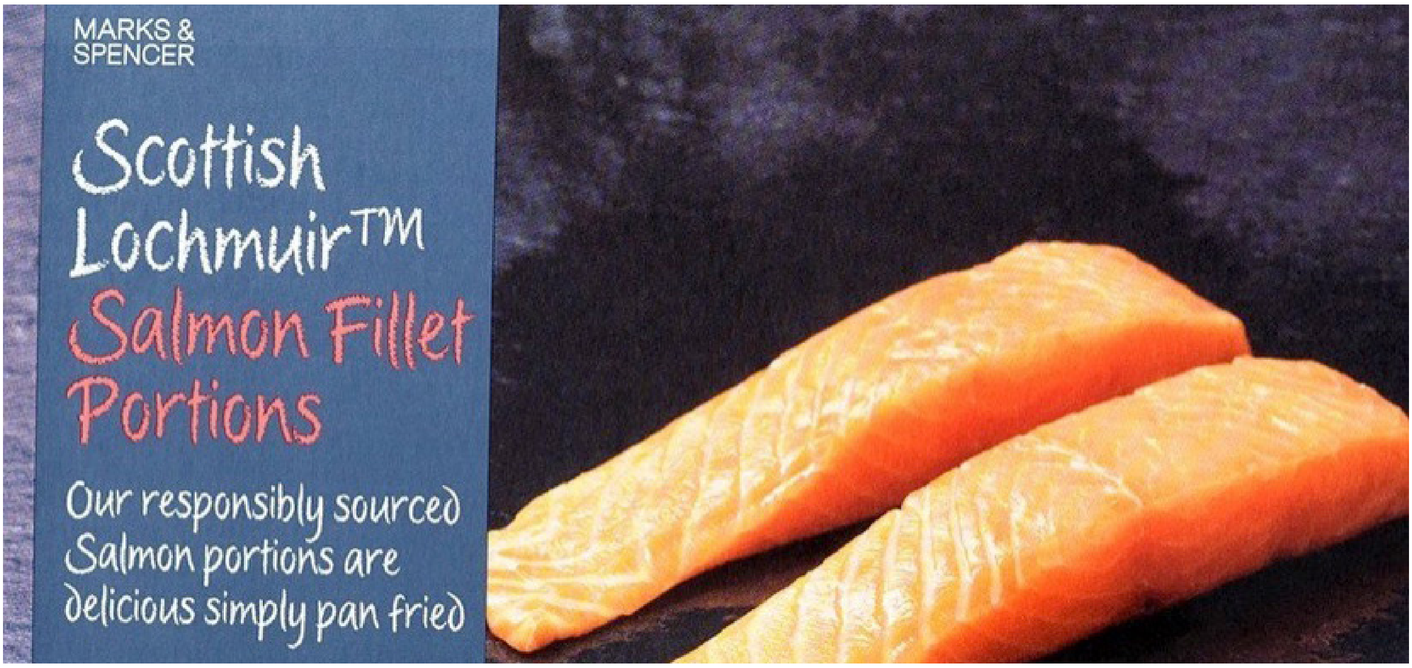


Figure 1: A Marks & Spencer Lochmuir advert (Moore 2018b).

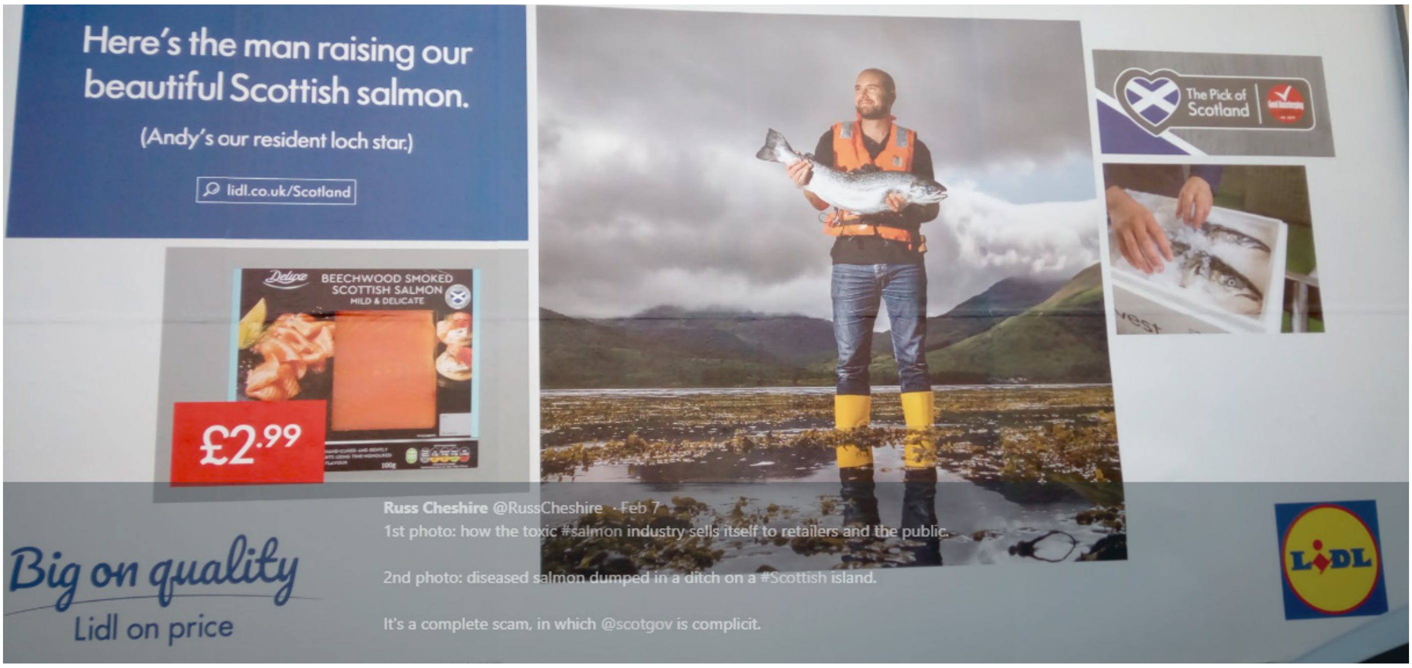
a brand name rather than an actual location or site of production in Scotland. When this discrepancy became a news story in 2006 a Marks and Spencer's spokesperson said to The Times: "It's a name chosen by a panel of consumers because it had the most Scottish resonance. It emphasises that the fish is Scottish." (Allardyce 2006)

Turning to Omega-3 content, in order to supply a differentiated product in the global market, Scottish farmed salmon production relies on a higher marine ingredient content in feed than the global industry standard (Shepherd, Monroig, and Tocher 2017). Omega-3 content in salmon largely relies on the quantity and quality of fish oil used in salmon feed. This higher marine content than other production sites, Norway for example, reinforces the idea that Scottish salmon is 'healthy and natural' (Shepherd, Monroig, and Tocher 2017).

In addition, Scottish salmon was the first fish to be awarded the French Label Rouge quality assurance. While this may help the industry command high prices and support export sales, it creates a barrier to reducing the marine content of fish feed because the Label Rouge requirements specify a minimum marine feed content of 51%. While in 2014, only 4% of the Scottish market was produced to comply with the Label Rouge standards (Shepherd, Monroig and Tocher, 2017), beyond this official certification, many Scottish companies use their higher marine feed content as a marketing asset.

This marketing device extends down the supply chain to retailers. Sainsbury's packaging for their Scottish salmon fillets states their product is 'High in Omega 3' and "The salmon are fed a bespoke diet designed to protect our natural resources from overfishing and guarantee great taste and nutritional benefit for you." (Sainsbury's 2019)

> "Our salmon are fed a higher Fish Meal and Fish Oil content diet than farmed salmon from Norway, Canada or Chile."
>
> The Scottish Salmon Company n.d.



Credit: Russ Cheshire/Twitter, 7 February 2019.

Figure 2: A billboard advertisement for Lidl Scottish salmon range, featuring imagery relying heavily on Scottish associations.

FROM LUXURY PRODUCT TO EVERYDAY ITEM

In the UK, few consumers may realise that the pink salmon fillets available in their supermarkets are farmed - the last wild Scottish salmon fisheries closed in 2018 (Watson 2018). The Scottish salmon aquaculture industry has worked hard to cultivate a a market reputation of sustainability and quality, which, alongside aggressive growth strategies, has led to a massive expansion in farmed salmon consumption in the UK. Data from Defra shows that since 1974 purchases of salmon have risen by 550% (Kelly and Bates, 2016). Meanwhile, consumption of 'traditional' whitefish such as cod and haddock has been in decline since the 1980s (Seafish 2016). Salmon is widely available from retailers as fillets, smoked or sliced. In addition, it now frequently appears in sandwiches, ready-meals and other foods to go. Salmon is now the number one purchased seafood by value, with consistent growth over the past decade and a 36% increase in price (Seafish 2016).

5. THE SCOTTISH SALMON INDUSTRY

INTRODUCING THE INDUSTRY

The Scottish salmon industry is a significant growth industry. In 2017, the industry produced 189,707 tonnes of salmon (around 42 million fish[3]), an increase of 16.5% on the previous year and the highest ever production in Scotland (Marine Scotland Science 2018). This represents a staggering increase of over 90% in the 20 years since 1997[4], even though the industry predicted a decrease in production in 2018 (Marine Scotland Science 2018). Scotland is the largest producer of farmed Atlantic salmon in the EU and the third largest producer globally after Norway and Chile (Kenyon and Davies 2018).

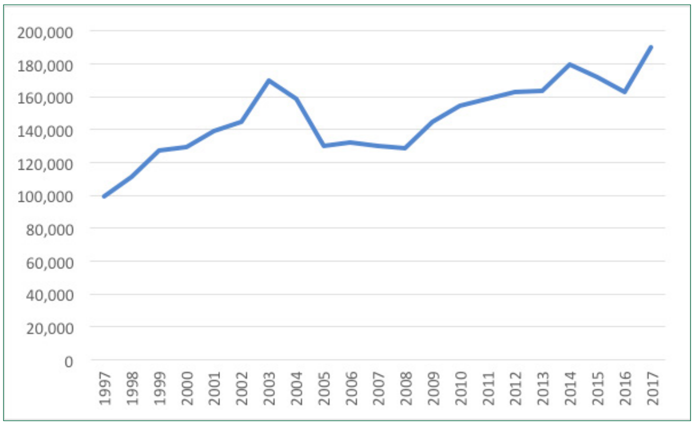


Figure 3: Annual production of farmed salmon in Scotland (tonnes) (Marine Scotland Science 2018)

Salmon farms are seawater cages located around the Western Isles of Scotland, Shetland and Orkney.

In addition to considerable expansion over the past 20 years, the industry has also undergone a remarkable process of consolidation. Eight companies were authorised and actively producing salmon in 2017, a decrease from 28 in 2007. Six of the eight companies in production in 2017 controlled 99% of farmed salmon production in Scotland (Marine Scotland Science 2018). These six were:

- MOWI (formerly Marine Harvest)
- Grieg Seafood
- Scottish Sea Farms
- The Scottish Salmon Company
- Cooke Aquaculture
- Loch Duart

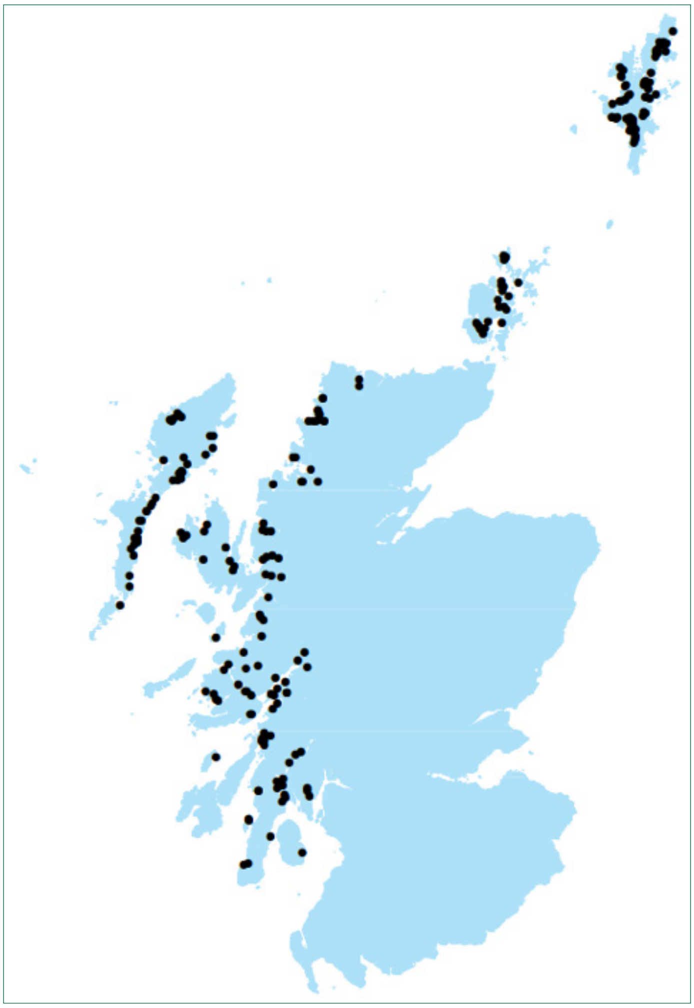


Figure 4: The distribution of active Atlantic salmon production sites in 2017 (Marine Scotland Science 2018)

3 Calculated based on assumed average harvest weight of 4.5 kilos per fish (MOWI 2018).

4 Calculation based on Scottish government data (Marine Scotland Science 2018).

In addition to consolidation, Scottish salmon farming has become an increasingly foreign-owned industry, with much of the Scottish industry listed in countries such as Norway, Switzerland and Canada. The publicly available information about the ownership of the top six Scottish salmon producers is set out below.

Figure 5: The key players in the Scottish industry

Formerly known as Marine Harvest. Listed on the Norwegian stock exchange and also trades on the US OTC market. The world's largest producer of Atlantic farmed salmon.

Listed on the Norwegian stock exchange and with headquarters in Bergen. Farms in the Shetland Islands, the Isle of Skye, Norway and British Columbia, Canada.

Owned by SalMar and the Leroy Seafood Group ASA, both Norwegian seafood companies listed in Norway. Farms in Orkney, the Shetland Islands and the west coast of Scotland.

The Scottish Salmon Company is over 70% owned by a Swiss shareholding company, SIX SIS Ltd. It operates only in Scotland, with 43 marine sites.

Cooke Aquaculture is a Canadian business owned by the Cooke family, with subsidiaries listed in Uruguay, the US and Chile.

Loch Duart is majority owned by Pacific Sequoia Holdings LLC, based in Palo Alto, USA.

While the location of production sites may be Scottish, the financial ownership and shareholder beneficiaries of the industry largely lie outside Scotland.

The Scottish salmon industry was worth over £765 million in 2016 (Kenyon and Davies 2018). Scottish salmon has a strong export market. France was the top market for Scottish salmon in 2018 with a value of £168 million, followed by the USA at £139 million. Salmon exports to China have also risen rapidly, from negligible in 2009 to nearly £68 million in 2018 (SSPO 2018).

THE INDUSTRY'S EXPANSION PLANS

The Scottish salmon industry, largely represented by the Scottish Salmon Producers Organisation, has a large appetite for expansion, planning to increase finfish production to 300,000-400,000 tonnes by 2030 (Scotland Food and Drink 2016). Salmon production for 2017 was 189,707 tonnes and the industry estimates production at 150,774 tonnes in 2018, meaning that reaching 300,000 tonnes would represent a 100%-165% increase in production from a 2018 baseline (see footnote 1 on page 4). Mowi, Scotland's largest salmon farmer, reported a 36% drop in production in 2018 (MOWI 2019). These latest production figures raise questions on industry expansion capacity despite its growth ambitions, particularly in the context of very high mortalities in 2018.

In 2018 the Scottish Rural Economic and Connectivity committee highlighted that the regulatory regime and production methods were untenable, with regards to animal health and environmental impact, and questioned the industry's plans to expand. Despite this warning, planning applications for new farms or to expand existing farms continue to be submitted.

> "The Committee strongly agrees with the view of the Environment, Climate Change and Land Reform Committee (ECCLR) Committee that if the industry is to grow, the "status quo" in terms of regulation and enforcement is not acceptable. It is of the view that urgent and meaningful action needs to be taken to address regulatory deficiencies as well as fish health and environmental issues before the industry can expand."

Scottish Government 2019

THE INDUSTRY'S LOCAL ENVIRONMENTAL IMPACTS

The industry has been dogged by considerable controversy in the media and been the target of vigorous campaigns by some local groups against the impacts of salmon farming on landscapes and wildlife. Campaigners have also questioned the local economic benefits accruing from the salmon industry (Rural Economy and Connectivity Committee 2018). In 2018 Salmon and Trout Conservation Scotland issued a call for an immediate moratorium on further industry expansion, supported by 27 environmental bodies and local groups (Salmon and Trout Conservation Scotland 2018).

BOX 2: LOCAL ENVIRONMENTAL ISSUES

There have been multiple reports about the adverse effects of salmon farming on the local environment and wild fish in Scotland (The Scottish Parliament, 2018). The last commercial wild fishery closed in 2018 as there was simply not enough fish available to support the business (Watson 2018). Due to environmental change and a range of human impacts across the Northern Hemisphere, wild salmon stocks in Scotland are dangerously low (Cockburn 2019). In the words of Fisheries Management Scotland (2019), "this iconic species is now approaching crisis point".

A recent report published by The Scottish Parliament (2018) details the environmental impacts of salmon farming, including the fact that "more farmed salmon implies more sea lice" and more favourable conditions for the spread of diseases some of which can spread between farms and wild salmon populations: "Increasing sea lice burdens on wild salmonids add to pressures on the wild populations already impacted by climate change, river modification and commercial fishing." The report also notes that sea lice populations appear to be developing resistance to existing chemical treatment options and that despite strict regulation these treatments "might be harming other organisms, and perhaps, ecosystems". Antibiotics continue to be used to treat bacterial infections in farmed salmon (MOWI 2018a; The Scottish Parliament 2018). At the same time, the industry is finding that in a context of greater sea lice resistance to medication, increasing the amount of fish oil and fishmeal in the diet may produce salmon better able to manage stress from sea lice (Einstein-Curtis 2019). This would further exacerbate pressures on wild-caught forage fish.

The efficiency of farmed salmon production in Scotland appears to experience quite wide variations from year to year. Mortality due to disease and other causes, and losses due to fish escapes – around 30,000 fish escaped from seawater cages in 2017 according to industry data (Marine Scotland Science 2018).

THE INDUSTRY'S KEY INPUT: WHAT DOES FARMED SALMON EAT?

Scottish salmon feed typically contains 60-70% plant-based ingredients, 20-40% marine ingredients, plus around 5% of supplements such as vitamins and minerals.

Table 1 shows that there can be significant variation in salmon feed composition.

Table 1: Composition of Scottish salmon feed (Estimates based on publicly available information in Shepherd, Monroig and Tocher 2017, MOWI 2018a, Ytrestøyl et al. 2011)

Ingredient	Estimated percentage of total diet
Fishmeal	14.7 – 25%
Fish Oil	10.3 – 15%
Vegetable protein (soymeal, sunflower expeller, wheat gluten, peas, fava beans, etc) and guar bean gum	23 – 35%
Vegetable oils (often rapeseed)	18-22%
Cereal crops (wheat, corn)	19.5 – 25.5%
Supplements	4-5%

The feed is sourced globally, from fisheries and land-based agriculture in Europe, South America and West Africa. In the next two chapters we explore the implications of these global sourcing policies on wild fish stocks, land and environmental impacts in particular, in order to better understand the long-term sustainability implications of the industry.

6. CAN THE SCOTTISH SALMON INDUSTRY MEET ITS GROWTH AMBITIONS WHILE DECREASING ITS RELIANCE ON WILD FISH STOCKS?

We now turn to the first of the three key questions we wish to pose to the Scottish farmed salmon industry. Feedback estimates that an additional 310,000 tonnes of forage fish will need to be captured every year[5] to produce the fish oil needed in Scottish salmon diets if the industry expands as projected and forage fish dependency ratios for oil in feed do not improve.

> Essentially we feed fish to fish, so we catch fish in various parts of the world, process them into salmon food, and then feed them to salmon. That is highly inefficient.
>
> Professor Ian Boyd, Chief Scientific Adviser, Department for Environment Food and Rural Affairs (Environmental Audit Committee 2019)

REDUCTION FISHERIES AND THE PRESSURES ON GLOBAL FISH STOCK

Two thirds of the fishmeal and fish oil used in fish feed globally are produced from wild-caught fish, largely small pelagic fish or 'forage' fish such as anchoveta, mackerel, whiting and sardines which are the prey of larger ocean animals (Alder et al. 2008). The industry involved in fishing these wild fish and converting them to fishmeal and fish oil is known as reduction fisheries. The other third of fishmeal and fish oil is produced from fishery by-products (IFFO 2017a).

So-called 'trash' or forage fish at a fishmeal factory. Credit – Shutterstock

15 million tonnes out of a total of 90 million tonnes of fish captured globally in 2016 was reduced (i.e. processed) into fishmeal and oil (FAO 2018). In 2016, nearly 70% of aquaculture relied on external feeds (Fry et al. 2018). The Scottish salmon industry has largely managed the impacts of its marine ingredients through certification schemes such as the Global Standard for Responsible Supply, administered by The Marine Ingredients Association (IFFO RS) and the standards administered by the Aquaculture Stewardship Council. Some Scottish producers also commit to only sourcing feed ingredients from fisheries certified by the Marine Stewardship Council (MSC), while others rely on the IFFO RS scheme (see box 3).

5 This figure accounts for the fact that 33% of marine ingredients come from fish by-products (IFFO, 2016) and is in addition to the estimated 460 thousand tonnes of wild-caught fish currently used for fish oil production every year by the industry. See full calculations, assumptions and data sources in the appendix.

BOX 3: CERTIFICATION SCHEMES

There is a multitude of fisheries and aquaculture certification standards, but the two most relevant to Scottish salmon feed sourcing are described below:

Marine Stewardship Council (MSC) certification: The MSC certification 'Blue Tick' is a widely recognised consumer-facing certification and label, based on standards which cover sustainable fishing practices and traceability. Fisheries are assessed by third party accreditors against the MSC standard, based on the FAO's Code of Conduct for Responsible Fishing. It is widely considered the best current standard for sustainable fisheries, though MSC Certification has also experienced some controversy, with a House of Commons Environmental Audit Committee inquiry reporting that an increasing number of controversial or damaging fisheries have received certification (Environmental Audit Committee 2019). In 2015 only very small volumes of fish from MSC-certified fisheries were being made into fishmeal or fish oil (Purchase and Dom 2015).

IFFO Responsible Supply Standard: The IFFO RS certification is a business-to-business standard developed by a multi-stakeholder committee including industry and NGO experts. The standard covers responsible raw material sourcing and good manufacturing practice, based on review of the fishmeal/fish oil factories rather than the fisheries they source from directly. In 2015 it was reported by the Seas at Risk coalition that approximately 80% of fisheries supplying European aquaculture were IFFO RS certified (Purchase and Dom 2015).

Feed producer BioMar reports that 81% of its fish oil and 89% of its fishmeal is certified under the IFFO RS 'or equivalent' (Biomar 2018). However, the IFFO RS scheme does not necessarily meet the objectives of Maximum Sustainable Yield as set out by the Common Fisheries Policy (the maximum level at which fish stocks can be routinely exploited without long-term depletion), nor is it an ecosystems-based management system (Purchase and Dom 2015). In the European Economic Area (EU plus Norway and Iceland), up to 20% of fishmeal and fish oil still come from non-certified sources (Purchase and Dom 2015).

Global fisheries sustainability is a complex question, however there is expert agreement that heavy fishing of forage fish can have an impact not only on stocks of that fish but also on the wider ocean ecosystem (Pikitch et al. 2016). In other words, "fishing these species at conventional maximal yield levels can have large impacts on other parts of the ecosystem" (Smith et al. 2011) as the cumulative effects of the wider certified and non-certified fisheries are not taken into consideration (Purchase and Dom 2015). The Scottish Association for Marine Sciences report to the Scottish Parliament in January 2018 stated that 'the global harvest of forage fish is already at its limit' and that further demand may increase pressure for unsustainable harvesting of fish (SAMS 2018).

As a result, a panel of fishery and marine scientists has recommended that management should be more precautionary, and catch target levels should be significantly reduced in order to leave more of these fish populations in the ocean and safeguard the health of the ecosystem (Pikitch et al. 2012). Pikitch et al. (2012) also point to the pitfalls of using single species quotas in managing fish stocks, given the susceptibility of forage fish species to population collapse when the effects of fishing and unfavourable environmental conditions act together. The major knock-on impacts on animals that rely on forage fish as a food source also need to be considered.

Research has reported that reduction fisheries increasingly target a wider range of species (Cashion et al. 2017), but to date, many studies assessing the environmental impact of seafood did not account for species-specific and ecosystem-specific factors. The application of a more refined research method to the Norwegian salmon farming industry, which accounted for species and eco-system specific factors, shows that previous "research may have substantially underestimated the marine biotic impacts of fishery products" (Cashion et al. 2016).

Krill, a small shrimp-like creature which plays a crucial role in the Antarctic ecosystem, is another wild-caught species promoted in the use of salmon feed (Aker BioMarine 2016).

Antartic krill. Credit Norkrill – Flickr

Recent research has pointed to the need to reduce the fishing of krill if we are to ward off collapse in a context of climate change and prevent serious knock-on effects on predator species such as penguins (Klein et al. 2018). The sustainability question around krill fisheries is controversial and much contested, and Feedback plans to further research this important question.

Although progress has been made, it is hard, it is hard to justify the use of wild-caught fish in Scottish salmon when over 93% of global fish stocks are either maximally sustainably fished or overfished (FAO 2018). The Scottish Parliament's Environment, Climate Change and Land Reform Committee reported in 2018 its understanding that sustainable fisheries for salmon feed had reached maximum sustainable yield and therefore could not supply the additional fishmeal and fish oil needed for industry expansion (Scottish Government 2019). Further, it is hard to see how the Scottish salmon industry can justify increasing its share of demand on the 7% of global fish stocks (FAO 2018) that have not yet reached their limits.

FISH IN, FISH OUT – FOLLOWING THE TREND

In assessing the sustainability of the industry's growth ambitions, a key concern is an accurate understanding of the likely impact of increased production on feed input requirements. Globally there has been a significant decrease in the proportion of marine ingredients used in aquaculture feed. Similarly, the Scottish salmon industry has pursued a policy of seeking to reduce the ratio of fish oil and fishmeal sourced from wild fish required to rear farmed salmon (Shepherd, Monroig and Tocher, 2017).

The method used to calculate the extent to which feed for farmed fish uses fishmeal and fish oil from wild-caught fish is controversial and contested. The most well-known approaches are the 'fish in, fish out' ratio (FIFO) and the 'forage fish dependency ratio' (FFDR). A much-cited paper (Tacon and Metian 2008) used the 'fish in, fish out' ratio to point to the particularly unsustainable nature of salmon farming, finding that a massive 4.9 kilograms of wild-caught fish were needed to produce one kilogram of salmon.

BOX 4: MORTALITIES AND WASTE

Waste during the production of Scottish salmon, both during the rearing period and after 'harvest' has serious implications for the ratio of feed to salmon made available for human consumption. Mortalities at salmon farms are often high, due to variety of factors including disease, human error and damage due to poor weather. The mortality information published by the Fish Health Inspectorate Scotland shows that in 2018, 326 reported mortality incidents occurred at salmon farms, with approximately 3,754,000 fish mortalities. Within these reported incidents, 25% did not disclose the level of mortalities (Scottish Government Fish Health Inspectorate 2019), so the actual number of mortalities is likely to be much higher. To provide some context, MOWI reported that in 2018 the salmon mortality rate in Scotland was 9.4%, while Grieg Seafood reported a mortality rate of 17% (Global Salmon Initiative 2019a). It is notable that in addition to incidents where companies decline to disclose mortalities, there is a variance between companies who appear to be reporting exact mortality numbers, and those who appear to report estimates (rounded whole numbers), further suggesting the range of actual mortalities could be large. In addition to mortalities, 'escape incidents' where equipment failure or poor weather allow fish to escape from farms, also contributes to 'waste' in the industry: in 2018, MOWI lost 24,000 fish in one incident (Global Salmon Initiative 2019a). It is not clear to Feedback whether mortalities, and other types of waste, are accounted for in calculating the 'fish in, fish out' or forage fish dependency ratio. Failure to account for such wastes would have major impacts on the perceived sustainability of the industry's dependence on wild fish. We will explore this issue in more detail in future reports.

WHAT DO PIGS AND SALMON HAVE TO DO WITH ONE ANOTHER?

An interesting industry justification has emerged in response to the criticism of high use of marine ingredients. With regard to the much-cited ratio of 4.9 kilograms of wild-caught fish per 1 kilogram of farmed salmon, the industry argued that the researchers behind this figure (Tacon and Metian 2008) failed to analyse the reliance on fish oil in salmon feed alongside a complementary need for fishmeal in pig, poultry, carp and shrimp farming (Jackson 2009).

As seen in the industry FFDR figures cited in Table 2 below, the farmed salmon industry relies on larger quantities of fish oil than fishmeal in salmon feed. A proportion of the fishmeal produced in the process of manufacturing fish oil is used for feed in carp and shrimp aquaculture and to raise pigs and poultry (Jackson 2009). The salmon industry argue that the feed conversion ratio of salmon farming is made more efficient by these additional markets for fishmeal, because salmon farming uses only a proportion of total wild fish catch for reduction. In this way, the ratio of wild-caught fish used to produce a given quantity of farmed salmon is lowered. According to the Marine Ingredients Organisation (IFFO 2016), using an approach that accounts for these market efficiencies means that on average 0.82 kilogram of wild-caught fish is now needed to produce 1 kilogram of salmon.

However, this also means that the salmon industry is symbiotic with other industries which have a high environmental footprint, like shrimp and pig production. Indeed, the industry relies on these other forms of animal agriculture in order to justify its sustainability credentials when in fact these animal food production systems are highly problematic. Shrimp farming is associated with mangrove destruction, water pollution, illegal fishing and labour practices (WWF 2019). Farmed crustaceans on the whole have significant environmental impacts with higher greenhouse gas emissions and water pollution potential than pig and poultry farming (Poore and Nemecek 2018). Similarly, freshwater aquaculture of species such as carp carries environmental problems, including water pollution (Poore and Nemecek 2018) and greenhouse gas emissions (Robb et al. 2017). The worst types of freshwater aquaculture ponds emit more methane, a very powerful greenhouse gas, than dairy cows (Poore and Nemecek 2018)[6].

At the same time, the livestock industry, which itself has considerable environmental impact, can claim that in using fishmeal they take up a by-product of the aquaculture industry. However, scientific consensus has been reached on the urgent need for significant reductions in the consumption of meat in favour of plant-based proteins in order to shrink the impact of the food system on the environment (Willett et al. 2019; Godfray et al, 2010). In the context of this consensus, sustainability claims of the fish feed industry that rest on a co-dependence with farmed animal systems are flawed.

6 Freshwater aquaculture ponds create up to 450 grams of methane per kilogram of liveweight – for context, enteric fermentation in dairy cows creates 30 to 400 grams of methane per kilogram of liveweight (Poore and Nemecek 2018).

THE USE OF FISHMEAL AND FISH OIL IN SCOTTISH SALMON

In order to better understand the dependency on marine ingredients of the Scottish salmon industry, Feedback reviewed data from two companies operating in Scotland (we applaud these companies for making this data publicly available and call on all companies operating in Scotland to follow suit). We observed that the FFDR for meal and oil vary significantly year to year, with no linear downward trend, and no apparent relation between fishmeal and fish oil use between the two companies. With such variance over time and between companies, and without a clear downward trend, it is unclear how the industry accounts for fishmeal and fish oil reliance in salmon diets when projecting future growth. In order to clarify the impact of industry expansion on wild fish stocks, we recommend that the industry publishes a breakdown of the marine ingredients used for feed currently, including species and fishery locations. In addition, if the industry plans to increase its use of fish oil and fishmeal to support expansion, it should clarify where it plans to source this increased level of feed.

Table 2. FFDR for meal and oil for Mowi and Grieg Seafood

Mowi Scottish data	FFDR – fishmeal	FFDR – fish oil
2017	0.4	1.5
2016	0.65	2.52
2015	0.86	1.96
2014	0.95	2.09
2013	0.78	1.72
Average	0.728	1.958

Grieg seafood Scottish data	FFDR – fishmeal	FFDR – fish oil
2017	1.12	1.89
2016	0.83	2.04
2015	0.72	2.58
2014	0.73	2.88
2013	1.24	2.66
Average	0.928	2.41

Source: Global Salmon Initiative Sustainability Indicators for Scotland (Global Salmon Initiative 2019a).

THE OMEGA-3 QUESTION

An obvious solution to the concern over use of wild fish in farmed fish feed is to turn to alternative ingredients, and indeed the industry has increased use of sources of plant-based protein in feed. However, the industry faces a challenge in terms of maintaining the nutritional content of farmed salmon, in particular Omega-3 content, since the Omega-3 content of farmed salmon mainly depends on the quality and volume of fish oil in the salmon feed (Shepherd, Monroig, and Tocher 2017).

Omega-3 fatty acids – EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) – are both an important nutrient in human diets and a key element in the market positioning of Scottish salmon. MOWI (2018a), the largest player in the Scottish industry, sums up the conundrum facing the industry:

"We believe the coming years will be key to finding alternative EPA and DHA-rich sources that could further reduce our dependence on fish oil. Our efforts to source sustainable feed ingredients will always go hand-in-hand with the goal of ensuring that our salmon remain a rich source of Omega-3 fatty acids."

Alternative, non-fish sources of Omega-3 do exist. One alternative is to use plant-based sources. The Scottish Parliament (2018) report points to transgenic oilseed crops as an alternative source of sustainable Omega-3, but this is not currently possible because of the Scottish ban on Genetically Modified (GM) crops and the widespread European reluctance to allow GM products in diets. The most promising source of plant-based Omega-3 appears to be algal oil. Recently, Norwegian salmon producer Lingalaks has started commercial production of salmon fed on Omega-3 marine algal oil delivered by companies Skretting and Veramaris (Veramaris 2019). Algal oil is also used as a direct human food supplement of Omega-3, although there might still be questions around the bio-availability of

such algae-based sources of Omega-3 (Lane et al. 2014). Whilst algal oil is a strong contender, it is important to use life cycle assessment and wider environmental impact research to understand the environmental impact of algal oil extraction and production. We expect to see evidence that these impacts have been considered by the industry before a partial or full switch to algal oil as a source of Omega-3 is conducted.

USE OF FISHERY BY-PRODUCTS

The second alternative to wild-caught fishmeal and fish oil as a source of Omega-3 is greater use of trimmings and by-products 'recycled' into farmed salmon feed. Research funded by IFFO shows that when industry invests in maintaining food grade quality of salmon by-products and maximising their use in human consumption, there is an opportunity to achieve a 803% increase in by-product revenue and up to a 61% increase in food production (Searby 2018; Stevens et al. 2018). After the use of trimmings and by-products in human food is maximised, further by-products can be converted into fishmeal and oil for feed of other fish species such as seabass and gilthead bream (Stevens et al. 2018). Furthermore, if more oil from salmon aquaculture by-products is used in the feed of other aquaculture species, the overall demand for oil from wild-caught fish can be reduced (Shepherd, Monroig, and Tocher 2017).

Currently 33% of fishmeal and fish oil globally is produced from fishery by-products (IFFO 2017a). Regarding Scottish salmon feed, we have not been able to find publicly available data on the proportion that comes from by-products. Data on the exact species, provenance and type of fishery by-products used for producing fishmeal and fish oil in salmon feed is required for researchers, NGOs and policy-makers to further assess the sustainability merits of these ingredients.

A recent study found fishmeal to be a "reservoir of antibiotic resistant genes" which "serves as a vehicle to promote antibiotic resistance gene dissemination internationally" (Han et al. 2017). IFFO (2017b) has argued that there are methodological issues with this study, but since antibiotics continue to be used to treat bacterial infections in farmed salmon (MOWI 2018a; The Scottish Parliament 2018) and 33% of fishmeal and oil now comes from by-products, it is critical that increasing the use of trimmings is carefully monitored for unintended consequences.

From the above analysis we can see that the industry faces several options in regard to fisheries sourced ingredients for farmed salmon feed. It can continue business as usual – leaving many questions unanswered as to where it will source greater quantities of certified, sustainably sourced fishmeal and fish oil to power expansion. The industry must provide publicly available information that justifies the long-term sustainability of its decisions.

7. CAN THE SCOTTISH SALMON INDUSTRY MEET ITS GROWTH AMBITIONS WHILE REDUCING ITS LAND FOOTPRINT?

Turning to our second question to industry, we now consider the increasing use of terrestrial – i.e. crops grown on land – ingredients in farmed salmon feed.

The reduction in marine ingredients in farmed salmon feed to date has largely been possible as a result of the inclusion of plant-ingredients such as wheat, maize, sunflower, rapeseed and soya (see table 1). Pressure on ocean resources has been partially replaced by pressure on global agricultural land. Crops such as soya, even certified soya, can directly or indirectly drive Amazon deforestation. A report from Rainforest Foundation Norway (2018) shows that expansion of farmed salmon will drive demand for soya which can have negative environmental consequences.

Feedback has estimated that – assuming the proportion of soya in salmon diets remains the same as in 2014 – an additional 30,000 tonnes of soya protein concentrate would need to be imported to satisfy demand in relation to the Scottish industry's expansion plans (see appendix for full calculations and data sources). While this quantity is very small in comparison with soya demand for other animal production, such as pig and chicken feed, in the context of the urgent need to decrease global animal feed production to tackle climate change and biodiversity loss, an additional demand for soya production requires close scrutiny.

SOYA, RAPESEED AND OTHER PLANT-BASED INGREDIENTS

Over the past 50 years, the production of soya has increased faster than any other crop from 27 million tonnes to 269 million tonnes, and the FAO predicts that global soya production may reach 515 million tonnes by 2050 (WWF 2017, 10). Soya is a key ingredient in livestock feed and fast becoming a more prominent ingredient in the diets of farmed salmon. In 2017, Cargill Aqua Nutrition's feed for the Scottish industry contained 13,071 tonnes of soya (Cargill 2017). This soya was certified Pro Terra Organic. However, Trase[7] data show that during the last decade soya traders in the Brazilian market with zero deforestation commitments – Cargill, Bunge, ADM and Amaggi – have been associated with similar deforestation risk as companies that have not made such commitments (West, Green, and Croft 2018). In other words, it seems deforestation commitments may have very little value in terms of guaranteeing zero deforestation soya to the supply chain.

Deforestation in Brazil, aerial view of a large soya field eating into the tropical rainforest.
Credit – Shutterstock.

7 Database generating indicators of deforestation risk using localised data on commodity production, sourcing patterns and deforestation. https://trase.earth/

BOX 5: DEFORESTATION AND SOYA PRODUCTION

Efforts to tackle deforestation like the Brazilian Soya Moratorium and "Cerrado Manifesto" currently focus on the Amazon and Cerrado in Brazil, and provide incentives for companies like Bunge and Cargill to shift deforestation to frontiers like Argentina and Paraguay (Mighty Earth, FERN, and Regnskogfondet 2018, 14). Even so, in May 2018, five traders and multiple soya farmers were fined a total of US $29 million by the Brazilian government for soybean cultivation and purchasing that is connected to illegal deforestation (Byrne 2018a). Two of the five companies fined – Cargill and Bunge – are among the top five soya exporters from Brazil, who had adopted zero deforestation commitments. The fine demonstrates the vulnerability of the companies' systems for monitoring and tracking their supplies and the fact that they cannot guarantee that their sources are deforestation-free (Vasconcelos and Burley 2018). In other words, reducing demand may be one of the only ways to guarantee no further deforestation.

Rapeseed oil is another important ingredient for fish feed (Ytrestøyl, Aas, and Åsgård 2015) and comes with its own environmental challenges. Growing rapeseed for oil is less land efficient than producing palm oil (May-Tobin et al. 2012, 12), meaning that it raises pressure on global agricultural land use. Using rapeseed oil in fish feed rather than for biofuel raises the pressures to grow palm oil elsewhere, which indirectly contributes to deforestation. Another study found that substitution of fishmeal and oil by plant meals and oils did not reduce environmental impacts of salmon diets, due to factors such as acidification, terrestrial ecotoxicity, and climate change (Boissy et al. 2011).

It is paramount that in the aquaculture industry's drive to reduce its dependency on wild-caught fish in feed, it does not simply substitute marine ingredients for potentially unsustainable sources such as soya or rapeseed oil. IFFO recognises this:

'It is also important to recognize that the certification of such materials from agriculture lags well behind that of marine ingredients, for example soy as one of the major vegetable feed ingredients has only 2-3% of total annual production certified to independent standards' (Auchterlonie 2019).

POTENTIAL ROLE OF INSECTS AND FOOD WASTE

Terrestrial feed alternatives to soya and other plant-based proteins do exist. Protix has succeeded in producing fishmeal free salmon, replacing the fishmeal content with black soldier fly larvae meal (Byrne 2018b). But the diet in the fishmeal free salmon contains the same amount of fish oil as standard salmon diets so the key challenge of fish oil being the driving factor in demand for wild-caught fish remains (Moore 2018a). Another challenge is that under current legislation, insects may only be fed on what is permitted in livestock feed, which excludes mixed food waste or manure for example, two highly available 'waste' products in the current food system. This may lead to a reliance on feedstocks such as rye meal and soybean meal (Smetana et al. 2016) and these may not offer significant sustainability benefits compared to fishmeal. If renewable energy is not available for the heat inputs required for insect farming then the environmental benefits are not clear (van Zanten et al. 2015).

Further investigation is required as to whether farmed fish could play a role in keeping food waste in the food supply chain, either through consuming surplus food that has been heat-treated and dried into pellets, or more likely, by feeding food waste to insects which then form an ingredient in farmed fish feed. Research has found that food waste, including meat, can be safely fed to omnivorous non-ruminants if heat-treated (Luyckx et al. 2019). The UN estimates that enough grain could be freed to feed an extra three billion people if all livestock globally was fed with surplus and by-products of the food industry (UNEP 2009). Appropriate portions of different types of food waste could satisfy basic nutritional requirements of lower trophic-level fish species such as grass carp and tilapia (Wong et al. 2016), but Feedback has not found information on whether salmon farming could play such a recycling role. Furthermore, Life Cycle Assessments need to elucidate the most effective recycling routes for different leftover streams. For example, while pigs may not have such high feed conversion ratios compared to salmon, they can thrive on low quality liquid food waste (van Hal et al. 2019). Surplus food can be heat-treated in liquid form to ensure disease is eliminated, and does not need additional energy to be dried into pellets (Salemdeeb et al. 2017).

LAND ANIMAL BY-PRODUCTS

Another way in which reliance on soya in fishmeal could be reduced would be through land animal by-products (LAPs) such as chicken and pork by-products. Their use in fish feed was recently approved by the European Commission (2013). However in the UK, in response to consultation with retailers, there is a voluntary ban on use of LAPs in salmon feed (Shepherd, Monroig, and Tocher 2017). This is despite technical benefits and different practice outside the EU. For example, MOWI (2018a) uses "high-quality by-products from poultry" in their salmon feed in Chile and Canada. There is also a contradiction in that imported prawns and pacific salmon may all have been fed on LAPs, even if UK produced salmon is not (Shepherd, Monroig, and Tocher 2017). It is therefore important to further research the possibility of using LAPs in Scottish salmon feed[8].

Overall, it is crucial that sustainability analyses of different types of food production are not done in isolation, but consider linkages and knock-on effects across the food supply chain and across different food production systems.

8 Further research should take a wider environmental and food waste perspective to ensure that only unavoidable by-products are used to produce feed. It would also be important to ensure that demand for LAPs does not surpass projections for the reductions in livestock production which are needed to ensure we can feed a growing global population within planetary boundaries (Willett et al. 2019). Current environmental impacts of livestock production would impact on the environmental performance of using by-products in feed. For example, a life cycle assessment of salmon farming in Tasmania where land animal by-products are commonly used in salmon feed, found that adopting a feed composition without such by-products would result in a decrease of 70% of GHG emissions (Parker 2018). The results of these kinds of life cycle assessments are very sensitive to the extent to which the researchers decide to attribute environmental burdens from livestock production to the main product (meat for human consumption) versus the by-product.

8. IS SCOTTISH SALMON AN ENVIRONMENTALLY SOUND WAY TO HELP MEET THE WORLD'S PROTEIN NEEDS?

Drastic dietary change, including the reduction of animal proteins, is unavoidable if we are to keep the global food system within planetary boundaries (Godfray et al. 2010; Bajželj 2014; Willett et al. 2019). Most research points to a very low-meat or fish, or plant-based diet, which relies on legumes and nuts for protein, to provide the theoretical maximum reduction of land use and greenhouse gas emissions on a global level. Our final challenge to industry, and to policy-makers, concerns a wider question than tweaking feed ingredients in order to lessen environmental impacts. Within this wider context, is Scottish farmed salmon an environmentally sound way to help meet the world's nutritional needs?

QUESTIONING THE PROTEIN PANACEA – THE FOOD/ FEED COMPETITION

Just like other livestock farming, salmon farming relies on feed ingredients that could be consumed directly by humans, such as vegetable oils, wheat and beans, and food-grade wild-caught fish. This matters because more calories and proteins go into animal feed than are ultimately made available in human food: farming animals for food is not efficient (Cassidy et al. 2013; Fry et al. 2018; Poore and Nemecek 2018). In the context of global food security within environmental limits, this is a vital consideration.

Using a combination of measures on feed composition, feed conversion ratios[9], and nutritional content of edible portions of fish, Fry et al. (2018) estimated that for every 100g of protein in salmon feed, 28g are made available in the human food supply. In other words, despite being more a more efficient way to convert protein in feed to human consumption than other forms of animal agriculture such as pigs and chickens, salmon still does not stack up against direct human consumption of available protein, either plant-based or marine. In the context of the many challenges to sustainable feed sourcing we have set out in the preceding chapters, greater production and consumption of farmed salmon may simply not be a sustainable choice.

COMPETITION WITH HUMAN DEMAND FOR WILD FISH

According to the FAO (2018) aquaculture production will expand from 70 million tonnes to 100 million tonnes by 2025. Given that 33% of global fish stocks are already overfished and 60% are maximally sustainably fished (FAO 2018), there is a risk that this expansion begins to encroach on human food security, particularly in parts of the world that are likely to be particularly vulnerable to the impacts of climate change on food production.

Fishing boats in the harbor. Pucusana, Lima, Peru. Credit – Shutterstock.

9 Feed Conversion Ratio (FCR) is the weight of feed administered over the lifetime of an animal divided by the weight gained.

The farmed salmon industry addresses the concern that wild fisheries for salmon feed may be competing with local human consumption by stating that the marine ingredients in feed come from "low-consumer preference" fish (MOWI 2018a). However, research shows that 90% of fish used in fishmeal and oil production comes from food-grade or prime food-grade fish (Cashion et al. 2017). Food-grade fish has varying levels of consumer acceptability depending on geographic region; for example, female capelin are considered a delicacy in Japan (Norwegian Seafood Council 2019), but on the supply to produce anchoveta for direct human consumption is limited.

IFFO has argued that "the criticism of the use of fish as raw material for fishmeal and fish oil production exhibits a lack of basic understanding of the seafood market, where fish destined for food markets achieve considerably higher prices than those for fishmeal production" (Auchterlonie 2019). Feedback plans to further examine fish market data in different countries across the world to better understand how this assertion relates to reports on fishmeal buyers distorting local fish markets for human consumption.

This is particularly pertinent in light of reports finding that forage fish used in the production of fishmeal and fish oil may be impacting supplies of fish in some markets (Changing Markets & Compassion in World Farming 2019). For instance, media reports have found that people in Senegal are no longer being able to buy certain fish as prices are rising in response to demand for fishmeal and oil (Wickens 2016; Green 2018).

In Peru, where anchoveta fish support the world's largest reduction fishery, there has been an increase in the direct human consumption of anchoveta from 5,000 to 160,000 tonnes over a few years (Christensen et al. 2014). While such consumption is still minimal compared to the volumes going to fishmeal and oil, one of the barriers to increased local anchoveta consumption in Peru is the fact that "the increased global demand for fishmeal and fish oil has created a perverse incentive in that fishing boats currently are paid more for landing anchoveta for reduction than they are for landing a fresh product for direct human consumption" (Christensen et al. 2014). It is also important to note the importance of anchoveta as a food source for other fish species that are destined for direct human consumption in Peru, where seafood is a very important part of the diet (Christensen et al. 2014).

In the meantime, Scottish farmed salmon is a premium product aimed at consumers in wealthy countries. The largest export market for Scottish salmon are France and the USA which together make up 63% of total exports (SSPO 2018)- where, as in the UK, individuals consume more than the recommended levels of protein (Searchinger et al. 2018). Further research is needed to understand the impact on local fish markets elsewhere as a result of growing demand and the increased variety of fish species used in fishmeal and oil.

OTHER SOURCES OF OMEGA-3 FOR HUMAN DIETS

Omega-3 is undoubtedly an important micro-nutrient in human diets, though a recent Cochrane Review presents evidence that its benefits for heart health have been widely overstated (Abdelhamid et al 2018), it does not follow that farmed salmon is the most efficient or sustainable way to ensure availability and access to this nutrient. One option is consuming some of the fish currently used in farmed fish feed directly.

The industry uses the terms "unmarketable fish" or "low consumer preference fish". What does "unmarketable" mean in relation to fish suitable for human consumption? Fundamentally this question comes down to how we believe consumer demand is shaped. We know that new or revived markets for human consumption are being found for many former reduction species, such as capelin, Atlantic and Pacific herring (Cashion et al. 2017). Therefore while it may be convenient for the food industry to claim that there is no market for forage fish, the reality is that consumer food preferences are to a large extent shaped by the businesses which produce our food (Feedback 2018). Monkfish used to be considered a fish for the poor and banned from some markets in France because of its appearance – now it is very sought after and expensive (Barrie 2018).

Novel sources of Omega-3, and indeed other micronutrients essential for human health, are emerging in the form of 'future foods', such as algae, insects, mussels and cultured meat. Recent research has demonstrated that such foods may deliver equal or even far greater quantities of essential nutrients, while minimising negative environmental impacts including land use and Greenhouse Gas emissions (Parodi et al. 2018). The role of one such novel food is explored in box 5.

BOX 6: MUSSELLING IN ON THE ACTION

A plate of mussels. Credit – powerplantop Flickr

Mussels are a delicious and widely available marine food which does not require feed. Not only do mussels possess real nutritional power in terms of their Omega-3 and Vitamin B12 content (Parodi et al. 2018), but if certain criteria are respected, bivalve aquaculture also has potential as a restoration and remediation tool for marine environments (Gallardi 2014). Algae-based food supplements, and mealworm larvae have Omega-3 potential too (Parodi et al. 2018), but mussels may be easiest to increase in human diets immediately. Of course, we need to further research the conditions under which mussel production could be expanded while not causing harm. For example, if the scale of bivalve aquaculture increases beyond a certain level relative to the local ecosystem, it could lead to abiotic depletion which refers to the depletion of resources such as minerals and other abiotic (non-living) nutrients. What we do know is that mussels deliver plenty of Omega-3 without the need for external feed. And we also know that in fed aquaculture, feed is by far the biggest contributor to the environmental impact of farmed fish, including climate change.

9. CONCLUSION

Sea gulls take off from a salmon farm in Scotland. Credit – Theleom, Flickr

We have set out three questions we believe remain unanswered as the Scottish salmon farming industry continues down a path of increasing expansion. These questions are intended to be considered by both the industry and by wider stakeholders including policy-makers.

Farmed salmon is ultimately a luxury product, with a resource intensive production method. It also has very high impacts on the local environment where fish farms are sited. Drawing on the evidence presented in this report, it seems unclear that salmon farming as an approach to protein and Omega-3 production and resource use provides the best route to sustainable and healthy global diets.

The Scottish industry relies heavily on provenance as a marketing tool. Yet despite this the industry is largely not in Scottish hands. While the industry has undoubtedly made efforts to lessen its proportionate resource burden on wild fish stocks, we now challenge it to go further, and answer difficult questions about the impacts of its expansion plans.

Can the Scottish salmon industry meet its growth ambitions while decreasing its reliance on wild fish stocks?

The industry's current expansion plans, alongside its desire to maintain high levels of Omega-3 in the final salmon product, imply an additional use of fish oil made from an estimated 310,000 tonnes of wild fish annually. These 310,000 tonnes of wild fish would need to be caught in addition to an estimated 460,000 tonnes already caught annually in order to provide the fish oil for salmon feed (see appendix for calculation). In addition, the lack of a clear downward trend for the forage fish dependency ratio for fishmeal and fish oil in the data the current quantity of wild fish fed to farmed Scottish salmon is roughly equivalent to the amount purchased by the entire UK population (Seafish 2018), and to fulfil growth ambitions this amount would need to increase by approximately two thirds.

The risk of miscalculating the burden aquaculture can sustainably place on wild-fish stocks and other natural resources and ecosystems appears high. Collapse in wild fish stocks due to over-fishing can have long-term and devastating impacts on ecosystems, as well as threatening wider human food security. Up to twenty percent of ingredients in European fish feed are from uncertified sources, and sustainable fish stock management quotas do not always bear in mind wider eco-system impacts. Even if the potential for using by-products and 'waste' products in aquaculture is fully realised and supports the role of aquaculture in a sustainable food system, no assumptions should be made when the stakes are so high.

Can the Scottish salmon industry meet its growth ambitions while reducing its land footprint?

Industry efforts to reduce marine ingredients in salmon feed have led to an increased reliance on human-edible crops such as soya and wheat. Reliance on soya production is a widely understood challenge to any food sector's sustainability, and increased demand for this product should be carefully balanced against other possible sources of plant-based protein. Salmon farming now shares the very difficult challenge of sourcing zero-deforestation soya with the livestock industry. Moreover, through providing 'leftover' fishmeal from the fish oil produced for salmon aquaculture, the salmon industry is symbiotic with other industries which have a high environmental footprint, like shrimp production and pig production: indeed, the industry relies on these damaging forms of animal agriculture in order to make its sustainability claims.

Scottish salmon plays a relatively small role in the global aquaculture industry in terms of volumes of fish produced. However, it plays a high-profile role in terms of leading the way towards sustainability. This is particularly important if we consider the local environmental impacts alongside wider global impacts through feed sourcing.

Is Scottish salmon an environmentally sound way to help meet the world's nutritional needs?

It is important that policy-makers assess wider sustainability and food security questions regarding the use of fishmeal and fish oil, taking into consideration all farming sectors using these marine ingredients. While individual food industries organise their goals around maximising returns and improving quality and quantity of production, it is vital that civil society and policy-makers adopt a holistic approach. To facilitate this, the industry must commit to transparency to allow independent verification and analysis, over and above industry-supported certification schemes.

Feedback calls on the industry to publish a breakdown of marine ingredient used in farmed salmon feed, including the sites of source fisheries and the varieties of wild fish involved, as well as a breakdown of the quantities, types and provenance of plant proteins and other ingredients used in feed. We call for clear, industry-wide reporting on the proportion of by-products used in feed, and where these are sourced. We also call on the industry to set out how it will source the feed inputs, both marine and terrestrial, to support its expansion plans, and its plans for identifying alternative feeds. Without clear answers to these questions, the Scottish salmon industry's claim to be able to double in value, sustainably, by 2030, is not credible.

10. APPENDIX

Calculation of additional fish oil, wild-caught fish and soya needed for Scottish salmon industry expansion plans					
Description	Figure	Metric	Data source	Data source category	Assumptions / Notes
Total Scottish salmon feed in 2014	220,000	Tonnes	Shepherd et al. 2017	Academia in collaboration with industry	
Fishmeal in Scottish salmon feed in 2014	55,000	Tonnes	Shepherd et al. 2017	Academia in collaboration with industry	
Fish oil in Scottish salmon feed in 2014	33,000	Tonnes	Shepherd et al. 2017	Academia in collaboration with industry	
Fish oil yield (amount of fish oil produced relative to the amount of whole fish used)	4.8%		IFFO 2017	Industry	This is a global industry average
Total amount of fish needed to produce 33,000 tonnes of of fish oil.	687,500	Tonnes	Calculation		
Percentage of fish currently used in fishmeal and oil production that is wild-caught fish	67%		IFFO 2017	Industry	33% now comes from fishery by-products. This is a global industry average, but it appears that Scottish salmon feed might have a lower by-product content, meaning that Feedback's calculation might be underestimating the amount of wild-caught fish needed for fish oil in salmon diets
Total amount of wild-caught fish needed to produce 33,000 tonnes of fish oil	460,625	Tonnes	Calculation		
Scottish salmon production for 2014	179,022	Tonnes	Marine Scotland Science, 2018	Government	
Projected total salmon production for 2030	300,000	Tonnes	Scotland Food and Drink, 2016. The Scottish Parliament, 2018	Industry and government	Industry projection is 300,000 to 400,000 for all finfish, of which we assumed 96% is salmon based on Marine Science Government data. Parliament report states 300,000 for salmon only.
2014 total production is 60% of 2030 projected total production	60		Calculation		We assumed forage fish dependency ratios for fish oil (FFDRo) would remain the same as they were in 2014. It may be possible to improve FFDRo but a look at industry specific data shows that to date FFDRo tends to go up and down over the years (see table 2 in report). We would be interested to see how the 2018 drop in production has affected FFDRo for that year.
Amount of fish oil needed in 2030.	55,300	Tonnes	Calculation		
Additional fish oil needed compared to 2014.	22,300	Tonnes	Calculation		
Additional fish needed for fish oil production through application of IFFO average yield for fish oil.	464,593	Tonnes	Calculation		
Total amount of wild-caught fish needed to produce 22,300 tonnes of fish oil	311,277	Tonnes	Calculation		This figures assumes no increase in the proportion of fishmeal and oil (33%) that now comes from fishery by-products. This is a global industry average, but it appears that Scottish salmon feed might have a lower by-product content.

Calculation of additional soya needed for Scottish industry expansion plans					
Soya protein concentrate used in 2014	50,000	Tonnes	Shepherd et al. 2017	Academia in collaboration with industry	We assume soy protein concentrate proportion in salmon feed does not change from 2014. The calculation assumes that if 2014 total salmon production was 60% of projected production for 2030, then soya used in 2014 would be 60% of that used in 2030.
Total tonnes of soy protein concentrate needed in 2030	83,333	Tonnes	Calculation		
Additional tonnes of soy protein concentrate to be imported yearly	33,333	Tonnes	Calculation		

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